ICED23
Bordeaux

BOOK OF ABSTRACTS

Design in a complex world

24th International Conference on Engineering Design

Bordeaux, France, 24 - 28 July 2023

université de **BORDEAUX**

the **Design Society**
a worldwide community

S.mart
Systems.Manufacturing.Academics.Resources.Technologies

ICED23

24th International Conference on Engineering Design
Bordeaux, France, 24 - 28 July 2023

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ICED23
Bordeaux

Topics

Sustainability and resilience

Design for societal challenges

New design methods and processes

Innovation and new business models

Design on different and multiple scales

Design of industrial and societal systems

Design education and skills development

Digital engineering, simulation, and smart systems

Design for advanced manufacturing and supply chains

PREFACES

ICED23 – President's Welcome

Prof. Tim C. McAloone
President, Design Society (2019-2023)

Dear ICED23 participants

It is my pleasure to welcome you to ICED23, on behalf of the Design Society's Board of Management, Advisory Board and the extensive Scientific Committee, which has helped to ensure the scholarly quality of the papers from the many authors and co-authors that have contributed to the conference. Held biennially, ICED is the flagship conference of the Design Society, gathering colleagues from all over the world to discuss Design Science, specifically in the form of Design Research, Design Education and Design Practice.ICED23 will be the 24th in the series and our community is stronger than ever, with more rigorous research, education and practice being developed, implemented and presented for each conference that is held. This year's conference theme is Design in a Complex World, prompting us to consider how our common profession can help tackle the challenges we face globally and leverage the opportunities of new socio-technical solutions. Design plays a role in tackling complex sustainability challenges; in fostering advanced technological solutions to human needs; in harnessing new and automated problem-solving techniques; and in creating better, cheaper, faster solutions to our society – to name but a few examples. But each of the above are neither simple nor straightforward to solve. The solution to a climate-related sustainability problem might lead to a burden-shift to a more harmful solution for biodiversity. An advanced technological solution to a specific human need might lead to an increase in cost to the end-user. Automated problem-solving techniques and technologies, such as Artificial Intelligence, bring a host of dilemmas with them. And better, cheaper, faster solutions might be less sustainable than their predecessors … and so the cycle continues. Our job as design researchers, educators and practitioners is to analyse these complexities and find ways to design with and in our complex world, to eliminate or at least minimise sub-optimal solutions and help to foster better solutions for our world. A special welcome goes out to the early career design scholars and practitioners, for some of whom ICED23 might be their first conference. The Design Society is proud of its early career members and has several special events, also at ICED, to facilitate dialogue and to listen to ideas and research plans of our younger community members. Another aspect of the Design Society that we are extremely proud of is our catalogue of Special Interest Groups (SIGs) and regional Chapters. The SIGs are governed and driven by Design Society members with expertise and passion for a particular aspect of design; we can currently count 17 different SIGs in our community. SIGs emerge over time and address the complex challenges of our society. They are free for our members to join and will all be represented at ICED23. Our regional Chapters ensure consolidated and heightened Design Society activity in particular regions of the world. To close, I would like to express our deepest gratitude to the Organising Committee and the Programme Committee of ICED23. Organising an ICED conference is no mean feat and both committees have worked tirelessly for the past couple of years, to provide an inspiring and welcoming conference setting, and an exciting and insightful programme for us all.

Welcome to ICED23 – enjoy the conference!

ICED23 – University of Bordeaux's welcome

Prof. Denis Teissandier
Prof. Nicolas Perry
Prof. Christophe Merlo

Welcome to the International Conference on Engineering Design ICED23 organized by the Design Society, University of Bordeaux, Arts et Métiers, ESTIA, and the Scientific Interest Group S.mart. This is a great pleasure to meet physically again after these four years of delay due to Covid period. Bordeaux is a beautiful place for such a reunion in a convivial and friendly spirit.
This proceeding gather here for this prestigious event, we embark on a journey that celebrates the convergence of creativity, innovation, and engineering excellence.
Design has always been at the heart of human progress, enabling us to envision and shape a better world. The ICED23 conference stands as a testament to the boundless possibilities that emerge when brilliant minds from diverse disciplines come together to explore the frontiers of design.

This year's conference theme, «Design in a complex world», reflects our collective commitment to addressing this challenge. More than 400 papers will deal with the broader issues of designing hyper-connected complex world in a complex socio-technical environment with limited resources, but full of promising technologies.

ICED23 brings together a global community of researchers, practitioners, educators, and industry leaders who share a common passion for advancing the field of engineering design. The conference provides a platform for intellectual exchange, fostering collaboration, and nurturing the next generation of design pioneers.

Throughout the conference, you will have the opportunity to engage in thought-provoking discussions, attend inspiring keynote lectures, and explore a wide range of research papers and presentations that push the boundaries of design knowledge. From cutting-edge methodologies to transformative case studies, the ICED23 conference will showcase the latest advancements and emerging trends in the field.

We extend our sincere gratitude to the organizing and program committees, the dedicated volunteers, and the numerous contributors who have made this conference possible. Their tireless efforts have ensured a program that is both enriching and enlightening.

Welcome and enjoy ICED23!

ICED23 – Welcome

Prof. Lionel Roucoules
General Chairman of the Scientific Interest Group S.mart

From their creation, human societies evolved socially by setting up organizations, and intellectually through the discoveries, development, representations and acquisition of Knowledge. More recent developments have seen the birth and rise of "industry" allowing the design and manufacturing of technical systems at the service of societies and their uses. Those evolutions, from the beginning, was supported by a natural environment (the planet) which exists for much longer and which provides the necessary resources (materials, energy…). These three pillars society/planet/industry have evolved together since the end of the 18th century following different levers of social and industrial values.
Today, this systemic triptych is disturbed/influenced by increasingly frequent and different economic, ecological, societal and technological elements (pandemic, exchange of energy resources, climate change, digital transformation, etc.). Environmental values must regain an important place in decision-making levers in order to guide future decisions of the societal, industrial, technological and environmental system and drive what the "industry of the future" should be.

The academic international community, including the Design Society (designsociety.org), therefore has an extremely important role in developing adequate knowledge for understanding this holistic system in order to be able to experiment and validate potential future situations and be agile in an ever-changing world. The research laboratories should develop experimental environments to test different characteristics and situations, and analyse system behaviours. The ICED23 international conference is therefore an important event for the scientific community to meet, exchange, share and participate in the development of this fundamental and experimental knowledge relating to the «design of socio-technical systems in an increasingly complex world».

On a national scale, the S.mart Scientific Interest Group (s-mart.fr) brings together a large part of the French academic community which investigates this subject. Our community brings together around 40 academic establishments on topics related to the Industry of the Future (Systems Engineering, advanced manufacturing, sustainability, digitalization, etc.). Beyond scientific and educational activities, S.mart is a place for sharing material resources (for carrying out experiments) and immaterial resources (educational resources, scientific benchmarks, etc.).

It is with great pleasure and pride that S.mart supports the ICED23 conference.

ICED23 – Welcome by the Committees

Prof. Kevin Otto
Programme Committee Chairperson

Welcome to ICED23, the 24th International Conference on Engineering Design. ICED is the flagship conference of the Design Society, with a very long tradition. People from all over the world come together to present their scientific work in design, and learn about new developments in design research. This year, the conference is hosted by the University of Bordeaux on the west campus of Montesquieu in Bordeaux France.

The theme for ICED23 is "Design in a complex world." We have definitely entered a world full of promising technologies, a hyper-connected world where information is paramount. In such a world, true value creation for people and companies and simplicity of solutions will be the keys to success. Design must therefore reinvent itself by embracing the broader issues of designing complex systems. These complex systems are made up not only of physical products but also of automation, human services, process, organizations, infrastructures, skills training and a host of socio-technical, ethnological and cultural realities and socio-economic compromises. Where design paradigms are changing is that these complex systems are also made of people or actors, and include or are interfaced with other systems. We as a design society should participate to tackle these challenges by educating new generations and renewing theories and practices of design and engineering. ICED23 should be a unique opportunity to collectively discuss the state of the art and future of our discipline.

This year's ICED continues with the successful structure of both discussion and podium sessions. Discussion sessions include four topical paper presentations with no questions, followed by a moderated discussion of the topic area with authors and the open audience. Podium sessions include more papers with traditional question and answer periods after each presentation. We also have several academic and industry keynote speakers. And we have a marketplace exhibition on Thursday's coffee and lunch breaks for researchers to present their more interactive research demonstrators such as software and hardware. Through these formats we hope to foster new design oriented discussions and collaborations.

We hope you enjoy the conference, the engaging speakers and innovative design research presented and discussed. We hope you take time to enjoy the campus venue and the city and surroundings. We know you will leave Bordeaux with new knowledge, inspirations for innovative research ideas, new friends and colleagues, and we hope with the wish to visit with us again.
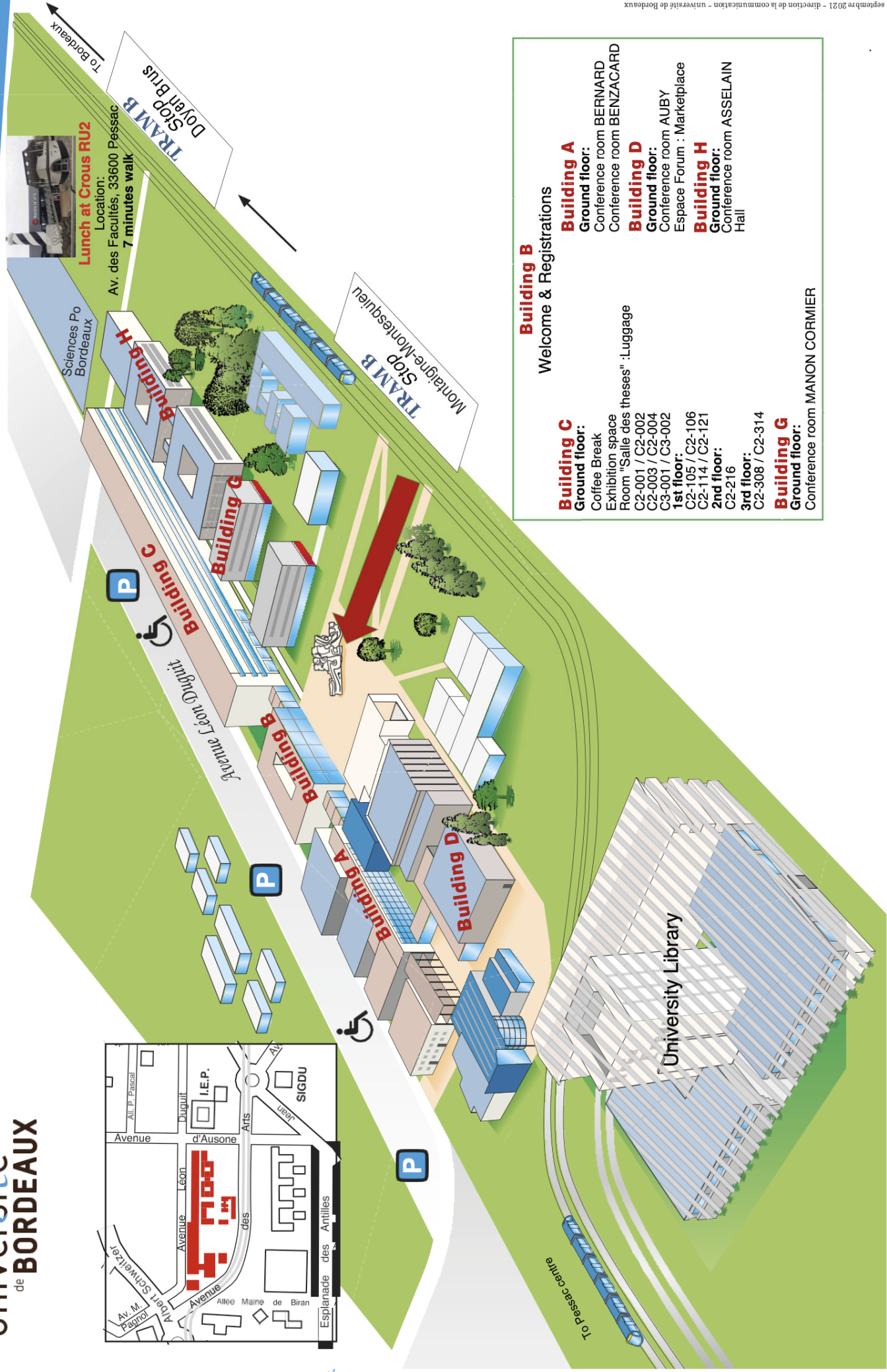
Welcome to ICED23!

Design in a complex world
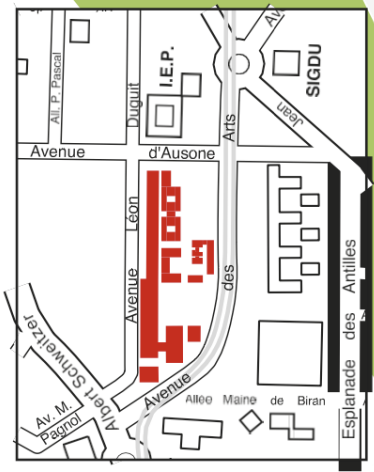
SPONSORS

PARTNERS

ICED23 Bordeaux

24-28 july 2023
Conference at a glance

Monday 24 July

08:30 am – 09:30 am	*Welcome & Registration*
09:30 am – 12:30 pm	1st SIG Parallel Sessions
12:30 pm – 1:45 pm	*LUNCH*
1:45 pm – 4:45 pm	2nd SIG Parallel Sessions
5:00 pm – 6:30 pm	Young Member Event & Outreach of DS to GOV and Industry

Tuesday 25 July

9:00 am – 9:45 am	**Opening Ceremony**
9:45 am – 10:30 am	**Keynote**
10:30 am – 11:00 am	*COFFEE BREAK*
11:00 am – 12:30 pm	Podium Sessions
12:30 pm – 1:45 pm	*LUNCH*
1:45 pm – 2:30 pm	**Keynote**
2:30 pm – 3:30 pm	Discussion Sessions
3:30 pm – 4:00 pm	*COFFEE BREAK*
4:00 pm – 6:00 pm	Podium Sessions
7:00 pm – 9:00 pm	*Reception at Town Hall*

Wednesday 26 July

9:00 am – 9:45 am	**Keynote**
9:45 am – 10:45 am	Discussion Sessions
10:45 am – 11:15 am	*COFFEE BREAK*
11:15 am – 12:45 am	Podium Sessions
12:45 pm – 2:00 pm	Mentoring Programme Event & *LUNCH*
2:00 pm – 2:45 pm	**Keynote**
2:45 pm – 3:45 pm	Discussion Sessions
4:00 pm – 5:00 pm	General Meeting DS
7:30 pm – 12:00 pm	*Gala Dinner*

Thursday 27 July

9:00 am – 9:45 am	**Keynote**
9:45 am – 10:45 am	Discussion Sessions
10:45 am – 11:15 am	Marketplace & *COFFEE BREAK*
11:15 am – 12:45 am	Podium Sessions
12:45 pm – 2:00 pm	Marketplace & *LUNCH*
2:00 pm – 3:00 pm	Discussion Sessions
3:00 pm – 3:30 pm	Marketplace & *COFFEE BREAK*
3:30 pm – 4:30 pm	Podium Sessions
4:30 pm – 5:15 pm	**Keynote**
5:15 pm – 6:00 pm	**Closing Ceremony**
7:00 pm – 8:30 pm	*Farewell Party*

Friday 28 July

08:15 am – 12:30 am	**Industrial Visits**
09:30 am – 12:30 pm	Panel Discussion Workshop

Campus Montesquieu

université de **BORDEAUX**

Building B
Welcome & Registrations

Building A
Ground floor:
Conference room BERNARD
Conference room BENZACARD

Building D
Ground floor:
Conference room AUBY
Espace Forum : Marketplace

Building H
Ground floor:
Conference room ASSELAIN
Hall

Building C
Ground floor:
Coffee Break
Exhibition space
Room "Salle des theses" :Luggage
C2-001 / C2-002
C2-003 / C2-004
C3-001 / C3-002
1st floor:
C2-105 / C2-106
C2-114 / C2-121
2nd floor:
C2-216
3rd floor:
C2-308 / C2-314

Building G
Ground floor:
Conference room MANON CORMIER

To Bordeaux

Sciences Po Bordeaux

Lunch at Crous RU2
Location:
Av. des Facultés, 33600 Pessac
7 minutes walk

TRAM B
Stop
Doyen Brus

TRAM B
Stop
Montaigne-Montesquieu

Building H

Building C

Building G

Avenue Léon Duguit

Building B

Building A

Building D

University Library

To Pessac centre

P

I.E.P.
SIGDU
Avenue   d'Ausone
Alt P. Pascal
Duguit
Arts
Jean
Avenue   Léon   des
Allée   Maine   de   Biran
Av. M. Pagnol
Albert Schweizer
Esplanade   des   Antilles

24th International Conference on Engineering Design ----Bordeaux, France, 24 - 28 July 2023

ICED23 Bordeaux

Social events

Tuesday 25 July
Reception at Town Hall
From 7:00pm at 09:00pm

Public Transport : Tram **B** : Hôtel de Ville

Location:
Mairie de Bordeaux
Place Pey Berland
33045 Bordeaux Cedex

Wednesday 26 July
Gala Dinner at Hangar 14
From 7:30pm at 01:00am

Public Transport : Tram **B** : Cours du Médoc

Location:
Hangar 14
115 Quai des Chartrons
33000 Bordeaux

Thursday 27 July
Farewell Party at Campus of Talence
From 7:00pm at 8:30pm

Public Transport : Tram **B** : Béthanie

Location:
University of Bordeaux
Campus of Talence Peixotto
Esplanade du A22

Berges de la Garonne — Claveau — Brandenburg — New-York — Rue Achard — La Cité du Vin — Les Hangars — Cours du Médoc — Chartrons — CAPC — Quinconces — Grand Théâtre — Gambetta — Hôtel de Ville — Musée d'Aquitaine — Victoire — Saint Nicolas — Bergonié — Barrière Saint-Genès — Roustaing — Forum — Peixotto — Béthanie — Arts et Métiers — François Bordes — Doyen Brus — Montaigne Montesquieu — Unitec — Saige — Bougnard — Camponac Médiathèque — Pessac Centre — Châtaigneraie — Cap Métiers — Hôpital Haut-Levêque — Gare de Pessac Alouette — France Alouette

B

Farewell Party

Reception at Town Hall

Gala Dinner

MONDAY 24th July 2023

PROGRAM

&

ABSTRACTS

24th International Conference on Engineering Design
Bordeaux, France, 24 - 28 July 2023

8:30am - 9:30am	**W&R: Welcome and Registration**							
9:30am - 12:30pm	**SIG 1-01: Data-Informed Design** Location: **Bât C - RDC: Salle C2 - 004** **Data-Informed Design** Data-Informed Design in practice *Kostas Stylidis, Bastian Quattelbaum, Cyriel Diels, Florian Konrad, Julia Orlovska*	**SIG 1-02: Design Creativity** Location: **Bât C - 1er étage: Salle C2 - 106** **Design Creativity** Encouraging creativity through effective feedback to ideas *Mayu Akaki, Akane Matsumae*	**SIG 1-03: Design Practice** Location: **Bât C - 2ème étage: Salle C2 - 216** **Design Practice** AI technology as support in Early Phase Design *Mohsen Moghaddam, Tucker J. Marion, Ola Isaksson*	**SIG 1-04: Decision Making** Location: **Bât C - 1er étage: Salle C2 - 121** **Decision Making** Supporting the choices of embedded sensors in the product design process *Camille Jean, Julie Le Cardinal*	**SIG 1-05: Design Processes** Location: **Bât C - 1er étage: Salle C2 - 114** **Design Processes** Current status and trends in design process modelling and management *Kilian Gericke, Claudia Eckert, Dietmar Göhlich*	**SIG 1-06: Health Systems Design** Location: **Bât C - RDC: Salle C2 - 002** **Health Systems Design** Health Systems Resilience by Design *Anja Maier, Maaike Kleinsmann, John Clarkson*	**SIG 1-07: Robust Design** Location: **Bât C - RDC: Salle C2 - 001** **Robust Design** Design Research for achieving product robustness *Tobias Eifler, Benjamin Schleich, Felician Campean, Stephan Husung*	**SIG 1-08: New Initiative** Location: **Bât C - RDC: Salle C2 - 003** **New Initiative** Computational Design Methods *Markus Zimmermann*
12:30pm - 1:45pm	**LB 01: Lunch Break**							
1:45pm - 4:45pm	**PHD 01: PhD Forum** Location: **Bât C - RDC: Salle C2 - 001** Chair: **Philip Cash**, DTU Technical University of Denmark, Denmark Chair: **Emmanuel Caillaud**, University of Strasbourg, France	**SIG 2-01: Design Theory** Location: **Bât C - 1er étage: Salle C2 - 106** **Design Theory** Design Theory to face grand challenges *Pascal Le Masson, Eswaran Subrahmanian*	**SIG 2-02: Human Behaviour in Design** Location: **Bât C - 1er étage: Salle C2 - 114** **Human Behaviour in Design** Design in a Complex World - Bridging capacities: Supporting exploration and learning from complex systemic challenges *Yvonne Eriksson, Ulrika Florin, Karolina Uggla*	**SIG 2-03: Sustainability Design** Location: **Bât C - 2ème étage: Salle C2 - 216** **Sustainability Design** Investigating and fostering education in sustainable design *Yuri Borgianni, Sophie Hallstedt, Els Du Bois, Jeremy Faludi, Tatiana Reyes*	**SIG 2-04: Design of Product-Service Systems** Location: **Bât G - Rez de jardin: Amphi MANON CORMIER** **Design of Product-Service Systems** Extended Reality (XR) - technologies for PSS design *Giulia Wally Scurati, Marco Bertoni, Carl Toller Melen, Tobias Larsson, Francesco Ferrise, Monica Bordegoni*	**SIG 2-05: Chapter Africa Design** Location: **Bât C - 1er étage: Salle C2 -105** **Chapter Africa Design** Towards Creating a Design Society African Chapter *Bernard Shibwabo, Richie Moalosi, Samuel Boahen, Peter Oviroh, Panos Papalambros, Mugendi K. M'Rhithaa, Susanne Nilsson, Margareta Norell Bergendahl, June Madete Kenyatta*	**SIG 2-06: Collaborative Design** Location: **Bât C - RDC: Salle C2 - 001** **Collaborative Design** An interactive experiment to investigate a fundamental concept that defines collaborative design 2.0 *Ian Whitfield, Ross Brisco, Dorothy Evans, Avril Thomson*	**SIG 2-07: Design for Additive Manufacturing** Location: **Bât C - RDC: Salle C2 - 004** **Design for Additive Manufacturing** Leveraging Data-Driven Design Methods to Support Complex and Multidisciplinary Design Scenarios in Additive Manufacturing *Tino Stankovic, Nicholas Meisel, Serena Graziosi*
5:00pm - 6:30pm	**OUT 01: Outreach of DS to GOV and INDUSTRY** Location: **Bât A - RDC: Amphi BERNARD**				**YME 01: Young Member Event** Location: **Bât H - RDC: Amphi ASSELAIN** Chair: **Kristin Paetzold**, TU Dresden, Germany Chair: **Lou Grimal**, Univesité de Technologie de Troyes, France			

Design in a complex world

Location: Building C – 1st floor: Room C2 – 004

9:30am
12:30pm

SIG 1-01: Data-Informed Design

Data-Informed Design in practice

Kostas Stylidis, Bastian Quattelbaum, Cyriel Diels, Florian Konrad, Julia Orlovska

Current design practice heavily depends on designers' tacit knowledge. While this of course can lead to successful design, we here propose a new approach which involves incorporating data to enhance the design process. The future of Design Science is implicitly connected with datasets. Engineering Design in a paradigm of Industry 4.0 already relies on an increasing data flow in Advanced Engineering activities. In contrast, automotive, architectural and product design often relies on tacit knowledge, guided by heuristics, or suffering by "tribalization" of design teams. Design in this context is blind. We need to introduce data literacy and power of analytics to design teams. This is why we need Data-Informed Design. Data-Informed Design (D-I D) can be distinguished from Data-Driven Design in which data is paramount, a primary input and at the center of design decisions. Data-Driven approaches are suitable for engineering design where requirements can be defined explicitly but are less suitable and appropriate for the design teams involved in more open-ended advanced design activities. In this workshop we introduce Data-Informed Design vision where the design teams use data to inform their decisions. In the first round we will apply "traditional" collaborative design approach and Data-Driven Design approach using DALL·E 2, a new AI system that can create realistic images and art from a description in natural language. Afterwards we will present D-I D activities where data output is one of many references, including design intuition, creative expression, and qualitative feedback. The aim of D-I D is to enhance design practices by helping designers to make mindful decisions and empower their creativity and increase design efficiency and effectiveness by sizing or shaping the design space. In this workshop we are planning a series of activities and information about how to use Data-Informed Design approach in design activities.

Location: Building C – 1st floor: Room C2 - 106

9:30am
12:30pm

SIG 1-02: Design Creativity

Encouraging creativity through effective feedback to ideas

Mayu Akaki, Akane Matsumae

The positive impact of feedback within the team on creativity is indicated in previous studies. To further explore effective feedback leading to creativity, we compare regular feedback and feedback using the feedback card in this workshop.

Feedback card is designed for the teams to use during the ideation mode of design thinking to diverge ideas the individual members generated. Perspectives to feedback are described on each card. By offering feedback from diverse perspectives, we seek the teams to deeply understand each other's idea and accept it. The figure below shows the design of the method, which supports the multi-disciplinary participants to feedback systematically. Before starting the feedback inside the team, we guide important attitudes when giving feedback. The cards support the person to give feedback (feedbacker) on 'how' to communicate what they felt or thought listening to the idea. The first card encourages positive feedback and the second card encourages asking questions instead of giving one-sided comments. The third, fourth, and fifth cards are used to broaden the ideas from time, spatial and semantic approaches, which are the systematic approaches.

The systematic feedback method is verified to have a positive effect on the acceptance of ideas and team creativity so far, however, further researches are necessary to improve the method. The motivation for this workshop is to discuss the design of effective feedback and its process to lead to creativity with multidisciplinary researchers and practitioners interested in the implementation of creativity and bringing back feedback tips for their teams.

As such, we have the following goal: Explore effective feedback within teams to encourage creativity during ideation mode..

Design in a complex world

Location: Building C – 2nd floor: Room C2 – 216

9:30am
12:30pm

SIG 1-03: Design Practice

AI technology as support in Early Phase Design

Mohsen Moghaddam, Tucker J. Marion, Ola Isaksson

In early phase product development, a classical challenge is to gain an insight in what users and customers expect form new products and solutions. In this work, we explore the possibilities and limitations with AI and NLP (Natural Language Processing) to capture and analyze user preferences based on reviews and feedback to similar/existing designs from multiple sources, and leverage the insights obtained from user preference for automated data-driven design concept evaluation and generative design.

The objective is to get firsthand insights, guided by Dr. Moghaddam and Dr. Marion who recently edited a special issue in the Journal of Mechanical Design on the topic and will facilitate the session together with members and participants interested in learning about the latest research and experiences in the field and discussing the practical implications and opportunities that arises. From a practitioner's perspective – what needs to be considered and what measures need to be taken to explore these technologies in practice?

The session is organized as a three-hour session, with introductions and experience sharing from experts, followed by a facilitated exercise to explore selected techniques. Finally, a panel discussion follow that seek to articulate both remaining research areas as well as recommendations for practical applications.

Location: Building C – 1st floor: Room C2 – 121

9:30am
12:30pm

SIG 1-04: Decision Making

Supporting the choices of embedded sensors in the product design process

Camille Jean, Julie Le Cardinal

With the rapid development of electronic technologies, smart connected products have become more accessible. The collection and use of data from embedded sensors has developed alongside as they have proven to be a valuable means of monitoring the entire product lifecycle for optimisation purposes. Despite their widely acknowledged potential, the integration of embedded sensors into smart connected products still faces significant challenges that hinder their deployment. The financial costs of the data capture, storage and analysis, as well as the associated environmental costs, are the primary hindrances. In addition, designers are confronted with challenging ethical and technological considerations. Decision-making during the product design process is therefore particularly important and complex, as the choices made will define the impact of sensors over the entire life cycle. Industrial designers have reported a lack of support in this regard.

In the light of all these considerations, the Decision Making SIG is proposing a workshop. The objective of the workshop is to explore how to support embedded sensors choices in the design process. This workshop is an opportunity to provide all participants with an overview of current practices as well as to share knowledge within the Design Society community. The workshop will also introduce a proposition of a decision support tool to consider. Finally, participants will discuss of new opportunities to support companies with embedded sensors choices in the product design process.

Design in a complex world

Location: Building C – 1st floor: Room C2 – 114

9:30am
12:30pm

SIG 1-05: Design Processes

Current status and trends in design process modelling and management

Kilian Gericke, Claudia Eckert, Dietmar Göhlich

Engineering products go through a wave of unprecedented changes as the products are adapted to respond to the great societal challenges of our time like sustainability, carbon neutrality or circular economy. Engineers from different disciplines come together to design the next product generations making use of digital technology like simulation, AI or digital twins. At the same time established engineering paradigms, such as stage gate processes, are shifting.

These developments have a substantial effect on the way engineering projects are managed and how processes are modelled and used. However, empirical data that captures these developments and illustrates the broad range of scenarios in different industry sectors is scarce.

This workshop brings together industry participants and academics to discuss current trends and current practice in design process modelling and management. The workshop is the start of a collaborative effort that aims to conduct a global study on current practice in a variety of industry sectors. We seek interested researchers that would like to get actively involved in this study, and place their own empirical studies or tools and methods development in a broader context..

Location: Building C - ground floor: Room C2 – 002

9:30am
12:30pm

SIG 1-06: Health Systems Design

Health Systems Resilience by Design

Anja Maier, Maaike Kleinsmann, John Clarkson

The covid-19 pandemic has revealed an urgent need for improved resilience in health systems worldwide. Yet, it is still unclear how to define, recognize, measure and improve health systems resilience. These issues, recognized as relevant for design disciplines and in particular for health systems design, will constitute the topic of this workshop.

The workshop will include the following activities. First, the overall approach the SIG takes to health systems design will be introduced. Ignite talks will be given by DTU – Technical University of Denmark, TU Delft and Cambridge University around their individual yet complementary strategies for health systems design. Then, the concept of resilient health systems will be collaboratively explored in randomly allocated groups. Following, groups will be asked to define and present one or more examples of a (hypothetical) health systems design intervention aimed at improving health systems resilience. The different characterizations of health systems resilience and the different proposed interventions will finally be discussed between participants, looking for interesting difference and similarities.

Overall, the workshop is expected to result in a collection of definitions of health systems resilience and in a shortlist of examples of design interventions aimed at improving health systems resilience. Through collaboration and discussion, different perspectives from the design community will be collectively collected, explored and compared.

Design in a complex world

Location: Building C - ground floor: Room C2 – 001

9:30am
12:30pm

SIG 1-07: Robust Design

Design Research for achieving product robustness

Tobias Eifler, Benjamin Schleich, Felician Campean, Stephan Husung

Well-established in the quality-by-design domain, Robust Design offers a coherent and widely appreciated approach for the parametric exploration of the design space. From the perspective of design research however, the exclusive focus on the corresponding (physical/virtual) experimentation strategies and sensitivity studies is a significant hurdle to the overall potential of RD thinking. Per definition, the focus lies on the optimization of a fairly complete solution without questioning the design itself.
Particularly in light of emerging technologies and new application areas, it is therefore essential to extend the available approaches towards a more design driven RD toolbox. At the same time, there are various contextual requirements for RD methods and current design research falls short on providing clear evidence for the reproducibility of results and the generalisability of methods and tools beyond simplified, largely contextual academic case examples.
The workshop consequently aims at exploring new angles to the discussion and suggests directions for action and new research areas, both with respect to a methodical RD approach as well as the question of systematic research procedures. The workshop will be structured into 3 subsequent parts:
1 Mapping of robustness challenges across industries and different research areas, and consideration of differential contextual requirements for RD methods and tools;
2 Presentation and discussion of potential Robust Design cases examples for aligning terminology, better reproducibility of suggested methods, and thus a better link between academic research and industry application
3 Consolidation of discussion and outline future directions for RD research (question of necessary/combined efforts from different design research fields to address the identified challenges).

Location: Building C - ground floor: Room C2 – 003

9:30am
12:30pm

SIG 1-08: New Initiative

Computational Design Methods

Fabian Duddeck, Alexander Hasse, Michael Kokkolaras, Harrison Kim, Timos Kipouros, Panos Papalambros, Ole Sigmund, Axel, Schumacher, Benjamin Schleich, Kristina Shea, Stefan Tremmel, Sandro Wartzack

Design in a complex world can be supported and improved by computational methods. In engineering, they are useful, e.g., in systems design to produce highly integrated architectures, or in mechanical component design to achieve optimal weight, performance, manufacturability, etc. The purpose of this workshop shall lie on computational design methods as opposed to simulation methods: the first produce a candidate design, representing the (partial) description of a solution to a specific design problem, while the latter only replicate or predict the performance or output of a given design. Established computational design methods are, for example, numerical optimization methods, identifying non-intuitive solutions to problems with many interacting design variables, or Machine Learning methods, providing access to large amounts of data representing existing knowledge and experience, etc.
The goal of this workshop is to bring together researchers from the design society with related research interests and produce a landscape of existing approaches, areas of application, research interests and current challenges.
Example Research Questions:
   - How to formalize engineering problems to make them accessible by computational methods?
   - How to integrate restrictions w.r.t. to viability/feasibility, e.g., on manufacturability?
   - How to reduce required resources, e.g., w.r.t. to computational effort, modelling effort, data, etc.
   - How to produce results that are easy to integrate into the development process?
   - How to reduce dimensionality / complexity?

Design in a complex world

Location: Building C – 1st floor: Room C2 – 106

1:45pm
4:45pm

SIG 2-01: Design Theory

Design Theory to face grand challenges

Pascal Le Masson, Eswaran Subrahmanian

Design theory deepens the scientific foundations of design and engineering; it bridges the gap with other design professions (such as industrial design) and helps in addressing critical, contemporary innovation issues; providing scientific models of generativity, design theory also contributes to address generativity issues in many disciplines (biology, agronomics, chemical engineering, philosophy, management,…). The symposium will provide some illustrations of these results, in three contrasted streams of research. This symposium will unfold in three parts:

- It gives the opportunity to present an historical perspective on the development of design theory at CMU and how it related to the 'grand challenges' of the time;
- We will discuss new engineering education initiatives that rely on design theory to improve design capacities to face grand challenges;
- We will discuss new formal models of generativity based on category theory and topos theory. These models are particularly relevant to design in complex engineering systems, and to address one critical issue of grand challenge for complex systems: the necessity of a creative preservation, ie the necessity to preserve (resources, way of life, common goods….) while radically innovating.

Location: Building C – 1st floor: Room C2 – 114

1:45pm
4:45pm

SIG 2-02: Human Behaviour in Design

Design in a Complex World - Bridging capacities: Supporting exploration and learning from complex systemic challenges

Yvonne Eriksson, Ulrika Florin, Karolina Uggla

Visualizations are often created, and used, to materialize what we as humans experience as abstract or intangible. They have properties that can be useful when exploring and learning together from complex challenges, whether resulting in renewed systems, artifacts, or processes. Visualizations, including models, can be both two- and three-dimensional, physical and virtual, analogue and digital, but all types have knowledge bridging qualities. Qualities that can aid the understanding of different systems and the interrelation between systems, including how individuals, groups, technologies and their surrounding environment interact. Systems can be perceived as abstract and invisible, but still humans are a part of them, and we design, develop, and alter them over time. With this comes responsibility, self-reflection, and care about all parts in a system.

One example of such abstract and invisible systems is Artificial Intelligence, AI, which generates virtual agents, image analysis tools, search engines, voice and face recognition systems, or machine trans-lations. It is embedded in robots, self-driving cars, drones, interfaces and Internet of Things, IoT. That means we experience the manifestations of AI, but at the same time we cannot see the system behind it. The same goes for production systems, logistics and organizational systems of various kinds, some more complex than others. It is often hard to get an overview of the structures behind and to understand how the different parts work and how they build a wholeness. This workshop aims to provide insights on how visualizations can concretize abstract and invisible phenomena and systems, by demonstrating knowledge-bridging potentials of visual material. This means qualities that are both concrete and ab-stract, specific and general, conventional and adaptable and that visual material can be designed to be simultaneously weak and strong in their structure, and therefore be adaptable to people from different knowledge and practice domains.

With a variety of practice-related examples in the form of integrated short demonstrations – workshops within the workshop – the participants are invited to a sorting session building on Star and Griesemers typology of boundary objects: repositories, ideal types, coincidental boundaries and standardized forms, used as a categorizing tool for the discussion of the potential and meaning of visualizations as a bridging capacity in and between different contexts on a concrete level.

Location: Building C – 2nd floor: Room C2 – 216

1:45pm
4:45pm

SIG 2-03: Sustainability Design

Investigating and fostering education in sustainable design

Yuri Borgianni, Sophie Hallstedt, Els Du Bois, Jeremy Faludi, Tatiana Reyes

The growing demand of engineering students to integrate socio-ecological issues and the implementation of regulations for the integration of sustainability competences in education by some states are pushing universities to integrate these competences at all levels of higher education, and more particularly in the professions related to design. Therefore, it should be expected that sustainability has pervaded education also in fields that are not typically focused on sustainability, such as environmental studies. Within design and close disciplines, priming students with sustainability-related concepts can result in fundamental improvements in the way products, processes and systems will be developed in the future. Nevertheless, sustainable design education has been poorly investigated so far. This workshop aims to involve the whole design community in making a step forward in the understanding and promotion of best practices for education on sustainable design. Its long-term objectives include the creation of a community or working groups interested in sustainable design education, and possibly the development of one or more project applications centered on boosting the diffusion of sustainable design concepts in University and school. To this goal, it is required to conduct a state of the art of initiatives that have been launched in several countries

- identify the main competencies on sustainability that designers should obtain and characterize the level of expertise for each competency
- identify the module and pedagogical methods allowing the development of design curriculum competencies.

The workshop is expectedly preceded by the launch of an online survey to be answered by lecturers to collect data on University education on sustainable design, with a focus on:

- Relevant sustainable competencies/skills/learning outcomes to develop in design education
- Treated topics and illustrated methods/concepts (link with competencies/skills)
- Quantity of students attending courses that explain concepts of sustainable design
- Level (Bachelor, Master, PhD) and nature (elective, mandatory) of courses on sustainable design
- Verification format and teaching methods
- Possible connections with companies and practitioners to identify case studies and apply sustainable design
- Resources and materials leveraged (to be possibly shared)
- Possible barriers and administrative obstacles faced to fit sustainable design teaching in University curricula.

Design in a complex world

Location: Building G – ground floor: Conference room MANON CORMIER

1:45pm
4:45pm

SIG 2-04: Design of Product-Service Systems

Extended Reality (XR) - technologies for PSS design

Giulia Wally Scurati, Marco Bertoni, Carl Toller Melen, Tobias Larsson, Francesco Ferrise, Monica Bordegoni

Background: Nowadays, multisensory virtual experiences of products and service mock-ups are envisioned to become a commodity in the engineering design toolbox, to support design decision making in an early stage. The need for complete engaging experiences in PSS design is mentioned regularly both in an academic and industrial setting, mostly as a way to improve the understanding of a design concept, making possible for non-experts (e.g., non-engineers coming from different disciplines and with different backgrounds) to contribute with their idea and knowledge to the creation of innovative, value-adding solutions.

Aim: The workshop will involve participants in the discussion related to the use of Extended Reality (XR) technologies for the design of PSS. XR is an umbrella term for Mixed Reality (MR), VR, and AR, that stresses the dynamic, blended, and continuous nature of the new virtual worlds and the real one – which makes it possible to integrate digital information and real-world data through Digital Twins and exploiting visualization and immersive experiences capabilities.

Execution (hardware and software support): The co-chairs will provide VR headsets and computers to make it possible for participants to have a 'live' experience of the XR environment in a selected case study. The room hosting the workshop shall be equipped with a projector and movable furniture, to allow presentations and a seamless transition from 'plenary' sessions to teamwork in smaller groups. Large A0 papers with post-its (or a digital workspace for visual collaboration) will be used to document the break-out discussion. A platform similar to Mentimeter.com will be used to gather more feedback at the end of the session.

Execution (research focus): The workshop will involve researchers, investigators and practitioners in a dialogue related to how XR technologies are envisioned to benefit the PSS concept generation process, from sketching to design reviews, facilitating an open dialogue in the team. Participants will be divided into smaller groups to have a first hands-on experience – and then reflect upon – how immersive virtual worlds can blend reality and digital artefacts to provide a feeling of presence and support synchronous/asynchronous communication among designers, either co-located or remotely.

The workshop will also discuss the challenges linked to shifting from a computer-aided design (CAD) workflow to an XR-supported one when designing the PSS hardware. It will touch upon the 'switching cost' issue for XR applications in a multi-user setting. Eventually, it will discuss the designers' expectations and wishes when interacting with the virtual world (e.g., being able to manipulate an artefact using a head-mounted device in AR), moving past 'passive interactions' where individuals simply stare at a digital artefact

Location: Building C – 1st floor: Room C2 -105

1:45pm
4:45pm

SIG 2-05: Chapter Africa Design

Towards Creating a Design Society African Chapter

Bernard Shibwabo, Richie Moalosi, Samuel Boahen, Peter Oviroh, Panos Papalambros, Mugendi K. M'Rhithaa, Susanne Nilsson, Margareta Norell Bergendahl, June Madete Kenyatta

Motivation: The proposed workshop builds on activities undertaken under the Design Society's Africa-Design Initiative since 2019. Previous workshops and publications at ICED19, DESIGN 2020, ICED21, and DESIGN 2022 explored the state of the art and the needs for mutual learning activities on design for sustainable development in Africa. Several Barazas also took place; these were community-driven events led by members of the design community at large (a baraza is a Swahili word for a public meeting place). Other modalities of mutual learning have been discussed including workshops, short courses, on-site local events, knowledge repositories. Building upon these experiences, the need and desire for creating a formal Design Society African Chapter led by Africa-based members has been expressed and further encouraged by the Design Society Board of Management. An exploratory steering committee has been formed towards this goal. The proposed workshop will provide a forum for assessing progress to date, challenges and opportunities, and a plan for moving forward.

Objectives: The workshop's objectives are: (i) assess the current environment for forming an African Chapter including challenges and opportunities; (ii) explore strategic objectives and specific immediate objectives of a chapter, if formed; (iii) brainstorm different modalities of chapter activities to meet objectives and prioritize them for the short and long term; (iv) discuss chapter structure (steering committee etc.) per Design Society guidelines; (v) identify initial team and plan actions to undertake following the workshop.

Workshop Conduct: Preceding the workshop, we will invite the community to submit ideas in the form of a survey and also solicit short presentations or white papers. These will be shared prior to the workshop and select ones will be incorporated into the program to seed discussions and brainstorming. Specific topics to be addressed will be related to the workshop objectives described above. As many participants from developing countries will not have the resources to travel or pay workshop fees, we plan a hybrid event and anticipate a fee waiver for Africa-based participants.

Location: Building C - ground floor: Room C2 – 001

1:45pm
4:45pm

SIG 2-06: Collaborative Design

An interactive experiment to investigate a fundamental concept that defines collaborative design 2.0

Ian Whitfield, Ross Brisco, Dorothy Evans, Avril Thomson

Visualizations are often created, and used, to materialize what we as humans experience as abstract or iSuccessful collaborative engineering practices have demonstrated significant benefits to industry improving efficiency eliminating rework due to information inconsistencies managing complexity and automating parts of the collaborative design process Despite these benefits, collaborative endeavours fail due to obstacles such as sharing knowledge through ineffective communication methods co ordinating stakeholders with divergent objectives managing teams with cultural and leadership differences and configuring collaborative networks towards a long term and strategic vision Changing innovation landscapes have the potential to radically advance collaborative practices to develop more user centred, innovative and customised products in a timelier manner.

Description of activities and expected outcomes:
The aim of this workshop is to conduct an interactive investigation to explore the validity of a key concept that is considered to be fundamental to our understanding of Collaborative Design Workshop participants will engage in an innovative interactive experiment to test this concept. The first stage of the workshop will involve participants interacting within groups through the use of a well established and familiar collaborative design tool which has been adapted for online use within the workshop. The groups will be expected to complete one of approximately five different and easily understood design tasks. Once the group has completed the task, the participants will be instructed to collectively choose the solution that best satisfies the specification, and rate how well it does.

The second stage of the workshop will use two online tools to gather participants' views in relation to the outcome of the first stage. Participants will initially be invited to provide a qualitative opinion within their groups using the online tool Mentimeter to gather responses with respect to factors that define the effectiveness of the collaborative exercise. Participants will then be asked to complete an online survey using a set of Kansei Engineering adjectives that reflect their psychological response to the collaborative exercise. This survey will be conducted online to allow the immediate processing of the responses.

The third stage of the workshop will be to present the outcome of each of the stages. Participants will be provided with an explanation of what the experiment aimed to investigate, followed by the outcome of the collaborative design task from each of the groups. They will then be presented with each of the word graphs from Mentimeter. The analysis of the results from the Kansei Engineering survey will be presented to analyse the validity of this key concept. The final stage will involve exploring factors that influence, and are influenced by this fundamental concept. The intention of this is to create a sub map of the relationships between collaborative design factors.

Participation will be entirely voluntary, and ethical data collection practices will be adopted throughout the experiment. The results will be used as a basis to write a paper for publication at the DESIGN 2024 conference, and for adaptation for submission to the DESIGN SCIENCE journal.

Location: Building C - ground floor: Room C2 – 004

1:45pm
4:45pm

SIG 2-07: Design for Additive Manufacturing

Leveraging Data-Driven Design Methods to Support Complex and Multidisciplinary Design Scenarios in Additive Manufacturing

Tino Stankovic, Nicholas Meisel, Serena Graziosi

The digital essence of Additive Manufacturing (AM), and thus the possibility to quite quickly generate and store a significant amount of digital data, has led to a growing interest in studying how to exploit datadriven approaches to support process planning, optimization, and monitoring in AM. The need for more reliable technologies and defect-free and repeatable processes has also driven that interest. However, examples and insights on how such approaches could be leveraged to further unlock Design for AM (DfAM) freedom are still limited. Our current attitude toward data-driven AM technology may explain the reasons behind this gap; does data just serve as a means to analyze specific situations and make informed process decisions? Or is there a greater opportunitity to leverage data-driven design methods to help us exploit and master the complex and multidisciplinary design scenarios made available through AM? What design tasks and aspects are ready for a data-driven search space exploration? What role will the DfAM expert play after the massive introduction of computational algorithms? AM has also torn down barriers for multiscale design; hence there are significant differences in design strategies and representations among the length scales at which AM operates. It is, therefore, crucial to understand how to unify them and how ready data-driven approaches are to support this unification. The development of data-driven support technologies for AM is much more than an informed search of unconventional design solutions and alternatives within a theoretically unlimited space. It concerns tackling new design needs and finding reliable, effective, and sustainable solutions that only the design freedom allowed by AM can guarantee. Discussions are needed to clarify what data to use and how to combine them and elaborate on them. However, these discussions should also consider integrating these data into human-based intellectual processes driven by specific industrial and societal challenges. Effective data-driven solutions should be able to complement DfAM experts' existing design thinking. This workshop will challenge participants and lecturers to reflect on several open questions. How can we as researchers improve the ability of designers to utilize the complex relationships between different length scales and oviduct abstractions (architected materials, product geometries and functions) in AM? How can we enable the practical search of the underlying solution spaces using generative design? Which aspects of the design process are ready for AI-backed support? How will the design rationale be expressed within AI algorithms to support the DfAM innovation process? How can we develop design support methods that foster human creativity in the context of their design workflows while respecting all ethical issues regarding big data? Which competencies, skills, cross-domain knowledge, and methodological support are required to enable data-driven DfAM? The workshop will offer an opportunity for design practitioners to discuss state-of-the-art methods and tools to support data-driven DfAM and their implementation in the industry. The participants will be guided towards engaging the invited lecturers using these questions and pushed to reflect on how they can contribute to data-driven DfAM through their research activities.

TUESDAY 25th July 2023

PROGRAM
&
ABSTRACTS

24th International Conference on Engineering Design
Bordeaux, France, 24 - 28 July 2023

ICED23 Bordeaux

Time										
9:00am - 9:45am	**OC: Opening Ceremony**									
9:45am - 10:30am	**KN 01: Keynote: Complexity and System Design** Location: Bât D - RDC: Amphi AUBY Chair: Anja Maier **Complexity and System Design** *Olivier de Weck, MIT*									
10:30am - 11:00am	**CB 01: Coffee Break**									
11:00am - 12:30pm	**P - AM 01:** Architecture and New Materials Location: Bât C - RDC: Salle C2 - 004 Chair: Serena Graziosi	**P - DE 01:** Design Education and Training Location: Bât C - 3ème étage: Salle C2 - 308 Chair: Mickael Gardoni	**P - DE 02:** Gaining Design Experience Location: Bât G - Rez de jardin: Amphi MANON CORMIER Chair: Peter R.N. Childs	**P - DW 01:** AI enhanced design processes Location: Bât C - 1er étage: Salle C2 - 114 Chair: Christopher McComb	**P - I&S 01:** Design of Complex Systems Location: Bât C - 2ème étage: Salle C2 - 216 Chair: Steven Eppinger	**P - IBM 01: 3D** Printing Design Location: Bât C - 1er étage: Salle C2 - 106 Chair: Chris Snider	**P - S&R 01:** Strategy & Sustainable Design Location: Bât H - RDC: Amphi ASSELAIN Chair: Sophie Hallstedt	**P - S&R 02:** Circular Product Design Location: Bât A - RDC: Amphi BENZACAR Chair: Daniela Pigosso	**P - SD 01:** Systems Engineering Location: Bât C - RDC: Salle C3 - 002 Chair: Ola Isaksson	**P - SD 02:** Virtual Interface Design Location: Bât C - RDC: Salle C3 - 001 Chair: Stephan Husung
12:30pm - 1:45pm	**LB 02: Lunch Break**									
1:45pm - 2:30pm	**KN 02: Keynote: Towards an integrative approach to the study of a protected natural environment: The Lascaux Cave** Location: Bât D - RDC: Amphi AUBY Chair: Claudia Eckert **Towards an integrative approach to the study of a protected natural environment: The Lascaux Cave** *Delphine Lacanette, Bordeaux INP* *Colette Sirieix, University of Bordeaux*									
2:30pm - 3:30pm	**D - DE 03:** Empathy and Design Cognition Location: Bât G - Rez de jardin: Amphi MANON CORMIER Chair: Katja Thoring	**D - DW 02:** Review of State of the Art of Data Applications Location: Bât C - RDC: Salle C3 - 001 Chair: Massimo Panarotto	**D - H&W 01:** Supporting Patients Location: Bât C - RDC: Salle C3 - 002 Chair: Anja Maier	**D - HB 01:** Prototyping In Design Location: Bât C - 1er étage: Salle C2 - 106 Chair: Gordon Krauss	**D - IBM 02:** Applications of Additive Manufacturing Location: Bât C - 2ème étage: Salle C2 - 216 Chair: Roland Lachmayer	**D - M&P 01:** Working with Digital Tools Location: Bât C - 1er étage: Salle C2 - 114 Chair: Jonathan Cagan	**D - SC 01:** Design for DIY & Repairability Location: Bât A - RDC: Amphi BENZACAR Chair: Francesco Ferrise	**D - SC 02:** Sustainable and Risk Design Evaluations Location: Bât H - RDC: Amphi ASSELAIN Chair: Yuri Borgianni	**D - SD 03:** Research Design Methods Location: Bât D - RDC: Amphi AUBY Chair: Tobias Eifler	
3:30pm - 4:00pm	**CB 02: Coffee Break**									
4:00pm - 6:00pm	**P - DC 01:** Design Cognition Location: Bât C - 1er étage: Salle C2 - 106 Chair: Joshua Summers	**P - DW 03:** Human Factor and AI Location: Bât H - RDC: Amphi ASSELAIN Chair: John Gero	**P - DW 04:** Generative Design for Engineering Location: Bât C - 1er étage: Salle C2 - 114 Chair: Georg Hackenberg	**P - H&W 02:** Methods and Processes for Medical Applications Location: Bât C - 3ème étage: Salle C2 - 308 Chair: P. John Clarkson	**P - HB 02:** Agile Systems Development Location: Bât A - RDC: Amphi BERNARD Chair: Bryan Howell	**P - I&S 02:** Advancements in Systems Engineering 1 Location: Bât C - RDC: Salle C3 - 001 Chair: Jeffrey Herrmann	**P - IBM 03:** Design Innovation Location: Bât C - RDC: Salle C3 - 002 Chair: Gaetano Cascini	**P - M&P 02:** Design Validation Location: Bât C - 2ème étage: Salle C2 - 216 Chair: Andreas Hein	**P - S&R 03:** Addressing Sustainability Challenges in Design Location: Bât A - RDC: Amphi BENZACAR Chair: Elies Dekoninck	**P - SD 04:** Product Architecture Design 1 - Applications Location: Bât G - Rez de jardin: Amphi MANON CORMIER Chair: Dieter Krause
7:00pm - 9:00pm	**REC: Reception at Town Hall**									

Design in a complex world

Location: Building D - ground floor: Conference room AUBY

9:45am
10:30am

KN 01- Keynote : Complexity and System Design

Olivier de Weck, MIT, United States of America

*Session Chair: Anja Maïer, University of Strathclyde ,
United Kingdom and DTU-Technical University of Denmark*

The degree of complexity of today's products and systems is significantly higher than it was in the 20th century or earlier. This increased complexity, similar to what we see in highly evolved natural biological systems, yields higher levels of performance and potentially resilience. However, I will show that there are diminishing returns in further increasing complexity, because design effort increases super-linearly with complexity while approaching fundamental physical limits. In this talk I will postulate that Conservation of Complexity should be considered as the First Law of System Design, similar to conservation of energy in thermodynamics, or conservation of momentum in classical mechanics. I will show examples of design evolution for air-breathing engines, as well as digital printing systems to provide empirical evidence for this claim. In a nutshell, complexity should be explicitly quantified and tracked during the design process.

BIO

Olivier de Weck *is the Apollo Program Professor of Astronautics and Engineering Systems at the Massachusetts Institute of Technology (MIT). He earned degrees in Industrial Engineering from ETH Zurich (dipl. Ing. '93) and Aerospace Systems from MIT (SM '99, PhD '01) where he is the faculty director of the Engineering Systems Laboratory (http://systems.mit.edu) His main research is in Systems Engineering with a focus on how complex technological systems are designed and optimized and how they evolve over time. He has authored or co-authored over 400 publications for which he has been recognized with twelve best paper awards since 2004. He is a Fellow of INCOSE and AIAA and served as Editor-in-Chief for the journal Systems Engineering from 2013-2018. He is a former Senior Vice President of Technology Planning and Roadmapping at Airbus where he was responsible for roadmapping a $1-billion R&D portfolio for the world's largest aircraft manufacturer. His most recent book on Technology Roadmapping and Development was published by Springer-Nature in 2022. His passion is to improve life on our home planet Earth through research and education in design and systems engineering, while paving the way for humanity's future off-world settlements.*

Design in a complex world

Location : Building C - ground floor: Room C2 – 004

Additive Manufacturing

11:00am
12:30am

Session Chair: Serena Graziosi, Politecnico di Milano, Italy

Application of Bio-Bricks & its benefits

Priyabrata Rautray 1, Avik Roy 2, Boris Eisenbart 3
1 IIT Hyderabad; 2 KIIT School of Architecture and Planning; 3 Swinburne University

The practice-led research focuses on how agro-waste can be used to build a structure, gather relevant knowledge, and identify its various challenges. Based on the compressive strength of Bio-Bricks, it was decided to use a frame structure, and instead of using Bio-Bricks as a modular unit, the material used was cast in situ with the help of a specially designed mould. The roofing of the structure was also built using Bio-Bricks material over an MS frame. The prototype was plastered with cement mortar and finished with two coats of distemper paint. After the completion of the prototype structure, comprehensive documentation was done to analyse the data generated from the process to identify the desired improvements. A secondary study of sustainable building materials was done to understand the comparative strength and weaknesses of Bio-Bricks as construction materials. Based on the work done at different stages of construction, detailed lists of findings and inferences were drawn to improve the overall manufacturing process. The research project findings will help guide the future development of Bio-Bricks as a commercial building material

Optimisation of a design-to-fabrication framework for individualised homeless housing design in Melbourne, Australia

Nadia Haquillah, Deviana Anam, Linus Tan Swinburne University of Technology

Digital design tools and technologies offer new opportunities for designers to generate a diverse range of design solutions. Previous research have discussed the multifaceted use of such technologies for 1) rapid visualisations, 2) generating design options, and 3) predicting design solutions. However, such research have focused more on simplifying design for fabrication and less on the integration of individual needs in design processes. This research adopts a human-centric design approach to merge user-to-design and design-to-fabrication processes. Through a scoping review on homelessness, design, and fabrication, we contribute a user-design-fabrication framework devised for the specific and dynamic needs of homeless individuals living in Melbourne, Australia. Our findings suggests that to optimise digital design processes for individuals with specific and dynamic needs, designers need to understand, translate, and embed the social, design, and fabrication complexities of a design problem. Future research should therefore test the real-world application of our user-design-fabrication framework and evaluate the impact of such digital design processes, for the provision of more individualised homeless housing design solutions.

Design in a complex world

Location : Building C - ground floor: Room C2 – 004

Additive Manufacturing

11:00am
12:30am

Session Chair: Serena Graziosi, Politecnico di Milano, Italy

Systematic Classification Of Adaptive Façades – Preparing A Database

Michael P. Voigt, Daniel Roth, Matthias Kreimeyer, University of Stuttgart

Adaptive façades (AF) present a promising approach to reduce environmental impacts in the Architecture, Engineering, and Construction sector. However, the automatization of the façade produces new challenges as the complexity of the system increases. To support the early phase of interdisciplinary development, solution collections such as databases are helpful. Previous research identified that existing solution collections of AF do not meet the requirements that such a method demands. In the effort to develop an optimized database, this paper investigates how the state of the art can be structured in terms of content in order to present it in the database. Here, a set of design parameters is developed based on identified requirements and on the main characteristics of AF that were previously elaborated. This set offers a comprehensive perspective on the previously realized functions and mechanisms of AF and can also contribute to finding creative solutions in the form of new concepts by combining the design parameters in new ways. Finally, 40 case studies of previously implemented adaptive façades are used to evaluate the set of design parameters.

Operationalising concepts of digital twins on different maturity levels (foetal, child, adult) for the architectural design process

Gülbahar Emir Isik, Henri Hubertus Achten, Czech Technical University in Prague

A digital twin is the mapping of a physical twin between hybrid spaces. The lifecycle of digital and physical twins occurs through the concepts of foetal, child, and adult twins. This technology can be used to assist clients and designers with real-time data. The use of digital twin technology in architectural design can be realised at various stages, from design to operation. Designers will be able to gain knowledge of the past, present, and future using this technology. This will reveal possible design scenarios. In this study, a hypothetical scenario is designed, in which designers build a building while already having a digital twin template. To do this, Building Information Modelling (BIM) is used as a reference model for digital twins, along with the fidelity levels of digital twins and the level of detail-development of BIM. When designers want to design a new project related to their predecessors, they already use the same type of digital twin-building portfolio they can use for their new design. A digital twin will help optimise the new process. Therefore, the digital twin of a building with a similar building type can be used to extract relevant data for the design process.

Design in a complex world

Design Education and Training

Session Chair: Mickaël Gardoni, ETS Montréal, Canada

Fostering divergence during conceptual design with industrial-based students

Tijana Vuletic, Alexander «Freddie» Holliman, Avril Thomson, University of Strathclyde

Teaching the same design module to two different cohorts, traditional design students and industry-based students, the outcomes of the conceptual design stage has shown differences in divergence achieved, looking at both number and quality of concepts. The activities of both cohorts across two years are explored, combining on campus studio based teaching and online teaching, through comparison of teaching approaches for both cohorts and their effect on the design outcomes. Findings show that the traditional design students create significantly larger number of concepts, discussed in more detail and engage more fully in the divergence-convergence design process. Then the recommendations are provided for approaches and techniques that could be implemented to the industry-based student teaching to encourage divergence during idea generation. These include increased levels of studio work focused design work separated from industry needs, more structure and mandatory use of all instructed design techniques by inclusion in the assessment, increased focus on intermediate tasks and contextualisation of design terms to the fields they are familiar with.

Find the gap: An approach for visualizing and analysing design competencies in a university with interdisciplinary

Sumbul Khan, Immanuel Hendra, Shravya Thandlam Sudhindra, Nur Liyana Binte Abdul Muthalib, Lucienne Blessing, Singapore University of Technology and Design

Design education needs to be continually investigated and improved to stay relevant. The Singapore University of Technology and Design (SUTD) is a leading university focused on all elements of technology-based design. The overarching motivation of our research is to enhance design education curriculum at SUTD. Our research objectives are (1) to understand how design competencies are implemented in SUTD's curriculum and courses (2) to identify gaps in teaching of design competencies at SUTD. We analyse competencies in 28 design courses at SUTD. We develop the visualization and analysis of 12 skills grouped under two abilities from the Design competency assessment framework. Our main contributions are: (1) We present an approach to map the design competencies that are taught across design courses at a university with an interdisciplinary curriculum, (2) We present an approach for mapping design competency progression based on ITAE (Introduced, Taught, Assessed, Expected) categorization, (3) Based on the above, we provide preliminary findings on two skill gaps in the curriculum, substantiated with insights from interviews with course coordinators.

Design Education and Training

Location: Building C – 3rd floor: Room C2 – 308

11:00am
12:30am

Session Chair: Mickaël Gardoni, ETS Montréal, Canada

Comparing academics and practitioners Q & A tutoring in the engineering design studio

Ada Hurst 1, Shirley Lin 1, Claire Treacy 1, Oscar G. Nespoli 1, John S. Gero 2
1 University of Waterloo; 2 University of North Carolina, Charlotte

In the design studio, academic (professor) and practitioner tutors provide individual mentoring to students as they progress in their design projects. Prior studies suggest that design practitioners may follow a different design process compared to academics, but little is known about how this difference relates to their design tutoring. This study explores the similarities and differences in tutoring by academics and practitioners. We use a question-asking lens to characterize the tutoring styles of four tutors - two academics and two practitioners - over a five-week design project in an engineering design studio. We find that academic tutors ask questions at a significantly higher rate than practitioner tutors, suggesting a more question-centred tutoring style. We also find that proportionally more of practitioner tutors' questions are generative in nature, while the academic tutors employ more convergent thinking in their questioning. This may be an indicator of the practitioners' own design thinking, which might be more solution-focused than that of academics. These preliminary findings motivate future investigations of the relationship between differences in tutoring and impact on student design learning..

Re-thinking design representations in design education: an interview study with professional designers

Siw Eriksson, Pontus Wallgren, MariAnne Karlsson, Chalmers University of Technology

Design representations are important tools for designers in the design process. To help designers choose the appropriate representation, taxonomies have been proposed based on type, degree of fidelity, and when to use them. However, Design representations may also play an important role in designers' communication with users and enabling users as co-designers. Therefore, new taxonomies, focusing on design representations' potential mediating roles in collaborative design processes with users, have been developed. The purpose of this interview study, with twelve designers within Swedish industry, was thus to investigate how designers use design representations in communication with users in the design process. The study indicates that the designers mainly interacted with users in order for them to answer specific design questions or to evaluate design solutions. If design representations' value for facilitating communication and collaboration with users should be emphasized, we need to shift from teaching mainly taxonomies related to fidelity levels or when to use them in the design process, and rather educate future designers about design representations inherent potential to mediate and enhance the dialogue with users

Location: Building G - Ground floor: Conference room MANON CORMIER

Gaining Design Experience

11:00am
12:30am

Session Chair: Peter R.N. Childs, Imperial College London, United Kingdom

Assessing Eye Gaze Patterns between Intermediate and Advanced Design Sketchers

Bryan Howell, Asa River Jackson, Alexandra M. Edwards, Katherine Kilbourn-Barber, Kaylee Bliss, Addie Payne Morgan, Brigham Young University

One difficulty with sketching pedagogy is the tendency to assess growth according to outcomes, as opposed to processes. We assessed eye gaze patterns between advanced and intermediate design sketchers and anticipated correlations between eye-gaze practices and sketching proficiency. Participants sketched two different objects using analogue materials, a potted plant from memory, and a MacBook from observation.

The study utilised Tobii 3 adjustable eye-tracking glasses and Tobii Pro data processing software. Twenty-five design sketching students and six design sketching instructors participated in the study. Metrics measured include the quantity of reference line gazes, eye movement during line creation (targeting vs tracking), eye fixation duration, work checks per minute and subject gazes per minute.

The results show a difference in gaze patterns between intermediate and advanced sketchers, both in terms of practice and consistency. Eye-tracking sketching behaviours has revealed a new understanding of how teaching gaze habits could lead to improved methods of design sketching instruction.

Increasing Student Confidence through Experiential Design Exercises in Engineering Science Courses

Gordon Krauss, Harvey Mudd College

This study investigates the impact on student confidence of completing in-lecture engineering design activities focused on the application of specific engineering science topics within a materials engineering course. Many times, engineering science courses are taught with the expectation that the course content can be easily translated by students at a later time to apply in engineering design activities. By measuring student self-reported confidence across several related topics before and after completion of the in-lecture design exercises the impact of the exercises on student confidence has been quantified. On average, students have a lower than desired confidence in applying the specific materials engineering topics to a design problem after completing only the course content on the subject. Following completion of the related seventy-five minute design exercise, student confidence increased by a statistically significant degree. These results suggest that close integration of topical content learning with design application activity may be a useful method to improve engineering student confidence and, by extension, retention

Design in a complex world

Location: Building G - Ground floor: Conference room MANON CORMIER

Gaining Design Experience

11:00am
12:30am

Session Chair: Peter R.N. Childs, Imperial College London, United Kingdom

A Qualitative Investigation of Students' Design Experiences in a Work-Integrated Learning Setting

Jordan Nickel 1, Chris Rennick 1, Gregory Litster 2, Carol C.W. Hulls 1, Ada Hurst 1
1 University of Waterloo; 2 University of Toronto

Work-integrated learning (WIL) – a pedagogy that integrates academic studies with workplace experiences – presents an excellent opportunity for students to "deliberately practice" their design skills. To date there has been little investigation into the effect(s) of WIL experiences on developing novice designers' design skills.

We performed a series of longitudinal interview case studies following three engineering students through the course of a 4-month work term. Interviews were semi-structured to gather rich contextual descriptions of participant experiences designing in WIL settings. Transcripts were analysed using an iterative thematic analysis approach.

Results indicate specific areas where WIL helps develop novice designers' engineering design skills and mindsets beyond their early experiences in the engineering classroom. These include their experiences interacting with clients/users, the importance of project transition considerations, resource coordination, teamwork/collaboration, and the design process. We discuss how the structure of design tasks and their environment differ from the classroom experience, highlighting how WIL can supplement traditional design education.

How and Why Instructors Include and Exclude Social, Policy, and Ethical Considerations in Design Education

Madhurima Das 1, Jana I. Saadi 1, Marina Santos 2, Gillian Roeder 1, Anastasia K. Ostrowski 1, Stella Lee 3, Cynthia Breazeal 1, Catherine D'Ignazio 1, Maria Yang 1, Aditi Verma 4
1 Massachusetts Institute of Technology; 2 Wellesley College; 3 Johns Hopkins University; 4 The University of Michigan

Design and engineering are socio-technical enterprises used to solve real-world problems. However, students in these fields are often under-equipped to consider the ethical and societal implications of their work. Our prior work showed that these societal considerations are more consistently embedded in design pedagogy in non-engineering than in engineering courses at MIT. Here, we examine underlying causes for this through a survey of instructors (231 courses from 29 departments). The main contribution of this work is an analysis of whether and how instructors incorporate social, ethical, and policy considerations in design pedagogy. The majority of respondents (60.6%) included these topics in their courses, primarily through discussion of social justice, identity groups, and ethics. These concepts were included more in non-engineering courses (65.8%) than engineering courses (46.9%). Many instructors, especially in engineering, cited irrelevance as the reason for not engaging with these topics in their courses (86.1% compared to 44.2% in non-engineering). We suggest that instructors question this perception and use the examples provided as a starting point to explore integration of these concepts into their technical content.

Design in a complex world

AI enhanced design processes

Location: Building C – 1st floor: Room C2 – 114

11:00am
12:30am

Session Chair: Christopher McComb, Carnegie Mellon University, United States of America

Multisensor fusion-based digital twin in additive manufacturing for in-situ quality monitoring and defect correction

Lequn Chen 1,2, Xiling Yao 1, Kui Liu 1, Chaolin Tan 1, Seung Ki Moon 2
*1 Singapore Institute of Manufacturing Technology, A*STAR, Singapore; 2 School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore*

Early detection and correction of defects are critical in additive manufacturing (AM) to avoid build failures. In this paper, we present a multisensor fusion-based digital twin for in-situ quality monitoring and defect correction in a robotic laser-directed energy deposition process. Multisensor fusion sources consist of an acoustic sensor, an infrared thermal camera, a coaxial vision camera, and a laser line scanner. The key novelty and contribution of this work are to develop a spatiotemporal data fusion method that synchronizes and registers the multisensor features within the part's 3D volume. The fused dataset can be used to predict location-specific quality using machine learning. On-the-fly identification of regions requiring material addition or removal is feasible. Robot toolpath and auto-tuned process parameters are generated for defect correction. In contrast to traditional single-sensor-based monitoring, multisensor fusion allows for a more in-depth understanding of underlying process physics, such as pore formation and laser-material interactions. The proposed methods pave the way for self-adaptation AM with higher efficiency, less waste, and cleaner production.

AI vs. Human: The Public's Perceptions of the Design Abilities of Artificial Intelligence

Leah Chong 1, Maria Yang 2
1 Massachusetts Institute of Technology; 2 Massachusetts Institute of Technology

With the increasing implementation of artificial intelligence (AI) in the design process, it is crucial to understand how users will accept AI-designed products. This work studies how the public currently perceives an AI's design capability as compared to a human designer's capability by conducting an online survey of 205 people via Amazon Mechanical Turk. The survey collects the respondents' perception on 16 specific bicycle design goals, demographic information, and self-reported level of design and AI/ML knowledge. Findings reveal that people think an AI would perform worse than a human designer on most design goals, particularly the goals that are user-dependent. This work also shows that the higher people's self-reported level of knowledge in design and the older they are, the more likely they are to think an AI's design capability would exceed a human designer's capability. The insights from this work add to the understanding of user acceptance of AI-designed products, as well as human designers' acceptance of AI input in human-AI teams..

Design in a complex world

Location: Building C – 1st floor: Room C2 – 114

AI enhanced design processes

11:00am
12:30am

Session Chair: Christopher McComb, Carnegie Mellon University, United States of America

New Opportunities and Benefits in the Product Development Process using the Machine Learning based Direct Inverse Method for Material Parameter Identification

Paul Meißner, Thomas Vietor Institute for Engineering Design, Technische Universität Braunschweig

Finite element (FE) simulations can be used both in the early product development phase to evaluate the performance of developed components as well as in later stages to verify the reliability of functions and components that would otherwise require a large number of physical prototype tests. This requires calibrated material cards that are capable of realistically representing the specific material behavior. The necessary material parameter identification process is usually time-consuming and resource-intensive, which is why the direct inverse method based on machine learning has recently become increasingly popular. Within the neural network (NN) the generated domain knowledge can be stored and retrieved within milliseconds, which is why this method is time and resource-efficient. This research paper describes advantages and potentials of the direct inverse method in the context of the product development process (PDP). Additionally, arising transformation opportunities of the PDP are discussed and an application scenario of the method is presented followed by possible linkage potentials with existing development methods such as shape optimization.

Understanding the challenges around design activities that incorporate behavioral data.

Alejandra Gomez Ortega, Jacky Bourgeois, Gerd Kortuem, Delft University of Technology

Recently, methods and approaches such as Participatory Data Analysis, Data-Enabled Design, and Contextual Inquiry have highlighted how design activities can benefit from behavioral data. This data offers new ways to learn from what people do and how they do it, across time and space. However, behavioral data introduces changes and frictions to design activities and poses several challenges for designers to overcome. In this paper, we conduct two workshops with 18 expert designers, from industry and academia, to understand the nature of these challenges, beyond the technical aspects. We contribute by underlining the challenges and opportunities of incorporating behavioral data into design activities; including a design perspective on data, interacting with participants, and interacting with regulatory bodies. We translate our findings into opportunities for a better alignment between regulatory bodies, designers, and participants. We propose to harness the iterative nature of design activities and embedded it into a process that allows for continuous reflection, reassessment, and review of highly dynamic datasets.

Design in a complex world

Location: Building C – 1st floor: Room C2 – 114

AI enhanced design processes

11:00am
12:30am

*Session Chair: Christopher McComb, Carnegie Mellon University,
United States of America*

Enhanced findability and reusability of engineering data by contextual metadata

*Osman Altun 1, Pooya Oladazimi 2, Max Leo Wawer 1, Selina Raumel 3, Marc Wurz 3, Khemais Barienti 4, Florian Nürnberger 4, Roland Lachmayer 1, Iryna Mozgova 5, Oliver Koepler 2, Sören Auer 2
1Leibniz University Hannover, Institute of Product Development; 2Leibniz Information Centre of Science and Technology University Library; 3Leibniz University Hannover, Institute of Micro Production Technology; 4Leibniz University Hannover, Institut für Werkstoffkunde (Materials Science); 5Paderborn University, Data management in mechanical engineering*

Complex research problems are increasingly addressed by interdisciplinary, collaborate research projects generating large amounts of heterogeneous amounts of data. The overarching processing, analysis and availability of data are critical success factors for these research efforts. Data repositories enable long term availability of such data for the scientific community. The findability and therefore reusability strongly builds on comprehensive annotations of datasets stored in repositories. Often generic metadata schema are used to annotate data. In this publication we describe the implementation of discipline specific metadata into a data repository to provide more contextual information about data. To avoid extra workload for researchers to provide such metadata a workflow with standardised data templates for automated metadata extraction during the ingest process has been developed. The enriched metadata are in the following used in the development of two repository plugins for data comparison and data visualisation. The added values of discipline-specific annotations and derived search features to support matching and reusable data is then demonstrated by use cases of two Collaborative Research Centres (CRC 1368 and CRC 1153).

Design in a complex world

Location: Building C – 2nd floor: Room C2 – 216

Design of Complex Systems

11:00am
12:30am

Session Chair: Steven Eppinger, Massachusetts Institute of Technology, United States of America

Applications of Rotational Manipulators in the Manufacture and Characterization of Highly Curved Thin Films

Finn McIntyre 1, Mathieu Sellier 1, Shayne Gooch 1, Volker Nock 2, Nigel Sharplin 3
1 University of Canterbury, Mechanical Engineering Department; 2 University of Canterbury, Electrical & Computer Engineering Department; 3 Infact Limited, Christchurch, New Zealand

What do common devices such as smartphones, CD's and solar panels all have in common? They are all examples of innovative technology that is still limited to flat, rigid geometries. This is primarily due to the limitations of the manufacturing processes used to create components within these devices, key among them the thin polymer films produced through spin coating.

Spin coating is a technique used due to its ability to effectively create uniform films on the scale of micro or nanometres. However, it relies on a planar substrate to produce uniform layers, thus restricting the design of components manufactured using this process to simple, flat objects. As the requirement for curved device geometries expands, complex alternative fabrication methods are being implemented in industry.

For spin coating to remain relevant, a viable process for controlling the fluid flow over curved surfaces must be developed. This research investigates the hypothesis that coating distributions can be controlled through optimized rotation of a curved substrate. Where a multi-axis rotational manipulator and novel characterization system have been developed to investigate the fabrication of curved devices using the improved spin coating technique

Preliminary design of non-linear systems based on Global Sensitivity Analysis and Modelica language.

Bruno Vuillod 1,2, Enrico Panettieri 2, Ludovic Hallo 1, Marco Montemurro 2
1 French Atomic Energy Commission; 2 Arts et Metiers Institute of Technology, Univ. Bordeaux, CNRS, Bordeaux INP, Hesam Universite, I2M, UMR 5295

In the last few years, the growing need of highly reliable and time-effective strategies to perform preliminary design of complex systems has led industries to adopt the Model Based System Engineering (MBSE) approach. In MBSE, systems are split into multiple sub-systems and the relevant physical phenomena are described via analytical or numerical models. When a significant number of design variables are to be considered, a smart approach to reduce the number of analyses to perform would be to make use of the Global Sensitivity Analysis (GSA) to higlight those variables that have a more significant influence on the system output. Moreover, an even more significant reduction of computational cost to perform the GSA can be achieved if the complex system modelled via the MBSE approach is exported under the Functional Mock-Up Interface (FMI) norm. In this context, this paper proposes an original approach to address the study of two constructive solutions of an acceleration measuring device typically used on airbags for which the use of a new solution characterized by a porous material is compared with a classical one..

Design in a complex world

Design of Complex Systems

Location: Building C – 2nd floor: Room C2 – 216

11:00am
12:30am

Session Chair: Steven Eppinger, Massachusetts Institute of Technology, United States of America

When is a robot a cobot? Moving beyond manufacturing and arm-based cobot manipulators

Matthias Guertler 1, Laura Tomidei 1, Nathalie Sick 1, Marc Carmichael 2, Gavin Paul 2, Annika Wambsganss 1, Victor Hernandez Moreno 1, Sazzad Hussain 3
1 University of Technology Sydney: Centre for Advanced Manufacturing; 2 University of Technology Sydney: Robotics Institute; 3 Centre for Work Health and Safety, NSW Department of Customer Service

Collaborative robots ("cobots") have attracted growing attention in academia and industry over the last years. Due to in-built safety features and easy programming, they allow for close human-cobot collaboration and support e.g. flexible manufacturing. However, the lack of a common understanding what a cobot is along with its traditional focus on arm-based cobots complicates further research and industry adoption. Thus, this paper analyses the variety of definitions in literature incl. standards and practice examples to derive a consistent and holistic definition and taxonomy of what a collaborative robot is. Aside from contributing a structured overview of various forms of human-robot collaboration, this builds an important foundation for future research as it systematically differentiates different cobot types. Companies and other organisations will benefit by a better understanding of what type of cobot they need and how to ensure safe collaboration.

Dealing with extreme requirement values: What methods to design school chairs and offshore wind turbines have in common

Andreas Florian Haselsteiner 1, Klaus-Dieter Thoben1, Lucienne Blessing 2
1 University of Bremen, Institute for Integrated Product Development; 2 Singapore Univeristy of Technology and Design (SUTD), SUTD-MIT International Design Centre

Many designs are "driven" by requirements that describe maximum or minimum values of high-variability variables that must be considered. In ergonomics, minima and maxima of anthropometric variables like body height shape the design of a product. Similarly, in structural design, the highest environmental loads that can be expected during the lifetime of a product drive the design. Consequently, a wide range of methods that help designers deal with extreme requirement values has been developed. In this paper, we review these methods and propose a model for the process of dealing with extreme requirement values. The model comprises two broad stages. In the first stage, requirement values are statistically defined and in the second stage, a design is synthesized and evaluated against the requirement values. Throughout the paper, we use two examples: the design of an ergonomic chair and of an offshore wind turbine. We focus on how requirement values are defined for these two products and how they are used throughout the design process. Although these products are vastly different, both are designed by statistically deriving requirement values and then systematically designing against these values.

Design in a complex world

3D Printing Design

Location: Building C – 1st floor: Room C2 – 106

11:00am
12:30am

Session Chair: Chris Snider, University of Bristol, United Kingdom

Creating an open-source, low-cost composite feeder design to improve filament quality of high-performance materials to be used in Fused Filament Fabrication (FFF)

Henrik H. Øvrebø, Svein-Andre Koldre, Ole S. Nesheim, Sindre Wold Eikevåg, Martin Steinert, Christer W. Elverum NTNU

Composite filaments are getting increased attention in additive manufacturing (AM). More and better solutions for filament production are needed to assist researchers in discovering new materials capable of producing AM-made high-performance parts. This article presents a method for producing composite filament, including an open-source, low-cost automatic composite feeder designed to increase the accuracy and quality of the filament. The feeder includes a fibre screw designed through an iterative prototyping process to accurately control the filament's fibre percentage while reducing lumps' occurrence in a single step. An experiment evaluating the quality of filament made of Polylactic Acid (PLA) and carbon fibre (CF) tested the use of the feeder compared to manual mixing. Filament with a nominal diameter of 2.85mm with 4.5%, 7.9%, 11.2% and 14.5% CF was made. The results suggest that the composite feeder improved the filament quality. The filament diameter RMSE value was reduced from 0.08 to 0.06 and 0.15 to 0.13 for both 4.5% and 11.2%, respectively. The article concludes that the feeder design may help researchers develop and discover new materials while improving the quality of the filament.

Analysis of the differential-growth method's potential for designing complex heat-transferring walls for compact heat exchanger

Alexander Seidler, Stefan Holtzhausen, Maximilian Sander, Kristin Paetzold-Byhain
Technische Universität Dresden

Water scarcity and resource depletion can be expected during the climate crisis. Therefore, thermally loaded processes in particular, must be made more efficient in the future. Heat exchangers will play a key role in this optimization process. More efficient designs allow a greater heat flow to be removed from processes while mass flows remain constant. In this context, the heat-transferring wall of heat exchangers is a focus of current research on the design of heat exchangers. The aim is to increase the heat-transferring surface of the wall as much as possible and to keep the design space as compact as possible. Therefore, this study investigates the suitability of the differential-growth method for generating complex heat-transferring walls for heat exchangers using CFD-analysis. Firstly, a framework for generating the wall structures and a computational model for predicting the design influence of such structures for the thermal and fluid-dynamic behavior of the heat exchanger are presented. Thereby, the potential of such wall structures is analyzed in this study. Furthermore, the study identified weaknesses of such walls designed with the differential-growth method, which should be the focus of future investigations.

Location: Building C – 1st floor: Room C2 – 106

3D Printing Design

11:00am
12:30am

Session Chair: Chris Snider, University of Bristol, United Kingdom

Reducing prototype fabrication time through enhanced material extrusion process capability

Georgia Rose Parry, Harry James Felton, Robert Ballantyne, Shuo Su, Ben Hicks University of Bristol

3D printing is a widely used technology for automating the fabrication of prototypes. The benefits are wide reaching, and include low required expertise, accurate geometric form and the processibility of many materials. However, production of certain forms – especially large forms – can be slow. From review of the sub-systems, the hotend is commonly found to be the limiting factor. To improve this, a modified nozzle design is considered that incorporates a flat copper plate within the flow stream. Analytical simulation was used to guide this design before experimental methods validated the modifications. The maximum volumetric rate for the standard hotend nozzle is 14 mm3/s. The best performing modified nozzle increased the maximum volumetric flow rate to 26 mm3/s – an 86% increase. A series of popular parts were further considered, demonstrating a maximum ~48% fabrication time reduction, and a mean of ~23%. This enables 3D printed prototypes to be made more efficiently – both with regards to the design cycle and energy use – and allows designers to use the technology more rapidly than previously possible. By extension, this improves the efficiency of the design process.

Towards realistic numerical modelling of thin strut-based 3D-printed structures

Satabdee Dash, Axel Nordin Lund University

The as-built geometry and material properties of parts manufactured using Additive Manufacturing (AM) can differ significantly from the as-designed model and base material properties. These differences can be more pronounced in thin strut-like features (e.g., in a lattice structure), making it essential to incorporate them when designing for AM and predicting their structural behaviour. Therefore, the aim of this study is to develop a numerical model with realistic characteristics based on a thin strut-based test artefact and to use it accurately for estimating its compressive strength. Experiments on test samples produced by selective laser sintering in PA 1101, are used to calculate geometrical deviations, Young's modulus, and yield strength, which are used to calibrate the numerical model. The experimental and numerical results show that the numerical model incorporating geometrical and material deviations can accurately predict the peak load and the force-displacement behaviour. The main contributions of this paper include the design of the test artefact, the average geometrical deviation of the struts, the measured material data, and the developed numerical model..

Design in a complex world

3D Printing Design

Location: Building C – 1st floor: Room C2 – 106

11:00am
12:30am

Session Chair: Chris Snider, University of Bristol, United Kingdom

Vibration Reduction of a Hammer Drill with a Top-Down Design Method

Philip Le, Duo Xu, Anand Vazhapilli Sureshbabu, Markus Zimmermann
Technical University of Munich

Designing vibrating systems is challenging due to component interaction. One approach to reduce the resulting complexity is top-down design where requirements on components are formulated such that the overall system achieves the design goal. Previous work showed how to derive quantitative and solution-neutral requirements on components of a vibrating system, expressed as permissible ranges of impedance. This work adapts the methodology to a practical use case and provides a concrete technical solution: A hammer drill that can cause white finger syndromes to users is equipped with an appropriate vibration absorber. The hammer drill is represented by a lumped mass model and validated using experimental data of a reference design. Solution-neutral and quantitative component requirements on the overall dynamics of the vibration absorber expressed by impedance are derived. They provide a clear target for the component design. A vibration absorber in form of a Tuned Mass Damper (TMD) is designed accordingly. The final design is validated experimentally and shown to reduce the vibration by 47%.

Location: Building H - ground floor: Conference room ASSELAIN

11:00am
12:30am

Strategy & Sustainable Design

Session Chair: Sophie Hallstedt, Chalmers University of Technology, Sweden

Laying the foundations for a methodology to integrate and manage the Corporate Social Responsibility issues of a company in the Product Development Process

Anne-Laure Capomacci o1,2, Tatiana Reyes Carrillo 1, Sophie Richet 2
1 Université de Technologie de Troyes, Centre de Recherches et d'Etudes Interdisciplinaires sur le Développement Durable, Troyes, France; 2 Stellantis, Centre technique de Vélizy, France

Manufacturing companies are urged to take responsibility for their impacts on the environment and on society, to contribute to a more sustainable development. The concept of Corporate Social Responsibility (CSR) has therefore gained a lot of interest in the last decades. The Product Development Process (PDP) is a key activity in the operationalization of CSR in a company. However, little is known about the capabilities needed for companies to integrate and manage their CSR issues in their PDP. Therefore, this article aims at contributing to (1) identifying the capabilities to integrate and manage the CSR issues during the PDP, and (2) providing a maturity model to assess the level of capabilities for the integration of the CSR issues in the PDP. Insofar as CSR aims at contributing to sustainable development, the existing literature on capabilities for integrating sustainability in the PDP has been studied and taken as a basis to identify the capabilities for integrating and managing CSR in the PDP. A maturity model has then been built based on these capabilities. This contribution lays the foundation for a methodology to support companies in the improvement of their maturity level in terms of CSR-PDP interaction.

Complex Systems Design : Sustainability Challenges For Shipbuilding

Anne Bouyssou 1, Capt./Dr. Raphaël Baumler 2, Dr. Anna Öhrwall Rönnbäck 3
1 Luleå University of Technology; 2 World Maritime University; 3 Luleå University of Technology

Ships are complex technical systems resulting from large scale and scope projects in which integration plays a key role, particularly because trade-offs have to be made between conflicting objectives.
Merchant ships are usually built with a perspective of twenty-five years of service. Ship owners detail their requirements and ship specifications in line with their strategy to remain competitive on specific segments of the shipping markets. Ships serve and organize global trade flows. The rise in environmental regulations and technological changes generate unprecedented uncertainties for ship owners.
Ships do not follow the usual systems engineering process, as there is no full-scale prototyping. Rules and standards deeply influence the design of ships and limit the possibilities to 'think outside the box'. The purpose of this paper is to present environmental drivers relating to the operation of the ship which have, or will have, an influence on the way it is designed.

Design in a complex world

Location: Building H - ground floor: Conference room ASSELAIN

11:00am
12:30am

Strategy & Sustainable Design

Session Chair: Sophie Hallstedt, Chalmers University of Technology, Sweden

Identification of Perceived Relationships Between Environmental Performance Indicators in Ecodesign Projects: the Case of Rail Infrastructure Projects

Joseph Mansour Salamé 1, Yann Leroy 1, Michael Saidani 1,2, Isabelle Nicolaï 1
1 Laboratoire Genie Industriel, Université Paris-Saclay, CentraleSupélec, France; 2 Department of Industrial and Enterprise Systems Engineering, University of Illinois at Urbana-Champaign, USA

Sharing information between stakeholders is a critical success factor for ecodesign projects. This sharing is based on indicators that can be interrelated, i.e., impacting each other.
This article focuses on the perception of environmental performance indicators' relationships during the design phase of projects. It uses a DEMATEL approach combined with a graph-database visualization linking environmental performance indicators. While the DEMATEL approach highlights the critical environmental indicators, the graph-based visualization maps the primary interrelations of these factors and defines the best scale to manage them. The novelty here lies in the complementary use of these two methods to facilitate environmental project monitoring.
This research is applied to rail infrastructure projects. The main results insist on land optimization, landscape insertion, carbon footprint, economic benefits, and biodiversity measures as critical factors when designing these projects. The graph-based visualization maps the main oriented links between indicators, allowing managers to identify the gaps between the perceived knowledge and the ground truth, facilitating their project monitoring.

A multi-objective decision-making approach to support the design of social innovations in the Energy sector

Basma Samir, Audrey Abi Akle, Iban Lizarralde, ESTIA

Social innovations in the energy sector (SIE) are essential for accelerating the transition to clean, renewable, and democratic energy while encouraging citizens' involvement. However, SIE lacks clear boundaries, making it challenging to make design decisions. Clear and effective design decisions can help identify opportunities and constraints that may impact the success of social innovations. To support decision-making in SIE design, this paper proposes a multi-objective decision-support model based on the definition and exploration of the SIE design space. The model integrates various objective functions related to economic, environmental, and social perspectives, to ensure that selected solutions are tailored to the needs of citizens. By exploring the SIE design space, the model allows designers to evaluate the feasibility and effectiveness of different design options and select the most suitable solutions. To illustrate the proposed approach, this paper applies the model to a specific case of SIE: photovoltaic self-consumption. The findings of this paper provide a decision support model to assist SIE designers in making informed design decisions.

Design in a complex world

Location: Building H - ground floor: Conference room ASSELAIN

11:00am
12:30am

Strategy & Sustainable Design

Session Chair: Sophie Hallstedt, Chalmers University of Technology, Sweden

Potentials and goals of models in strategic product planning and innovation management

Prof. Dr.-Ing Iris Gräßler, Anna-Sophie Koch, Alena Marie Tušek
Paderborn University, Heinz Nixdorf Institute

New trends and technologies in product creation increase complexity, but at the same time create new potentials such as efficiency rise in task processing by Artificial Intelligence. Established models in the early phase of product creation such as the W-model or the Aachener Innovation Management model, do not fully exploit these new potentials in the field of strategic product planning and innovation management (SPPIM). For this reason, existing models are analysed in SPPIM in order to derive a requirements profile consisting of potentials and goals for a new model. A new model in SPPIM lays the foundation to support companies in enabling a more efficient task fulfilment by taking advantage of new technologies and trends. To guide the development of advanced SPPIM models, the derived potentials and goals are applied to the guideline VDI 2220:1980.

Design in a complex world

Location: Building A - ground floor: Conference room BENZACAR

11:00am
12:30am

Circular Product Design

Session Chair: Daniela Pigosso, Technical University of Denmark, Denmark

Exploiting the sustainability potential of modular products by integrating R-imperatives into product life phases

Richard Breimann 1, Christoph Rennpferdt 2, Sven Wehrend 2, Eckhard Kirchner 1, Dieter Krause 2
1 Institute for Product Development and Machine Elements (pmd), Technical University Darmstadt; 2 Institute of Product Development and Mechanical Engineering Design (PKT), Hamburg University of Technology

Climate change and the growing consumption of natural resources has made it increasingly clear that engineering must focus on the development of more sustainable products. To do so, the methodologies for developing products need to address sustainability. However, many of the frequently used method-ologies, such as Modular Function Deployment (MFD) or the Life Phases Modularisation (LPM), do not do that sufficiently. The product life phases, these methodologies are based, only address sustainability in the form of recycling. That is why a broader approach to sustainability, such as the R-imperatives, is not considered. Therefore, in this contribution, the model of product life phases is extended by in-tegrating the R-imperatives. Furthermore, the module drivers resulting from the extended product life phases that are necessary to apply the MFD and the LPM are developed. Finally, the positive impact of the developed module drivers on the product architecture is shown by applying the resulting method onto an industrial example.

Circularity of plastics through ecodesign : the case of French WEEE

Nicolas Nève 1, Carole Charbuillet 2, Stéphane Pompidou 3, Nicolas Perry 2
1 Arts et Métiers Institute of Technology, University of Bordeaux, CNRS, Bordeaux INP, I2M Bordeaux, F-33400 Talence, France; 2 Arts et Métiers Institute of Technology Chambéry, University of Bordeaux, CNRS, Bordeaux INP, I2M Bordeaux, F- 33400 Talence, France; 3 University of Bordeaux, CNRS, Arts et Métiers Institute of Technology, Bordeaux INP, I2M Bordeaux, F-33400 Talence, France

While innovation in waste treatment processes continue to advance, plastics are still often put aside in comparison to other materials. It is especially the case for WEEE-plastics: as they are included in complex equipment, their recovery is disregarded, in aid of critical metals and rare earths. The recycling of plastics is hindered by the low re-integration rate of these materials, due to concerns around their quality and their availability. Ecodesign of EEE thus seems to be a robust solution. This paper details two approaches to assess product design, by respectively evaluating the product recyclability and the implementation of predefined ecodesign guidelines. Based on these methods, the construction of a quality standard for recycled plastics in France is presented. The definition of the quality includes mechanical properties, but chemical, logistics, and regulatory aspects are also at stake. Eventually, ecodesign indexes and indicators are selected, and a method for their formal construction is proposed. The goal of this study is to provide ways to assess the overall quality and usability of recycled plastics, along with design for circularity methods to integrate them in new manufactured products.

Location: Building A - ground floor: Conference room BENZACAR

11:00am
12:30am

Circular Product Design

Session Chair: Daniela Pigosso, Technical University of Denmark, Denmark

Examining the role and future potential of design for disassembly methods to support circular product design

Giovanni Formentini 1, Devarajan Ramanujan 1,2
1 Department of Mechanical and Production Engineering – Design and Manufacturing, Aarhus University, Katrinebjergvej 89 G-F, 8200 Aarhus N, Denmark; 2 Centre for Digitalisation, Big Data and Data Analytics, Aarhus University, Aarhus 8200, Denmark

Design for disassembly (DfD) approaches are crucial in supporting the industrial circular economy transition. In literature, a great amount of DfD methodologies is available, however, it is still not clear how they can be used to improve product circularity. To address this gap, our work proposed a systematic literature review of DfD methodologies applied in the field of product design with the aim to provide an overview of the topic in the last decade (i.e., from 2012 to 2022) in terms of methods applicability (i.e., design phase), required parameters and integration capability with circularity assessment. As a result, the paper shows that DfD methods are mainly used in the later design phase to improve product sustainability performances, but a method that simultaneously considers DfD and CE is currently missing. Based on the obtained results, we outlined the requirements that a new DfX method would need to consider both DfD and CE simultaneously. Finally, we proposed a modified version of the butterfly diagram in which DfD parameters are linked to CE indicators to help visualize the connection between the two areas..

Beyond the overview effect: a virtual reality experience for sustainability awareness in decision-making

Giulia Wally Scurati 1, Nicolò Dozio 2, Francesco Ferrise 2, Marco Bertoni 1
1Blekinge Tekniska Högskola, Department of Mechanical Engineering; 2Politecnico di Milano, Department of Mechanical Engineering

The challenges of sustainable development require a consistent transformation of decision-making practices in society and in the industry. In this regard, Virtual Reality (VR) is an effective tool, providing experiences that are not accessible in the real world. The overview effect is a feeling of interconnectedness and responsibility towards our planet and its inhabitants described by astronauts after seeing the Earth during spaceflights. We present a VR application merging the overview effect with data visualization. We illustrate the design process and perform a pilot test to assess the emotions raised by the VR experience. Furthermore, we report feedback from design engineering and sustainability experts discussing the applications' potential in decision-making contexts, including product development processes.

Design in a complex world

Systems Engineering

Location: Building C - ground floor: Room C3 – 002

11:00am
12:30am

Session Chair: Sandro Wartzack, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

Optimizing requirements for maximum design freedom considering physical feasibility

Eduardo Rodrigues Della Noce, Markus Zimmermann, Technical University of Munich (TUM)

Solution spaces are sets of designs that meet all quantitative requirements of a given design problem, aiding requirement management. In previous works, ways of calculating subsets of the complete solution space as hyper-boxes, corresponding to a collection of permissible intervals for design variables, were developed. These intervals can be used to formulate independent component requirements with built-in tolerance. However, these works did not take physical feasibility into account, which has two disadvantages: first, solution spaces may be useless, when the included designs cannot be realized. Second, bad designs that are not physically feasible unnecessarily restrict the design space that can be used for requirement formulation.

In this paper, we present the new concept of a requirement space that is defined as the largest set of designs that (1) allows for decomposition (e.g., into intervals when it is box-shaped), (2) maximizes the useful design space (good and physically feasible), and (3) excludes the non-acceptable design space (bad and physically feasible). A small example from robot design illustrates that requirement spaces can be significantly larger than solution spaces and thus improve requirement decomposition.

Mitigating uncertainty in conceptual design using operational scenario simulations: a data-driven extension of the EVOKE approach

Alessandro Bertoni, Blekinge Institute of Technology

The paper presents an approach where the iterative replication of Discrete Event Simulations on future operational scenarios is used to derive data-driven design merit functions. The presented contribution proposes an extension of the EVOKE (Early Value Oriented Design Exploration with Knowledge Maturity) approach determining when and how the experience-based judgment about maximization, minimization, optimization, and avoidance functions, correlating value drivers and quantified objectives, can be substituted by data-driven mathematical functions obtained by scenarios simulations. The approach is described through a simplified case concerning the development of autonomous electric vehicles to complement the public transport system in the city of Karlskrona in Sweden. The consideration of value drivers and quantified objectives presented is meant to support a preliminary screening of potential design configurations to support the definition of high-level product and system-related functional requirements, to be run before a more detailed conceptual design analysis.

Design in a complex world

Location: Building C - ground floor: Room C3 – 002

Systems Engineering

11:00am
12:30am

Session Chair: Sandro Wartzack, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

A new research protocol for using system maps in systemic design research

Stine Moons, Esther Noëth, Els Du Bois, Alexis Jacoby, Universiteit Antwerpen

System maps are established tools in design practice and education as well as non-design research, both as a process and an outcome of systemic analysis and synthesis. Applying causal loop diagrams (CLD's) in (systemic) design research could be of great value to tackle the growing societal complexity. At this moment there is, however, no clear research protocol to include the rich data necessary for systemic research and ensure a scientifically valid system map in the context of design research. In this paper, we propose a protocol using CLD's as a research method and outcome in design-inclusive research. The protocol synthesises rich data from qualitative research in a way that the representation yields higher validity compared to the regular approach to systems mapping, using a process of reflection and iteration on boundary setting. An iterative process of qualitative research methods with lean validation methods was used to come to a conceptual proposal. The protocol can support systemic design researchers and practitioners to include a scientifically grounded CLD in the explorative research actions phase, thus bridging the research towards a phase of creative design actions.

Compositional Models for the Internet of Things

Spencer Briener1, Jooik Jung 1, Eswaran Subrahmanian 2,1, Ram Sriram 1
1 National Insititute of Standards and Technology; 2 Carnegie Mellon University

The modularity of components has enhanced the ability to create IoT systems by composing them from off the shelf. However, the breadth of technological choices and capabilities of component devices has made designing these systems harder to select, compose, implement and test, especially for dynamic systems. In this paper, we adopt formal tools from category theory (CT), a branch of mathematics whose central tenet is compositionality, to generate models for IoT systems. More specifically, we introduce a port-graph operad to represent the architectural designs of IoT systems. We use presheaf categories to construct generic IoT schemas to support modularity. Given this information, we briefly describe its relationship to control strategies of dynamical systems that model the interaction of components. Our approach balances genericity and specificity, providing interlinked schematic representations of system architecture and component representation.

Design in a complex world

Location: Building C - ground floor: Room C3 – 001

Virtual Interface Design

11:00am
12:30am

Session Chair: Stephan Husung, Technische Universität Ilmenau, Germany

Free-energy model of sense of agency for human-machine interface design based on comparator model

Kensaku Taniyama, Hideyoshi Yanagisawa, The University of Tokyo

Sense of agency is the sense that one is causing an action. The increase in machine or system autonomy leads to an increase in the loss of sense of agency for the operation causing the loss of pleasure in the operation or sense of responsibility for the consequences of operations. Designing a sense of agency is necessary, especially in the context of machine autonomy. This calls for the control of the sense of agency, which requires the construction of a model to predict the sense of agency and establishing a design methodology to manipulate the factors of sense of agency. We propose the mathematical model that predicts the sense of agency in a human-machine system based on the comparator model and free-energy principle and what to design to enhance the sense of agency. Proposed model explains the effects of prediction error, prediction uncertainty, and observation uncertainty for body, machine, and environment feedback on the sense of agency. The model generally reveals the interaction effect between prediction error and prediction uncertainty and between prediction error and observation uncertainty. The model prediction can be widely applied as a design guide for enhancing sense of agency of human-machine interfaces.

Effects of Immersive Virtual Reality in Enhancing Creativity

Vijayakumar Nanjappan, Akseli Uunila, Jukka Vaulanen, Julius Välimaa, Georgi V. Georgiev
Center for Ubiquitous Computing, University of Oulu, Finland

In recent years, the use of virtual reality (VR) has been a promising opportunity to improve the immersive experience in virtual environments. In this study, we explore the effectiveness of immersive VR experiences on an individual's creativity. To do this, we first identified the characteristics of VR that are closely related to creative performance. Considering these factors, we designed and implemented the interaction method and the three outdoor and indoor virtual environments (Wilderness, City Park, and Office). We evaluated the effectiveness of the virtual environments with 12 participants. The user study results show that outdoor and indoor immersive virtual experiences improved their creativity skills. We concluded by analysing how factors such as simulator sickness and perceived workload influence creativity levels. Moreover, our study showed the potentiality of using immersive virtual environments to enhance individuals' creative performance.

Location: Building C - ground floor: Room C3 – 001

Virtual Interface Design

11:00am
12:30am

Session Chair: Stephan Husung, Technische Universität Ilmenau, Germany

How Does Virtual Reality (VR) Facilitate Design? A Review of VR Usage in Early-Stage Engineering Design

Ting Liao 1, Jinjuan She 2
1 Stevens Institute of Technology; 2 Miami University

Virtual reality (VR) has been widely used in engineering design in different ways. It has the potential to enhance some design aspects, such as visualization and interaction, but might be incapable of solving the others. There are no consensus or general guidelines on how VR can facilitate design processes. This paper aims to understand how VR is currently used in engineering design at an early stage, so that researchers and practitioners can better know when and how to use VR for efficient design activities. Specifically, this paper reviews the research questions and applications addressed by using VR technology. The study helps identify the design questions currently studied, and gaps to be filled in order to use VR effectively for optimal design outcomes. This review also provides guidelines about when and how to use VR in design research and practices.

VR or Not? Investigating Interface Type and User Strategies for Interactive Design Space Exploration

Ananya Nandy 1, James Smith 1, Nicholas Jennings 1, Mike Kuniavsky 2, Bjoern Hartmann 1, Kosa Goucher-Lambert 1
1 University of California, Berkeley; 2 Accenture Labs

Computational design tools allow the generation of vast numbers of possible designs, entrusting the human designer with describing constraints or specifications to guide exploration of the design space. Designers can have many different decision considerations when conducting this type of exploration, including form, function, users, or context. In this work, we investigate strategies that emerge when people are tasked with exploring a large design space within either a non-immersive (2D) or immersive (VR) interface and equipped with action-based interactions to set or envision specifications related to their considerations. Results from a 28 participant user study uncovers that people have varying strategies to enact their decision considerations that are not unique to the type of interface. However, the interfaces differ in perceptions of enabling breadth or depth of exploration holistically, with preference towards 2D interfaces to compare options, and VR to understand single designs. These results have implications for the user experience of systems that allow designers to explore the outputs of large design spaces, both at the interaction and interface levels.

Design in a complex world

Location: Building D - ground floor: Conference room AUBY

1:45pm
2:30pm

KN 02 - Keynote : Towards an integrative approach to the study of a protected natural environment: The Lascaux Cave

Delphine Lacanette, Bordeaux INP, France
Colette Sirieix, University of Bordeaux, France

Session Chair: Claudia Eckert,
The Open University, United Kingdom

The Cave of Lascaux is a UNESCO World Heritage Site due to the exceptional quality of the paintings and sculptures that decorate its walls, dating back 20,000 years. Since its closure in 1963, the cave has benefited from special conservation measures for its rock art, under the supervision of a scientific committee. The I2M laboratory has acquired more than 50 years of climatic data thanks to monitoring in the cave and more than 10 years of geophysical data in the immediate external environment of the cave. The combination of thermal studies, numerical simulation, and geophysical skills, as well as the large amount of validation data, allows us to consider a global project to study heat and mass transfer in the rock surrounding the cave. Geophysics provides information on the heterogeneity of the rock, which must be related to the thermo-physical properties (in particular the diffusivity) of the different materials traversed by the thermal waves coming from the surface. The temperature data inside the cave is necessary to model the transfers in the rock and to provide boundary conditions at any point of the air/rock interface of the cave. The simulation of thermo-aerodynamic flows in the cave is made possible by the knowledge of these temperatures and the consequent work to consider the complex morphology of this underground environment. The applications for conservation are numerous: in addition to a better understanding of the phenomena of alteration of the walls, this work will be able to predict behaviors that could lead to these alterations. This is where the concept of preventive conservation takes on its full meaning.

BIO

Delphine Lacanette is an associate professor at Bordeaux INP. She has been studying thermo-aerodynamic flows in underground environments in general and in the Lascaux cave in particular for more than 15 years, with an interdisciplinary point of view. In recent years, she has been particularly interested in heat and mass transfer in the karstic environment surrounding the cave. She is a member of the Commission Nationale de l'Architecture et de Patrimoine (National Commission for Architecture and Heritage), in the section dedicated to decorated caves, and provides expertise to the curator of the Lascaux cave in terms of climatology of the cave.

Colette Sirieix, After 6 years at the BRGM, Colette Sirieix joined the University of Bordeaux as an associate professor. She is currently a full professor. Her research specialty is near-surface geophysics. She has been working on karst environments for more than 10 years. She is particularly interested in the environment of decorated caves and archaeological sites that develop in the unsaturated zone of limestone rocks. In 2021, she organized the International Congress of Subsurface Geophysics (NSG'21) in Bordeaux under the auspices of the EAGE (President of the Local Advisory Committee and of the Scientific Committee). Her work is always at the crossroads of several disciplines: geophysics, geology, archaeology, prehistory, thermal sciences.

Location: Building G - Ground floor: Conference room MANON CORMIER

Empathy and Design Cognition

2:00pm
3:30pm

Session Chair: Katja Thoring, Technical University of Munich, Germany

Using Likelihood Ratio Table and Naïve Bayes Classifier Method to Holistically Assess Codesign Programmes and Methods

William Siew 1, Arlindo Silva 1, Bina Rai 2
1 Singapore University of Technology and Design; 2 National University of Singapore

The concept of inclusivity involved an understanding of people, programmes and places, embedded with complex issues. 21 student designers took part in a first-of-its-kind five-day codesign programme to develop solutions for inclusive and engaged communities with residents. This quasi-experimental study aimed to develop a value-based approach using likelihood ratio table and a Naïve Bayes classifier method to assess the success of a codesign programme, in comparison to past programmes with different design challenges. Methodology proposed a systematic investigation to evaluate this programme holistically. Students discussed with stakeholders to uncover the complexities of human and environmental factors in design at early stage of ideation, and semi-structured participants' observation tasks were considered instead of researcher's observations in the method of assessment. Selected teams were introduced to two new design methods to empathise better with seniors, i.e., Care Circle and See and Shoot. Findings revealed that these teams showed greater levels of critical inquiry when overcoming three key challenges, i.e., (1) identifying key personas, (2) examining potential use environment, and (3) access to market.

Aligning functional analysis processes with designers' natural cognitive flow

Hunter Scott Reeling, Jinjuan She, Miami University

Engineering design in new product development is a constant battle between creativity and strict structure. As researchers look to optimize the process, each stage is placed under a microscope to put designers in the best position to develop better products for companies in a cost effective manner. One idea in improving product development is the concept of incorporating the Human-centered Design into functional analysis. However, critiques of these functional analysis methods cite an unnecessary amount of resources needed to invest in these steps, a restriction in creativity, and a high necessary level of effort from the design teams. The goal of this research will be to address these critiques by incorporating theories from cognitive research and Human-centered Design into the functional analysis process. This work will propose a new method aimed to improve the quality of the function model of the design space, increase the creativity freedom of the designers, and be accessible to engineering students and industry engineers alike.

Location: Building G - Ground floor: Conference room MANON CORMIER

2:00pm
3:30pm

Empathy and Design Cognition

Session Chair: Katja Thoring, Technical University of Munich, Germany

A competence portfolio for future leaders in Advanced Systems Engineering

Sebastian Impertro 1, Katharina Duehr 2, Hendrik Rust 1, Albert Albers 2, Nikola Bursac 3
1 Karlsruhe University of Applied Sciences (HKA); 2K arlsruhe Institute of Technology (KIT); 3 Hamburg University of Technology (TUHH)

Due to the increasing importance of advanced systems, whose development calls for interdisciplinary and integrative approaches, and fundamental changes in the work environment, leaders are required to have a wide range of competences. Therefore, the aim of this work is to identify competences of future leaders, that are specifically relevant in Advanced Systems Engineering (ASE). Thus, professional, social, methodological, and self competences developed by a literature review are validated through expert interviews and prioritized by a survey. The insights are then presented in a competence portfolio including 30 areas of competences. The portfolio consists of areas of competence that are either relevant in the context of ASE (e.g. intercultural and interdisciplinary competence), New Work (e.g. competence to empower employees) or are relevant to leaders in general. It was possible to add further aspects that are necessary in ASE to the aspects from the literature review. The experts interviewed emphasized various aspects of interdisciplinary work and made clear that in future, leaders should place their employees at the heart of their activities and empower them according to their strengths and weaknesses.

An Instinct Approach to Design

Shuichi Fukuda, Keio University

The word "Design" is used in many ways. But most of them consider it from the standpoint of artificial or man-made. In other words, as "Human Intelligence", But we should remember we are born to "Design". That is "Instinct". We are born with instinct to survive. "Instint" is "Natural Intelligence". "Instinct" plays an important role for making decisions. In decision making, we need to prioritze them. If the first one fails to satisfy our expectation, we take the next one. But our world is increasing complexity and complicatedness, and our bodies and movements are different from person to person. To cope with such increasing diversification, "Instinct" is calling for support. Therefore,Mahalanobis Distance-Pattern (MDP) approach is proposed in this paper as one of the tools to support our "Instinct". MDP combines ordinal Mahalanobis Distance and pattern which is a non-verbal communication tool.

Building C - ground floor: Room C3 – 001

2:00pm
3:30pm

Review of State of the Art of Data Applications

Session Chair: Massimo Panarotto, Chalmers University of Technology, Sweden

Four Patterns of Data-Driven Design Activities in New Product Development

Boyeun Lee, Saeema Ahmed-Kristensen, University of Exeter Business School

In the midst of Industry 4.0 where digitalisation is stimulated through the Internet of Things (IoT), Big Data, and machine learning technologies, an increasing volume of valuable data has been acquired from sensors and interconnected devices. This data-driven paradigm can enable organisations to create new or improved products and services, build long-term customer relationships in a value co-creation manner, adapt to continuous business reconfiguration or address societal challenges such as sustainability. Scientific research addressing Data-driven design has increased steadily in the last few years. However, despite this, there is still a need for a comprehensive understanding of data-driven design processes. Thus, through a systematic literature review, we review the data-driven design activities observed in the new product and service development and types of data utilised in New Product Development (NPD) process. This paper contributes to design research and through reviewing the current landscape of Data-driven design identifies ten data-driven design activities and four-dimensional aspects in NPD process.

Function-oriented development of complex mechatronic products from an HTO perspective: a systematic literature review

Ekin Uhri 1,2, Ingrid Isenhardt 1
1 Institute for Information Management in Mechanical Engineering, RWTH Aachen University, Aachen, Germany; 2 BMW Group, Department of Total Vehicle Development, Munich, Germany

A component-orientated approach is commonplace in the automotive industry where the development focus lies on components. However, current challenges in the industry necessitates a mindset change in the development. Shifting the perspective from the components to functions can help with changing requirements, manage increasing complexity, support cross-disciplinary development, and foster innovation. To successfully implement this approach, it is essential to address not only the technical aspects of the solution, but also the human and organizational aspects affecting the process for its long-term success.

This paper investigates the function-oriented development methods of complex mechatronic products. A systematic literature review is conducted to analyse the current state of research. The existing function-oriented development approaches are summarized, the technological, human, and organizational perspectives are analysed, and the research gaps are highlighted. It is concluded that while function-orientation gains significance in industry and academia, and the importance of human and organizational factors are highlighted in the literature, they are not yet widely considered within the current function-oriented approaches.

Design in a complex world

Building C - ground floor: Room C3 – 001

2:00pm
3:30pm

Review of State of the Art of Data Applications

Session Chair: Massimo Panarotto, Chalmers University of Technology, Sweden

Proposal of Cluster Analysis Method for Products Considering Exploration and Exploitation in Engineering Design

Masahiro Okamoto, Tamotsu Murakam, The University of Tokyo

It is important for organizations to balance exploration and exploitation in order to respond quickly and sustainably to the needs of society and users in a rapidly changing business environment. However, there is insufficient research on design methods to balance exploration and exploitation in product design, and a method to objectively identify the product groups to be balanced has not yet been established. In this paper, on the basis of the characteristics of exploration and exploitation in design, a cluster analysis using functional and attribute distances between products is proposed. To validate the proposed method, it was applied to past product cases in which the relationship between exploration and exploitation was known. The results showed that in the cases of cameras, in addition to known product groups forming large clusters, reasonable minor classifications that had not been identified were also obtained. This indicates that the proposed method is capable of analyzing reasonable clusters in the cases and is potentially effective in identifying product groups taking into consideration the relationship between exploration and exploitation.

Managing data-driven design: A survey of the literature and future directions

Julie Johnson, Ada Hurst, Frank Safayeni, University of Waterloo

Data-driven design is expected to change design processes and organizations in significant ways. What actions should design managers take to ensure the best possible outcomes in this new data-driven design environment? This paper employs an interdisciplinary literature survey to distill key impacts that data-driven design may have on designers, design teams, organizations and product users. Findings reveal that designers may need a broader set of skills to be successful. For data-driven design to be most effective, design managers will be challenged with many integration tasks, including the integration of AI-based tools into design teams, the closer integration of interdisciplinary teams, the integration of qualitative design thinking methods with new data-driven design paradigms, and the integration of data and algorithms into traditional human-centred design practice, in an effort to overcome cognitive limitations and augment human skill. This paper identifies gaps in the literature at the intersection of data-driven design and design management, design thinking, and systems thinking.

Design in a complex world

Supporting Patients

Location: Building C - ground floor: Room C3 – 002

2:00pm
3:30pm

Session Chair: Anja Maier, University of Strathclyde and DTU-Technical University of Denmark, United Kingdom

Designing for Rehabilitation Movement Recognition and Measurement in Virtual Reality

Ummi Khaira Latif, Zhengya Gong, Vijayakumar Nanjappan, Georgi V. Georgiev, Center for Ubiquitous Computing, University of Oulu, Finland

Virtual reality (VR)-based rehabilitation has been widely implemented to maintain and increase patient motivation during therapy sessions. Researchers nowadays design VR-based rehabilitation by leveraging off-the-shelf VR devices for easy access and application. However, researchers need to implement additional custom hardware or incorporate a specific algorithm to perform a real-time evaluation of each therapeutic movement. This study aims to design and develop a system with features for recognizing and measuring the upper limb rehabilitation movement in VR using off-the-shelf VR devices such as VR headsets, controllers, and trackers. This system is bundled and distributed as a single toolkit to accommodate other researchers in providing the evaluation feature for their VR-based rehabilitation system. The user experiment was conducted to verify the usability of this proposed design system. The experiment results show that the system can recognize 16 upper limb movements and provide several measurement data that researchers can use in providing the evaluation feature based on their design requirements.

'indriya' - Participatory design of a multi-sensory learning aid for children with communication disorder

Kavyashree Venkatesh, Shakuntala Acharya, Indian Institute of Technology Guwahat

Designing for disability is a very specialised area as it requires interdisciplinary expertise, and designing assistive devices for children with communication disorder, is especially a challenge as these users are incapable of providing adequate and coherent feedback. With the adoption of participatory design approach, in collaboration with experts/professionals/educators, as pivotal stakeholders and a proxy for the end-users; a game-based, multi-sensory learning aid has been developed to train children on the concept of sense organs.Several concepts were generated and evaluated through special educator participation and based on a preliminary survey of external special educators as evaluators, the prototype was found to be suitable for the target user to enhance their communication skills. This paper captures a research through design perspective on the design of customisable solutions for beneficiary user groups, who are unable to offer feedback.

Design in a complex world

Supporting Patients

Location: Building C - ground floor: Room C3 – 002

2:00pm
3:30pm

Session Chair: Anja Maier, University of Strathclyde and DTU-Technical University of Denmark, United Kingdom

Mapping The Journeys Of Atrial Fibrillation Patients And Citizens Using Wearable Devices For Remote Cardiac Monitoring

Sagar Suresh Kumar 1, Eva Andreakou 2, Marianna Tzachsan 2, Anja M. Maier 1,2
1 University of Strathclyde; 2 DTU-Technical University of Denmark

Atrial Fibrillation (AF) is one of the most prevalent cardiac diseases in the world. How might we design patient journeys improving quality of life using wearable cardiac devices for continuous out of hospital monitoring and support? Most of the studies to date have emphasised the technical aspects of implementing such devices with less focus on human factors. As such, remote cardiac monitoring appears to be burdened by poor patient adherence. This research study proposed a journey map based on Roger's technology adoption model to understand the challenges faced by AF patients and non/asymptomatic patients in using wearable devices to monitor their health. Data from semi-structured interviews conducted in Denmark with 12 participants aged 24 to 65 years was used. Interview results show that citizens prefer tracking heart activity only in conjunction with other measures such as steps or sleep and do not feel motivated to track their heart activity on a daily basis. Patients view wearables as a valuable tool to check if their health is all right, although apprehension that devices can cause unnecessary worry can lead to their rejection. Finally, recommendations for the design of patient journeys when using wearables were made.

Reframing Hearing Aids – Exploring The Design Space Of Analogue Fashionable Hearing Aids For Users With Mild Hearing Impairments

Hermann Klöckner, Martin Wiesner, Anhalt University of Applied Sciences

Contemporary digital in ear hearing aids are of significant importance for social participation of users with hearing impairments. Through the advancement of technology, extreme miniaturisation of these devices has been achieved. However, by no means all people who could benefit from a hearing aid actually use one. Cormack and Fortnum state that the majority (80%) of adults aged 55–74 years who would benefit from a hearing aid, do not use them. This is in line with Arnold and Makenzie who estimate a gap of a factor of 5 between people who would benefit from the use of a hearing aid than actually do acquire and use one. Even according to the statistics from the Federal Guild of Hearing Aid Acousticians in Germany, only 3.7 million use a hearing aid out of 5.4 million who have an induced hearing loss. This article explores the design space of fashionable analogue contemporary hearing aids.

Location: Building C – 1st floor: Room C2 – 106

Prototyping In Design

2:00pm
3:30pm

Session Chair: Timothy W. Simpson, The Pennsylvania State University, United States of America

Collaborative teamwork prototyping and creativity in digital fabrication design education

*Georgi V. Georgiev 1, Vijayakumar Nanjappan 1, Hernan Casakin 2, Sohail Soomro 1,3
1 Center for Ubiquitous Computing, University of Oulu, Finland; 2 Ariel University, Israel; 3 Sukkur IBA University, Pakistan*

Digital fabrication laboratories play a role as an educational environment in which different learning activities incorporate advanced technological developments. Digital fabrication design education often involves exploratory and scaffolded processes of materialising ideas into products. However, FabLabs poses multiple challenges for pedagogy and design learning. Based on a large-scale digital fabrication course in a higher education institution, we examine whether teamwork carried out in a digital fabrication environment improves creativity. Furthermore, we analyse if teamwork affects self-assessment of learning activities involving building tangible artefacts. Finally, we examine whether the type of produced prototype affects the team's overall performance. The results allow for digital fabrication design education recommendations, including interventions intended for improving the creativity of the outcomes, team performance, and learning of different digital fabrication issues.

From Experience-based to Knowledge-Driven Design: A Case Study of a 3D-Printed Product

Jakob Højeng-Swensson, Victor Mathias Pisinger, Herle Kjemtrup Juul-Nyholm, Brian Nyvang Legarth, Tobias Eifler, Technical University of Denmark

In this paper, a case study of a redesign process for 3D-printed parts has been analysed. The purpose was to compare the implementation of specialist knowledge in hands-on engineering tasks with the previous experience-based approach. Here, specialist knowledge refers to systematic experimental work as a basis for Computer Aided Engineering (CAE). The case involves a set of compliant arms for an oil extraction device developed by a start-up company. Tensile tests of 3D printed dog-bone were performed to characterise the Young's modulus, tensile strength, and orthotropic behaviour of the material to build a material model based on Finite Element Analysis (FEA). With the material characteristics and three simple tests to estimate the optimisation constraints, the existing solution was disproven. Then, new solution candidates were generated and evaluated with input from the start-up company. The process resulted in a feasible solution as well as a reduction of maximum stress from 54MPa to 20MPa. The case highlights the value of specialist knowledge for characterisation of new technologies and design space constraints to reduce and improve iterations to solve a practical design problem.

Design in a complex world

Prototyping In Design

Location: Building C – 1st floor: Room C2 – 106

2:00pm
3:30pm

Session Chair: Timothy W. Simpson, The Pennsylvania State University, United States of America

A Critical Appraisal of Mixed Reality Prototyping to Support Studio Design Education

Charlie Ranscombe 1, Wendy Zhang 2, Chris Snider 3, Ben Hicks 3
1 Swinburne University of Technology; 2 University of Canterbury; 3 University of Bristol

Mixed Reality (MR) technologies are widely available and applied in a variety of design and engineering applications. MR prototypes capture the respective benefits of physical and digital prototypes by merging these domains saving the time and resources required to create them. This advantage is compelling in the context of design education where tight time and resource constraints exist. However, it is known that new digital prototyping tools can cause problems for students applying appropriate prototyping tools during practice-based studio design projects. Our paper contributes a systematic appraisal of MR prototyping's proposed dimensions value against constraints and issues in design studio education. This highlights MR Visualisation and Knowledge Management dimensions as most readily realised in education. Recommendations are then reflected on via an illustrative case study into the implementation of MR prototyping via these dimensions. Reflections corroborate the value proposition, but also highlight a need for further research exploring activities to scaffold MR prototyping to further support reflective design thinking.

Information flow analysis enabling the introduction of additive manufacturing for production tools- Insights from an industrial case

Tina Hajali 1, Adam Mallalieu 1, Arindam Brahma 1, Massimo Panarotto 1, Ola Isaksson 1, Lina Stålberg 2, Johan Malmqvist 1
1 Chalmers University of Technology; 2 Mälardalen University

Additive Manufacturing (AM) has traditionally been used for prototyping of products, however, in the last few decades, it has seen a rising growth in the manufacture of final products. The addition of AM as a manufacturing method in the portfolio of a company's production capabilities increases the complexity of decision-making. This is because the decisions are often not based on the same criteria and constraints, as related to conventional manufacturing processes. In this paper, we investigate this challenge by studying how AM affects the current workflow and the associated information flow for a design-make process in a Swedish manufacturer before and after the integration of AM. In this paper, it is argued that apart from an understanding of how to design for AM, it is equally important to consider how introducing AM alters the existing information flow and how to benefit from information available in various design-make process steps to facilitate decision making process. The result clarifies that the current process relies largely on tacit and experiences-based knowledge, whereas to take advantage of AM, more precision is required to capture and process the available information.

Location: Building C - 2nd floor: Room C2 – 216

2:00pm
3:30pm

Applications of Additive Manufacturing

Session Chair: Roland Lachmayer, Leibniz Universität Hannover, Germany

Comparison between experimentation and multiphysics modelling to identify priority contradiction

Sebastien Dubois 1,2, Hicham Chibane 1,2, Roland De Guio 1,2
1 INSA Strasbourg; 2 Icube, CSIP

The contradictions of TRIZ are now widespread and recognized as an effective inventive design tool. They make it possible to find solution concepts to problems that cannot be solved by optimization approaches. However, many contradictions could be formulated and it could be difficult to choose the priority one. The authors propose here two methods to formulate the contradictions and identify the priority contradiction: an experimental approach on the one hand, and a multiphysics approach on the other hand. This analysis, illustrated through an example of 3D printing of parts, shows that these two approaches are similar in terms of result, and indeed make it possible to formulate contradictions taking into account all the complexity of a system.

Application of unsupervised learning and image processing into classification of designs to be fabricated with additive or traditional manufacturing

Baris Ördek, Yuri Borgianni, Free University of Bozen-Bolzano

Manufacturing process (MP) selection systems require a large amount of labelled data, typically not provided as design outputs. This issue is made more severe with the continuous development of Additive Manufacturing systems, which can be increasingly used to substitute traditional manufacturing technologies. The objective of this paper is to investigate the application of image processing for classifying MPs in an unsupervised approach. To this scope, k-means and hierarchical clustering algorithms are applied to an unlabelled image dataset. The input dataset is constructed from freely accessible web databases and consists of twenty randomly selected CAD models and corresponding images of machine elements: 35% additively manufactured parts and 65% manufactured with traditional manufacturing technologies. The input images are pre-processed to have the same colour and size. The k-means and hierarchical clustering algorithms reported 65% and 60% accuracy, respectively. The algorithms show comparable performance, however, the k-means algorithm failed to predict the correct subdivisions. The research shows promising potential for MP classification and image processing applications.

Design in a complex world

Location: Building C - 2nd floor: Room C2 – 216

2:00pm
3:30pm

Applications of Additive Manufacturing

Session Chair: Roland Lachmayer, Leibniz Universität Hannover, Germany

Derive and integrate sustainability criteria in design space exploration of additive manufactured components

Adam Mallalieu 1, Julian Martinsson Bonde 1, Matilda Watz 2, Johanna Wallin Nylander 3, Sophie I. Hallstedt 2, Ola Isaksson 1
1 Chalmers University of Technology; 2 Blekinge Institute of Technology; 3 GKN Aerospace

Additive manufacturing has the potential to decrease the climate impact of aviation by providing more light-weight designs. Sustainability is however required to be assessed from a systemic view, including all lifecycle phases, and from a social, ecologic, and economic dimension. This is however challenging in early phase design, where also a large design space need to be explored. A case study is carried out with an aerospace company where two candidate engineering design tools are combined to address this. The integration of these two engineering tools are applied on a Turbine Rear Structure, and shows promising results in enabling a systemic view of sustainability to be integrated and assessed in early phase design space explorations of additive manufactured components. It is recommended that the integration between the two tools is further established and validated.

Further development of the design process for hybrid individual implants

Martin Pendzik 1, Stefan Holtzhausen 1, Sascha Heinemann 2, Kristin Paetzold 1
1 TU Dresden; 2 Innotere GmbH

Additive manufacturing (AF) is characterised by a high degree of individuality and flexibility with regard to design and product layout. This enables the integration of different functions in a component. Due to these properties, AM has established itself in medical technology for the production of implants. Depending on the application, parameters such as resilience, biocompatibility and manufacturing restrictions play a varying role. So far, however, only limited research has been done on the design, manufacturing and application of hybrid implants (use of several materials). Although initial design and manufacturing guides exist, the problem of removing the hybrid implant from the shaping negative is hardly addressed. The aim is to analyse and evaluate an existing procedure for the design of hybrid implants depending on individual requirements and to further develop it regarding the removability from the shaping negative. In this context, the extent to which the adhesive properties between the elements can be influenced by design changes is to be investigated.

Design in a complex world

Location: Building C – 1st floor: Room C2 – 114

Working with Digital Tools

2:00pm
3:30pm

*Session Chair: Jonathan Cagan, Carnegie Mellon University,
United States of America*

GitHub for product development. How could that look like?

Georg Hackenberg, Christian Zehetner, Dominik Frühwirth, School of Engineering, University of Applied Sciences Upper Austria

Product development is facing new challenges due to increasingly complex and individualized products in small batch sizes and short time to markets at high quality standards. Integrated product data management along with systematic requirements engineering and early stakeholder involvement are known to be key enablers for the success of future product development. In software development, established platforms such as GitHub exist, which have been shown to improve stakeholder communication, requirements elicitation, and software design decisions. In product development, similar platforms exist with impressive functionality, but which have some drawbacks such as closed source licenses, vendor-specific data formats, and expert-level user interfaces. To overcome the current situation, we study how the ideas of GitHub can be translated to an open source solution for product development and which concepts can be reused or must be changed. Core deliverables of our work are (1) an integrated data model of requirements (or design tasks), project schedules, and revisions of computer-aided design (CAD) models as well as (2) an interface model.

Use Cases for a Hybrid Augmented Reality Computer Workstation in CAD Workflows

Jakob Harlan, Stefan Goetz, Sandro Wartzack, Friedrich-Alexander-Universität Erlangen-Nürnberg

Many immersive approaches for design activities show a great potential for their specific use cases, but still overall usage of extended reality technology in product developers day-to-day work is little. The user's workflow between classical desktop work environment and its immersive counterpart is interrupted by both a data gap and an interface gap. The three-dimensional product data usually needs preparation and the user has to physically change the interface in use. The hybrid augmented reality computer workstation aims to close these gaps. A hologram of the current model is visualized next to the screen in reach of the user for intuitive inspection and spatial interactions. In this paper we present use cases for this novel immersive workstation in the CAD workflow. An explorative user study of the typical product designer`s workflow reveals the most common activities. Guided by those, eight uses cases are formulated and classified into fundamental, drafting, and modelling CAD tasks. These cases include novel hybrid augmented reality interactions derived from literature, which are assessed with respect to their applicability.

Location: Building C – 1st floor: Room C2 – 114

Working with Digital Tools

2:00pm
3:30pm

Session Chair: Jonathan Cagan, Carnegie Mellon University, United States of America

What Determines VR Integration in Design Practice? An Investigation of Industrial Designer's Acceptance of VR Visualisation Tools

Wendy Zhang 1, Charlie Ranscombe 2, Thammathip Piumsomboon 1, Prabha Mallya 1
1 University of Canterbury; 2 Swinburne University of Technology

Emerging visualisation tools based on eXtended Reality (XR) platforms offer designers new possibilities and benefits, attracting increasing interest from academia and industry. However, as the users and consumers of these tools, practising designers' perceptions of XR visualisation tools need to be further verified as they shape the tools' acceptance and integration in the industry. This paper investigates industrial designers' acceptance of VR visualisation tools using the Unified Theory of Acceptance and Use of Technology (UTAUT) model. Semi-structured interviews were undertaken with 12 designers from 3 countries to discuss their attitudes, motivations, experiences, and expectations regarding adopting VR visualisation tools as professional tools. The study highlights key opportunities to promote VR integration in industrial design as the tools' practical capabilities to support design performance and the social influence of stakeholders and peer designers on the professional use of VR. The main barriers lie in designers' expected effort to learn and use the tools and the investment and upkeep of VR systems and facilities in the industry. The paper concludes with recommendations for reaping benefits and overcoming barriers.

Extended reality in industry: past, present and future perspectives

Elena Spadoni, Monica Bordegoni, Marina Carulli, Francesco Ferrise, Politecnico di Milano

The industry's interest in Virtual and Augmented Reality (VR and AR) technologies started from the beginning of their appearance in the research world. Over the years, scholars observed ups and downs, to which various factors contributed. In recent years these technologies, now known as eXtended Reality (XR), have returned to fascinate the industrial world, mainly because most of the related enabling technologies have improved to the point of pushing companies to re-invest in them.

The introduction of approaches such as the digital twin one and the recent hype on the metaverse is also a push in this direction. A few questions arise: what are the benefits of such technologies in the industry today, and what are the unexplored possibilities? Starting from a systematic literature review and exploring the practical implications of integrating technologies in the industrial field, the paper tries to answer these questions. The paper is not intended as a technological forecast but as a stimulus for future research.

SC 01

TUE
25 JUL

2:00pm
3:30pm

Design for DIY & Repairability

Session Chair: Francesco Ferrise, Politecnico di Milano, Italy

A Framework model for facilitating Do-It-Yourself Design

JanWillem Hoftijzer, David Keyson, TU Delft

Today's global context of mass-produced items has resulted in an increasing 'distance', or alienation, between people and the origins of the items they buy and use: an unhealthy human-product relationship. This observation permits the search for an alternative interpretation of well-being: a transformation that would support resilience and self sufficiency, and a better human product relationship or 'a new partnership', as advocated by various scholars.

In this paper, this new partnership is considered through supporting 'Do-It-Yourself' (DIY) product design: a scenario in which professional designers facilitate laypersons to design for themselves. Anticipating (1) the designer's responsibility, and (2) the layperson's innate desire to create, this paper introduces a 'Design for DIY' framework method to help bridge the knowledge gap between the product designer and the layperson.

The initial starting points of this study, complemented by a range of 'Design for DIY' studies, and an exploration of existing design frameworks and design models, resulted in the design of a 'Design-for-DIY' framework. This paper concludes with recommendations for the testing and further development of the Design-for-DIY framework.

The Right-to-repair Movement and Sustainable Design Implications: a Focus on Three Industrial Sectors

Michael Saidani, Alicia Kim, Madeline Kim University of Illinois Urbana-Champaign, IL, USA

While products get more challenging to repair, the right-to-repair movement aims to empower consumers in their ability to "use, modify, and repair" a device "whenever, wherever, and however" they want. Here, the best design practices and remaining challenges of three industrial sectors – namely, consumer electronics, biomedical devices, and clothing industry – are investigated in light of the right-to-repair movement. Based on literature reviews and industrial surveys, a SWOT analysis is provided for each sector, and sustainable implications for product repair readiness are drawn. Concretely, recommendations to design, develop and sell products with right-to-repair in mind are given by sector. Future directions for a more quantitative assessment and implementation of design for product repair are discussed to ensure the augmentation of the circularity and sustainability performance of products.

SC 01

TUE
25 JUL

2:00pm
3:30pm

Design for DIY & Repairability

Session Chair: Francesco Ferrise, Politecnico di Milano, Italy

Barriers and opportunities to repair in repair cafes

Cédric Masclet, Jasmine Laura Mazudie, Jean-François Boujut, Univ. Grenoble Alpes, CNRS, Grenoble INP, G-SCOP, 38000 Grenoble, France

For some years now, a part of the population in Europe has been willing to moderate its consumption and to enter into a sustainable waste reduction perspective. Repair is an important lever in the sustainability of products. It requires appropriate approaches depending on the actors involved, whether they are public, private or at the consumer level. Repair cafés are thus born of local citizen initiatives to act on the life cycle of everyday consumer products. We conducted a qualitative study based on a series of semi-structured interviews with the actors of repair cafés in the Grenoble area (France) and carried out an analysis of qualitative data. This analysis, according to three pre-defined fields, technology-competencies-motivations, reveals the perception of the actors on the current obstacles and opportunities for the development of the amateur repair practice. The results obtained support studies already carried out on the subject and show that design is still failing to match amateur reparation requirements. Besides, the social role of these third places takes precedence over the ecological and economic dimension of repair.

A Designer's understanding of the maker movement

Vilhelm von Platen, Yoji Kitani, Kyoto Institute of Technology

The maker movement has garnered interest from many disparate fields, from engineering to business management, to behavioural science, to city planning. The reason for this interest no doubt stems from the promised potential of the maker movement to revolutionize not only product creation and manufacturing, but in extension the economy around it. This paper examines existing literature across disciplines for evidence of what the maker movement has achieved so far, with a focus on implications for the field of Industrial Design.

Location: Building H - ground floor: Conference room ASSELAIN

2:00pm
3:30pm

Sustainable and Risk Design Evaluations

Session Chair: Yuri Borgianni, Free University of Bolzano-Bozen, Italy

Transport efficiency of delivery trucks: A study of coupling vehicle design and transport system through functional modelling and optimisation

Khashayar Shahrezaei 1,2, Ciarán J. O'Reilly 1,2, Timo Lähivaara 3, Peter Göransson 1,2
1 KTH Royal Institute of Technology, Department of Engineering Mechanics, Teknikringen 8, SE-100 44 Stockholm; 2 The Centre for ECO2 Vehicle Design at KTH, Teknikringen 8, SE-100 44, Stockholm, Sweden; 3 Department of Technical Physics, University of Eastern Finland, P.O. Box 1627, FIN-70211 Kuopio, Finland

To enable the emergence of new and efficient vehicle design from the transport system perspective, a formulation of a multifunctional vehicle-transport design optimisation problem is presented. System-wide measures of transportation and vehicle efficiency measures are conceptually considered in an integrative design approach to drive the transport solutions towards more resource-efficient and eventually more sustainable solutions. Considered efficiency measures associated with the system-wide aspect are namely, productivity and service efficiency, and measures associated with vehicle attributes are namely mass and shape efficiency. The conflicting nature of these measures is balanced using optimisation methodologies through multiple transportation scenarios with varying transport demand and deterministic drive cycles. The obtained optimisation results demonstrated that there is a strong interconnectivity between the vehicle's overall configuration and transportation aspects. Thus, conceptually demonstrating how the inclusion of various transport-vehicle efficiency measures simultaneously in an integrative design approach during the early vehicle design may yield a more efficient and better overall system performance.

Multi-criteria Decision-making Methods Applied to Achieve Sustainable Design: A Systematic Review

Tianming Xu 1, Wei Liu 1, Zicheng Zh u2
1 King's Collage London; 2 Sartorius Ltd

Sustainability is an issue concerned with social, economic and environmental problems. The primary aim of sustainability is to fulfil the needs of the present society without compromising potential needs of future generations. Product design has a significant impact on sustainability, and a sensible decision-making process that considers trade-offs at early design stage is critical to the success of product design that addresses environmental sustainability issues. This study aims to identify and review the decision-making process for environmentally sustainable design. A comprehensive literature review has been performed to establish the trends over the past two decades. The decision-making process for sustainable design has been summarised, and the frequently-used decision-making methods, such as ANP/AHP, TOPSIS, and BWM, have been identified and discussed. A framework for the selection of Multi-criteria Decision-making (MCDM) methods has been developed to aid researchers to select appropriate MCDM methods in sustainable design. In addition, future research opportunities have also been identified.

Design in a complex world

Location: Building H - ground floor: Conference room ASSELAIN

2:00pm
3:30pm

Sustainable and Risk Design Evaluations

Session Chair: Yuri Borgianni, Free University of Bolzano-Bozen, Italy

Reducing the Risk of Patent Infringement

Larry Stauffer, University of Idaho

One life-cycle issue that is often overlooked in the design process is that of intellectual property (IP). Yet the IP associated with a product is a valuable asset of the company, sometime comparable to the materials produced or the manufacturing infrastructure. In particular, this paper addresses the IP of patents, the opportunity for patent infringement, and ways to reduce the risk of getting into this situation. One poorly managed patent infringement case could cost the company millions of dollars, wiping out years of profit from production of that product. Patent infringement is a complex topic that combines design and law with many uncertainties. Designing products that do not infringe the patent rights of others is a goal that cannot be done with certainty. A primary reason is due to the uncertainty of understanding what is protected in a patent and the uncertainty of the patent infringement process. The purpose of this paper is to educate the designer on what constitutes patent infringement and explain some ways to reduce the risk of infringing the patent rights of others.

Design for Safe Reuse of Labware: Investigating Methods for Quality Assurance

Joren Van Loon, Els Du Bois, University of Antwerp

The problem of plastic waste in research laboratories is a significant one, with an estimated 5.5 million tonnes generated annually worldwide. Reusable labware has the potential to reduce this waste significantly, but the design of such products must take into account quality assurance to guarantee the accuracy of experiments. Insights were gathered through the generation of an overview of the available techniques for verifying labware after use and decontamination. As during different design cycles verification of prototypes is needed, these techniques were evaluated and translated to be applicable in the specific context of a design lab. Therefore, this study presents a protocol which can be used as a verification tool while designing safe, reusable labware for chemical laboratories. This protocol consists of four different steps: (i) visual inspection, (ii) mass & size comparison, (iii) leak test, and (iv) chemical stability test.

Location: Building D - ground floor: Conference room AUBY

2:00pm
3:30pm

Research Design Methods

Session Chair: Tobias Eifler, Technical University of Denmark, Denmark

Methods of change impact analysis for product development: A systematic review of the literature

Viktoria Mordaschew, Jan-Phillip Herrmann, Sven Tackenberg, OWL University of Applied Sciences and Arts

During product development, the customer or internal stakeholders initiate changes concerning the components or functions of a cyber-physical system (CPS). The complexity of such a CPS causes difficulties in evaluating the effects of a component change. Accordingly, product developers need an assistance system to quantify the impact of a component change on hardware, software, system functions, and production processes. Therefore, this paper focuses on concepts to evaluate the effects of component, functional, and process changes and contributes to its clarification and further understanding of the importance and requirements for such an assistance system. The literature review assesses the identified methods regarding their objectives, application objects, level of automation, and relations characteristics. However, the literature review pointed out that the change prediction method from Clarkson et al. (2004) is well-established in the literature and able to quantify the impact of a change.

Environment-based design (EBD): Using only necessary knowledge for designer creativity

Jiami Yang 1,2, Yi Dou 1, Yong Zeng 1
1 Concordia University; 2 University of Calgary

Design is a highly nonlinear chaotic dynamic process with many possible solutions, which requires enormous knowledge for designers. This paper investigates how environment-based design (EBD) methodology can help designers use only necessary knowledge for their creativity based on three methods: information search, knowledge acquisition and knowledge application. The methods are applied in an aircraft pylon design, which is evaluated by two aerospace design specialists. The paper discussed the different roles of EBD for novice and expert designers in regard to overcoming emotion and knowledge barriers to achieving designer creativity.

Design in a complex world

Location: Building D - ground floor: Conference room AUBY

2:00pm
3:30pm

Research Design Methods

Session Chair: Tobias Eifler, Technical University of Denmark, Denmark

Environment-based design (EBD): Using only necessary knowledge for designer creativity

Jiami Yang 1,2, Yi Dou 1, Yong Zeng 1
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"We always think it's never going to happen to us": Understanding What Motivates Communities to Engage in Emergency Preparedness

Tera Maher, Christine Toh, University of Nebraska at Omaha

Community-based disaster risk reduction is an effective approach for emergency management to address the needs of communities. This approach focuses on identifying the community-specific needs and context of emergency management in that area to develop technologies that help mitigate effects of disasters. The complex network of community, technology, and user motivation makes it challenging to understand how to encourage users to adopt preparation efforts, as opposed to reactive measures that have been shown to be less effective and can lead to inequitable results. To address this research gap, qualitative interviews were conducted with participants from one medium-sized midwestern city in the United States to understand how community members think about preparation and make decision about adopting preventative technologies. The results of the qualitative analysis reveal that there were 5 main themes that are important to consider when developing technologies for emergency preparedness; Importance of communication during emergencies, the role of technology in emergency management, unequal access to resources, reaction instead of preparation, and motivation to engage in community preparedness and response.

SD 03

TUE
25 JUL

Location: Building D - ground floor: Conference room AUBY

2:00pm
3:30pm

Research Design Methods

Session Chair: Tobias Eifler, Technical University of Denmark, Denmark

Can Pareto Fronts meet the splitting condition? Comparing two Generative Design Algorithms based on the variety of design parameters combinations they generate

Maxime Thomas 1,2, Lorenzo Nicoletti 3, Pascal Le Masson 1, Benoit Weil 1
1 Mines de Paris; 2 EPF-Ecole d'ingénieurs; 3 Technical University of Munich

Generative Design (GD) is a design approach that uses algorithms to generate designs. This paper investigates the role of optimisation algorithms in GD process. We study how Pareto Fronts – a classical optimization algorithm output – help designers to browse the variety associated with a design problem. Thanks to the "splitting condition" from design theory, we show that valuable Pareto Fronts for designers are those that allow the exploration of a variety of design parameters without modifying substantially the performance of the designed solution. We call "Splitting Pareto Front" the Pareto Fronts that display this property and investigate how to generate them. We compare, on an electrical battery design problem, two optimization algorithms – NSGA-II and MAP-Elites – based on the design parameters variety they generate. Our results show that MAP-Elites generates Pareto Fronts that are more splitting than those generated by NSGA-II. We then discuss this result in term of the design process: which algorithm is best suited for which design task? We conclude with the importance for future research on Generative Design Algorithms (GDA) to study jointly the functioning of GDA and their expected contribution to the design process.

Design in a complex world

Design Cognition

Location: Building C – 1st floor: Room C2 – 106

4:00pm
6:00pm

Session Chair: Joshua Summers, Clemson University, United States of America

A Spectrum of Stakeholder Perspective Taking in Early-Stage Design

Elizabeth Rieken 1, Kathleen Bond 2, Rachel Moore Best 2, Grace Burleson 1, Eric Reynolds Brubaker 1
1 NASA Langley Research Center; 2 The Human Factor

Stakeholder perspective taking is a critical skill in early-stage problem exploration and framing. We examined stakeholder perspective taking within an early-stage design team of engineers at NASA to begin to understand in what ways and under what conditions designers adopt stakeholder perspectives in the context of professional engineering organizations. Our findings identify a spectrum of perspective taking during problem framing deliberations that ranges from (1) fully taking the stakeholder's point of view (POV), (2) interpreting the stakeholder's POV using the designer's POV, (3) implanting the stakeholder's POV into the designer's POV, to (4) fully taking the designer's own POV. We also identify and describe conditions that appeared to encourage or hinder perspective taking in this setting. These findings are significant because they suggest ways to gauge and encourage the skill of stakeholder perspective taking among professional engineers working on real-world design challenges with societal implications.

The design mindset inventory (D-Mindset0): a preliminary instrument for measuring design mindset.

Jakob Clemen Lavrsen 1, Jaap Daalhuizen 1, Claus-Christian Carbon 2
1 Technical University of Denmark - DTU; 2 University of Bamberg

Mindset has been identified as an essential aspect of design and innovation, impacting both behaviours and performance. However, the concept of design mindset is elusive. Often design mindset is used indistinguishably from design behaviour, diminishing the complexity of the mechanisms and cognitive processes underlying design behaviour. As the initial step in researching these mechanisms, we operationalise the concept of design mindset and present the design mindset inventory (D-Mindset0) to measure it. The initial inventory centered around 16 agreement-to-value statements related to design practice. To analyse the inventory, we conducted an exploratory factor analysis based on 473 master students from different engineering disciplines participating in a course on innovation in engineering. The analysis revealed a four-factor structure with 11 final items. The four factors align with the concepts of 'conversation with the situation,' 'iteration,' 'co-evolution of problem-solution,' and 'imagination.

Design in a complex world

Design Cognition

Location: Building C – 1st floor: Room C2 – 106

4:00pm
6:00pm

Session Chair: Joshua Summers, Clemson University, United States of America

Changes in Cognition and Neurocognition when Thinking Aloud during Design

Tripp Shealy 1, John Gero 2, Paulo Ignacio 1, Inuk Song 1
1 Virginia Tech; 2 University of North Carolina at Charlotte.

The think-aloud protocol provides researchers an insight into the designer's mental state, but little is understood about how thinking aloud influences design. The study presented in this paper sets out to measure the cognitive and neurocognitive changes in designers when thinking aloud. Engineering students (n=50) were randomly assigned to the think-aloud or control group. Students were outfitted with a functional near-infrared spectroscopy band. Students were asked to design a personal entertainment system. The think-aloud group spent significantly less time designing. Their design sketches included significantly fewer words. The think-aloud group also required significantly more resources in the left and right dorsolateral prefrontal cortex (DLPFC). The left DLPFC is often recruited for language processing, and the right DLPFC is involved in visual representation and problem-solving. The faster depletion of neurocognitive resources may have contributed to less time designing. Thinking aloud influences design cognition and neurocognition, but these effects are only now becoming apparent. More research and the adoption of neuroscience techniques can help shed light on these differences..

Chronobiology in divergent thinking: how designers are affected by time of day

Samuele Colombo 1, John S. Gero 2, Marco Cantamessa 1
1 Department of Management and Production Engineering, Politecnico di Torino, Turin (Italy); 2 Department of Computer Science and School of Architecture, University of North Carolina, Charlotte (USA)

Chronobiology is the science that studies the role of time in biology. The study of time in human bodies revealed the presence of internal rhythms related to the time of day. Considering divergent thinking as one of the essential cognitive activities of conceptual design, this paper presents the results of investigating the effect of time of day on designers' brain activity while performing divergent thinking tasks. An experiment was run with a revised Alternative Uses Task, measuring brain activity with an electroencephalogram (EEG) device. Students with different educational backgrounds were recruited for this experiment, including engineering and industrial design students, to determine if the time of day affected them differently. The brain waves and related power results show significant differences with respect to the time of day and educational background. The differences are particularly evident considering the interaction of these factors. Further studies are required to understand the relationship between the differences detected and the designers' behavioural performance and to identify which time of day is most effective for idea-generation activities for designers.

Design in a complex world

Design Cognition

Location: Building C – 1st floor: Room C2 – 106

4:00pm
6:00pm

Session Chair: Joshua Summers, Clemson University, United States of America

A framework for understanding mental imagery in design cognition research

Rebecca Louise Macfie, Laura Anne Hay, Paul Rodgers, University of Strathclyde

Mental imagery is the experience of perceiving an object within one's own mind and is a subjective experience, leading to difficulties in the research and understanding of the phenomenon. This paper documents the development and verification of a framework for researching the elements of mental imagery. The framework was developed following a review of both psychology and design literature which signified three fundamental conceptual viewpoints of mental imagery: imagery modalities, dimensions of imagery ability, and imagery processes. The aim of this framework is to allow for structured research on mental imagery in any given research field. This is verified through discussion for the product design engineering discipline and provides a base for future work on this topic. The conclusions made in this paper reveal that mental imagery, and particularly visual mental imagery, is largely considered to be integral in design overlooking the different realities of designers and confirming a greater need to understand mental imagery experiences in product design engineering.

The Systematic Feedback Method for Ideation Mode in Workshops

Mayu Akaki 1,2, Takashi Maeno 1
1 Keio University; 2 Shunan University

To encourage creativity through ideation mode in design thinking, we conducted three workshops dealing with regional challenges with 44 participants. The systematic feedback method applied to the workshops supports the multi-disciplinary participants to feedback during the ideation mode to diverge ideas from diverse perspectives. The method is composed of feedback cards and the process of using them. Two kinds of cards encourage communication within the team. The next three cards aim to diverge the viewpoints of the feedback systematically to support the team to imagine the possibility of the idea evolving from a bird's eye view.

Through quantitative analysis of the survey, we identified the significant and positive correlations between acceptance of the team's idea and team creativity, the effectiveness of the method on team creativity, and the team's characteristics that firmly realized the effect of the method. By categorizing the free comments, we indicated the valid functions and improvements that need further research in the future. Identified valid functions were not only diverging minds and perspectives but encouraging communication and understanding of the team members leading to acceptance and creativity.

Location: Building H - ground floor: Conference room ASSELAIN

4:00pm
6:00pm

Human Factor and AI

Session Chair: John Gero, UNC Charlotte, United States of America

Exploring the role of text-to-image AI in concept generation

Ross Brisco, Laura Hay, Sam Dhami, University of Strathclyde

Artificial intelligence (AI) capable of generating images from a text prompt are becoming increasingly prevalent in society and design. The general public can use their computers and mobile devices to ask a complex text-to-image AI to create an image which is in some cases indistinguishable from that which a human could create using a computer graphics package. These images are shared on social media and have been used in the creation of art projects, documents and publications. This exploratory study aimed to identify if modern text-to-image AI (Midjourney, DALL-E 2, and Disco Diffusion) could be used to replace the designer in the concept generation stage of the design process. Teams of design students were asked to evaluate AI generated concepts from 15 to a final concept. The outcomes of this research are a first of its kind for the field of engineering design, in the identification of barriers in the use of current text-to-image AI for the purpose of engineering design. The discussion suggests how this can be overcome in the short term and what knowledge the research community needs to build to overcome these barriers in the long term.

Focus and Modality: Defining A Roadmap to Future AI-Human Teaming in Design

Christopher McComb, Peter Boatwright, Jonathan Cagan, Carnegie Mellon University

The evolution of Artificial Intelligence (AI) and Machine Learning (ML) enables new ways to envision how computer tools will aid, work with, and even guide human teams. This paper explores this new paradigm of design by considering emerging variations of AI-Human collaboration: AI used as a design tool versus AI employed as a guide to human problem solvers, and AI agents which only react to their human counterparts versus AI agents which proactively identify and address needs. The different combinations can be mapped onto a 2×2 AI-Human Teaming Matrix which isolates and highlights these different AI capabilities in teaming. The paper introduces the matrix and its quadrants, illustrating these different AI agents and their application and impact, and then provides a road map to researching and developing effective AI team collaborators.

Design in a complex world

Location: Building H - ground floor: Conference room ASSELAIN

4:00pm
6:00pm

Human Factor and AI

Session Chair: John Gero, UNC Charlotte, United States of America

Designing for Human Factors: Development and Evaluation of a Harmonistic Knowledge-based Design Decision Support Tool

Sean Agius, Philip Farrugia, Emmanuel Francalanza, University of Malta

Dual ontological products are a physical construction and an emotional construction. Multitude of human factors must be considering when designing dual ontological products. To increase the product's impact and reach, designers should also understand the requirements of potential users. A design stage conflict exists between the emotional construction and the physical construction of a product when considering human factors. Designers find it difficult to achieve the right compromise between these constructions and hence, the balancing of the two is crucial. This research therefore contributes a novel harmonistic knowledge-based framework which makes designers aware of design stage conflicts and consequences of commitments made on human factors in the use-phase of the artefact. This approach was implemented in a machine learning based computational tool which exploits harmonistic knowledge and information collected from potential users to proactively assist, guide, and motivate product designers. This paper also presents a descriptive study for the evaluation of the framework and its implementation as a computer-based prototype tool. Results show the necessity and beneficial use of the tool for design engineering practice.

The Augmented Designer: A Research Agenda for Generative AI-enabled Design

Katja Thoring 1, Sebastian Huettemann 2, Roland M. Mueller 2
1 Technical University of Munich, Germany; 2 Berlin School of Economics and Law, Germany

Generative AI algorithms that are able to generate creative output are progressing at tremendous speed. This paper presents a research agenda for Generative AI-based support for designers. We present examples of existing applications and thus illustrate the possible application space of Generative AI reflecting the current state of this technology. Furthermore, we provide a theoretical foundation for AI-supported design, based on a typology of design knowledge and the concept of evolutionary creativity. Both concepts are discussed in relation to the changing roles of AI and the human designer. The outlined research agenda presents 10 research opportunities for possible AI-support to augment the designer of the future. The results presented in this paper provide researchers with an introduction to and overview of Generative AI, as well as the theoretical understanding of potential implications for the future of the design discipline.

Design in a complex world

DW 03

TUE
25 JUL

4:00pm
6:00pm

Human Factor and AI

Session Chair: John Gero, UNC Charlotte, United States of America

★ Bridging Designer-User Gap with a Virtual Reality-based Empathic Design Approach: Contextual Information Details

Xinhui Hu 1, Hernan Casakin 2, Georgi V. Georgiev 1
1Center for Ubiquitous Computing, University of Oulu; 2School of Architecture, Ariel University

Without shared experiences, empathy gaps between designers and users are difficult to bridge. Advancing Virtual Reality (VR) has shed new light on this regard by enabling designers to simulate and experience their users' living scenarios in a virtual environment (VE). However, implementing VR-based empathetic design approach requires dealing with critical design questions, such as: (1) whether VR operators can develop empathy for unfamiliar user groups solely based on objective experience and (2) whether VR operators can utilize task-irrelevant contextual information in the VEs. To explore these issues, we designed an experiment based on two VEs with varying levels of detail that simulated the scenes viewed by people with red-green color vision deficiency (CVD). Participants were randomly assigned to either detail-rich or detail-simple VEs to complete neutral item-searching tasks. Results indicate that objective and neutral experience alone cannot elicit empathy towards users, and VR operating designers will utilize task-irrelevant contextual information.

Design in a complex world

Location: Building C – 1st floor: Room C2 – 114

4:00pm
6:00pm

Generative Design for Engineering

Session Chair: Georg Hackenberg, University of Applied Sciences Upper Austria, Austria

Design Descriptions In The Development Of Machine Learning Based Design Tools

Alison McKay, Thomas A Hazlehurst, Alan de Pennington, David C Hogg, University of Leeds

Applications of machine learning technologies are becoming ubiquitous in many sectors and their impacts, both positive and negative, are widely reported. As a result, there is substantial interest from the engineering community to integrate machine learning technologies into design workflows with a view to improving the performance of the product development process. In essence, machine learning technologies are thought to have the potential to underpin future generations of data-enabled engineering design system that will deliver radical improvements to product development and so organisational performance. In this paper we report learning from experiments where we applied machine learning to two shape-based design challenges: in a given collection of designed shapes, clustering (i) visually similar shapes and (ii) shapes that are likely to be manufactured using the same primary process. Both challenges were identified with our industry partners and are embodied in a design case study. We report early results and conclude with issues for design descriptions that need to be addressed if the full potential of machine learning is to be realised in engineering design.

Observations on the Implications of Generative Design Tools on Design Process and Designer Behaviour

Jana Saadi, Maria Yang, Massachusetts Institute of Technology

Developments in artificial intelligence (AI) are opening the possibilities for the development of more advanced design tools. An example of these innovations are generative design tools, in which the generation of complex and high performing products is possible. This study investigates the use of generative design tools and how they may influence the design process and designer behaviour. Six interviews of interdisciplinary designers were conducted to understand the implications of using generative design tools. It was observed that generative design tools primarily allow for quantitative inputs to the tool while qualitative metrics, such as aesthetics, are considered indirectly by designers. The subjectivity of the designer and how they incorporate the quantitative and qualitative metrics in the generative design tool can lead to differing outcomes between designers. Notable differences in tool usage are also observed between expert and novice computational designers. Additional studies should be conducted to further understand the extent generative design tools impact the design process, designer behaviour, and design outcomes.

Design in a complex world

Location: Building C – 1st floor: Room C2 – 114

4:00pm
6:00pm

Generative Design for Engineering

Session Chair: Georg Hackenberg, University of Applied Sciences Upper Austria, Austria

Are Generative Adversarial Networks Capable of Generating Novel and Diverse Design Concepts? An Experimental Analysis of Performance

Parisa Ghasemi, Chenxi Yuan, Tucker Marion, Mohsen Moghaddam, Northeastern University

Generative Adversarial Networks (GANs) have shown stupendous power in generating realistic images to an extend that human eyes are not capable of recognizing them as synthesized. State-of-the-art GAN models are capable of generating realistic and high-quality images, which promise unprecedented opportunities for generating design concepts. Yet, the preliminary experiments reported in this paper shed light on a fundamental limitation of GANs for generative design: lack of novelty and diversity in generated samples. This article conducts a generative design study on a large-scale sneaker dataset based on StyleGAN, a state-of-the-art GAN architecture, to advance the understanding of the performance of these generative models in generating novel and diverse samples (i.e., sneaker images). The findings reveal that although StyleGAN can generate samples with quality and realism, the generated and style-mixed samples highly resemble the training dataset (i.e., existing sneakers). This article aims to provide future research directions and insights for the engineering design community to further realize the untapped potentials of GANs for generative design.

Measuring Patent Novelty using Natural Language Processing

Ali Yassine, Carlo Lipizzi, Stevens Institute of Technology

This paper develops a novelty measure for patents. We devise a text-based novelty measure using natural language processing (NLP) techniques. The proposed method is applied on patents that belong to a common category, which represents a subset of patents under a specific patent class. We then extract the novelty-value profile of those patents and discuss a use case for product design and development (i.e., extracting patent novelty and predicting inventive value).

Design in a complex world

Location: Building C – 1st floor: Room C2 – 114

4:00pm
6:00pm

Generative Design for Engineering

Session Chair: Georg Hackenberg, University of Applied Sciences Upper Austria, Austria

Extracting latent needs from online reviews through deep learning based language model

Yi Han 1, Ryan Bruggeman 1, Joseph Peper 2, Estefania Ciliotta Chehade 1, Tucker Marion 1, Paolo Ciuccarelli 1, Mohsen Moghaddam 1
1 Northeastern university; 2 The University of Michigan

Aspect-based sentiment analysis (ABSA) provides an opportunity to systematically generate user's opinions of specific aspects to enrich the idea creation process in the early stage of product/service design process. Yet, the current ABSA task has two major limitations. First, existing research mostly focusing on the subsets of ABSA task, e.g. aspect-sentiment extraction, extract aspect, opinion, and sentiment in a unified model is still an open problem. Second, the implicit opinion and sentiment are ignored in the current ABSA task. This article tackles these gaps by (1) creating a new annotated dataset comprised of five types of labels, including aspect, category, opinion, sentiment, and implicit indicator (ACOSI) and (2) developing a unified model which could extract all five types of labels simultaneously in a generative manner. Numerical experiments conducted on the manually labeled dataset originally scraped from three major e-Commerce retail stores for apparel and footwear products indicate the performance, scalability, and potentials of the framework developed. Several directions are provided for future exploration in the area of automated aspect-based sentiment analysis for user-centered design.

★ Shape Generation System for Optimizing Aesthetic Interest associated with Novelty and Complexity

Shimon Honda, Hideyoshi Yanagisawa, The University of Tokyo

Design aesthetics are one of the most important factors affecting the attractiveness of industrial products. Psychological theory suggests that a moderate level of novelty and complexity yields pleasant feelings in users. A design that is initially surprising to consumers and acceptable over time requires aesthetic interest associated with its novelty and complexity. In this study, we formulated the perceived novelty and complexity of a closed contour shape. Based on this formulation, we developed "Hybrid-GAN," which is a shape-generation system capable of generating a variety of shapes of arbitrary novelty and complexity. In a series of experiment, we obtained subjective evaluations of novelty and complexity, as well as beauty and interest, for the generated shape samples. The results indicated that our novelty and complexity formulations had significant positive correlations with subjective evaluations. The sum of the formulated novelty and complexity also had a significant positive correlation with interest. The results of this study are expected to be used to support the design of attractive shapes by providing feedback to designers regarding the degrees of novelty and complexity that users find most pleasant.

H&W 02

TUE
25 JUL

4:00pm
6:00pm

Methods and Processes for Medical Applications

Session Chair: P. John Clarkson, University of Cambridge, United Kingdom

Multidisciplinary Design Analysis and Optimization Framework for Regulatory Driven Medical Device Development

Soumya Ranjan Mishra, Kamran Behdinan, University of Toronto

Multidisciplinary design optimization (MDO) is a technique used in the design of systems involving the integration of many disciplines. The architecture and formulation of MDO has an impact on the solution time and optimality of final designs. The process of developing medical devices requires the combination of medical and technical knowledge and abilities. Developing a medical device is done by a complicated collection of Product Development Processes that entail tremendous oversight to ensure conformity to regulatory requirements. Regulatory standards often provide stern "Go / No-Go" policies which may discretize the design variables further increasing the complexity of the optimization problem. This work proposes a novel design approach which utilizes systems engineering practices to undertake complex multidisciplinary design optimization while implementing regulatory guidelines for medical devices. The formulated model is then applied and examined in a case study towards the development of a piezoe-lectric respiratory sensor. It is observed that the novel framework would extensively improve the design space definition and process driven product development practices.

New Product Development Process for MedTech Combination Products

Yaroslav Menshenin, Romain Pinquié, Pierre Chevrier, Univ. Grenoble Alpes, CNRS, Grenoble INP, G-SCOP

The MedTech product development is experiencing a growing complexity of the design process. The design challenge is to keep the medical device simple and user-friendly while maintaining its inter-connectivity with the other systems and products. The additional layer of complexity comes from the need to satisfy both - direct customers (pharma companies), and indirect ones (patients, health care practitioners, and pharmacists). Solving those design challenges must not compromise the safety of the end-user and must follow the regulatory requirements.

This research proposes the systematic design process for MedTech combination product development with the emphasis on product strategy and concept development operationalized by design thinking participative toolkit. The proposed approach serves the purpose of increasing the traceability between the early made business decisions on a product strategy level of MedTech company, and the engineer-ing decisions made on product concept level. The ultimate goal of the research is to support the deci-sion-makers with methods and tools which would allow them to make informed decisions on investment in a new MedTech combination product by Pharma and MedTech companies.

Design in a complex world

Location: Building C – 3rd floor: Room C2 – 308

4:00pm
6:00pm

Methods and Processes for Medical Applications

Session Chair: P. John Clarkson, University of Cambridge, United Kingdom

Design and development of a low-cost pediatric videolaryngoscope

Maria José Londoño 1, Jose Fernando Arango 2, Juan Felipe Isaza 1
1 EAFIT university; 2 Hospital Pablo Tobón Uribe

Endotracheal intubation is performed to provide ventilatory support to a patient of any age. Every medical procedure that requires general anesthesia requires intubation, and for this reason, it is a life-saving procedure. This maneuver is a challenge in pediatric patients between 0 months and 12 years of age, since their anatomy and oxygen consumption differ compared to an adult.
In patients with difficult airways, where there is no good visibility of the structures, a videolaryngoscope is used. It has higher success rates compared to a conventional laryngoscope. Its use has become widespread since the COVID-19 pandemic, as it reduces exposure to respiratory secretions.
This article presents the design, manufacture and testing of a low-cost pediatric videolaryngoscope, for patients between 6 and 12 months, and which are intended to respond to the low availability of this type of equipment in Colombian health care centers. The BioDesign Innovation Process methodology was adapted for its creation. The prototypes were manufactured using 3D printing. Validation was performed by 28 experts using simulators and the results were promising, obtaining a success rate of 98.8% for the designed device.

What do an Anaesthesiologist, a Nurse, two Designers, and a Professor in Architectural Technology do together in a room? Crafting Interdisciplinarity as response to emerging infectious diseases

Marianna Nigra 1, Anna Silenzi 2, Michele Di Marco 3
1 Politecnico di Torino, DIST - Interuniversity Department of Regional and Urban Studies and Planning and Full: Future Urban Legacy Lab; 2 Politecnico di Torino DAD - Department of Architecture and Design; 3 Politecnico di Torino DAD - Department of Architecture and Design

The health sector in the humanitarian context is currently experiencing great pressure in delivering adequate care, due to a number of increasing emerging diseases. The World Health Organization (2022) reports that: '…since 2011, there have been more than 1200 outbreaks of epidemic-prone diseases in 188 countries around the world, causing widespread death and suffering…'. A key factor that can contribute to ensure high quality care is the possibility to rely on adequate infrastructure and products. This paper presents the interdisciplinary methodology deployed to design and develop an innovative infectious diseases treatment module that could be deployed and utilised in the very first phases of health emergencies. The methodology proposed is organised around a three-level approach to ensure both core disciplinary solidity, and holistic understanding of the complexity of the challenge. The contribution of this work is the definition of key aspects in the proposed methodology that can help overcome difficulties in delivering high quality interdisciplinary research and work, as well as highlighting behavioural patterns that can ensure successful delivery of innovative products and facilities for the humanitarian health sector.

Location: Building C – 3rd floor: Room C2 – 308

4:00pm
6:00pm

Methods and Processes for Medical Applications

Session Chair: P. John Clarkson, University of Cambridge, United Kingdom

Development Of A Classifier And A Simulator To Support The Design Of An Anti-Decubitus Active Mattress

Agnese Brunzini, Marta Rossi, Marco Mandolini, Federica Cappelletti, Michele Germani
Università Politecnica delle Marche, Department of Industrial Engineering and Mathematical Sciences

Approximately 10% of hospitalized patients develops decubitus ulcers that quickly degenerates into chronic illness that reduces the quality of life and requires expensive clinical management. The use of an anti-decubitus active mattress, that automatically redistributes the pressure loads, reduces the occurrence of new lesions and promotes the healing of the pre-existing ones.
The aim of this work is to design and develop two tools to support the design of an anti-decubitus active mattress. Almost all the systems found in literature are based on the classification of pressure maps through machine learning and are difficultly usable in the design context.
This work proposes a pressure map Classifier and an Interactive Simulator of the mattress, based on a simpler logic, by integrating image processing techniques and functioning simulations. The Classifier can recognize the patient's pressure maps and classify them according to six reference sleep postures. The Interactive Simulator allows to understand the operating mechanisms of the mattress and to test the controller and the various control logics in the absence of a physical prototype.

A new method for passive ankle foot orthosis design – Integration of musculoskeletal and finite element simulation

David Scherb, Patrick Steck, Harald Völkl, Sandro Wartzack, Jörg Miehling, Friedrich-Alexander-Universität Erlangen-Nürnberg

Motor disorders are diseases affecting the muscle function of the human body. A frequently occurring motor disorder affects the lower leg muscles resulting in a pathological gait called foot drop. Patients have a higher risk of stumbling and falling. The most common treatment is the use of a passive ankle-foot-orthosis (AFO). However, the compensation of foot drop is only limited due to the non possible support of all rotational directions of the ankle joint. Therefore, a newly developed concept for a passive AFO is currently in work. To ensure a best possible treatment of the patient, the provided support by the AFO and required support by the patient have to be in accordance. Thus, in this contribution a method is presented that integrates model order reduced finite element analysis for computing the provided support of the AFO and musculoskeletal human models for representing the patients' gait behaviour. With the method, the design of the force generating structures of the AFO can be realized regarding the patients' requirements. The presented method is further evaluated with a specific use case. The main focus lies here in the principal functionality of the method and the provision of valid results.

Location: Building A - ground floor: Conference room BERNARD

4:00pm
6:00pm

Agile Systems Development

Session Chair: Bryan Howell, Brigham Young University, United States of America

Design methods for Diagnosing and Locating Entangled Technical Debt in DevOps frameworks

José Bonet Faus 1, Pascal Le Masson 1, Ugo Pelissier 1, Nafissa Jibet 1, Antoine Bordas 1, Sébastien Pajot 2
1 Mines de Paris; 2 Ubisoft

In the IT landscape, DevOps is the preferred approach for developing and maintaining rapidly evolving systems that require continuous improvements. Yet, DevOps frameworks do not entirely prevent the accumulation of Technical Debt (TD), and under certain circumstances DevOps can even contribute to generating TD. This paper focuses on a specific type of TD, Entangled Technical Debt (ETD), that corresponds to the implicit complexification of a system's design and the appearance of unintentional couplings in its architecture over time. Our work seeks to inform methods for Diagnosing and Locating ETD in DevOps frameworks. Through a research partnership with Ubisoft's IT branch, an experimental case-study was conducted. It takes the form of an assessment of 6 innovative IT projects and a subsequent in-depth architecture analysis of an individual IT system, which enabled the characterization of the mechanisms linking DevOps to ETD. This allowed us to develop and test practical methods for diagnosing and locating ETD in IT systems.

The Hotdog model - How turn a tier 1 automotive company into an agile organization

Alexander Atzberger 1, Conny Dethloff 2
1 Webasto SE; 2 borisgloger consulting

The more dynamic the markets become, i.e., the more surprises the markets have in store for companies, the more important it becomes for companies to react quickly to these changes in order to have market-driven and individual solutions. This is especially important for tier 1 suppliers, as competition is fierce and the customers, the OEMs, also have to adapt to the changing market and thus customer needs.
In order to be best prepared for this, it is necessary to align one's own company in a flexible and responsive manner. In particular, the context-specific development and application of a framework as well as a model for the improvement of internal collaboration in companies is necessary.
In this paper, exactly such a framework has been developed in several pilot projects within the framework of an agile transformation at a tier 1 supplier over a period of two years by means of participative action research.
As a result, the conception and development of an individually scaled agile framework for a tier 1 supplier in the automotive industry, the AHEAD framework, is presented here. The Hotdog model is the central basis for the collaboration model, which is scalable to all company levels.

Agile Systems Development

Session Chair: Bryan Howell, Brigham Young University, United States of America

Managers' understanding of agile in hardware development

Silvia Orejuela 1, Damien Motte 1, Glenn Johansson 1,2
1 Lund University; 2 Mälardalen University

The agile methodology is gaining attention among practitioners and researchers in hardware development. As a new methodology, it is a source of misunderstandings and misinterpretations. This is problematic at the managers' levels as they may hinder its adoption or lead to its impractical implementation and use. This study, therefore, aims to explore the manager's level of understanding of the agile methodology. The study identifies the similarities and differences between the fundamental elements of the agile methodology and the elements mentioned by managers in hardware development. The fundamental elements of the agile methodology are identified based on the elements presented in the Scrum method; the elements mentioned by managers are identified based on ten semi-structured interviews with managers in hardware development. The study shows that the understanding of the agile methodology varies largely among managers. The obtained detailed insights in the managers' level of understanding of the agile methodology could be used to develop appropriate support to facilitate its adoption and implementation.

Identification and classification of uncertainties as the foundation of agile methods

Martin Pendzik, Philipp Sembdner, Kristin Paetzold, TU Dresden

To remain competitive, companies today are increasingly faced with the challenge of reacting adequately in dynamic development environments. For product development, in particular, it is necessary to organize decision-making processes so they can react quickly and flexibly to changes in the development environment. To describe the dynamics and changeability, the term VUCA is used, which is a synonym for volatility, uncertainty, complexity, and ambiguity, and thus summarises the most diverse forms of changeability. An adaptation of agile methods to the development context makes it necessary to specify the causes of uncertainty in more detail. The article presents a framework that analyses these influencing factors and differentiates them more precisely to specify problems in dealing with VUCA and to develop recommendations for action for the goal-oriented adaptation of agile methods.

Design in a complex world

Location: Building A - ground floor: Conference room BERNARD

4:00pm
6:00pm

Agile Systems Development

Session Chair: Bryan Howell, Brigham Young University, United States of America

★ Working agile to speed up research with industry: five independence principles

Massimo Panarotto, Ola Isaksson, Rikard Söderberg, Chalmers University of Technology

One of the obstacles to the ability of research to make an impact on industry resides on the research process itself. Today, there is a need to accelerate the means for research to support industrial transformation. At the same time, there is the need to maintain scientific rigorousness, which often requires time. To solve this trade-off, this paper evaluates existing research approaches through the lenses of agile development. The analysis is based on a simulation of research process architectures, and on observations made over several research projects with industry. The results of this analysis highlight five light-but-sufficient rules of research project behavior to keep momentum, motivation and trust when doing research with industry. The paper demonstrates the use of these five rules in a "research sprint" conducted iwith two automotive OEMs.

Location: Building C - ground floor: Room C3 – 001

4:00pm
6:00pm

Advancements in Systems Engineering 1

Session Chair: Sandro Wartzack, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

System Value Analysis: Model and Example

Emilia Lavi, Yoram Reich, Tel Aviv University

Systems design, being a socio-technical discipline, is highly affected by available technologies, the global economy, the state of the environment, and social issues. Hence, in recent years, the ultimate objective of design started to shift from best-performance systems to ones providing value to customers, enterprises, and society. This paper presents a holistic concept of system value, equipping the stakeholders participating in the design process with a broad view of this measure. The contribution of this paper includes a proposal for general system value taxonomy, which can be used as a foundation for a comprehensive, case-specific, system value model (SVM). As an all-round perspective of value is possible only when all stakeholders are represented, we suggest deploying the PSI framework for mapping the relevant stakeholders. The system value analysis of Tesla's Model Y electrical vehicle is demonstrated, as a test case for SVM application. We conclude that a detailed analysis of SVM, performed by a carefully chosen group of diverse stakeholders, highlights less conventionally discussed aspects of the system during design decision processes, hence is expected to improve the system's overall value.

DevOps for Manufacturing Systems: Speeding up Software Development

Till Blüher 1, Daniel Maelzer 2, Jessica Harrendorf 2, Rainer Stark 1
1 Technische Universität Berlin, Industrielle Informationstechnik; 2 Mercedes-Benz AG, Maintenance Engineering

The increasing importance of software as an essential functional provider in products and processes requires that companies master the development capabilities to continiously and quickly deliver high-quality software features. DevOps (acronym for Development and Operations) is an essential approach to these capabilities, which has so far been used predominantly in software-driven companies. This paper investigates the conditions under which DevOps can also be used in the industrial context of series manufacturing in order to be able to steadily develop and provide software features used in these environments (e.g. for monitoring and maintenance of manufacturing machines). A concept for DevOps for manufacturing systems was developed based on current best practices and the specific situation in the industrial company. The concept was then implemented and validated with experts on the basis of initial development cycles, demonstrating the usefulness of DevOps for manufacturing systems.

Design in a complex world

Location: Building C - ground floor: Room C3 – 001

4:00pm
6:00pm

Advancements in Systems Engineering 1

Session Chair: Sandro Wartzack, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

Function driven assessment of manufacturing risks in concept generation stages

Arindam Brahma 1, Massimo Panarotto 1, Timoleon Kipouros 2, Ola Isaksson 1, Petter Andersson 3, P. John Clarkson 2
1 Chalmers University of Technology, Industrial and Materials Science, Gothenburg, Sweden; 2 University of Cambridge, Department of Engineering, Cambridge, United Kingdom; 3 GKN Aerospace Engine Systems, Department of System Analysis & IP, Trollhättan, Sweden

Decisions made in the concept generation phase have a significant effect on the product. While product-related risks typically can be considered in the early stages of design, risks such as supply chain and manufacturing methods are rarely easy to account for in early phases. This is because the currently available methods require mature data, which may not be available during concept generation. In this paper, we propose an approach to address this. First, the product and the non-product (manufacturing and/or supply chain) attributes are modelled using the enhanced function means (EF-M) modelling method. The EF-M method provides the opportunity to model alternative solutions-set for functions. Dependencies are then mapped within the product and the manufacturing models, and also in between them. An automatic combinatorial method of concept generation is employed where each generated instance is a design concept-manufacturing method pair. A risk propagation algorithm is then used to assess the risks of all the generated alternatives.

Industrial Perspectives on the Adoption of Virtual Testing

Khadija Tahera 1, Iestyn Jowers 1, Cecilia Loureiro-Koechlin 2, Claudia Eckert 1, Helen Lockett 1
1 The Open University; 2 Royal Holloway, University of London

This research aimed to gain insight into current practices and challenges with respect to the adoption of virtual testing and integration with physical testing in product development processes. A focused workshop investigated industrial perspectives on adopting virtual testing and current challenges. This paper reports the findings from the workshop in which representatives from a range of industries explored how virtual testing is used to support physical testing in their different contexts. This paper discusses the current challenges industries face in adopting virtual testing and changing role of physical testing, with reference to recent literature on physical and virtual testing and supported by an earlier empirical case study. This paper reports areas where more research is needed to support industries in overcoming these challenges.

4:00pm
6:00pm

Advancements in Systems Engineering 1

Session Chair: Sandro Wartzack, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

Flow Heuristics for Functional Modelling in Model-Based Systems Engineering

Unal Yildirim 1, Felician Campean 2, Aleksandr Korsunovs 2, Aleksandr Doikin 2
1 Hubei University of Automotive Technology, China; 2 University of Bradford, United Kingdom

Model-Based Systems Engineering (MBSE) is increasingly used across industries for the integrated modelling of complex systems to support model-based development and provide enhanced traceability between requirements and verification and validation of the system. This paper seeks to strengthen the function modelling methodology in MBSE by introducing an approach based on flow heuristics guided by the System State Flow Diagram schema. This provides function representations with an enhanced integrity in MBSE facilitating the solution-agnostic architecture modelling, and supports integrated simulation and function failure reasoning based on MBSE. The approach is illustrated with a case study of an electric bicycle implemented in the MathWorks System Composer environment.

Design in a complex world

Design Innovation

Location: Building C - ground floor: Room C3 – 002

4:00pm
6:00pm

Session Chair: Gaetano Cascini, Politecnico di Milano, Italy

The Representation-Usage-Impact (RUI) method to better frame the potential social impacts of a highly disruptive product — Application to the autonomous vehicle

*Robin Lecomte 1,2,3, Bernard Yannou 1, Roland Cahen 2, Guillaume Thibaud 3, Fabrice Etienne 3
1 Laboratoire Génie Industriel, CentraleSupélec, Université Paris-Saclay; 2 Centre de Recherche en Design, ENSCi Les Ateliers / ENS Paris-Saclay, Université Paris-Saclay; 3 Stellantis, Centre Technique Vélizy, France*

Innovative products can be highly prospective and apt to disrupt usages profoundly. They can lead to multiple long-term social impacts influencing people's way of life and behaviour. So it is necessary to anticipate them without delay. Due to high uncertainty, designers may face the problem that conventional user-centred methods, which assess design performances from today's users, are not adapted. We think sociologists can help characterise the likely social impacts of future products. So we propose an original framework called the Representation-Usage-Impact (RUI) method to stimulate sociologists' projection and capture relevant knowledge about probable social impacts. The method includes a database structure encoding the knowledge of sociologists for further use in the design process. Its goal is to help designers avoid making choices today that may be regretted in decades. We illustrate the method and its process with the design of autonomous vehicle scenarios, as it will likely bring many new usages in the future. As the method is still under construction, we present an intermediate validation step involving sociologists. The first results suggest that the method might be a safeguard for the design of disruptive products.

The effects of scenarios on decision-making quality in early design – an empirical study

Giácomo Parolin, Tim C. McAloone, Daniela C. A. Pigosso, Technical University of Denmark (DTU)

Scenario planning is often used in design practice to foster futures thinking, reduce uncertainties and improve decision-making. Scenarios are especially relevant for innovation activities in manufacturing companies, such as technology development, a particularly uncertain process where many trade-offs occur. This study is, to the authors knowledge, the first to empirically measure the effect of scenarios in decision-making quality, in the context of technology development. In a quasi-experiment, engineers from a manufacturing company and university students were independently asked to analyse a trade-off situation between environmental and financial aspects of a technology concept, with and without scenarios. The quality of decision-making quality for control and experiment groups was measured through a standardized questionnaire. The results show that scenarios had a positive impact in 6 of the 7 quality decision-making practices (QMDP), although the effect size is small. The results suggest that both expert and novice designers may benefit from using scenario planning when performing early-stage design activities by having awareness of the decision context, a more structured decision process, and clearer decision criteria.

Design in a complex world

Design Innovation

Location: Building C - ground floor: Room C3 – 002

4:00pm
6:00pm

Session Chair: Gaetano Cascini, Politecnico di Milano, Italy

Evolutionary Perspective on System Generation Engineering by the Example of the iPhone

Felix Pfaff, Gregor Theodor Götz, Simon Rapp, Albert Albers, Karlsruhe Institute of Technology (KIT)

Industrial practice shows that products are developed in generations. Innovation success with complex technical systems can only be achieved economically by using existing solutions as references. These references come from predecessors, competitors, and even industry-external sources. The model of SGE – System Generation Engineering describes these relationships. The iPhone is often used as an example of an innovative product developed in generations. Multiple studies have examined the iP-hone. However, none of these studies systematically considers the influence of the product context on references and variations. In this contribution, an evolutionary descriptive model based on the model of SGE is applied to 15 iPhone product generations. The central result is an overview of the variation shares over the generations and the relationships between context factors, reference-based variation activities, and innovation success and hypotheses for causalities. This is one of a series of case studies to investigate these causalities. The study showed how the iPhone remained successful in its context: not through a high new development share, but through strategically placed variations and the use of references from various sources.

Dimensions of proximity in stakeholder choice reflected in the creation of knowledge-based innovation ecosystem partnerships

Vikki Eriksson, Teo Keipi, Tua Björklund, Design Factory, Aalto University

In order to better understand the stakeholder choices of knowledge-based organisational actors, this study focuses on a novel application of Huber's (2012) dimensions of proximity salience, namely spatial proximity, social proximity and cognitive proximity. The population of the study is made up of knowl-edge-based organisational actors involved in developing an innovation ecosystem, in terms of stakeholder network creation. The extent to which the three proximity dimensions of stakeholder salience is evident in the stakeholder choices of these innovation-focused actors seeking knowledge-based collaborators is explored. Our findings show how various forms of proximity prompt the decision of who to work with among a diverse population of experts involved in building a cross-national innovation ecosystem. The various explanations that motivate stakeholder choice matched Huber's proximity dimensions. The findings provide new insight into stakeholder choice among knowledge-based organisations, and high-light a new proximity dimension indirectly linked to cognition proximity. Termed the "potential proximity" dimension, it involves attraction to stakeholders that represent strategic value.

Design in a complex world

Design Innovation

Location: Building C - ground floor: Room C3 – 002

4:00pm
6:00pm

Session Chair: Gaetano Cascini, Politecnico di Milano, Italy

Modelling Technical Systems in the Early Phase: Proposing a Formal Definition for the System Concept

Albert Albers, Sebastian Hünemeyer, Alexander Kubin, Felix Pfaff, Michael Schlegel, Simon Rapp, Karlsruhe Institute of Technology (KIT)

The task of developing "concepts" is common in all fields of engineering, especially in the early phases of product development. However, an in-depth literature analysis showed that authors - often depending on different contexts in design research, education, and industry - define the term "concept" in differing ways. The aspect of reference-based development is rarely addressed in existing definitions. This indicates that there is a need for an updated and concise concept definition. In this paper, the authors propose a new definition of the term "system concept" within the context of SGE - System Generation Engineering that incorporates the findings from the literature analysis. The definition was reflected on in two case-studies. The first one contained the system concept for automotive display and operating systems, the second one the system concept for a kinesthetic-haptic VR interface. The proposed definition contains the relevant characteristics identified from the literature review and supports both current activity-based process models and reference-based development, as practical application has shown.

Design in a complex world

Design Validation

Location: Building C – 2nd floor: Room C2 – 216

4:00pm
6:00pm

Session Chair: Andreas Hein, University of Luxembourg, Luxembourg

Identifying successful approaches during testing activities in engineering design

Oliver Liewerenz, Patric Grauberger, Thomas Nelius, Sven Matthiesen, Karlsruhe Institute of Technology

Testing activities to gain specific design knowledge play an essential role in engineering design, when a structure needs to be developed, for which knowledge from analytical models or documentation is missing. As research into these testing activities is difficult, few insights into successful approaches exist. In this contribution, we investigate testing activities to gain specific design knowledge through a laboratory task, where 10 engineering students optimize a system using a web-based process chain including rapid prototyping and testing. Design and testing data are acquired from 110 prototypes in 3 hours. A differentiation of performance is conducted and approaches of high- and low-performers are investigated to identify patterns.
Based on these patterns, hypotheses, and metrics indicating successful and non-successful approaches are derived as basis for development of metrics for testing to gain specific design knowledge. A successful approach was overstep the limit, where participants accept destruction of their system to identify boundaries. An unsuccessful approach was the change of many parameters in later tests. These hypotheses and their metrics can then be used in development and validation of support for testing.

Experimental Validation of a Method for Systematic New Development

Jan Kuechenhof, Dieter Krause, Hamburg University of Technology

Creativity is an essential factor in the development of innovative products. 4 Step Creation (4SC) is a method for systematic ideation and can be used to enhance the new product development process. It aims to promote creativity in interdisciplinary teams and provides a framework for collaboration so that original ideas can emerge, laying the foundation for innovation. At the same time, the method can be used for continuous improvement of existing systems. In this contribution 4SC is used in a design method experiment following the Design Method Validation System (DMVS) to validate design methods in product development. The experiment was carried out at PAD2022 International Summer School on the example of a vacuum cleaner robot. Findings show, that the developed method promotes transparency, traceability of ideas and thus communication in the team. It also facilitates the integration of different stakeholders in the ideation phase. The experiment also shows that the DMVS is well suited for planning, conducting, and evaluating design experiments.

Design Validation

Session Chair: Andreas Hein, University of Luxembourg, Luxembourg

Renovating Engineering Departements' Creation Heritage To Meet Contemporary Challenges: Frugal Validation Patterns And Constructive Proof Logics For New Engineering Rules

Nafissa Jibe t1,2, Pascal Le Masson 1, Benoît Weil 1, Blandine Chazelle 2, Dominique Laousse 2
1 Mines Paris, PSL University; 2 SNCF Network

Engineering departments design infrastructure by applying rule systems. The latter are an old creation heritage, based on decades of engineering, that makes it possible to design and govern the operation of the physical heritage which is the infrastructure. Replacing the infrastructure is not sustainable in the meaning of grand challenges; renovating it by applying engineering rules is but could appear too expensive. The literature highlights situations where renovation by respecting the state of the art is too costly and so is the validation of new renovation rules. Are there forms of frugal validation that allow for sustainable renovation of existing systems? This paper tries to explore a third way, a renovation of the physical heritage from a renovation of the system of rules, conceiving in the system of rules, new propositions, and their validation. Using the C-K theory, a case analysis was performed within the French national rail network manager (SNCF Network), a company that has a historical engineering heritage and is at the same time implementing a renovation of it. The paper shows that the renovation of engineering departments' creation heritage can go through frugal validation patterns and constructive proof logics.

Will Model-Based Definition accelerate the inspection phase in the manufacturing process?

Pekka Uski 1, Joni Nieminen 2, Asko Ellman 3
1 Etteplan; 2 Tampere University of Applied Sciences; 3 Tampere University

Model-Based Definition provides several benefits for communicating between engineering and other downstream stakeholders. Particularly, semantic PMI information included in 3D models benefits both CAM programming and inspection phases. However, the efficiency of generating CAM- and CAI codes automatically according to the semantic PMI information varies due to the compatibility of different systems. This paper focuses on the experiment that we made on inspecting three different parts with the Coordinate Measuring Machine (CMM). We compared four different programming methods and found that the efficiency of inspecting depends on the serial size of the parts. The completely automatic CAI-programming method does not necessarily produce the most effective CAI code compared to the competent human programmer. This is notable, especially in large series due to achieved cumulative time savings in the inspection of each part. With small series, fully automatic PMI method and human-assisted automatic PMIfp method provide significant benefits in the inspection process due to time savings in CAI-programming work.

M&P 02

TUE
25 JUL

Design Validation

4:00pm
6:00pm

Session Chair: Andreas Hein, University of Luxembourg, Luxembourg

B-spline based metamodel of the thermal analysis of the wire arc additive manufacturing process.

Mathilde Zani 1, Marco Montemurro 1, Enrico Panettieri 1, Philippe Marin 2
1 Arts et Métiers Institute of Technology, Université de Bordeaux, CNRS, INRA, Bordeaux INP, HESAM Université, I2M UMR, F-33405 Talence, France; 2 Grenoble Alpes - Laboratoire G-SCOP UMR 5272, F-38000 Grenoble, France

Among additive manufacturing processes, wire arc additive manufacturing (WAAM) is one of the most promising methods for manufacturing complex near-net-shape parts, as it allows the layer-by-layer deposition of welded material at a high deposition rate. However, this technology is highly dependent on deposition conditions and thermomechanical phenomena during the process. Therefore, process simulation could be used to analyse the effects of different deposition parameters on the thermomechanical results to optimise the process. However, as the computing time required for this study may become prohibitive, a dedicated strategy is needed to reduce it while maintaining a good level of accuracy. In this study, only the thermal analysis of the process is investigated. An efficient metamodel based on B-spline entities is developed to emulate the thermal response of the WAAM process when building a mild steel four-layer wall structure. Thanks to B-spline entities, the temperature profile at different locations is approximated as a function of a subset of deposition parameters of WAAM process, and the results are compared with the simulated temperature profile resulting from a validation dataset.

Location: Building A - ground floor: Conference room BENZACAR

4:00pm
6:00pm

Addressing Sustainability Challenges in Design

Session Chair: Elies Dekoninck, University of Bath, United Kingdom

Management Practices For Sustainable Product Development: Insights From A Systematic Literature Review

Sachira Vilochani, Tim C. McAloone, Daniela C. A. Pigosso, Technical University of Denmark

Sustainable Product Development (SPD) has been gaining increased attention in academia, industry, and policy. Over the past three decades, significant progress has been observed in incorporation of environmental issues into the product development process, through the so-called ecodesign management practices. Nevertheless, systematisation of the SPD practices, which simultaneously consider the environmental, social and economic dimensions of sustainability, is still missing. To address this gap, this research aims to identify the existing SPD management practices in the academic literature, with special focus on how sustainability dimensions are currently being considered, their coverage in relation to key knowledge areas for product development and their applicability across the SPD phases. Through a systematic literature review, 362 practices were identified and further classified according to a classification criteria. While environmental considerations are still the most prominent ones, the research highlights the importance of the early stages of product development for SPD, as well as the key knowledge areas which are currently being covered by the practices, such as sustainability evaluation and sustainability improvement.

Environmental considerations in engineering: Systemic differences between experts and novices

Senni Kirjavainen 1, Sine Celik 2
1 Aalto University; 2 Delft University of Technology

Engineering knowledge forms an essential part of our planetary fight against climate change. Traditionally, engineering curricula emphasizes the importance of technical knowledge and encourages to specialize in niche areas, where engineers develop themselves into experts. However, it is important to be able to reflect on complex societal challenges from a variety of perspectives to produce not only innovative, but also long-lasting and inclusive solutions for the greater good. This paper aims to understand the extent of systems thinking abilities of engineers by differentiating experts from novices. The study traces sustainability connections made by professional engineers and master's level engineering students when solving engineering design problems. This qualitative study highlights seven recurring themes that relate to the global sustainability discourse and describe a problem-centred approach through a real-life case that focuses on paper and pulp production, through a thematic analysis of 59 responses. The results portray system-level differences in how novice and expert engineers approach sustainability questions and how these differences shape their solution spaces.

Design in a complex world

Location: Building A - ground floor: Conference room BENZACAR

4:00pm
6:00pm

Addressing Sustainability Challenges in Design

Session Chair: Elies Dekoninck, University of Bath, United Kingdom

Barriers leading to Building Services Overdesign

Darren Anthony Jones, Claudia Margot Eckert, The Open University

Sustainable Product Development (SPD) has been gaining increased attention in academia, industry, The research of this paper provides a useful insight into the many barriers leading to building services overdesign, within the context of NHS hospitals. The issue of overdesign in building services is a systemic problem, whereby numerous contributing factors manifest into an issue that inevitably leads to poor system performance and excess costs. A key factor leading to oversizing is the excessive and unco-ordinated application of design margins across the various stages of a building services project. Poor communication between project stakeholders is another significant barrier that inhibits the distribution of information between design groups; unknown requirements, system redundancy and poor system specifications further add to the problem. There are many complex interrelationships associated with the building service design process in hospitals, with external stakeholders adding to the complexity. This points to the importance of effective communication between stakeholders and clear contractual terms between NHS Trusts and external private sector organisations. Many of the barriers identified within this paper are by no means limited to building service systems but also impact on a range of other engineering disciplines.

Environmental considerations in engineering: Systemic differences between experts and novices

Senni Kirjavainen 1, Sine Celik 2
1 Aalto University; 2 Delft University of Technology

Engineering knowledge forms an essential part of our planetary fight against climate change. Traditionally, engineering curricula emphasizes the importance of technical knowledge and encourages to specialize in niche areas, where engineers develop themselves into experts. However, it is important to be able to reflect on complex societal challenges from a variety of perspectives to produce not only innovative, but also long-lasting and inclusive solutions for the greater good. This paper aims to understand the extent of systems thinking abilities of engineers by differentiating experts from novices. The study traces sustainability connections made by professional engineers and master's level engineering students when solving engineering design problems. This qualitative study highlights seven recurring themes that relate to the global sustainability discourse and describe a problem-centred approach through a real-life case that focuses on paper and pulp production, through a thematic analysis of 59 responses. The results portray system-level differences in how novice and expert engineers approach sustainability questions and how these differences shape their solution spaces.

Design in a complex world

Location: Building A - ground floor: Conference room BENZACAR

4:00pm
6:00pm

Addressing Sustainability Challenges in Design

Session Chair: Elies Dekoninck, University of Bath, United Kingdom

Towards Sustainable Life Cycles of Making in Small Scale Fabrication Spaces

George Edward Moore 1, Alice M. Agogino 2, Kosa Goucher-Lambert 2
1 Massachusetts Institute of Technology; 2 University of California, Berkeley

Small scale fabrication spaces have shown their potential to support our local supply chains during the collapse of many global supply chain networks at the onset of the COVID-19 pandemic. In anticipation of these spaces becoming more significant in local supply chains, it is increasingly important to reduce their environmental impacts. This work investigates the life cycle of small scale fabrication spaces by interviewing 18 participants from these spaces in the United States. Key insights from the interviews include the following: a) material selection, robust inventory management, and user support for material disposal are factors influencing optimal flow of materials and equipment through a fabrication space; b) lack of information from manufacturers and suppliers is a critical obstacle to achieve optimal use of materials and equipment, and informed decision making related to environmental sustainability and ethical labor practices; c) there are opportunities to take advantage of where financial and sustainability goals align; d) individual motivators for fabrication influences sustainable behaviors; and e) effective education about material and equipment use helps fabrication space users with more sustainable decision making.

Durabot: the tool to introduce durability in the design process

Federica Cappelletti, Giacomo Menchi, Marta Rossi, Michele Germani, Università Politecnica delle Marche

The extension of the product lifecycle is crucial in the application of Circular Economy principles. However, when Energy Related Products are concerned, managing a durable product does not necessarily mean dealing with sustainable products. This happens because components and/or materials are affected by aging and lead to increased requirement of resources to run (i.e. electricity); there are certain trends that, although distinct from the previous facts, balance the effects of aging, i.e. energy grid mix decarbonization. In the present work an approach that considers both the economic and environmental consequences of durable products is proposed. The Durabot tool has been developed to accomplish the environmental analysis. The work overcomes the main literature criticalities: enables the assessment of environmental consequences of durability ; the evolution of energy grid mix is introduced; the environmental consequences of durable products in different lifecycle scenarios can be assessed during the design phase; therefore, the components to substitute and to make accessible are identified. The tool is intended to be used aiming at design for product lifecycle extension, maintaining both economic and environmental convenience

SD 04

TUE
25 JUL

4:00pm
6:00pm

Product Architecture Design 1 - Applications

Session Chair: Dieter Krause, Hamburg University of Technology, Germany

Integrated Design Methodology: a proposal for a scientific research-based design process for stimuli-responsive products

Julieth Carolina Cano-Franco, Mónica Lucía Álvarez-Láinez, Design Engineering Research Group - GRID, School of Applied Sciences and Engineering, EAFIT University

Complex global problems, such as sustainable crop production, where conventional products do not fully solve the problem due to their low efficacy and negative environmental impact, require rationally designed products. Generally, these products are based on efficient technologies and stimuli-responsive and high-performance materials. Considering the product design approach with a science-based approach such as drug development through QbD. We propose to merge the most relevant elements of these approaches in an integrated design methodology. Regarding the conceptual analysis, we propose two phases: initially, an early phase with conceptual solutions, followed by an advanced phase based on QbD elements to define the research hypothesis. Hence, optimal product conditions defined in the design space must comply with the required performance of the stimuli-responsive product. So, with this proposed integration we pretend to potentialize and strengthen the established tools for product design, achieving an advanced and robust design methodology.

Embedding perception: how changes in manufacturing approach influence interaction-design preferences

Lewis Urquhart, Andrew Wodehouse, University of Strathclyde

This paper explores how small-but–detectable changes in manufacturing protocol can alter interaction-design preferences for users. Building on a number of previous studies by the authors, this paper focuses on the manufacture of a set of emotionally attuned pattern-based surface texture designs by means of computer-numerically controlled (CNC) machining. An experiment is subsequently reported that explores how the variations in toolpath rastering approach can affect the visual and tactile qualities of the textures in relation to interaction-design preferences, with a focus on psychological experience. The implications with respect to user-centred design (UX) and manufacturing protocol more broadly are subsequently discussed, with recommendations for a reconfiguration of computer-aided manufacturing (CAM) approaches to better encode the diverse preferences that users may have when considering how products are manufactured.

Design in a complex world

Location: Building G - Ground floor: Conference room MANON CORMIER

4:00pm
6:00pm

Product Architecture Design 1 - Applications

Session Chair: Dieter Krause, Hamburg University of Technology, Germany

Co-create Financial Planning Services for an Aging Population: Designers' Perspectives

Sheng-Hung Lee 1,6, Joseph F. Coughlin 6, Maria Yang 1, Olivier L. de Weck 2, Chaiwoo Lee 6, Eric Klopfer 5, John Ochsendorf 3,4
1 Massachusetts Institute of Technology Department of Mechanical Engineering; 2 Massachusetts Institute of Technology Department of Aeronautics and Astronautics; 3 Massachusetts Institute of Technology Department of Architecture; 4 Massachusetts Institute of Technology Department of Civil and Environmental Engineering; 5 Massachusetts Institute of Technology Comparative Media Studies/ Writing; 6 MIT AgeLab

The purpose of the study is to understand the design considerations for creating a provocative financial planning toolkit with services to help facilitate more constructive and meaningful conversations to build trust and empathy between financial advisors and senior people. We conducted four rounds of 60-minute co-creation workshops with eight invited participants from various design disciplines to work in pairs to generate four preliminary concepts suggesting design considerations. We used ATLAS.ti to do qualitative research analysis under an NCT (notice, collecting, thinking) model to identify 22 codes synthesized from verbal and behavioral data. The study concluded with three design principles: 1) the concept of financial planning is about people's expectation management, 2) a financial planning toolkit is designed under service systems, and 3) the tailor-made and modular design features can give financial advisors more flexibility to engage with senior people and enable them to share more about their life stories and needs to recommend financial planning packages precisely according to personal preference, health conditions, and financial status.

Systematic optimisation process for an eBike Drive Unit in a highly variable environment

Marco Steck 1,2, Stephan Husung 2, Julien Hassler 1
1 Robert Bosch GmbH; 2 TU Ilmenau

Drive units of eBikes are used in every type of bicycle and for different riding scenarios and riders. Due to the different riders and bike types, an enormous variety of influencing parameters and load spectra must be considered during the design process. Therefore, in this paper, a systematic approach for the optimization of the drive unit is presented, which adopts and combines several approaches from design theory. The focus is on efficient modeling and simulation of the relevant parameters and load spectra to minimize uncertainties in the design process.
Based on a system analysis, dimension-reduced parameter spaces are formed for the simulation of the system, meta-models are integrated into the simulation model and the results of the simulation are transferred into a data-based surrogate model to cover the parameter space in an efficient way with a minimum number of time consuming FE simulations. Furthermore, a coordinate-based evaluation method is presented for the FE model in order to form the input for the surrogate model, reduces the amount of data, and to allows a geometry- and mesh-independent evaluation to compare different models.

Location: Building G - Ground floor: Conference room MANON CORMIER

4:00pm
6:00pm

Product Architecture Design 1 - Applications

Session Chair: Dieter Krause, Hamburg University of Technology, Germany

Platform approach for modularising battery electric fast ferries

Tobias Seidenberg 1, Jan-Philipp Disselkamp 1, Christoph Jürgenhake 1, Harald Anacker 1, Roman Dumitrescu 2, Apostolos Papanikolaou 3
1 Fraunhofer Research Institute for Mechatronic Systems Design IEM; 2 University of Paderborn; 3 National technical university of Athens

The transportation sector is responsible for a relevant share of the total emissions and offers great potentials. It is necessary to implement as many zero-emission mobility systems as possible in the shortest time. For fast ferries, which are a relevant transport manner for a large share of the global population, technical issues could be solved and the successful operation was demonstrated. Up to today high-speed ships have been fully individually designed because physical effects demand for an individual optimisation for each use-case. Specifically for battery electric ships the overall efficiency is crucial to ensure not only an ecological but also economical operation.
With today's methods the design and production of such an individual designed ferry does take too long. To cover the rising demand, new approaches for mass production need to be established.
In this paper we describe a method for designing a platform for ships with the example of a battery electric fast ferry. The focus is on the actual modularisation, as other aspects like requirements or results of our example case are published elsewhere and are therefore just included briefly.
The method is validated on the world's first battery powered high-speed ferry.

WEDNESDAY 26th July 2023

PROGRAM
&
ABSTRACTS

24th International Conference on Engineering Design
Bordeaux, France, 24 - 28 July 2023

9:00am - 9:45am

KN 03: Keynote: The challenge of preserving and improving the quality of wines in a changing context
Location: Bât D - RDC: Amphi AUBY
Chair: Pascal Le Masson

The challenge of preserving and improving the quality of wines in a changing context

Philippe Darriet, University of Bordeaux

9:45am - 10:45am

D - AM 02: Additive Manufacturing	D - AM 03: Data Driven Manufacturing	D - DE 04: Hybrid Education	D - DW 05: Practical Applications of Data Driven Design	D - H&W 03: Supporting Specific Medical Conditions	D - HB 03: Design Collaboration Behaviour	D - IBM 04: The Virtual and the Physical	D - M&P 03: Applications in Design Modeling	D - S&R 04: Circular Design of Packaging	D - S&R 05: Product Lifecycle Management
Location: Bât A - RDC: Amphi BERNARD	Location: Bât C - 1er étage: Salle C2 - 114	Location: Bât G - Rez de jardin: Amphi MANON CORMIER	Location: Bât C - 2ème étage: Salle C2 - 216	Location: Bât C - RDC: Salle C2 - 004	Location: Bât C - RDC: Salle C3 - 001	Location: Bât C - RDC: Salle C3 - 002	Location: Bât C - 1er étage: Salle C2 - 106	Location: Bât A - RDC: Amphi BENZACAR	Location: Bât H - RDC: Amphi ASSELAIN
Chair: Tino Stankovic	Chair: Kevin Otto	Chair: Charlie Ranscombe	Chair: Nikola Bursac	Chair: Jonathan Borg	Chair: Christopher McMahon	Chair: Larry Stauffer	Chair: Alison McKay	Chair: Frido Smulders	Chair: Francois Cluzel

10:45am - 11:15am

CB 03: Coffee Break

11:15am - 12:45pm

P - DE 05: Educating and Learning Design	P - DW 06: VR-Enhanced Design	P - H&W 04: Medical Design	P - HB 04: Cognitive Processes in Design	P - HB 05: Human in Behaviour in Design	P - I&S 03: PSS and Service Design	P - S&R 06: Designing for the Circular Economy	P - SD 05: Design Theories and Approaches 1	P - SD 06: Product Architecture Design 2 - Analysing Modularity and Impact Effects	P - SD 07: Robust Design & Tolerance Management
Location: Bât G - Rez de jardin: Amphi MANON CORMIER	Location: Bât C - 1er étage: Salle C2 - 106	Location: Bât C - 3ème étage: Salle C2 - 308	Location: Bât C - RDC: Salle C3 - 002	Location: Bât H - RDC: Amphi ASSELAIN	Location: Bât A - RDC: Amphi BERNARD	Location: Bât A - RDC: Amphi BENZACAR	Location: Bât C - 2ème étage: Salle C2 - 216	Location: Bât C - RDC: Salle C3 - 001	Location: Bât C - 3ème étage: Salle C2 - 314
Chair: Ross Brisco	Chair: Kristina Shea	Chair: Mario Storga	Chair: Yoram Reich	Chair: Kristin Paetzold	Chair: Marco Bertoni	Chair: Alessandro Bertoni	Chair: Alexander 'Freddie' Holliman	Chair: Marija Jankovic	Chair: Scott Ferguson

12:30pm - 1:45pm

MIP 01: Mentoring Programme Event (Hybrid)
Location: Bât C - RDC: Salle C2 - 001
Chair: Julie Stal-Le Cardinal
Chair: Sophie Hallstedt

12:45pm - 2:00pm

LB 03: Lunch Break

2:00pm - 2:45pm

KN 04: Keynote: The 4th industrial revolution: myth or reality
Location: Bât D - RDC: Amphi AUBY
Chair: Christopher McMahon

The 4th industrial revolution: myth or reality

Daniel Harari, LECTRA

2:45pm - 3:45pm

D - DC 02: Creativity and Collaboration	D - DE 06: Teaching Examples & Experiments	D - DW 07: Specific Applications Of AI	D - DW 08: Enhancements to CAD	D - M&P 04: Design Methods and Teams	D - S&R 07: Applications of Sustainable Design 2	D - S&R 08: Ecodesign & Circular Design Methods	D - SC 03: Industry Design Challenges	D - SD 08: Design for X - Applications and Examples
Location: Bât C - RDC: Salle C3 - 002	Location: Bât G - Rez de jardin: Amphi MANON CORMIER	Location: Bât C - 1er étage: Salle C2 - 114	Location: Bât C - 1er étage: Salle C2 - 106	Location: Bât H - RDC: Amphi ASSELAIN	Location: Bât A - RDC: Amphi BERNARD	Location: Bât A - RDC: Amphi BENZACAR	Location: Bât C - RDC: Salle C3 - 001	Location: Bât C - 2ème étage: Salle C2 - 216
Chair: Julie Stal-Le Cardinal	Chair: Lucienne Blessing	Chair: Benjamin Schleich	Chair: Mohsen Moghaddam	Chair: Petra Badke-Schaub	Chair: Nadege Troussier	Chair: Harrison Kim	Chair: Markus Zimmermann	Chair: Dietmar Göhlich

4:00pm - 5:00pm

GM: General Meeting DS
Location: Bât H - RDC: Amphi ASSELAIN

7:30pm - 11:59pm

GD: Gala Dinner

Design in a complex world

9:00am
9:45am

WED
26 JUL

Philippe Darriet, University of Bordeaux, France

Session Chair: Pascal Le Masson, Mines Paris - PSL, France

KN 03 - Keynote : The challenge of preserving and improving the quality of wines in a changing context

Since the beginnings of wine-making in the ancient times, man has not only sought through the production of wine, the elaboration of a banal fermented beverage. His quest was motivated by the search for a drink with aesthetic and cultural dimensions. The sensory perception of wine, in its hedonic characteristics, associated with color, aroma, taste is one of the first criteria. Sometimes, it represents such a level of exemplarity, that it can be considered by the wine-lover as a real work of art. The history of Bordeaux wine testifies for this search of quality.

However, the elaboration of a quality wine is based on a delicate balance. It is the result of interactions between a combination of favorable natural factors (associated with climate, topography, soil type...) and human choices. These human choices concern, for example, the types of varieties cultivated, the methods of cultivation, the empirical know-how and the scientific and technical knowledge in the methods of elaboration and conservation of wines, involving oenology.

Through the current context of environmental evolution, in particular with climate change, as well as the transformation of societal expectations for wine, the presentation will address the means developed today by research in the field of vine and wine sciences to accompany these transitions.

BIO

Philippe Darriet is Professor in Oenology (analytical chemistry, vinification process, wine composition, sensory analysis) and Director of Oenology research (UMR INRAE 1366 OENOLOGY) at Institute of Vine and Wine Science from University of Bordeaux.

After preparing a PhD thesis at Faculty of Oenology (University of Bordeaux) (1993) on Sauvignon blanc aroma (PhD thesis directed by Prof D Dubourdieu), he was recruited in 1994 as assistant professor at Bordeaux University. Habilitation thesis (2002) on wine aroma chemistry and biochemistry and Full professor position since 2007. His research activities mainly focus on the characterization of volatile odorant compounds, often present in trace amounts, which contribute to the typical aromatic nuances of certain grape varieties such as 'Sauvignon blanc', Riesling, Cabernet Sauvignon, Merlot, Viognier and noble rot sweet wines, or Cognac spirits. He also studies the chemical, biochemical and microbiological aspects related to volatile odorant compounds and their precursor forms in fruits, as well as the phenomena occurring during wine making and ageing, and their impact on the aromatic component. Deeply committed to the importance of research to support wine professionals, Philippe Darriet and his group have local, national and international collaborations with both vine ecophysiologists and plant pathologists concerning the impact of both climate change and cryptogamic diseases on wine quality, as well as with experimental economists in the context of consumer choice studies..

AM 01

WED

26 JUL

9:45am
10:45am

Additive Manufacturing

Session Chair: Tino Stankovic, ETH Zurich, Switzerland

File format selection for efficient digital process chains in additive manufacturing

Slim Krueckemeier, Reiner Anderl, Benjamin Schleich, Product Life Cycle Management, Technical University of Darmstadt, 64287 Darmstadt, Germany

Selecting a suitable file format for data exchange in additive manufacturing is fundamental when designing these digital process chains. Within the scope of this investigation, alternatives to the de-facto industry standard STL are to be found to overcome the disadvantages of the STL-based digital process chain. Therefore, suitable file formats are identified by conducting literature and market research and evaluated regarding their suitability to support a continuous digital process chain. In addition, typical use cases in additive manufacturing are defined, and their requirements for a file format for data exchange are derived. Finally, for each use case defined, recommended and suitable file formats are proposed.

★

Sensing In-Situ temperatures by coordinates in Fused Filament Fabrication for identifying interlayer anisotropic mechanical properties and enabling post-FEM analysis

Erik Amlie, Emil Fylling, Sindre Wold Eikevåg, Ole S. Nesheim, Martin Steinert, Christer W. Elverum, NTNU

In Additive Manufacturing (AM), new generations of polymer composites presented as engineering-grade materials provide high-end mechanical properties with the design freedom AM provides. Interlayer anisotropy is the main challenge in both in-situ optimization and post-analysis in transitioning from prototypes to high-performance components in fused filament fabrication (FFF). Recent studies show a direct correlation between layer fusion temperature and mechanical properties. In this paper, we present synchronized position and temperature data and study how a component changes based on layer height and geometry. An IR sensor transfers data while printing a G-code generated by FullControllGcode, printing in a single direction and recording temperature in front of the nozzle. Results show that within each layer, a Δt of 20°C at thinner geometries, the heat loss will provide a reduction in mechanical properties and further heat loss occurs when moving away from the heated bed. By using the presented temperature mesh in further studies, post- printed anisotropic components can be analyzed by FEM, and the FFF process can be adaptively optimized based on location, size and geometry.

Location: Building A - ground floor: Conference room BERNARD

9:45am
10:45am

Additive Manufacturing

Session Chair: Tino Stankovic, ETH Zurich, Switzerland

Feature-based method to formalise additive manufacturing related data at the mesoscale based on a mereotopological description

Chloe Douin 1, Elise Gruhier 1, Robin Kromer 2, Olivier Christmann 3, Nicolas Perry 1
1 I2M UMR 5295, Arts et Métiers ParisTech, Esplanade des Arts et Métiers, 33400 Talence, France;
2 Univ. Bordeaux, I2M UMR 5295, 33500 Gradignan, France; 3 LAMPA, Arts et Metiers ParisTech, 2 Boulevard du Ronceray, 49000 Angers, France

Research on additive manufacturing has highlighted methods and guidelines to optimise the design process and improving finished product quality. There is still room for improvement in making AM as reliable as more traditional processes when considering industrial use. In terms of manufacturing, managing print parameters properly can improve reproducibility and repeatability of a part, in addition to its fidelity to the basic geometric model. However, a topological optimised geometry requires more than good parameterisation. Efforts are therefore being made to formalise knowledge so that it is explicit and accessible to designers. This paper proposes an approach based on the spatio-temporal evolution of a geometry during printing to quantify data at the meso scale. Previous studies have been conducted on the description of features in time, space and space-time, and on the influence of their arrangement within a part. Building on this work, a parameterised test specimen was designed to measure the quantitative impact of these arrangements on the final product. The method is then presented and illustrated through a case study to help the designer with quantitative predictive values of geometric parameters.

A DFAM Framework For The Design Of Compliant Structures

Alan Air 1,2, Andrew Wodehouse 1
1 Design Manufacturing and Engineering Management, University of Strathclyde, Glasgow, UK; 2 National Manufacturing Instiute of Scotland, University of Strathclyde, Glasgow, UK

Additive manufacturing methods present prospects for designed mechanical deformation via the integration of controlled anisotropic lattice structure forms. Their assimilation into a Design for Additive Manufacturing (DfAM) process would create a novel framework for the design of compliant mechanisms (CM). The method uses lattice structures to replace rigid multi-part mechanisms, with integrated and controlled flexibility into a single, compact, and precise component. In recent years, a lot of research has gone into making algorithms that enable users to generate CMs for their designs. But by relying on algorithms to design solutions, are they neglecting to fully understand how these mechanisms work. This work undertakes the design and development of a novel DfAM Framework, that utilises controlled lattice structure deformations to create a standardised method of CM design. The authors have developed a method for this, whilst allowing users to tailor CMs to their design, by using a wide selection of pretested structures. Indicating suitable structures for their design using an integrated novel taxonomy. The framework is tested and developed using a series of case studies.

Design in a complex world

Location: Building C – 1st floor: Room C2 – 114

9:45am
10:45am

Data Driven Manufacturing

Session Chair: Kevin Otto, The University of Melbourne, Australia

Data-driven smart manufacturing: case study of workforce management process in an Italian leather goods company

Giorgia Pietroni, Marco Marconi, Università degli Studi della Tuscia

Digitalization is one of the fundamental pillars of Industry 4.0. Within smart factories, Big Data Analytics systems play a key role in supporting the decision-making process of various stages of business processes. In this context, this research aims to identify solutions able to process large volumes of data from digital business processes with the final goal of adding value to the organisation. More specifically, the research deals with the implementation of a digital manufacturing tool able to digitize the workforce management process. The research has been applied in the case study of an Italian manufacturing company operating in the leather goods sector through the digitalization of the workforce management by a cloud-based platform. The implementation of the tool increases the efficiency of the production process, provides efficient management and integrates workforce data into one system. The implemented tool generates a large volume of data, the final goal is to make data user-friendly to support business decisions. Digitisation provides an exchange of information to support managers to make confident decisions.

Barriers from a socio-technical perspective to implement digitalisation in industrial engineering processes – a literature review

Malin Hane Hagström, Dag Bergsjö, Henrik Wahrén, Chalmers University of Technology

With the paradigm shift towards Industry 4.0 and digitalisation, manufacturing engineers face several unexplored challenges; in the products for which they are designing production, in the equipment they are designing to realise production systems and in the digitalisation impact on engineering processes. Today's manufacturing system design processes are still based on traditional engineering methods and have difficulties to cope with increased complexity. The aim of this systematic literature review is to explore drivers and barriers to implement digitalisation in engineering processes from a socio-technical perspective. The identified general barriers were cyber security, lack of competence, lack of standards, large investments and resistance to change. For the engineering processes the main drivers were increased product complexity, servitisation, data driven design and engineering productivity, with the main barriers culture, excess amount of data, integration of tools. cyber security and data quality. The study shows the complexity of the challenge, and that it is not only the technology that is the top barrier. Further research is recommended to develop approaches of successful engineering digitalisation implementations.

Design in a complex world

Location: Building C – 1st floor: Room C2 – 114

9:45am
10:45am

Data Driven Manufacturing

Session Chair: Kevin Otto, The University of Melbourne, Australia

Operator 4.0 for Hybrid Manufacturing

Kenton Blane Fillingim, Thomas Feldhausen, Oak Ridge National Laboratory

Hybrid manufacturing, a combination of additive and subtractive manufacturing capabilities in one system, has recently become a more viable production option across several industries. Although current hybrid manufacturing research covers a broad range of topics, there is a lack of focus on how this new technology impacts both the designer and the operator of hybrid systems. This paper identifies areas of literature across design theory and Industry/Operator 4.0 research efforts and presents a path for applying this research to hybrid manufacturing users. The unique relationship between operator and designer is highlighted as they learn new strategies and develop new intuitive judgements over time to become the first experienced/expert users of hybrid manufacturing. The potential impact of excessive cognitive workload due to the novel combination of processes is discussed. This paper begins a critical discussion about proper knowledge transfer to other hybrid designers and operators, as well as towards efforts of monitoring, inspecting, and automating hybrid manufacturing processes.

★ HVLV Engineering with Module System(s), ETO and lean design - study on practitioner information needs

Tero Sakari Juuti 1, Teuvo Heikkinen 1, Tero Heino 2, Ilari Graf 3, Juha-Pekka Tomberg 3, Hannu Oja 4
1 Tampere University; 2 Valmet Technologies Corp.; 3 Meyer Turku; 4 Konecranes Corp.

This research elaborates the engineering design of high value low volume (HVLV) artefacts (aka Capital goods, investment goods). Our goal is to describe what information needs the practitioners have when doing sales engineering and engineering in HVLV projects. The research approach uses Design Research Methodology with four company cases.
Our findings are that engineering design of HVLV artefacts reuses several module systems, module libraries, technology catalogues, engineering-to-order and variety of design support systems, configurators, design guidelines, parametric models and lean-based design reasoning patterns etc. This poses major challenges for the engineers; how to use all relevant information and how to find it from different IT-systems.

Location: Building C – 1st floor: Room C2 – 114

9:45am
10:45am

Data Driven Manufacturing

Session Chair: Kevin Otto, The University of Melbourne, Australia

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This study indicates that in HVLV context such engineering strategy is required, which guides and drives tactical and operational engineering decisions not only within a project delivery but across project deliveries. Operative and tactical engineering is done during the delivery project and value capture is not achieved in full potential if the engineering strategy is neglected or overruled. This is challenge for current modularisation and ETO-methods and tools.

Design in a complex world

Location: Building G – ground floor: Conference room MANON CORMIER

9:45am
10:45am

Hybrid Education

Session Chair: Charlie Ranscombe, Swinburne University of Technology, Australia

Hybrid Education Content and Platform for Bachelor Curriculum in Technology and Engineering

Benoit Eynard 1, Pascale Bachmann 1, Sébastien Le-Loch 2, Damien Picard 2, Jean-Dominique Guérin 3, Matthieu Bricogne 1, Tatiana Reyes 4
1 Université de Technologie de Compiègne; 2 Université de Nantes; 3 Université Polytechnique Hauts-de-France; 4 Université de Technologie de Troyes

During coronavirus time, academic organisations and education institutions have been faced to amazing and radical changes from one day to the other of their teaching contexts, practices, materials and standards and so on. Due to pandemic, in many countries professors, teachers, educators have been obliged to switch on remote education and teaching models with numerous virtual and digital solutions that at the beginning were more or less efficient and professional based. The paper will present a experiment feedback for large hybridation of technology and engineering curriculum for bachelor degree in French higher education system. The educational content and platform has been developed by the consortium of 14 different universities and higher education institutions. In the global topics covered by the project, a specific focus will be given in the paper on subject dealing with engineering design, systems engineering and sustainability.

Design Teaching Integrating Additive Manufacturing Constraints

Robin Kromer 1, Elise Gruhier 2
1 University of Bordeaux,CNRS, Arts et Metiers Science and Technology, Bordeaux INP, I2M Bordeaux, Esplanade des Arts et Metiers, 33405 Talence, France; 2 CNRS, University of Bordeaux, Bordeaux INP, I2M Bordeaux, Esplanade des Arts et Metiers, 33405 Talence, France

Additive manufacturing (AM) processes are now integrated in industry. Therefore, new methods to design AM parts taken into consideration capabilities and limitations are necessary. It is very difficult for teachers to effectively guide students with ideas emerging from generative design tools. AM requires significant preparation and compromises. Topological optimization is also used depending on requirements. A significant impact on the final part quality is related to the part orientation and geometric dimensions. Therefore, this white paper focuses on detailed design steps to prepare future technicians and engineers to design for additive manufacturing. Active teaching pedagogy guideline is proposed. Students have to think in 3D and use analysis tools to create and validate the optimised design. They use immersive tools to review constraints and model diagnostic algorithm to generate data. Present approaches with design guidelines and tools enable to create AM rules based on it. Questionnaire shows that students need explicit knowledge information. Features recognition and geometry diagnostic are mandatory for complex model. Immersive tool helps to evaluate post-processing. They can now relate AM product-process relationship.

Design in a complex world

Location: Building G – ground floor: Conference room MANON CORMIER

9:45am
10:45am

Hybrid Education

Session Chair: Charlie Ranscombe, Swinburne University of Technology, Australia

Pilot Study Understanding Students' Perceptions of Failure in Product Design

Carlye Anne Lauff 1, Alexis Friesen 1, Jessica Menold 2
1 University of Minnesota; 2 Pennsylvania State University

Failure is part of the design process, and yet there is limited knowledge around how product design students perceive failure in their work. This pilot study aims to understand how a small sample size of undergraduate product design students conceptualize success and failure during specific stages of their design projects. This study uses a two-step data collection and analysis process. First, we collected responses from students on topics related to success and failure in a survey. Second, interviews were conducted with a subset of the survey respondents where these emergent topics were discussed and refined. In analyzing the responses, the research team used the Double Diamond Design process frame-work to organize what factors students deemed a success or failure within each stage. In summary, our preliminary findings indicate that determining success or failure is driven by the connection to the problem statement regardless of the stage; that student designers refer to failure as a spectrum but then in their examples showcase a binary view on the topic; and that examples of failure are often the opposite of success, reinforcing the notion of binary success vs. failure during student design projects.

Dimensions of Product Complexity from Designers' Perspectives

Alexander 'Freddie' Holliman, University of Strathclyde

The perceived complexity of a product (product complexity) is doubtless an influential phenomenon in a design project. Insight into this factor and how it can be measured, is key to understanding its influence, supporting project planning and resource demand estimation. Opinions on product complexity vary greatly, with many definitions, scales and techniques to measure product complexity available; many of which draw their conclusions from engineering design research. Yet the field of product (or industrial) design companies, whose designers work across a vast range of product types, from domestic to industrial remains under researched. These designers have a tacit understanding of many influences over their projects, of which product complexity is one.
This paper presents an analysis of the dimensions (or measures) of product complexity found in liter-ature and compares its findings to the measures defined by practicing product designers. This paper will demonstrate the process used to identify these dimensions and the scales developed to assess product complexity in a practical way and will make conclusions on the perspectives held on product complexity by product designers.

Design in a complex world

Location: Building C – 2nd floor: Room C2 – 216

9:45am
10:45am

Practical Applications of Data Driven Design

Session Chair: Nikola Bursac, Hamburg University of Technology (TUHH), Germany

What Users Want: a Natural Language Processing Approach to Discover Users' Needs from Online Reviews

Irene Spada 1,5, Simone Barandoni 2,5, Vito Giordano 1,5, Filippo Chiarello 3,5, Gualtiero Fantoni 4,5, Antonella Martini 3,5
1 School of Engineering, Department of Information Engineering, University of Pisa, Italy; 2 Department of Computer Science, University of Pisa, Italy; 3 School of Engineering, Department of Energy, Systems, Land and Construction Engineering, University of Pisa, Italy; 4 School of Engineering, Department of Civil and Industrial Engineering, University of Pisa, Italy; 5 B4DS - Business Engineering for Data Science lab, University of Pisa, Italy

Digital media are a means to deliver products and services, but also a channel to interact with consumers and a source of information on users' preferences. Data shared by customers on the web, the User-Generated Content (UGC), can give entrepreneurs a detailed perspective of the market. This work examines an application of Natural Language Processing techniques on UGC to discover insights on users' opinions. We collected more than 13.000 reviews of software from digital stores and review website to gather information on the customers' perspective and their response to a given marketing strategy in two case studies on digital product's launch. The objective is to give support to two Italian companies in the process of business model development through data-driven evidence. We aim to discover who are the users and which are their needs using a lexicon-based approach to mine unstructured text. The results provide qualitative and quantitative descriptions of the market segments. We propose a method to examine UGC and to explore customers' behavior on social media. The findings helped managers for the development of their business model, enhancing an informed decision-making process.

A knowledge-based ideation approach for bio-inspired design

Liuqing Chen 1,2, Zebin Cai 1, Zhaojun Jiang 3, Qi Long 4, Lingyun Sun 1,2, Peter Childs 5, Haoyu Zuo 5
1 Department of Computer Science and Technology, Zhejiang University, Hangzhou 310030, China; 2 Singapore Innovation and AI Joint Research Lab, Zhejiang University, Hangzhou 310030, China; 3 School of mechanical engineering, Tianjin University, Tianjin 300350, China; 4 Zhejiang University-University of Illinois at Urbana-Champaign Institute, Haining 314400, China; 5 Dyson School of Design Engineering, Imperial College London, London SW7 2AZ, UK

Bio-inspired design (BID) involves generating innovative ideas for engineering design by drawing inspiration from natural biological phenomena and systems, using a form of design-by-analogy. Despite its many successes, BID approaches encounter research challenges including unstructured data and existing models that hinder comprehension and processing, limited focus on finding biological knowledge compared to defined problems, and insufficient guidance of the ideation process with algorithms. This paper proposes a knowledge-based approach to address the challenges. The approach involves transforming unstructured data into structured knowledge, including information about natural sources, their benefits, and applications. The structured knowledge is then used to construct a semantic network, enabling designers to retrieve information for BID in two ways. Furthermore, a three-step ideation method is developed to encourage divergent thinking and explore additional potential solutions by drawing inspiration and utilizing knowledge. The knowledge-based BID approach is implemented as a tool and design cases are conducted to illustrate the process of applying this tool for BID.

Location: Building C – 2nd floor: Room C2 – 216

9:45am
10:45am

Practical Applications of Data Driven Design

Session Chair: Nikola Bursac, Hamburg University of Technology (TUHH), Germany

Designing for legal practitioners: Lessons learned from legal tech development and implementation

Marko Đurić 1, Tomislav Martinec 2, Marko Porobija 1, Mario Štorga 2,3
1 Law Firm Porobija & Špoljarić LLC; 2 University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture; 3 Luleå University of Technology

Recently, the design and digitalisation approaches have become increasingly utilised in the legal context, typically under the names of legal design and legal tech. One of their goals is to help legal practitioners be more efficient and to provide better quality and more comprehensive legal services. Also, given that both movements rely heavily on participatory and co-design, they will require increased support not only from design practitioners but also from design researchers and educators. Therefore, this paper investigates, from a design research viewpoint, the opportunities and challenges of developing and implementing legal tech, with a particular focus on legal practitioners. It reports on four cases of designing legal tech solutions and their implementation in a law firm. The main insights are related to the importance of value perception through participatory and co-design, the need for efficient and effective testing methodologies, and the opportunity to test a wide range of design methods and tools in the legal context. The paper also complements the legal design and legal tech literature with additional arguments on why designing in the legal context is challenging compared to designing in other domains.

Reliability Analysis for Sensor Networks and their Data Acquisition: A Systematic Literature Review

Sören Meyer zu Westerhausen, Jannik Schneider, Roland Lachmayer, Institut für Produktentwicklung und Gerätebau

The use of sensor networks (SNs) on the surface or the inside of large-scale components allows the continuous acquisition of data on the applied loads and their structural integrity. A lot of publications on SN's system reliability deal with this topic from a hardware- or a data- and energy-oriented viewpoint. To give an overview on the state of the art in the field of reliability-oriented concept-optimization of SNs, a Systematic Literature Review is conducted. The found literature is used to investigate how different models combine the different viewpoints to analyse the system reliability. By analysing the results regarding the used reliability indicators and methods to assess the system reliability from the different viewpoints, it can be observed that most publications deal with the accuracy, loss and delay of data as well as the energy consumption in SNs. Few publications use common modelling methods like reliability block diagrams or Markov chains with a focus on the hardware reliability. Furthermore, none of the found publications combines the data, hardware and energy perspective and uses them to optimize a SN regarding its reliability from all three viewpoints.

Location: Building C – ground floor: Room C2 – 004

9:45am
10:45am

Supporting Specific Medical Conditions

Session Chair: Avril Thomson, University of Strathclyde, United Kingdom

Development of a novel diabetic foot risk assessment for low-resource healthcare settings: A case study of lean design

Madison Reddie, Daniel Frey, Massachusetts Institute of Technology

Interest in applying a "lean" philosophy to design has been slowly growing in recent years, but there are still few broadly applicable methodologies and illustrative cases published in the literature to guide lean design processes. Lean approaches promise cost reduction and increased product value, which could be particularly beneficial in product development for low- and middle-income country markets, where value demands are high. We use the clinical need of efficient diabetic foot risk assessment in low-resource healthcare settings to present an example of lean early-stage design of a medical device. The background of existing medical literature and commercial products is intentionally leveraged throughout the design process to streamline development and minimize the need for independent validation of product strategies and design features. Our approach resulted in an efficient design process that generated a novel, purely mechanical plantar pressure evaluation device that can indicate high risk of diabetic foot ulcer in resource-constrained settings. This case provides a practical example of how design processes can be adapted to be leaner where there are large gains from minimizing design cycle time and cost.

Design thinking in data-intensive healthcare improvement: lessons from a perioperative case study

Daniel James Stubbs 1,2, Thomas Henry Bashford 1,3, Peter John Clarkson 1
1 University of Cambridge Department of Engineering, Health Systems Design Group; 2 University of Cambridge Department of Perioperative, Acute, Critical, and Emergency Care (PACE); 3 Department of Anaesthesia, Cambridge University Hospitals NHS Foundation Trust

Healthcare generates vast quantities of 'routinely collected' data that is recognised as a valuable substrate to drive improvement. Realising this benefit however, requires the sequential distillation of new knowledge before analytical findings are used to inform real-world change. This dichotomy requires the combination of techniques from data science (to derive meaningful knowledge) and improvement (to deliver change). Recognising this transdisciplinary need and the complexity of modern healthcare, we developed an improvement project to incorporate a 'systems approach' into the analysis of pseudonymised perioperative data for the purpose of redesigning the systems that deliver surgical care to older patients. This required the development of novel mixed-methods workflows combining tools used to realise a systems approach in practice and to support meaningful analysis, and to translate these findings towards 'better' care systems. This paper recounts the incorporation of these tools into 'data-intensive improvement' and reflects on the relevance of design thinking to improve the conduct of the necessary data science to achieve our ultimate aim, using data to improve services for older surgical patients.

Location: Building C – ground floor: Room C2 – 004

9:45am
10:45am

Supporting Specific Medical Conditions

Session Chair: Avril Thomson, University of Strathclyde, United Kingdom

Augmented reality Application for pulmonary auscultation learning aid

Lyna Hireche 1, Sergio-Camilo Medina-Galvis 1, Roger Rusca 2, Nicolas Pinsault 3, Guillaume Thomann 1

1 Univ. Grenoble Alpes, CNRS, Grenoble INP, G-SCOP; 2 Pol'Air, private physioterapist, Grenoble, France; 3 Univ. Grenoble Alpes, physiotherapy School

During some applied anatomy lessons, physiotherapist students must develop a skill of locating and recognizing underlying anatomical elements, from surface palpations, or through clinical tools on their classmates. For this, precise procedures exist and students have to mobilize knowledge acquired from different types of resources: support documents from the teacher, anatomical charts (books, drawings, diagrams), dissection videos or even internet resources. They also need more practical time and exercises. The issues facing students relate to the availability of these resources during the procedure, their relevance, the mobilisation of resources to practice and the applicability in a real situation. This project stems from a desire to make Augmented Reality technology available to students, to help in learning precise clinical procedure, in our case the location of the auscultation points using a stethoscope. The aim would be to supplement the real environment of the student during his learning on a person, by the possibilities of having additional resources according to its needs (auscultation points superimposed on a 3D representation of the lungs).

Design in a complex world

Location: Building C - ground floor: Room C3 – 001

9:45am
10:45am

Design Collaboration Behaviour

Session Chair: Christopher McMahon, University of Bristol - United Kingdom

Using design methods to explore the context of complex behavioral design problems in the early stages of behavioural design

Carolina Falcão Duarte, Jaap Daalhuizen, Danmarks Tekniske Universitet

Behavioural design has been gaining momentum to address critical societal challenges such as elderly care. At the same time, it struggles to deal with complex challenges and integrate multiple contextual factors' influence in domains like healthcare. Behavioural design processes lack guidance on how to prevent this and instead define problems that are ecologically valid. Conventional design methods do guide designers to do this. Thus there is a need to investigate how design methods can support behavioural designers to explore the context and integrate multiple perspectives on the problem, resulting in context-sensitive problem definitions. To respond to this need, we present a case where designers used a combination of design methods to investigate the complex context of hygiene in nursing homes. We show how combining different design methods supported the designers in advancing their understanding of a complex context and the problematic behaviours that occurred in it. We conclude by discussing the importance of using design methods to reveal important insights at the early stages of the behavioural design process.

Behavioural Design for Medical Errors during Patient Diagnosis Process

Swagatam Dey, Shweta Dabral, Pramod Khadilkar, Indian Institute of Technology, Delhi

The health and well-being sector has been of significant interest to the behavioural design domain since bringing in behavioural changes can help improve the overall well-being of a community. However, the domain's intervention in this sector has been limited to persuasive techniques for the adoption of healthier lifestyles. There is a need to consider the diagnostic actions and decisions undertaken by doctors as it represents an important part of health and well-being improvement of people. Medical errors committed by healthcare professionals are an important aspect of the healthcare domain. Since these errors result due to undesired or non-normative behaviours, behavioural design can be instrumental in their eradication. But the research on integrating behavioural design and medical error literature is still nascent. In this paper, we address this gap by identifying the categories of errors based on the performance levels within which they occur. Next, we contextualise these errors categories to medical literature focusing on the diagnostic stage. We further link it to the behavioural change model of COM-B to determine preliminary intervention functions that can be utilised by behavioural designers to deploy interventions.

Design in a complex world

Location: Building C - ground floor: Room C3 – 001

9:45am
10:45am

Design Collaboration Behaviour

Session Chair: Christopher McMahon, University of Bristol - United Kingdom

Evaluating reflective behavior in engineering design retrospectives: An initial coding scheme

Theresa Ammersdörfer 1, Darien Tartler 2, Simone Kauffeld 2, David Inkermann 1
1 Technische Universität Clausthal, Institute of Mechanical Engineering (IMW), Robert-Koch-Str. 32, 38678 Clausthal-Zellerfeld, Germany; 2 Technische Universität Braunschweig, Institute of Work, Organizational and Social Psychology (AOS), Spielmannstraße 19, 38106 Braunschweig, Germany

Considering transformation processes within organizations, reflection is an enabler for learning and adaption of engineering processes, methods, and tools. Moreover, reflection as a core element of agile engineering approaches. However, a sound understanding of reflection behaviors of engineers or engineering teams is lacking. In this paper we proposed a structured reflection procedure including different dimensions to reflect on. To analyse reflection behavior of engineers and engineering teams we propose a coding scheme comprising of nine behaviors. The coding scheme allows to evaluate the reflection behavior in real time and give feedbacks to improve the quality of reflection. The proposed coding scheme is initially tested within a workshop with industry partners.

Co-designing technological explorations in developing futures literacy through speculative design and an artistic intervention

Álvaro Aranda Muñoz 1,2, Nina Bozic Yams 2, Lisa Carlgren 2
1 Mälardalen University; 2 RISE - Research Institutes of Sweden

Futures Literacy is the capability to imagine and understand potential futures to prepare ourselves to act and innovate in the present. This pilot study aims to understand how artistic methodologies and speculative design can support the collaborative exploration of futures in the context of work and contribute to developing peoples' capability of futures literacy. Our premise is that technologies such as Artificial Intelligence and the Internet of things can augment people and support their needs at work. To illustrate this process, we have presented a collaborative method that integrates an artistic intervention with speculative design activities. We tested the method in a full-day workshop with seventeen (17) participants from a Swedish academy responsible for enabling learning and competence development at work in the healthcare sector. The results indicate that the artistic intervention, combined with the speculative design activities, can challenge current participants' perspectives and offer them new ways of seeing futures with technologies. These new ways of seeing reveal underlying premises crucial in developing the capability of futures literacy.

Location: Building C - ground floor: Room C3 – 002

9:45am
10:45am

Design Collaboration Behaviour

Session Chair: Larry Stauffer, University of Idaho, United States of America

Challenges of using Augmented Reality to support an efficient and error-free assembly in complex variant environments

Valesko Cedrik Dausch 1, Daniel Roth 1, Matthias Kreimeyer 1, Sebastian Bohr 2
1 University of Stuttgart; 2 MAN Truck & Bus SE

As part of the digital transformation towards Industry 4.0, the tasks of staff on the shop floor are changing. Despite increasing automation, complex assembly steps still have to be carried out by humans, especially when it comes to complex products rich in variants, whose assembly cannpt be fully automated for various reasons. Due to increasing individualization and the steadily growing complexity of products, providing the right information at the right time and in the right place is becoming more important. In this context, the visualization of information via novel technologies such as augmented reality plays a crucial role towards an efficient and error-free production process. This paper compiles existing challenges when using augmented reality as a visualization form for an assistance system. On the one hand, the challenges found originate from a systematic literature review and are organized according to predefined categories. On the other hand, these challenges are complemented and compared through findings gained from expert interviews, which are conducted with employees of two European commercial vehicle manufacturers in the field of production. The analysis of the two methods highlights the need for further research.

Virtually Hosted Hackathons for Design Research: Lessons Learned from the International Design Engineering Annual (IDEA) Challenge 2022

Daniel Nygaard Ege 1, Mark Goudswaard 2, Ole Nesheim 1, Sindre W Eikevåg 1, Øystein Bjelland 1, Kim A Christensen 1, Robert Ballantyne 2, Shuo Su 2, Chris Cox 2, Louis Timperley 2, Omsri Aeddula 3, Raj Jiten Machchhar 3, Ryan Ruvald 3, Jie Li 4, Sara Figueiredo 4, Saurabh Deo 4, Nikola Horvat 5, Ivan Čeh 5, Jelena Šklebar 5, Daniel Miler 5, James Gopsill 2, Ben Hicks 2, Martin Steinert 1
1 Norwegian University of Science and Technology; 2 University of Bristol; 3 Blekinge Institute of Technology; 4 Aalto University; 5 University of Zagreb

The International Design Engineering Annual (IDEA) Challenge is a virtually hosted hackathon for Engineering Design researchers with aims of: i) generating open access datasets; ii) fostering community between researchers; and, iii) applying great design minds to develop solutions to real design problems. This paper presents the 2022 IDEA challenge and elements of the captured dataset with the aim of providing insights into prototyping behaviours at virtually hosted hackathons, comparing it with the 2021 challenge dataset and providing reflections and learnings from two years of running the challenge. The dataset is shown to provide valuable insights into how designers spend their time at hackathon events and how, why and when prototypes are used during their design processes. The dataset also corroborates the findings from the 2021 dataset, demonstrating the complementarity of physical and sketch prototypes. With this paper, we also invite the wider community to contribute to the IDEA Challenge in future years, either as participants or in using the platform to run their own design studies.

Location: Building C - ground floor: Room C3 – 002

9:45am
10:45am

Design Collaboration Behaviour

Session Chair: Larry Stauffer, University of Idaho, United States of America

In search for shared characteristics of physical and virtual prototypes

Stefan Zorn, Michael Hemmer, Kilian Gericke, University of Rostock

Prototyping is essential for knowledge acquisition and, thus, for informed decision-making in product development. The gold standard is still the use of physical prototypes. However, with the increase in computing capacity, it is becoming easier also to use virtual prototypes.

he selection of prototyping approaches often starts with the distinction between physical and virtual prototypes and therefore excluding a broad range of possibilities early on.

This paper explains why a selection of prototypes based on the distinction between physical and virtual is not necessarily the best solution and suggests a selection approach based on characteristics which offer the possibility to avoid this limitation. Therefore the characteristics of physical prototypes commonly used in literature are analysed and reduced to a generally valid selection. Examples of virtual prototypes are selected and analysed regarding their characteristics. All elaborated characteristics are then tested for their applicability to the examples of virtual prototypes.

Barriers to the use of artificial intelligence in the product development - a survey of dimensions involved

Benedikt Müller, Daniel Roth, Matthias Kreimeyer, University of Stuttgart

Artificial intelligence (AI) is seen as a great opportunity to secure future competitiveness in many corporate sectors. Potential for its use also exists in product development (PD) activities due to the amount of data generated and processed. Nevertheless, there are problems in applying the technology. This paper addresses current challenges based on a literature review, considering three disciplines that are necessary for the scope of this paper as a minimum: AI itself, information technology infrastructures (ITI) in context of digital transformation (DT), and PD as an application area. Building on the basic considerations of the state of the art, a link between the domains is established by outlining a possible reference framework towards the utilization of AI applications in PD. This enables an expanded interdisciplinary understanding. Key obstacles appear specifically to be difficult collaboration conditions between the disciplines of PD and AI applications development due to communication problems. Reasons for this include:
• Meta models of PD do not provide a sufficient information base
• Lack of standardized process models for the deployment of AI

Location: Building C – 1st floor: Room C2 – 106

9:45am
10:45am

Applications in Design Modeling

Session Chair: Alison McKay, University of Leeds, United Kingdom

Accessible solar energy technology for domestic applications in the UK: Edge Solar

Alex Heaton 1, Kyungeun Sung 2, Patrick Isherwood 3
1 HiB Ltd, UK; 2 De Montfort University, UK; 3 Loughborough University, UK

Renewable energy is increasingly used and promoted. In the UK, for example, large scale renewable energy farms have been used to supply electricity with great effect. Given the large number of homes, there is considerable impact to be made by small scale residential renewable energy systems. Despite solar panels being the most common form of residential renewable energy technology, only 4% of buildings in the UK support solar technology of any kind. For direct electricity generation, silicon-based photovoltaic (PV) arrays are the most utilised, and when used in a residential setting, they are typically mounted on the sloped roofs. This is where the problem lies. The technology comes with a high cost, and there is further financial burden of installation and maintenance, making solar energy inaccessible for many UK homeowners. This paper presents a research and design innovation project to make PV technology more accessible in the UK. Edge Solar, the innovative, affordable, new PV system concept for UK homes may become a promising solution to significantly improve the accessibility to the PV technology and renewable energy at the household level in the UK and beyond with further development and commercialisation.

Design Process Modelling to Measure Engineering Productivity in Building Design

Yvonne Yu Bing Wong, Sam Conrad Joyce, Lucienne Blessing, Singapore University of Technology and Designt

A multi-domain Matrix (MDM) is used to identify and analyse rework loops within the Building Design (BD) process caused by building regulations. To model this process, we used information from official documents, plans of work, email archives, and anecdotal evidence as a case study. Findings reveal that MDM can identify the rework loops caused by building regulations, this information forms the basis to improve current BD processes. The complexity of the rework loop including the processes, people and, deliverables involved in the rework loop is also identified. Further analysis can also use the MDM to estimate the costs incurred with each rework cycle. This MDM can also identify rework loops in other engineering design processes due to design changes.

This study is part of a PhD project exploring engineering productivity in the construction industry using DRM. The results present an MDM that provides situation-specific insight, offering areas of process improvement, and support through engineering productivity measurement. This is one of the few studies that models rework loops in the BD process caused by regulations.

Applications in Design Modeling

Session Chair: Alison McKay, University of Leeds, United Kingdom

Toward a Human Systems Integration approach to the design and operation of a remote and virtual air traffic control center

Alexandre Disdier 1,2,3, Dimitri Masson 2, Thomas Brethomé 3, Marija Jankovic 1, Guy-André Boy 1,2
1 Université Paris-Saclay, CentraleSupélec, Laboratoire Génie Industriel, 91190 Gif-sur-Yvette, France;
2 Univ. Bordeaux, ESTIA INSTITUTE OF TECHNOLOGY, F-64210 Bidart, France; 3 CS Group, 22 Av. Galilée, 92350 Le Plessis-Robinson, France

Remote and virtual centers have been studied for the past twenty years as an alternative to the traditional air traffic control tower environment. Designing such complex sociotechnical systems requires a systems engineering approach that appropriately integrates the human element as well as the technological and organizational components. In this paper, we identify the challenges of implementing this human-systems integration in the design of complex systems. We present the feedback we obtained from a series of semi-structured interviews with people involved in the development of military air traffic solutions. The participants' responses helped us establish methodological guidelines for designing and building a disruptive remote and virtual air traffic control center. We discuss how virtualized human-in-the-loop simulations in particular should help designers analyze user activity and be more flexible in system acquisition.

Towards remote control of manufacturing machines through robot vision sensors

Nourhan Halawi Ghoson 1, Nisar Hakam 1, Zohreh Shakeri 1, Vincent Meyrueis 1, Stéphane Loubère 2, Khaled Benfriha 1
1 Arts et métiers - science et technologie; 2 PwC | Strategy&

The remote management of equipment is part of the functionalities granted by the design principles of Industry 4.0. However, some critical operations are managed by operators, machine setup and initialization serve as a significant illustration. Since the initialization is a repetitive task, industrial robots with a smart vision system can undertake these duties, enhancing the autonomy and flexibility of the manufacturing process. The smart vision system is considered essential for the implementation of several characteristics of Industry 4.0. This paper introduces a novel solution for controlling manufacturing machines using an embedded camera on the robot. This implementation requires the development of an interactive interface, designed in accordance with the supervision system known as Manufacturing Execution System. The framework is implemented inside a manufacturing cell, demonstrating a quick response time and an improvement between the cameras.

S&R 04

WED
26 JUL

9:45am
10:45am

Circular Design of Packaging

Session Chair: Frido Smulders, Delft University of Technology, The Netherlands

Sustainable Circular Packaging Design: A Systematic Literature Review on Strategies and Applications in the Cosmetics Industry

Linda Kaestner, Christoph Scope, Nikolas Neumann, Christian Woelfel, Technische Universität Dresden

Packaging protects products, keeps their value and reduces waste. This is especially crucial in domains with perishable goods such as food, medicine or cosmetics. But conventional packaging solutions yield negative environmental impacts. In the EU, the largest share of plastics is used for packaging, causing a corresponding footprint. The application of sustainable strategies to packaging should help to reduce carbon dioxide emissions and promote the development of sustainable consumption. In this paper, a review is conducted on research that brings together circular economy, packaging design and cosmetics industry, by systematic literature review and content analysis. In addition to the current standards of conventional packaging, packaging alternatives are presented, which are categorised according to the R-strategies Refuse, Reduce, Reuse and Recycle.

The use of organic residues to develop packaging: tests in molded pulp

Ricardo Marques Sastre, Cristiane Ferrari Zeni, Istefani Carisio De Paula, Ghissia Hauser, Stéfanie Da Conceição, Federal University of Rio Grande do Sul

At the end of its life the packaging may become a residue if it is not correctly discarded, becoming a visible component of the waste produced on the planet, with a defined shape and communicating with the world. In the same way, large-scale agricultural production generates organic residues that, although representing fiber-rich materials, are discarded, such as rice husk, coconut husk, wood fibers, among others. To contribute with solutions to minimize the environmental impact of packaging and organic residues, the present study aims at performing preliminary tests of molded pulp packaging manufacturing from organic residues, in a circular economy context. Action research was used as the method to guide the collective construction (project team and partner companies), and the direction of the preliminary tests of packaging to be manufactured. The tests performed on coconut fibers in transfer molding and thermoforming were promising, but they required the addition of binder substances like byproducts from starch, especially in the transfer molding method. Besides using fibers from alternative sources to cellulose, the proposed packaging is potentially compostable and may replace non-renewable material like oil-based polymers.

Location: Building A - ground floor: Conference room BENZACAR

9:45am
10:45am

Circular Design of Packaging

Session Chair: Frido Smulders, Delft University of Technology, The Netherlands

Promoting supply chain sustainability through industrial packaging eco-designing

Houssem Abdallah Bouhlel 1, Raoudha Gaha 2, Joanna Daaboul 2, Abdelbadia Chake r1
1 Laboratoire de Mécanique de Sousse, Université de Sousse, Tunisie; 2 Department of Mechanical Engineering, Université de Technologie de Compiègne, Roberval Institute, France.

The climate change and the new regulations imposed to slow down this process have pushed major actors around the world to apply sustainable measures in order to meet governmental obligations. The packaging industry has a major role in fighting climate change and the environmental social and financial disasters. In fact, packaging requires substantial number of natural resources and is often disposed of in ways that harm the environment. Supply chain managers realized that packaging design is the root to solve all the problems packages create throughout their entire life cycle. Therefore, a thorough study about influencing the design process should be prioritized. This paper provides a systematic review of industrial packaging eco-design applied to the supply chain. It aims to conceptualize the definition of industrial packaging eco-design and supply chain sustainability to categorize main parameters to its implementation and to identify the limitations of current research and its prospects.

Vegetables and fruits in a circular economy: packaging challenges and design opportunities

Juliette Broucke, Esther Noeth, Els Du Bois, University of Antwerp, faculty of Design Sciences, department Product Development

Packaging of potatoes, vegetables and fruits (PVF) currently deals with the fragile opposition of food waste reduction and packaging resource consumption. In order to understand how designers can re-think this always negative balance and outcome of waste creation, research was done to understand packaging and preservation of PVFs from both a technological and consumer perspective. A mixed research approach was applied, including literature study, expert interviews, packaging analyses, consumer survey and photo study. In sum, we concluded that the main function of packaging is preservation, including both protection from outside influences and conservation in best possible conditions. Optimal preservation should consider each PVF's respiration and transpiration needs, and ethylene sensitivity. Consumers are mostly not aware of correct preservation methods. However, on the other hand, their awareness evokes an important tendency to ban plastics without considering their positive impact on food preservation. In the paper, design opportunities are formulated for new reusable packaging, reducing waste creation and offering higher quality in food preservation and consumer experience.

Design in a complex world

9:45am
10:45am

Product Lifecycle Management

Session Chair: Francois Cluzel, CentraleSupélec, Université Paris-Saclay, France

Product Life Cycle Management with Digital Twins for Product Generation Development

Lars Arnemann, Sven Winter, Niklas Quernheim, Benjamin Schleich, Product Life Cycle Management (PLCM), TU Darmstadt

Digital Twins are virtual representations of a product-service-instance and, as a technology, represent an important part of the realization of Industry 4.0. They manage data of the associat-ed product instance and can also have functions for simulation to achieve cost and resource savings while simultaneously increasing product quality. In this paper, a need for action for the implementation of a systematic ap-proach for the returning of data of Digital Twins into the product design is identified and a methodology is developed as an answer. This methodology realizes an information management, which supports holistic data and information flows. It de-fines necessary steps for the implementation of data and information transport, starting from a data management up to information provision in product design. Based on a performed potential analysis for the identification of intended uses in the context of product design, the overall ap-plication focus is narrowed down to the development of new product generations to support the requirements development. The concept structure consists of Digital Twins, a data mining sys-tem for the transformation of data into information and a presentation system for managing the information provided.

A Method for Reducing Fuzziness and Accelerating New Product Modelling in CAD : the case of Design for Manufacturing

Jean-Bernard Bluntzer, Régis Barret, Egon Ostrosi, Université de Technologie de Belfort-Montbéliard, France

Improvements in product development can increase the competitiveness of firms. However, new product development in CAD systems involves difficulties and uncertainties that increase along with the pres-sure to develop the products. A distinct characteristic of CAD modeling for new product development is its uncertainty. This is because the information is usually approximate and incomplete during CAD modeling. Thus, the main objective of this paper is to propose a robust and flexible CAD approach to reduce uncertainty and accelerate new product modeling in the context of design for manufacturing. This methodology permits the convergence towards different product forms depending on the selected manufacturing process. Application of this approach has shown that when uncertainty is high, approving a complete CAD modeling results in a delay in product development. In contrast, CAD modeling using fuzzy models results in a gain of valuable development time because the model is completed when knowledge about manufacturing technologies, company fit and capabilities, and markets is available.

Location: Building H - ground floor: Conference room ASSELAIN

9:45am
10:45am

Product Lifecycle Management

Session Chair: Francois Cluzel, CentraleSupélec, Université Paris-Saclay, France

Method for the Integration of Computer Aided Manufacturing Data in Life Cycle Assessment

Niklas Quernheim, Sven Winter, Lars Arnemann, Benjamin Schleich, Product Life Cycle Management, TU Darmstadt

Precise sustainability assessment becomes increasingly important in decision-making, marketing, and regulations. Therefore, reliable and comparable LCA becomes mandatory. Currently, primary data is rarely available due to vastly complex value chains. Secondary data from eco-databases provide a remedy to estimate the sustainability impacts of up- and downstream processes. While giving insights and estimations, this data is seldom fitting exactly to the own processes and lacks comparability. Therefore, this paper proposes a method to close the gap between unreliable secondary data and unavailable primary data. This gap is to be closed by the integration of simulated process data. CAM is a tool during the work preparation to assess the design's manufacturability, decrease set-up times and optimize the NC code. However, integrating DES into LCA is still subject to research and will be discussed in this paper. This paper answers the question of the necessary steps to integrate the simulated production process in an LCA to increase the quality and reliability of sustainability indicators. A method is presented, and the implementation of the steps with the help of a developed assistance system on an example is performed.

Selection of Model Approaches and Modelling Methods for Lifetime Prognosis

Robin Steve Bauer, David Inkermann, Technische Universität Clausthal

Lifetime prognoses are fundamentally important to improve products regarding safety, costs, availability and sustainability. To modelling the lifetime of a system or its components and subsystems different methods and model approaches are available, which are not compatible in any case. Depending on the system, use case and available data, the existing model approaches and modelling methods are differently suitable for a precise lifetime prediction. In this contribution a procedure was developed to help in the selection of suitable approach-method combinations. For this purpose, the compatibility of method types with the different model approaches was assessed and criteria for the pre-selection of suitable approaches and methods for lifetime modelling were defined. The selection procedure was applied to the example of entities for electric powertrains of aircraft in early design stages. Finally, the results were summarized and evaluated. The insights gained in this paper can help to enhance lifetime models of products in early design phases.

DE 05

WED
26 JUL

11:15am
12:45am

Educating and Learning Design

Session Chair: Ross Brisco, University of Strathclyde, United Kingdom

Assessing performance in engineering design education from a multidisciplinary perspective: an analysis of instructors' course review reports

Yakhoub Ndiaye, Lucienne Blessing, Singapore University of Technology and Design

Performance assessment plays a crucial role in engineering education. Yet most instructor assessment focuses on student outcomes to analyse achievements. Although there is extensive research analysing student productions, however, few studies have explored assessment from instructor perspectives, especially when reporting their assessment practice. This study examines instructors' assessment of student performance through the lens of course review reports (CRRs). The CRRs were collected from 5 core undergraduate courses submitted for annual review and were related to the mappings of the measurable outcomes to performance indicators, assessment methods, and level of engagement. Regardless of the variability in reporting the student design experience, instructors' assessment and potential gaps, as well as strong existing correlations between some indicators and associated assessment methods, the study showed that the CRR may be a powerful and complementary approach to investigate the complexity of multidisciplinary design and design assessment.

Individualization in engineering design education: implementation of an adaptive E-Learning environment (AdE-Le)

Frederike Kossack, Beate Bender, Ruhr-Universität Bochum

Well-educated engineers are key for successful engineering design in product development. Due to varying school education and technical backgrounds, the students have different prerequisites for the acquisition of competences. Subject of this paper is to show the methodical implementation of the prototype AdE-Le suited to the curriculum at Ruhr-University-Bochum and the open source learning platform Moodle. Aim is to evaluate the didactic potential to support engineering students with heterogeneous competence levels. The general needs and existing approaches for E-Learning environments as a means to individualize learning content in engineering design are discussed. Major aim is to reduce the linkage between the students' technical background and their exam success. AdE-Le as an exemplary application is developed based on the didactical concept of Constructive Alignment. Due to a harmonization of learning methods and contents in Engineering Design across the members of the Scientific Society for Product Development the results of this investigation can be transferred to other Universities.

Location: Building G – ground floor: Conference room MANON CORMIER

11:15am
12:45am

Educating and Learning Design

Session Chair: Ross Brisco, University of Strathclyde, United Kingdom

A drawing education programme focusing on enhancing abstraction ability

Masaki Yagisawa, Junichi Iijima, Tokyo University of Science

This study considers the 'three sub-abilities' that constitute the abstraction ability and focuses on drawing as an education for acquiring them. Focusing on the similarity between the process of drawing and the semiotic triangle, elucidating their relationship with the sub-abilities that constitute the abstraction ability, it devises a drawing education programme that focuses on 'observing' rather than 'drawing'. The drawing education programme formulated is implemented on 177 students, and the result is determined using tests that enable objective evaluation to prove the effectiveness of the program in helping students acquire the 'three sub-abilities' that constitute the abstraction ability.
The educational programme proposed in this research, which focuses on the universality of the effects of learning drawing, as well as the quantitative criteria for evaluating it, will contribute to familiarize practical education in the field of art to the general public.

Affective Learning Goals - Key for Teaching Sustainable Product Development

Ludger Heide 1, Anne Magdalene Syré 1, Alexander Grahle 1, Dietmar Göhlich 1, Daniela Kattwinkel 2, Beate Bender 2
1 TU Berlin; 2 Ruhr-Universität Bochum

Sustainability in engineering sciences is of rapidly growing importance. However, its integration into engineering education is still in its infancy. This paper is based on the finding that, in addition to conventional cognitive learning outcomes, affective outcomes like mindset and attitude play a major role in teaching sustainability effectively. We present the didactical theory behind this and the evaluation of two university courses which serve as practical examples and research objects. These course puts high importance on affective learning outcomes, teaching not only design and assessment methods but also encourages students to reflect sustainability goals in broader contexts. We describe the theoretical course design following the principle of constructive alignment and conducted a quantitative and qualitative evaluation of the learning outcomes. The evaluation results confirm the importance of affective learning goals but also point out the need for further improvements to the course, which were implemented and re-evaluated.

Location: Building C – 1st floor: Room C2 – 106

11:15am
12:45am

VR-Enhanced Design

Session Chair: Kristina Shea, ETH Zurich, Switzerland

Optimised models for AR/VR by using geometric complexity metrics to control tessellation

Maximilian Peter Dammann, Wolfgang Steger, Kristin Paetzold-Byhain, Technische Universität Dresden, Chair of Virtual Product Development

AR/VR applications are a valuable tool in product design and lifecycle. But the integration of AR/VR is not seamless, as CAD models need to be prepared for the AR/VR applications. One necessary data transformation is the tessellation of the analytically described geometry. To ensure the usability, visual quality and evaluability of the AR/VR application, time consuming optimisation is needed depending on the product complexity and the performance of the target device.

Widespread approaches to this problem are based on iterative mesh decimation. This approach ignores the varying importance of geometries and the required visual quality in engineering applications. Our predictive approach is an alternative that enables optimisation without iterative process steps on the tessellated geometry.

The contribution presents an approach that uses surface-based prediction and enables predictions of the perceived visual quality of the geometries. This contains the investigation of different geometric complexity metrics gathered from literature as basis for prediction models. The approach is implemented in a geometry preparation tool and the results are compared with other approaches.

From haptic interaction to design insight: An empirical comparison of commercial hand-tracking technology

Christopher Michael Jason Cox, Ben Hicks, James Gopsill, Chris Snider, University of Bristol

Advancements in prototyping technologies – haptics and extended reality – are creating exciting new environments to enhance stakeholder and user interaction with design concepts. These interactions can now occur earlier in the design process, transforming feedback mechanisms resulting in greater and faster iterations. This is essential for bringing right-first-time products to market as quickly as possible. While existing feedback tools, such as speak-aloud, surveys and/or questionnaires, are a useful means for capturing user feedback and reflections on interactions, there is a desire to explicitly map user feedback to their physical prototype interaction. Over the past decade, several hand-tracking tools have been developed that can, in principle, capture product user interaction.

In this paper, we explore the capability of the LeapMotion Controller, MediaPipe and Manus Prime X Haptic gloves to capture user interaction with prototypes. A broad perspective of capability is adopted, including accuracy as well as the practical aspects of knowledge, skills, and ease of use. In this study, challenges in accuracy, occlusion and data processing were elicited in the capture and translation of user interaction into design insights.

Location: Building C – 1st floor: Room C2 – 106

11:15am
12:45am

VR-Enhanced Design

Session Chair: Kristina Shea, ETH Zurich, Switzerland

Functional Analysis In Physical And Virtual Reality (Vr) Environments - A Comparative Study

Niklas Steinhauser, Christoph Zimmerer, Patric Grauberger, Thomas Nelius, Sven Matthiesen, Karlsruhe Institute of Technology (KIT)

Product development is time-consuming and cost-intensive. Part of the costs can be attributed to physical tests. Therefore, new methods are being researched to save resources. One upcoming area that becomes important for the industry is Virtual Reality (VR) technology.
In the state of research studies have already compared VR with methods such as CAD visualizations. However, there is a need for research regarding the comparison to physical models.
Therefore, a comparative study between a physical system and a VR system is evaluated in terms of functional analysis. The study task was to analyze the mechanism of a lawn sprinkler. For evaluation, a function explanation in a final interview was used.
Although more different representations were possible with VR, there was no general improvement. This could be because movements were more difficult to visualize and recognize. The VR application is very suitable if you mainly have to look at systems that are difficult to view in reality. For example, some physical systems may be challenging to see in operation or may not allow a physical cut, so VR can be a solution. The advantages of physical systems can be in using other impressions, such as a feeling of certain forces.

Supporting student laboratory experiments with augmented reality experience

Jona Hallmann, Carsten Stechert, Syed Imad-Uddin Ahmed, Hans-Patrick Balzerkiewitz, Ostfalia University of Applied Sciences

The large availability of powerful mobile devices, such as smartphones or tablets, enables the location-independent use of augmented reality (AR) technology for various application areas with considerable added value. For example, AR experiences can be used to support students in laboratory courses during experiment preparation and execution to ensure a safe process and significantly improve the learning success. In addition, digital learning success controls can be realized with the extension of a database connection. In this paper, an AR-experience for the experiment of standing transverse and longitudinal waves is developed for the laboratory course of experimental physics. Finally, the effectiveness is tested with an evaluation by the students.

Location: Building C – 1st floor: Room C2 – 106

11:15am
12:45am

VR-Enhanced Design

Session Chair: Kristina Shea, ETH Zurich, Switzerland

A case study of the decision-making behind the automation of a composites-based design process

Pranav Milind Khanolkar, Ademir Vrolijk, Alison Olechowski, University of Toronto

Automation and artificial intelligence (AI) are increasingly seen as appealing tools to perform design tasks traditionally accomplished by human designers. In today's digital economy, industries aim to adopt these tools to improve the efficiency of their complex design processes. But how does one decide what parts of their existing design process should be automated and which automation/AI tool to implement? With these questions in mind, we present a case study highlighting a company's decision-making process in converting its existing designer-dependent design process to one supported by automation. In this case study, we observed the company's decisions in selecting and rejecting certain automation and AI methods before finalizing a heuristics-based automation method that proved highly efficient compared to the company's traditional human-driven design program. In addition, we present three key discussion points observed in this case study: (1) the importance of implementing the designer's heuristics in the automation framework, (2) the importance of a uniform and modular design automation framework, and (3) the challenges of implementing AI methods.

Design in a complex world

Location: Building C – 3rd floor: Room C2 – 308

11:15am
12:45am

Medical Design

Session Chair: Mario Storga, University of Zagreb, Faculty of Mechanical Enginee-ring and Naval Architecture, Croatia

Development of a 2D biomechanical model to simulate seated multidirectional arm stren-gth of people with C5-C7 tetraplegia

George Stilwell, Digby Symons, Shayne Gooch, University of Canterbury

People living with tetraplegia experience a significant loss of sensory and motor function; with the severity depending on their injury level and completeness. To complete tasks independently, people with tetraplegia often rely on assistive devices. To avoid upper extremity pain, designs should not re-quire applications of force near the limits of the user's physical strength. This paper establishes a 2D biomechanical model using static equilibrium and joint torque limits to predict multidirectional strength patterns in the sagittal plane for people with C5 to C7 tetraplegia in a seated position. The results from the biomechanical model highlight the areas and directions of high strength. The strength patterns observed in this paper provide an opportunity for designers to evaluate strength requirements and take advantage of areas and directions of high strength and ensure that users are not required to apply force near their physical limit. In doing this, designs such as assistive devices can be developed that enable users with a reduction in strength to operate them independently.

Simulating Bioresorbable Lattice Structures to Enable Time-dependent Stiffness in Frac-ture Fixation Devices

Barnaby Hawthorn 1, Andrew Triantaphyllou 2, Farhan Khan 2, Rosemary Dyson 3, Lauren E. J. Tho-mas-Seale 1
1 School of Engineering, University of Birmingham; 2 The Manufacturing Technology Centre (MTC) Ltd, United Kingdom; 3 School of Mathematics, University of Birmingham, United Kingdom

Additive manufacture (AM) enables a greatly increased design freedom owing to its ability to manufacture otherwise difficult or impossible geometries. However, design creativity can often present itself as a bar-rier to realising the advantages that AM could offer. In this study the use of AM, bioresorbable materials and lattice design is considered as a method of satisfying contradicting design requirements during fracture healing. Often, immediately after a fracture high stiffness fixation is required; contradictingly during the remodelling phase high stiffness can inhibit bone healing. This study proposes the use of a bioresorbable body centred cubic (BCC) or face centred cubic (FCC) lattice structure to meet the need for tailored variation in implant stiffness over time. To reduce computational expense of lattice modelling a method is outlined, including the use of homogenisation. Results show homogenised representations perform within 5.2% and 1.4% for BCC and FCC unit cells respectively, with a 95% reduction in compu-tational expense. Using resorption rates from the literature, time-dependent change in unit cell geometry was also modelled, showing the way in which a decrease in stiffness over time could be achieved.

Location: Building C – 3rd floor: Room C2 – 308

11:15am
12:45am

Medical Design

Session Chair: Mario Storga, University of Zagreb, Faculty of Mechanical Enginee-ring and Naval Architecture, Croatia

A Novel Model For The Material Selection Of Smart Objects For Hand-Rehabilitation: A Case Study

Mikaël Ivar Bos 1, Armağan Karahanoğlu 2, Juliet Haarman 3, Kostas Nizamis 1
1 Chair of Systems Engineering and Multidisciplinary Design, Department of Design, Production, and Management, Faculty of Engineering Technology, University of Twente, Enschede, Netherlands; 2 Inte-raction Design Research Group, Department of Design, Production, and Management, Faculty of En-gineering Technology, University of Twente, Enschede, Netherlands; 3 Human Media Interaction Group, Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente, Enschede, Netherlands

Home hand rehabilitation for stroke is becoming increasingly important due to logistic and financial challenges. Developing Daily-life Integrated Hand-rehabilitation Products (DIHP) aims to enable the application of at-home rehabilitation. The materials of these products are essential for their success, however, selecting materials for DIHP has not been investigated yet. Previous research on material se-lection showed that it is done strictly on material properties or based on a human-centered approach. Hence, in this study, we propose a hybrid model for choosing materials for DIHP. To achieve this, we first combined the findings of previous material selection processes into a comprehensive material selection model. We applied this model in a case study, in which we first selected three materials based on their properties. Following, we 3d printed a DIHP out of the chosen materials and tested the feeling of the materials with multiple expert groups. Our findings suggest that the proposed material selection method is promising and highlights that our comprehensive model provides more insights when compared to a strict material property-based selection.

Exploring health and design evidence practices in eHealth systems' development

Hosana Cristina Morales Ornelas, Maaike Kleinsmann, Gerd Kortuem, Delft University of Technology

Evidence-based practices play an essential role in the development of eHealth systems. Prior research has investigated the challenge of shared understanding between professionals from the fields of health sciences and design and has highlighted the need for effective alignment of development and research practices in eHealth. However, there is a limited understanding of epistemological differences between these fields and how professionals conceptualise evidence. In this paper, we investigate how healthcare and design professionals think about evidence and how they implement evidence practices in their work. We interviewed eight professionals and used reflexive thematic analysis to identify the challenges and strategies associated with their evidence practices. Our results identify five shared evidence practices between healthcare and design professionals: stakeholder-driven, process-driven, problem-driven, ef-fect-driven, and solution-driven. These five evidence practices indicate opportunities for closer alignment of development and research practices among healthcare and design professionals and offer a basis to create a shared understanding of evidence between both fields.

Location: Building C – 3rd floor: Room C2 – 308

11:15am
12:45am

Medical Design

Session Chair: Mario Storga, University of Zagreb, Faculty of Mechanical Enginee-ring and Naval Architecture, Croatia

Elements of a Prescriptive and Adaptive Prosthesis Development Service Framework

Nicholas Patiniott 1, Jonathan C. Borg 1, Emmanuel Francalanza 1, Joseph P. Zammit 1, Pierre C. Vella 1, Alfred Gatt 1, Kristin Paetzold 2
1 University of Malta; 2 Technical University of Dresden

Amputees face a number of challenges when acquiring and using a prosthesis, with major issues being the cost of the device, the time it takes for their custom prosthesis to be developed and delivered, as well as the challenges they face to get it regularly serviced and maintained. The other stakeholders involved, including the prosthetists and standard systems manufacturers, have a difficulty to collectively handle so many issues that occur to the different amputees. To address these challenges, our research reported in this paper contributes an approach to how these can be handled, through a Prescriptive approach entitled Adaptive Prosthetic Life-Cycle Service System (adProLiSS) Framework. Unlike other product service systems, adProLiSS is designed to explicitly involve and serve the amputee and their evolving needs during different phases throughout the amputee's life. This impacts how a prosthetic device needs to be designed to ensure a smoother interaction between the amputee and the device. The adProLiSS preliminary evaluation shows an improvement by which amputees can be efficiently provided with a prosthesis that evolves with their changing needs and aspirations, this fostering a longer term 'patient-centred care' service.

Design in a complex world

Location: Building C - ground floor: Room C3 – 002

11:15am
12:45am

Cognitive Processes in Design

Session Chair: Yoram Reich, Tel Aviv University, Israel

Let's take this offline: a thematic analysis of virtual conflict in hybrid collaborative design teams

Meagan Flus, Sharon Ferguson, Alison Olechowski, University of Toronto

Conflict can be both a productive and detrimental reality of design collaboration. While most studies on conflict characterize findings by type (conflict about the task, process, or interpersonal relationships), we extend this typology to understand the causes, topics, and outcomes of conflict. To do so, we analyze communications in a virtual chat platform, collected in a hybrid work environment. A thematic analysis on over 6000 messages between student design teams on the enterprise communication platform Slack revealed three emergent conflict themes: Engineering Design, Project Management, and Communication. A mapping of the themes to a widely-cited typology of conflict found an over-representation of task (productive) and process (detrimental) conflict in the Engineering Design and Project Management themes, respectively. The distribution of types of conflict in the Communication theme is representative of the entire dataset, suggesting that communication can be a cause and outcome in all types of conflict. Overall, our classification of conflict is the first step towards describing triads of the causes, topics, and outcomes of conflict, a contribution which will drive the development of interventions for design team conflict.

Exploring the impact of generative stimuli on the creativity of designers in combinational design

Da Wang 1, Ji Han 2
1 University of Liverpool; 2 University of Exeter

The ideation process has a significant impact on the initial concept generation and final product creativity of the design. Visual stimuli play an important role in the process of innovative product design. With the increase in computing capability, generative design methods are widely implemented. In this paper, features of design targets and combinational objects in 2 combinational design tasks are fused using adversarial neural generative networks to form the generated stimuli. It is also used with combinational object pictures to investigate the impact on creativity in design ideation. The study invited designers to use and subjectively self-evaluate the two stimuli in a design task. Through analysis of participant data (n=20), the results showed that the generative stimuli had an advantage over the combinational image stimuli in terms of the smoothness of creativity in the design ideation of outcomes. And there is a positive correlation between designers' years of design education and their tendency to prefer generative stimuli. Based on the results obtained, ideas are provided for the study of the influence of visual and generative stimuli on the designer's ideation process.

Location: Building C - ground floor: Room C3 – 002

11:15am
12:45am

Cognitive Processes in Design

Session Chair: Yoram Reich, Tel Aviv University, Israel

Effects of biophilic restorative experiences on designers' bodies, brains, and minds.

Paulo Ignacio Jr., Tripp Shealy, Virginia Tech

The research presented in this paper explores a novel method for assessing the effects of biophilic restorative experiences on designers' cognition by combining the use of physiological, neurocognitive and semantic measures. A total of 12 engineering graduate students participated in a three-step pilot experiment that consisted of (1) a stressor (the Trier Social Stress Test), (2) a destressing intervention (biophilic sound experience), and (3) a design task. Heart rate variability (HRV) was used to track subjects' autonomic nervous system (ANS) activity. Functional near-infrared spectroscopy (fNIRS) was used to track patterns of brain activation in subjects' prefrontal cortex (PFC). Changes in design quality were assessed by the semantic space they explored, measured through a natural language processing (NLP) technique. Preliminary findings suggest that an auditory biophilic restorative experience can change designers' bodies, brains, and minds. Results from this pilot study encourage further exploration of the use of exposure to nature-based stimuli as a method to help enhance engineering design cognition.

Examining the boundary between near and far design stimuli

Elisa Kwon, Kosa Goucher-Lambert, University of California, Berkeley

External sources of inspiration can promote the discovery of new ideas as designers ideate on a design task. Data-driven techniques can increasingly enable the retrieval of inspirational stimuli based on non-text-based representations, beyond semantic features of stimuli. However, there is a lack of fundamental understanding regarding how humans evaluate similarity between non-semantic design stimuli (e.g., visual). Toward this aim, this work examines human-evaluated and computationally derived representations of visual and functional similarities of 3D-model parts. A study was conducted where participants (n=36) assessed triplet ratings of parts and categorized these parts into groups. Similarity is defined by distances within embedding spaces constructed using triplet ratings and deep-learning methods, representing human and computational representations. Distances between stimuli that are grouped together (or not) are determined to understand how various methods and criteria used to define non-text-based similarity align with perceptions of 'near' and 'far'. Distinct boundaries in computed distances separating stimuli that are 'too far' were observed, which include farther stimuli when modeling visual vs. functional attributes.

Location: Building C - ground floor: Room C3 – 002

11:15am
12:45am

Cognitive Processes in Design

Session Chair: Yoram Reich, Tel Aviv University, Israel

Exploring the relationship between gender identity and the development of a shared understanding between designers.

Erin Johnson, Sandeep Krishnakumar, Cynthia Letting, Nicolas Soria-Zurita, Jessica Menold, Pennsylvania State University

Prior work has demonstrated that gender identity affects team psychological safety, which is critical to the development of a shared understanding of the task. Further, we know that a shared understanding can increase team cohesion and team performance. Little work has investigated how gender differences affect communicative acts within the context of design, and more specifically how gender differences may affect the development of a shared understanding of the design concept between designers. As a first step towards filling this gap, the current work presents findings from a controlled study conducted at The Pennsylvania State University with 22 design dyads (44 designers). The findings from this study indicate that gender identity within design dyads does not affect participants' shared understanding of a design concept.

Location: Building H - ground floor: Conference room ASSELAIN

11:15am
12:45am

Human in Behaviour in Design

Session Chair: Kristin Paetzold, Technical University of Dresden, Germany

Can abduction research enhance understanding of design processes accounted for by C-K theory?

Ehud Kroll 1, Lauri Koskela 2
1 Braude College of Engineering; 2 University of Huddersfield

Design process descriptions in the literature in general and those using C-K theory in particular lack some useful cognitive information that may affect the credibility of the process. Notions from abduction research are presented and proposed for enhancing such descriptions. Specifically, it is important to distinguish between design activities that are intuitive and those that result from deliberation; a topic that has long been discussed by philosophers of science and design scholars. The focus of the paper is on the ubiquitous design moves of proposing an idea and selecting among ideas, and on their execution by expert and novice designers.

The Influence of Representation on System Interpretation: A Search for Most Common Set Partitions

Alexander R. Murphy 1, Apurva R. Patel 1, Stefan Zorn 2, Kilian Gericke 2, Joshua D. Summers 1
1 University of Texas at Dallas; 2 University of Rostock

During engineering design, different representations are used to convey information about a systems' components, functionality, spatial layout, and interdependencies. These varying representations may have an impact on the interpretation of a system and consequently the decision-making process. This paper presents a research study that tries to capture these different interpretations by investigating how designers divide a system into subsystem clusters. These subsystem clusters can be considered partitions of a set-in combinatorial mathematics. Given designers' subsystem clusters for three products across three representation modalities, three different analysis methods for finding the most likely partition from observed data are presented. Analysis shows that the Variation of Information analysis method gives the most coherent and consistent results for the search of a most likely cluster. In addition, differences in clustering behaviour are observed based on representation modality. These results show that the way an engineer or designer chooses to represent a system impacts how that system is interpreted, which has implications for the decision-making process during engineering design.

Location: Building H - ground floor: Conference room ASSELAIN

11:15am
12:45am

Human in Behaviour in Design

Session Chair: Kristin Paetzold, Technical University of Dresden, Germany

Investigating the Effect of Sketch Quality on the Shared Understanding of Design Dyads

Cynthia Letting, Sandeep Krishnakumar, Erin Johnson, Nicolas Soria Zurita, Jessica Menold, The Pennsylvannia State University

While a significant amount of research has documented the importance of design artefacts in design communication, relatively little work has investigated the effect of design artefact quality on the development of a shared understanding between designers. In the current work we focus specifically on sketch quality and the effect of sketch quality on the shared understanding of design dyads. A controlled study with 22 design dyads (44 designers) was conducted to understand the relationship between sketch quality and shared understanding. Results suggest that design artefact quality, measured by sketch understandability, does not predict the shared understanding of a design concept. Our findings hold implications for the fundamental ways in which we evaluate sketch quality and the importance of artefact fidelity for communicative acts.

Identifying and Comparing Subproblems in Factory Design Processes

Jeffrey W. Herrmann 1, Erica Gralla 2, Mohammad Fazelpour 1
1 University of Maryland; 2 George Washington University

When a design team faces the problem of designing a complex system, they are required to make several decisions. Because such design problems are difficult to solve all at once, teams often decompose the design problem into several smaller subproblems. This paper discusses the results of a study designed to understand how design teams decompose a factory redesign problem into sets of related subproblems and compare the subproblems obtained for each design team. This exploratory study analyzed the design activities of eight teams of professionals and used clustering to group the variables that the design teams considered. We found that the design teams used different decomposition strategies and different subproblems, but they more often considered subproblems with design variables of the same type, and some teams followed a top-down design process.

Location: Building A - ground floor: Conference room BERNARD

11:15am
12:45am

PSS and Service Design

Session Chair: Marco Bertoni, Blekinge Institute of Technology, Sweden

Instantiating a generic process model for early-stage Product-Service System (PSS) design in two capital goods manufacturing companies

David Sarancic, Andrea Sánchez Díez, Daniela C. A. Pigosso, Tim C. McAloone, Technical University of Denmark

Product-Service Systems (PSS) are seen as key enablers of circularity. However, better sustainability performance of PSS when compared to transactional business models is not given and it must be carefully considered in the design process. The early-stage PSS design is considered crucial because it determines most of the future offerings' impact. Nevertheless, manufacturing companies struggle with PSS design and often rely on ad hoc intuitive approaches with low success rates. Current PSS design approaches have been dispersed in literature until a recent systematic literature review by the authors proposed a comprehensive generic process model to enable the inclusion of sustainability considerations in the early stages. This paper takes the generic process model as a starting point and instantiates it to the context of two manufacturing companies, seeking to (i) explore the instantiation process from a generic to company-specific process models to support manufacturing companies; and (ii) reflect upon and prepare an evaluation of the generic process model concerning eight predefined criteria. The study reveals a number of potential areas for improving both generic and instantiated process models.

Service Design in Action: Transformation, Consideration, and System Thinking

Sheng-Hung Lee 1,6, Maria Yang 1, Olivier L. de Weck 2, Chaiwoo Lee 6, Joseph F. Coughlin 6, Eric Klopfer 5, John Ochsendorf 3,4
1 Massachusetts Institute of Technology Department of Mechanical Engineering; 2 Massachusetts Institute of Technology Department of Aeronautics and Astronautics; 3 Massachusetts Institute of Technology Department of Architecture; 4 Massachusetts Institute of Technology Department of Civil and Environmental Engineering; 5 Massachusetts Institute of Technology Comparative Media Studies/ Writing; 6 MIT AgeLab

Service design has been an emerging transdisciplinary field that includes product, system, and social science, since the term was first introduced to academic research in the early 1990s. With socioeconomical shifts and emerging technologies, people have faced more complex and systemic challenges, which enable researchers to consider how to reapply service design not only as problem-solving tools but also as ways for communication and alignment to adapt to the change. The study focuses on the paradigm shifts of service from its definitions to applications by interviewing nine design experts from academia and industry, and utilizing survey results to help us explore applying service design to solve complicated social-technological challenges. We present four takeaways: 1) a new understanding of service design, 2) the purpose of using service design tools, 3) the evaluation of service quality through time, and 4) the applications of service design in the public sector. We proposed a macro-trend model with service systems: product, service, and experience to conclude 1) constructing service systems in the macro-trend context and 2) gaining holistic views and building service implementation capability in the era of transformations.

Design in a complex world

Location: Building A - ground floor: Conference room BERNARD

11:15am
12:45am

PSS and Service Design

Session Chair: Marco Bertoni, Blekinge Institute of Technology, Sweden

Requirements for a Smart Product-Service System Development Framework

Yevgeni Paliyenko 1, Daniel Heinz 2, Christian Schiller 3, Gregory-Jamie Tüzün 1, Daniel Roth 1, Matthias Kreimeyer 1
1 University of Stuttgart; 2 Karlsruhe Institute of Technology; 3 Fraunhofer Institute of Indsutrial Enginee-ring

Nowadays, companies operate in increasingly competitive and dynamic markets with fast-changing customer needs. Simultaneously, major advances are being made in information and communication technologies, and the digitization of products is progressing. Based on these economic and technological trends, smart product-service systems (PSS) are emerging as a new form of business model. Recent studies show that the transition to developing smart PSS is a major challenge for companies and that they require methodological support, as their internal structures are undergoing significant changes. In order to provide a sound basis for support, we have undertaken a comprehensive study to identify requirements for a smart PSS development framework. 24 interviews and 5 workshops with companies that have recently focused on the development of smart PSS provide a rich set of empirical data to explore the challenges faced by companies today. We systematically analyzed the data and evaluated the results with our respondents. To increase the robustness and generalizability of our findings, we performed a contextual literature review and analyzed additional cases. This led us to a set of 17 requirements for a smart PSS development framework.

⭐ How are emotional attachment strategies currently employed in product-service system cases? A systematic review underscoring drivers and hindrances

Marina Fernandes Aguia r1, Janaina Mascarenhas Hornos Costa 1, Daniela C. A. Pigosso 2
1 University of São Paulo; 2 Technical University of Denmark

Aiming to decouple value creation from resource consumption, the Circular Economy is considered an alternative to the current linear model of production and consumption. Among the innovative circular business models, Product-Service Systems (PSS) have been recognized as a possible route to achieve enhanced sustainability performance through the extension of product lifespans and the reduction of product substitution. However, PSS may lead to rebound effects due to less careful behavior during the use phase, which compromises product durability. Currently, the effect of non-ownership models on product care is not yet fully understood, nor are the strategies that could enable better product care. This research aims to deeper comprehend the consumer-product relationships in PSS solutions, as well as to shed light on the potential role of emotional durability in PSS development for product attachment. In order to do so, this paper analyses twelve Product-Service System cases derived from a systematic literature review, categorizing the emotional attachment strategies in each case, and identifying how these strategies might hinder or potentialize PSS solutions.

PSS and Service Design

Session Chair: Marco Bertoni, Blekinge Institute of Technology, Sweden

Supporting changeability quantification in Product-Service Systems via clustering algorithm

Raj Jiten Machchhar, Omsri Kumar Aeddula, Alessandro Bertoni, Johan Wall, Tobias Larsson, Blekinge Institute of Technology

The design of Product-Service Systems (PSS) is challenging due to the inherent complexities and the associated uncertainties. This challenge aggravates when the PSS being considered has a longer lifespan, is expected to encounter a dynamic context, and integrates many novel technologies. From systems engineering literature, one of the measures for mitigating the risks associated with the uncertainties is incorporating means in the system to change internally as a response to change externally. Such systems are referred to as value-robust systems, and their development largely relies on Tradespace exploration and synthesis. Tradespace exploration and synthesis can be challenging and a time-consuming task due to dimensionality. In this light, this paper aims to present an approach that enables the population of the Tradespace and then, supports the synthesis of such a Tradespace using a clustering algorithm for support changeability quantification in PSS. The proposed method is also implemented on a demonstrative case from the construction machinery industry.

Designing for the Circular Economy

Session Chair: Alessandro Bertoni, Blekinge Institute of Technology, Sweden

Designing business models for a circular economy

Michel Scholtysik 1, Malte Rohde 1, Christian Koldewey 1, Roman Dumitrescu 1,2
1 Universität Paderborn - Heinz Nixdorf Insitut; 2 Fraunhofer Institute of Mechatronic Systems Design

The megatrend sustainability will significantly change the future value creation of manufacturing companies. Their current linear value creation models need to change to conform to the requirements of sustainability. To face the challenges the circular economy has emerged as a promising economic model. With the shift from a linear to a circular economy, companies have to adjust their current business models. However, they still lack knowledge and adequate methods to develop circular business models. Hence, the aim of the paper is a circular business model canvas (CBMC) for designing circular businesses. A systematic literature review was conducted to identify significant criteria for circular business models. The criteria were analyzed utilizing a qualitative content analysis to derive the business model elements required for the circular economy. Existing elements from the Business Model Canvas were enriched and five new elements, e.g., reverse logistics, were found. Then, the business model elements were logically arranged resulting in the CBMC. It guides companies to systematically develop business models for the circular economy. The CBMC was evaluated by applying it within a medium-sized company in the electronics sector.

Mapping circular economy projects: A case study of a major company in the sports & outdoor industry

Nicole Sofia Rohsig Lopez 1, Jérémy Legardeur 1, Jenny Faucheu 2
1 Univ. Bordeaux, ESTIA Institute of Technology, F-64210; 2 Mines Saint-Etienne, Univ Lyon, CNRS, UMR 5307 LGF, Centre SMS, F - 42023

The sports industry is both a victim of climate change's impact, but also a contributor: adult active sports participants have an average annual carbon footprint of 844 kg of carbon dioxide-equivalent emissions. Thus, it is crucial to find solutions that reduce the sports industry's environmental impact. In this context, the circular economy emerges as a possible alternative. This paper analyses a sports production and retail company transitioning to the circular economy. First, we identified 154 internal circular projects concerning 89 product categories and classified them into different circular strategies and approaches. Then, we conducted interviews with 33 project representatives. Our results show that repair & maintenance is the most employed loop, but sharing economy and recycling also have an essential role. Each circularity loop presents specific challenges, but personal conviction is the common motivator. However, there is a need for greater allocation of resources such as time and budget. Additionally, strong governance is essential to structure these initiatives.

Design in a complex world

Location: Building A - ground floor: Conference room BENZACAR

11:15am
12:45am

Designing for the Circular Economy

Session Chair: Alessandro Bertoni, Blekinge Institute of Technology, Sweden

Circular ecosystem structure and orchestration: outlining actions to innovate, integrate, and invest

Adriana Hofmann Trevisan 1, Camila Gonçalves Castro 1,3, Leonardo Augusto de Vasconcelos Gomes 2, Janaina Mascarenhas 1
1 São Carlos School of Engineering, University of São Paulo, Department of Production Engineering, Av. Trabalhador São Carlense, 400, 13566-590, São Carlos, SP, Brazil; 2 Business Administration Department, School of Economics, Business Administration and Accounting, University of São Paulo, Av. Prof. Luciano Gualberto, 908, 05508-010 São Paulo, SP, Brazil; 3 Federal Institute of Education, Science, and Technology of Minas Gerais – Campus Congonhas, Av. Michael Pereira de Souza, 3007, 36415-000, Congonhas, MG, Brazil

Circular ecosystem is a growing research field that is gaining attention due to representing a more robust alignment structure than a single firm. However, prior research lacks empirical evidence on how circular ecosystems are structured and how orchestrators coordinate a set of actors towards a coherent circular value proposition. By studying nine organizations related to the carton packaging recycling ecosystem, we reveal the complexity of recovering and co-creating value in a systemic network with actors competing and collaborating simultaneously. Based on that, we propose a framework for orchestrating circular ecosystems. Our results indicate that orchestrators should integrate strategic actors, invest in infrastructure, and innovate in product design. We also discuss ecosystem resilience during and after the covid 19 pandemic, showing how the orchestrator was fundamental to the sustainability of the ecosystem. Overall, this paper contributes to increasing the understanding of inter-organizational relationships towards the circularity of resources.

Uncertainty management in circular business model innovation - the case of circular plastics

Verena Stingl, Linea Vibe Fuglsig, Cecilie Hoveling, Aalborg Universitet

The transition towards circular economy means a radical systemic shift that requires re-design and innovation of business models. However, this radical systemic shift also creates high levels of uncertainty, which pose challenges to the circular business model innovation (CBMI) process. Using the transition towards circular plastics as a case context, this study aims to conceptualize different forms of uncertainty affecting CBMI, and to link them with approaches for managing these uncertainties. Based on interviews with incumbent manufacturing firms that have transitioned to circular plastics, or are in the process of doing so, we identified three domains of uncertainty: goal uncertainty, development uncertainty, and outcome uncertainty. We discuss the nature and sources of these uncertainties, and present different approaches chosen by manufacturers to manage these uncertainties in the context of their business. Our findings highlight the complex nature of uncertainty, and the importance of a nuanced consideration of uncertainty as a factor in the CBMI process. Moreover, our mapping of core uncertainties for CBMI and approaches to manage these uncertainties can guide practitioners in the innovation process.

Location: Building A - ground floor: Conference room BENZACAR

11:15am
12:45am

Designing for the Circular Economy

Session Chair: Alessandro Bertoni, Blekinge Institute of Technology, Sweden

Circular ecosystem structure and orchestration: outlining actions to innovate, integrate, and invest

Adriana Hofmann Trevisan 1, Camila Gonçalves Castro 1,3, Leonardo Augusto de Vasconcelos Gomes 2, Janaina Mascarenhas 1
1 São Carlos School of Engineering, University of São Paulo, Department of Production Engineering, Av. Trabalhador São Carlense, 400, 13566-590, São Carlos, SP, Brazil; 2 Business Administration Department, School of Economics, Business Administration and Accounting, University of São Paulo, Av. Prof. Luciano Gualberto, 908, 05508-010 São Paulo, SP, Brazil; 3 Federal Institute of Education, Science, and Technology of Minas Gerais – Campus Congonhas, Av. Michael Pereira de Souza, 3007, 36415-000, Congonhas, MG, Brazil

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Design in a complex world

Location: Building C – 2nd floor: Room C2 - 216

11:15am
12:45am

Design Theories and Approaches 1

Session Chair: Julie Stal-Le Cardinal, CentraleSupélec, Université Paris-Saclay, France

Connecting design iterations to performance in engineering design

Ademir-Paolo Vrolijk, Yuanzhe Deng, Alison Olechowski, University of Toronto

No matter a system's size, complexity, or domain, iterations are fundamental to its design process. However, there is a duality: iterations are both signs of usefully exploring the system's design space and failure to find an appropriate solution. This ambiguity means that we have not been able to connect teams' iterating behavior to their design's performance, potentially obscuring a way to influence the design process.

As such, our exploratory study unpacks the relationship between design iterations and performance. We observed 88 teams in the 2020 Robots to the Rescue Competition in rich detail. Using logs of 7,956 iterations on a Computer-Aided Design platform, we analyzed how high- and low-performing teams revised their submissions, searching for consistent differences in their behavior. We found significant differences in the iterations' number, scale, and cadence between these groups of teams. These findings emphasized the correlation between certain iteration patterns and the success of a design: the best teams will likely revise differently than the worst ones. It also showed the importance of a fine-grained, time-dependent view of the design process to resolve open questions in the literature.

Expanding user need finding through abductive reasoning

Ryan Bruggeman, Estefania Ciliotta Chehade, Paolo Ciuccarelli, Northeastern University

Prior research has shown the importance of latent user needs for enabling innovation in early product development phases. The success of a product is largely dependent on to what extent the product satisfies customer needs, and latent user needs play a significant role in impacting the way the product or service unexpectedly delights the user. Complications arise because traditional need finding methods are not able to account for the nuances of latent user needs. A user's need is multidimensional while traditional methods are built on deductive reasoning. The traditional method isolates parts of the user's needs, only pointing to what is deducible within its search space. To address this, we introduce abduction as a way to broaden traditional need finding methods. From a logic based argument it is shown that abduction accounts for the dimensionality of user needs by integrating various traditional need finding theories using design knowledge to isolate the latent need. This theoretical development shows that latent need finding must go beyond a deductive focus, to developing methods that are able to conjecture with the deduced facts in order to abduce the latent user need.

Location: Building C – 2nd floor: Room C2 - 216

11:15am
12:45am

Design Theories and Approaches 1

Session Chair: Julie Stal-Le Cardinal, CentraleSupélec, Université Paris-Saclay, France

Development of a design support tool for synthesising multi-state mechanical device concepts

Anubhab Majumder, Amaresh Chakrabarti, Indian Institute of Science, Bangalore, India

Conceptual design synthesis, which focuses on generating solution alternatives, has a significant impact on the cost and quality of the final product. The development of radically new and significantly better solutions requires the generation and exploration of a large solution space. This work deals with the conceptual design synthesis of multi-state mechanical devices (MSMD). A scheme for representing a MSMD design task is described. Empirical studies have been carried out to develop a common understanding of the MSMD design synthesis process and use this knowledge for developing a prescriptive model. In order to support the effective and efficient use of the proposed prescriptive model, a web-based computational tool is developed.

Data-pushed projects: the role of anomalies to build design processes for subsequent exploration

Antoine Bordas, Pascal Le Masson, Benoit Weil, Mines Paris, PSL University, Centre for management science (CGS), i3 UMR CNRS, 75006 Paris, France

Data-pushed projects are common in companies and consist in the design of a model in order to deliver a desirable output. The design of data science models appears at the intersection of optimisation and creativity logic, with in both cases the presence of anomalies to a various extent but no clear design process.
This paper therefore proposes to study the possible design processes in data-pushed projects, highlighting distinct knowledge exploration logics and the role of anomalies in each. This research introduces a theoretical framework to study data-pushed projects and is based on design theory. Three case studies complete this theoretical work to examine each of the processes and test our hypothesis.
As a result, this paper derives three design processes adapted to data-pushed projects and put forward for each of them: 1) the various knowledge leveraged and generated and 2) the specific role of anomalies.

Location: Building C - ground floor: Room C3 - 001

Product Architecture Design 2 - Analysing Modularity and Impact Effects

11:15am
12:45am

Session Chair: Marija Jankovic, CentraleSupélec, Université Paris-Saclay, France

Modeling Complexity in the Structure of Design Regulation

David Myles Robinson, Andy Dong, Oregon State University

Government regulation shapes many aspects of the design of a product. This paper addresses the effect of the complexity of a regulation on product architecture through the structure of the regulation itself. The structure of a regulation derives from dependencies among requirements and parameters in the regulation that are ipso facto design elements. Since design elements such as requirements and parameters have no formal definition in regulation, it is difficult to identify them accurately and consistently. We apply two approaches to defining and coding requirements and parameters in the context of washing machine regulation. The two coding approaches generate networks of design elements that are analyzed to measure the complexity of the regulation and by extension the product. We find significant differences in the complexity of the regulation when coded in different ways and note deficiencies and strengths of each approach. These findings will support future research to measure the impact of regulatory complexity on product architecture.

Modular Maintenance Decision Architecture

Julie Krogh Agergaard, Kristoffer Wernblad Sigsgaard, Niels Henrik Mortensen, Simon Didriksen, Kasper Barslund Hansen, Jingrui Ge, Technical University of Denmark

The operation of large production assets requires many decisions from the acquisition and design of new assets to the choice of lubricant for a specific piece of equipment. The decisions made in maintenance have a direct effect on the management of the production process, making it important to ensure correct maintenance decision making. However, studies on maintenance decision making tend to focus on smaller areas of decisions being made in a process, but rarely the entire process. To introduce more studies that consider the entire maintenance process, this paper proposes using a modular Maintenance Decision Architecture. The paper introduces a framework for structuring information sources into standardized information modules and mapping them to maintenance decisions made across the entire organization. The application of approaches from product, system, and service engineering are used to support the management of the complexities of maintenance of large production facilities.

Design in a complex world

Product Architecture Design 2 - Analysing Modularity and Impact Effects

11:15am
12:45am

Session Chair: Marija Jankovic, CentraleSupélec, Université Paris-Saclay, France

Constructing a Product Architecture Strategy and Effects (PASE) Matrix for evaluation and selection of product architectures.

Scott E. Rice 1, Samuel A. McKinnon 1, Benjamin C. Sannar 1, Christopher A. Mattson 1, Carl D. Sorensen 1, Michael L. Anderson 2
1 Brigham Young University; 2 United States Air Force Academy

Product architecture decisions are made early in the product development process and have far-reaching effects. Unless anticipated through experience or intuition, many of these effects may not be apparent until much later in the development process, making changes to the architecture costly in time, effort, and resources. Many researchers through the years have studied various elements of product architecture and their effects. By aggregating observations on the effects of architecture strategies from a selection of the literature on the topic and storing them in a systematic data set, this information can be recalled in a matrix structure which allows for the identification, comparison and evaluation, and then selection of the most desirable product architecture strategies before expending resources along any development path. This paper introduces this matrix, referred to as the Product Architecture Strategy and Effect (PASE) Matrix, how to construct one, and a demonstration of its use.

Incorporating Field Effects into the Design of Modular Product Families

Jan Kuechenhof 1, Markus C. Berschik 1, Julia Beibl 1, Iñigo Alonso Fernández 2, Kevin Otto 3, Dieter Krause 1, Ola Isaksson 2
1 Hamburg University of Technology; 2 Chalmers University of Technology; 3 University of Melbourne

With advancing digitalization, new technologies with more and more digital components make it necessary to integrate new components into current and future products. Sensors and actuators, such as motors, emit electromagnetic and thermal fields that can greatly affect product performance. Recent work has considered fields at the functional level using functional structures and at the system level using DSM. In this paper, the effects of fields on product architecture are investigated at the component level. Using an appropriate visualization, the impact of fields on the product structure is considered. Architectural guidelines are then used to develop suitable product structures. The methodological approach is then applied to a product family of vacuum cleaner robots. The overlaid field information helps to gain deeper insights into the product architecture. The approach is useful for representing alternative structures. The new mapping of functional and structural relationships by moving module boundaries against fields can help promote architectural innovation.

Location: Building C – 3rd floor: Room C2 - 314

11:15am
12:45am

Robust Design & Tolerance Management

Session Chair: Scott Ferguson, North Carolina State University, United States of America

An Approach For The Inclusion Of Loading Conditions In A Polyhedral-Based Method For Early Variation Management

Carlos Andres Restrepo Garcia 1,2, Denis Teissandier 1, Nabil answer 2, Yann Ledoux 1, Vincent Delos 1, Laurent Pierre 2, Sonia Carolina Garcia Gomez 1
1 University of Bordeaux; 2 Paris-Saclay University

The variation management and product quality processes are important tasks to guarantee the assemblability of the systems, the scrap reduction and to avoid delays on production and launching. The compound of activities in Geometric Dimensioning and Tolerancing (GD&T) are necessary, especially in the early design stages, to take into account variations of different nature and from different sources. In this paper, an approach for considering the loading conditions in a polyhedral-based approach in tolerancing design is presented. The load boundary conditions are represented as additional displacement restrictions in the deviation space. The restrictions imposed by the physical limits of a system, the ones coming from the loading conditions and the degrees of freedom (DoF) can be all described and represented with a single polyhedron operand. The approach is illustrated using a simplified 2-D model for both ideal and non-ideal geometry. A 3-D model describing an unilateral contact is presented as a case study using Skin Model Shapes. By taking into account geometrical form defects, external loads, and the kinematics of the system, its sensitivity to variations can be reduced even from early design stages.

Utilizing the embodiment function relation and tolerance model for robust concept design

Jiahang Li 1, Dennis Horber 2, Christoph Keller 1, Patric Grauberger 1, Stefan Goetz 2, Sandro Wartzack 2, Sven Matthiesen 1
1 Karlsruhe Institute of Technology (KIT); 2 Friedrich-Alexander-Universität Erlangen-Nürnberg

The early use of Robust Design (RD) supports the development of product concepts with low sensitivity to variation, which offers advantages for reducing the risk of costly iterations. Due to the lack of approaches for early evaluation of product robustness, the embodiment-function-relation and tolerance (EFRT-) model was developed, which combines the contact and channel approach and tolerance graphs. The information exchange of both approaches offers a high potential for reliable robustness evaluation results. However, that potential currently relies unused, since the link between applicable robustness criteria and the extended information is missing. To solve this problem, four research steps were determined: (1) understanding of robustness, (2) collection of RD principles, (3) identification of EFRT-model information and (4) mapping of RD principles and information. The results show nine adapted RD principles, the identified model information for the robustness evaluation, the evaluation criteria as well as their mapping. Utilizing the mapping and the proposed criteria in this contribution, a more comprehensive robustness evaluation in early stages is enabled.

Location: Building C – 3rd floor: Room C2 - 314

11:15am
12:45am

Robust Design & Tolerance Management

Session Chair: Scott Ferguson, North Carolina State University, United States of America

Implementation and interpretation of a scrap and failure oriented multi-objective optimization considering operational wear

Christoph Bode 1, Stefan Goetz 1, Benjamin Schleich 2, Sandro Wartzack 1
1 Friedrich-Alexander-Universität Erlangen-Nürnberg, Engineering Design, Martensstraße 9, 91058 Erlangen, Germany; 2 Product Life Cycle Management, Technische Universität Darmstadt, Otto-Berndt-Straße 2, 64287 Darmstadt

The tolerancing of products for manufacturing is usually performed at the end of the design process and the responsibility of the designer. Although components are commonly tolerated to ensure functionality, time-based influences, like wear, that occur during operation, are often neglected. This could result in small amounts of scrap after production, but high quantities of failure during operation. To overcome this issue, this paper presents an approach to perform a multi-objective optimization considering tolerances based on a wear simulation. Thereby, mean shifts serve as optimization variables, while the aim of the optimization is to generate an optimal ratio of scrap to failure. In addition, the optimization results are interpreted and further options for the designer are presented. Moreover, the approach is exemplary applied to a use case.

Perspectives on Robust Design - an overview of challenges and research areas across industry fields

Tobias Eifler 1, Felician Campean 2, Stephan Husung 3, Benjamin Schleich 4
1 Technical University of Denmark; 2 University of Bradford; 3 Technische Universität Ilmenau; 4 Technische Universität Darmstadt

Robust Design offers a coherent and widely appreciated approach for the parametric exploration of the design space by means of simulation or experimentation, which is well-established in the quality-by design domain. From the perspective of design research, however, this only addresses a relatively narrow part of the design process and is not fully integrated with other design decisions such as concept exploration, the suitable configuration of system elements, or the design of interfaces. Particularly in light of the growing importance of developing technologically advanced and "smart" systems, it seems that a new methodical perspective on Robust Design is needed. Against this background, this paper consolidates knowledge and insights from different research fields and industry sectors. On this basis, new angles to the discussion on product robustness in different domains are explored in order to suggests directions for action and new research areas, both with respect to a methodical RD approach as well as the question of systematic research procedures.

11:15am
12:45am

Robust Design & Tolerance Management

Session Chair: Scott Ferguson, North Carolina State University, United States of America

Detecting and Characterizing Patterns of Failure in Complex Engineered Systems: an Ontology Development and Clustering Approach

Hannah Scharline Walsh 1, Andy Dong 2, Irem Tumer 2, Guillaume Brat 1
1 NASA Ames Research Center; 2 Oregon State University

While the causes of failures in complex engineered systems are often clear in hindsight, it can be challenging to predict failures proactively during the design of novel engineered products or systems. Identifying patterns can be useful for capturing common characteristics that may lead to failure. In this paper, we present a methodology for identifying patterns of failure from NASA's publicly available Lessons Learned Information System (LLIS). We apply an ontology development and clustering approach to identify representative patterns leading to failures in historical lessons learned. A joint inductive-deductive approach reveals the key themes in lessons that lead to failure, which are formalized and recorded as an ontology of complex systems failure causes. Documents from the LLIS are manually tagged with relevant characteristics from the ontology. From the tagged set, clustering is used to capture co-occurring sets of characteristics that lead to failure. The primary contribution of this work is a method for extracting a set of generic failure patterns in complex engineered systems and characteristics for these patterns that can be identified at design time, knowledge of which can be used to plan mitigation strategies.

Design in a complex world

2:00pm
2:45pm

KN 04 - Keynote : The 4th industrial revolution: myth or reality

WED
26 JUL

Daniel Harari, LECTRA, France

*Session Chair: Christopher McMahon,
University of Bristol, United Kingdom*

The most important transformations come from changes in business model, not from changes in technology:

What is a business model?

- Technology is just an enabler, pushing the boundaries of business models.
- The fourth industrial revolution was made possible by four technologies becoming mature at the same time: big data, the Internet of Things, the cloud and artificial intelligence.
- When we talk about Industry 4.0, we must not forget that it is above all the transformation of the industry itself and not about new technology.

Lectra is a technology company, what are its purpose, its value, its business model?

- Lectra's purpose is to enable its customers to adopt Industry 4.0, so that they can change their business model in depth.
- Lectra's value comes from its teams and its ability to innovate.
- How has Lectra itself repeatedly changed its business model over the past fifty years?

To build a strategy, you have to anticipate:

- How do you anticipate in an uncertain world?
- How do you identify structural phenomena from cyclical phenomena?
- What risks should you take?
- How do you apply the game theory, the only mature economic theory that enables you to build a strategy in an uncertain world?

Managing engineers is managing a population where everyone has ideas:

- This is what constitutes its value, subject to aligning ideas, sharing objectives and being mobilized on the same roadmap, while leaving room for creativity.
- Engineering and design only have value if they lead to industrial products, not if they just develop the technology itself.
- Engineers are often victims of thinking alike: they reason in the same way, and if they start from the same assumption, they come to the same conclusion. Yet the conclusion is often the wrong one, why?
- A technology company becomes mature when it is marketing driven: salespeople and engineers live in a world of certainty, marketing in a world of doubt, which is much more effective.

BIO

Daniel Harari is a graduate of École Polytechnique and holds an MBA from HEC in Paris. He began his career as Vice President of Société d'Études et de Gestion Financière Meeschaert, an asset management company (Paris, 1980-1983). He was then Chairman and Chief Executive Officer of La Solution Informatique (Paris, 1984-1990), a PC distribution and services company, and of Interleaf France (1986-1989), a subsidiary of the US software publisher, both of which he founded.

In 1986, Daniel Harari became Chief Executive Officer of Compagnie Financière du Scribe (Paris), a venture capital firm specialized in technology companies, where he was, together with his brother André Harari, the main shareholder until its merger with Lectra on April 30, 1998.

He became Chairman and Chief Executive Officer of Lectra in 1991, following its takeover by Compagnie Financière du Scribe at the end of 1990.

Daniel Harari has been Chief Executive Officer of Lectra since May 3, 2002, and returned to the combined position of Chairman and Chief Executive Officer July 27, 2017.

Design in a complex world

Location: Building C - ground floor: Salle C3 – 002

2:45pm
3:45pm

Creativity and Collaboration

Session Chair: Laura Hay, University of Strathclyde, United Kingdom

Let Me Finish My Thought: Process Interventions to Change Team Behavior during Remote Design Collaboration

Lawrence Domingo 1, Larry Leifer 1, Jan Auernhammer 2
1 Stanford University; 2 University of Technology Sydney

This research investigates changes in team behavior and communication through interruptions and gestures, due to design process strategies in pre-formed remote teams for conceptual design tasks. Understanding creative remote team behavior is important due to the increase of remote communication in knowledge work. Teams were given a creative or analytical condition intervention to facilitate their conceptual design team process. The research contributes to the human-computing interaction literature by characterizing changes in distributed team behavior due to process method interventions. The creative condition exhibited a decrease in interruptions. The analytical condition exhibited a decrease in gestures and an increase in problem characterization at the cost of ideation discussion. Remote team members can better gauge which meetings or work tasks are best to be done in person or remotely by gauging not just the task but also the team behavior.

Differences in analogical source selections between designers and non-designers during the collaborative analogical design process

Han Lu, Gang Sun, Jingyu Xu, Pujie Su, Xingyue Tang, Yajing Zhang, Tongji University

The selection of an analogical source is a critical step in the design-by-analogy process. Previous researchers have explored the reasons and preferences of individual designers or design teams in selecting analogical sources. Non-designers, who instead have more knowledge of other fields, may offer new possibilities for retrieving novel analogical sources. This study focuses on differences in the selection of analogical sources between collaborative design teams composed of designers and non-designers. There are indeed significant differences in the selection of the source type, the reasons for selecting the source, the level of abstraction in inspiration stimuli, and the novelty of design ideas between designers and non-designers. This work may provide theoretical guidance for the development of collaborative design tools and methods for teams composed of designers and non-designers with different knowledge bases.

Design in a complex world

Location: Building C - ground floor: Salle C3 – 002

2:45pm
3:45pm

Creativity and Collaboration

Session Chair: Laura Hay, University of Strathclyde, United Kingdom

Characteristics of Interpersonal Phonetic Communication in Resonance During Co-creation

Akane Matsumae 1, Karen Shichijo 2, Keisuke Shoji 2, Ken-ichi Sawai 1
1 Faculty of Design, Kyushu University; 2 Graduate School of Design, Kyushu University

This study is aimed to understand the relationship between resonance and interpersonal phonetic communication during co-creation from the following points of view: linguistic functional factors and paralinguistic factors. The novice designers were assigned a concept generation task in pairs from the two nouns, "weather" and "stationery". Linguistic function tags were contracted into five tag groups, Stuckness, Question, Seriousness, Proposition and Positiveness. The results suggest that phonetic communication in resonance showed significantly lower Stuckness and higher Positiveness towards the counterpart's utterances; Silence-based conversation was significantly observed when both were in creative states but had not reached resonance; Resonance was significantly more likely to occur with communication where one mainly spoke and the other also responded with utterances, neither one spoke in dominant amounts, or both spoke in equal amounts.
This study will contribute to understanding and facilitating resonance, which is an essential phenomenon in individual/interpersonal/group creativity, with practical implications, especially for co-creative concept generation and sustainable creative flow in collaborative design.

Effect of intermediary object use during collaborative design activities of immersive applications: focus on professional training application

Isaline Bisson 1,2, Morad Mahdjoub 1, Mohsen Zare 1, Frédéric Goutaudier 2, Franck Ravier 2, Jean-Claude Sagot 1
1 ERCOS Group (pole), ELLIADD Laboratory EA4661, UTBM - University of Bourgogne Franche-Comte, France; 2 Stäubli, 74230 Faverges, France

Industry 4.0 introduces innovative ways of professional training thanks to new technologies such as Virtual Reality and Augmented Reality. Despite improvements, there's still a lack of a good user experience and connection between user needs and these applications. To tackle this problem, designers of such applications must work in a collaborative way integrating final users. It's specifically true during design phases such as scenario creation. But the co-creation of scenario is a difficult task for designers and final users who don't have enough expertise with IT. A solution seems to stand in intermediary objects (IOs) which are well known for their characteristics of mediation, transformation, and representation. We have studied the use of different IOs during a project consisting in designing an immersive professional training application for risk hunting for Stäubli company. We used an IO1 made of an excel sheet and an IO2 made of 360 views of the workshop. Two ideation sessions with two groups of designers were conducted to propose a scenario consisting of several risks to spot in the future application. Results show that the scenario was improved using the IO2, and final users and designers were more collaborative.

Design in a complex world

Location: Building G - Ground floor: Conference room MANON CORMIER

2:45pm
3:45pm

Teaching Examples & Experiments

Session Chair: Lucienne Blessing, Singapore University of Technology and Design, Singapore

Usage and acceptance of management tools in project-based learning environments

Lisa Rößler, Kilian Gericke, University of Rostock

This paper aims to identify the reasons for neglecting and the motivations for using management tools among three groups of students participating in a project that was carried out and followed over a period of one semester. For this purpose, a survey in the form of questionnaires and interviews was created. Particular emphasis was placed on the use of project management methods, tools and techniques and respondents were asked to rate the effectiveness of their usage. Additionally, the participants were asked to report limitations or distractions they had encountered. The results revealed five aspects that mainly influenced the students' motivation in using management tools: the team atmosphere, determining responsibilities, performance transparency, expectations by the supervisors, feedback and performance evaluation. On that basis conclusions were drawn on what actions can be taken to motivate future students and designers.

Integrating Sensors in Products: A New Tool for Design Education

Tristan Briard 1,2, Camille Jean 1, Améziane Aoussat 1, Philippe Véron 2
1 LCPI, Arts et Métiers Institute of Technology, HESAM Université, Paris, France; 2 LISPEN, Arts et Métiers Institute of Technology, HESAM Université, Aix-en-Provence, France

This paper presents a pedagogical tool to address a lack of creative approach in traditional education on embedded sensors. The tool is built in a systematic way from the data sheet information of a large number of different sensors. The tool presents the main monitoring capabilities of embedded sensors on cards to assist students in the creative stages of product design. An experiment was conducted to test its educational potential with 30 Masters students in product design. The statistical analysis on the experiment data indicate that the tool enables the improvement of knowledge on embedded sensors, with a more significant gain in advanced thinking skills. Finally, the tool is easy to implement in product design education and accessible to a wide range of students.

Design in a complex world

Location: Building G - Ground floor: Conference room MANON CORMIER

2:45pm
3:45pm

Teaching Examples & Experiments

Session Chair: Lucienne Blessing, Singapore University of Technology and Design, Singapore

Needfinding Practice: Enhancing Students' Problem Framing Skills through Iterative Observation for Business Innovation

Seoyoung Kim 1, Sohyeong Kim 2, Jeamin Koo 3
1 Stanford Center at the Incheon Global Campus, Stanford University; 2 Stanford University; 3 Korea Advanced Institute of Science & Technology (KAIST)

The ambidextrous balance of combining quantitative and qualitative approach is crucial to achieve business innovation in our ever-changing society. While exploring the early stages of a problem space, profound and iterative observations of human behaviors allow designers to discover unusual insights and users' needs. In this regard, the purpose of this study is to introduce the Needfinding Practice course at KAIST and emphasize the importance of observational research to frame new business opportunities. Main learning goal of this course is to expand the problem finding phase for enhancing students' creativity and divergent thinking abilities. In this study, we have conducted a literature review on needfinding through observation and how the early stage of design thinking process is related to understanding users deeply. By presenting students' field research projects, we highlighted the process of identifying unexpected latent needs to gain qualitative data for future business implications.

Work in Progress: Development of educational kit for teaching additive manufacturing

Filip Valjak, Ana Kapetanović, Ivona Taradi, Nenad Bojčetić, University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture

Additive Manufacturing (AM) is a unique manufacturing technology that is being rapidly accepted in various industries, leading to increased demand for experts who know to work with AM and how to design AM products. This led to a broader adaptation of AM in an educational context with various research on how to teach AM. However, most approaches are focused on teaching advanced AM application and Design for AM (DfAM), including both restrictive and opportunistic approaches, with little attention to specialised educational tools to show and teach the basic principle, possibilities and characteristics of AM. This paper presents the development of an Educational Kit for AM to address the gap and help teachers to explain the basics of AM, with a current focus on the material extrusion process. The Educational Kit is made of 17 models and accompanied cards explaining the essential characteristics of AM through short textual explanations, graphics, examples and manufacturing data. The Educational Kit for AM is intended to be used in introductory lessons on AM, so the novices in AM can quickly grasp the characteristics of AM and the basic terms used in AM before advancing to other AM and DfAM topics.

DE 06

WED
26 JUL

2:45pm
3:45pm

Teaching Examples & Experiments

Session Chair: Lucienne Blessing, Singapore University of Technology and Design, Singapore

An Exploration of the Role of Creativity in Crowdfunding Product Design Projects

Ji Han 1, Pingfei Jiang 2, Min Hua 3, Peter R. N. Childs 4
1 University of Exeter; 2 Kingston University London; 3 Shanghai Jiao Tong University; 4 Imperial College London

Crowdfunding is becoming increasingly popular for funding projects, particularly in the domain of product design, by asking a large group of people. Previous studies have indicated that creativity plays a significant role in product design and is considered an important factor of success for new product design and development. However, these studies have not explicitly explored the role of creativity in crowdfunding product design projects. This paper investigates this issue by conducting a case study employing expert evaluations of selected successful and unsuccessful crowdfunding product design project samples. The results of the study show there is a positive relationship between the creativity of a product and the success of its crowdfunding campaign. Therefore, creativity can be considered a success factor of crowdfunding. The study also suggests creative products, especially useful ones, might have more potential to attract people's willingness to fund them. This paper has contributed to the research on design, creativity, product design and development, and funding business models. Most importantly, this paper has raised the significance of creativity in design and business.

Design in a complex world

Location: Building C – 1st floor: Salle C2 – 114

2:45pm
3:45pm

Specific Applications Of AI

Session Chair: Benjamin Schleich, Technical University of Darmstadt, Germany

Problems: easy to say but difficult to write

*Vito Giordano 1,3, Marco Consoloni 1,3, Filippo Chiarello 1,3, Gualtiero Fantoni 2,3
1 School of Engineering, Department of Energy, Systems, Land and Construction Engineering, University of Pisa, Italy; 2 School of Engineering, Department of Civil and Industrial Engineering, University of Pisa, Italy;; 3 B4DS - Business Engineering for Data Science lab, University of Pisa, Italy*

Patents are an invaluable source of data that can be beneficial for Engineering Design (ED). Patenting is one of the main means for disclosing the inventive process. For this reason, the description of the problem solved should also be included in any patents.

The ED literature lacks a proper definition of a problem, resulting in a fragmented scenario. Prior studies have employed Text Mining (TM) to extract problems from patents. We argue that TM can assist ED researchers in understanding how problems are articulated in text. Based on the literature, we propose two hypotheses: (1) problem-related text exhibits a negative sentiment polarity compared to other sections of patents; (2) problem-related keywords identified in the literature are predominantly used to describe problems rather than other aspects.

We analyse Japanese patents to validate our hypotheses, since they explicit Problem and Solution in the abstract. Finally, we compare our results with a set of problem-related sentences extracted from USPTO patents.

Our study reveals a higher positive sentiment in problem-related sentences compared to solution-related ones and highlights the inadequacy of using problem-related keywords alone to differentiate between the two.

Machine learning for parametric cost estimation of axisymmetric components

Luca Manuguerra, Marco Mandolini, Michele Germani, Mikhailo Sartini, UNIVPM Università Politecnica delle Marche

Machine learning (ML) is a well-established research topic in Industry 4.0 is boosting its adoption. ML is also used for manufacturing cost estimation during design. Such approaches are commonly used to estimate the cost of mass-produced parts. Many consolidated historical data are available for training the regression models. Unfortunately, very often, such a database of data is not available.

The paper defines an ML approach for parametric cost estimation of axisymmetric components. The data for training the ML model derives from automatic software for analytically estimating the manufacturing cost. With a proper set of simulations, the tool can generate a large amount of data for training. The paper presents the steps for developing a parametric cost model using ML. The approach is based on CRoss Industry Standard Process for Data Mining method. The proposed method was used to develop one cost model (to estimate the total cost that considered raw material and manufacturing cost). The obtained Relative Error is 23.52% ± 1.37%, coherent with E2516 – 11, Standard Classification for Cost Estimate Classification System.

Location: Building C – 1st floor: Salle C2 – 114

2:45pm
3:45pm

Specific Applications Of AI

Session Chair: Benjamin Schleich, Technical University of Darmstadt, Germany

Turbomachinery Design: Checking Artificial Neural Networks Suitability for Design Automation

Niccolo' Batini 1,2, Niccolo Becattini 1, Gaetano Cascini 1
1 Politecnico di Milano; 2 Baker Hughes

This paper explores the suitability of Artificial Neural Networks (ANNs) as an enabler of Design Automation in the turbomachinery industry. Specifically, the paper provides 1) a preliminary estimation of the effectiveness of ANNs to define values for design variables of reciprocating compressors (RC) and 2) a comparison of ANNs performance with traditional and more computationally demanding methods like CFD. A tailored ANN trained on a dataset composed by 350+ Baker Hughes' RC automatically assigns values to 8 geometrical variables belonging to multiple parts of the RC in order to satisfy two target conditions linked to their thermodynamic performance. The results highlight that the ANN-assigned parameters return an optimal solution for RC also when the target values do not belong to the training dataset. Their predictive capacity for RC thermodynamic performance, with respect to CFD, are comparable (i.e. less than 2% in terms of calculated absorbed power) and the approach enables a significant gain in terms of computational time (i.e. 2 minutes vs 10 hours). Future perspectives of this work may involve the integration of this tool in an advanced DA method to lead Design Engineers (DEs) during the whole design process.

Artificial intelligence techniques for improving cylindrical shrink-fit shaft-hub couplings

Muhammad Shahrukh Saeed 1,2, Jan Falter 1, Valesko Dausch 1, Markus Wagner 1, Matthias Kreimeyer 1, Boris Eisenbart 2
1 University of Stuttgart; 2 Swinburne University of Technology

Due to the continuous progress in information technology, complex problems of machine elements can be investigated using numerical methods. The focus of these investigations and optimizations often aims to reduce the stresses that occur or to increase the forces and torques that can be transmitted. Interference fit connections are an essential machine element for drive technology applications and are characterized by their economical fabrication. The transmission of external loads over a large contact surface between the shaft and hub makes it less vulnerable to impact loads. These advantages contrast with disadvantages such as the limited transmittable power, the risk of friction fatigue, and stress peaks at the hub edges, which can lead to undesirable and sudden failure, especially in the case of brittle hub materials. Analytical approaches already exist for optimizing these connections, which are expensive, time-consuming, and complex, so a high degree of expert knowledge is required to apply these methods in practice successfully. This paper presents a novel method using the example of optimizing the pressure distribution in the interface of a shrink-fit connection.

Location: Building C – 1st floor: Salle C2 – 106

2:45pm
3:45pm

Enhancements to CAD

Session Chair: Mohsen Moghaddam, Northeastern University, United States of America

From sketches to graphs: A deep learning based method for detection and contextualisation of principle sketches in the early phase of product development

Sebastian Bickel, Stefan Goetz, Sandro Wartzack, Friedrich-Alexander-Universität Erlangen-Nürnberg

The digitalization trend is finding its way more and more into product development, resulting in new frameworks to enhance product engineering. An integral element is the application of new techniques to existing data, which offers an enormous potential for time and cost savings, because duplicate work in product design and subsequent steps is avoided. The reduction of costs can be further increased through the application as early as possible in the product development process. One solution is outlined in this publication, where the source of available data is principle sketches from engineering design. These represent the basic solution for technical products in a simplified way and are often deployed in the early stages of the development process. This representation enables not only a search of similar sketches but also other fields of interest such as product optimization or the search of CAD-geometries. To utilize this data in a practical way, a procedure is presented which recognizes the symbols of the sketches and subsequently converts them into graphs. An exemplary dataset from different gearbox layouts is used to present the application opportunities by performing similarity searches with multiple input formats.

A Hierarchical Machine Learning Workflow for Object Detection of Engineering Components

Lee Kent, Chris Snider, James Gopsill, Mark Goudswaard, Aman Kukreja, Ben Hick, University of Bristol

Machine Learning (ML) techniques are showing increasing use and value in the engineering sector. Object Detection methods, by which an ML system identifies objects from an image presented to it, have demonstrated promise for search and retrieval and synchronised physical/digital version control, amongst many applications.
However, accuracy of detection often decreases as the number of objects considered by the system increases which, combined with very high training times and computational overhead, makes widespread use infeasible.
This work presents a hierarchical ML workflow that leverages the pre-existing taxonometric structures of engineering components and abundant digital models (CAD) to streamline training and increase accuracy. With a two-layer structure, the approach demonstrates potential to increase accuracy to >90%, with potential time savings of 75% and greatly increased flexibility and expandability.
While further refinement is required to increase robustness of detection and investigate scalability, the approach shows significant promise to increase feasibility of Object Detection techniques in engineering.

Location: Building C – 1st floor: Salle C2 – 106

2:45pm
3:45pm

Enhancements to CAD

Session Chair: Mohsen Moghaddam, Northeastern University, United States of America

A case study of multifunctional non-pneumatic tire design for the validation of meta-level design parameter in Domain Integrated Design (DID) method

Pavan Tejaswi Velivela, Nikita Letov, Lingchen Kong, Yaoyao Fiona Zhao, McGill University

The work introduced two novel multiscale multifunctional tire designs developed using the Domain Integrated Design (DID) method and modelled with the LatticeQuery geometric modelling software. Furthermore, this research validates the meta-level parameter "interaction area" proposed for selecting biological analogy in the DID method. These two use cases were simulated with Abaqus. The concepts covered in this work are an example of multi-functional design. The obtained results validate the meta-level parameter derived from the DID methodology.

Geometric Modelling of Heterogeneous Lattice Structures through Function Representation with LatticeQuery

Nikita Letov, Yaoyao Fiona Zhao, McGill University

Lattice structures are lightweight and possess other unique mechanical and physical properties. Additive manufacturing techniques are often used to produce these structures. Additive manufacturing provides manufacturing freedom that significantly surpasses the one provided by conventional subtractive manufacturing. However, a gap exists between the manufacturing freedom and the geometric modelling freedom in additive manufacturing: it can be extremely challenging to model the designed part because of its high geometric complexity, such as heterogeneous lattice structures. While several tools on the market allow geometric modelling of such structures available on the market, the customization of lattice parameters can still be significantly improved. Moreover, no open-source tools exist to address this issue or to model lattice structures in general. This work presents a novel open-source library for the geometric modelling of lattice structures with customized parameters. The parameter customization is enabled with the function representation approach.

Design in a complex world

Location: Building H - ground floor: Conference room ASSELAIN

2:45pm
3:45pm

Design Methods and Teams

Session Chair: Petra Badke-Schaub, Delft University of Technology, The Netherlands

The Role of Storytelling as an Analytical Tool in Scientific Research

Vishal Singh, Reet Tomar, Indian Institute of Science

This paper reports the preliminary findings from ongoing research on the potential role of storytelling as an analytical framework in assessing a research project. It is noted that most existing research on storytelling in science is focused on science communication. There is limited research on storytelling as an analytical tool for analyzing and synthesizing research plans and design. This research is based on the premise that the assessment of a research project and design is based on reviewing one or the other form of research communication, whether it is a research plan, a research report, or a presentation. Thus, the assessment is mediated by how well the research plan, proposal, report, or presentation, communicates the research to the reviewer and how well it connects the dots. The reported findings are based on studies with two different storytelling frameworks applied to assess research representations made by doctoral researchers as part of their annual research progress review. The paper reports the details of the research approach, the empirical study, and preliminary findings from the collected data.

Design Expertise: A Structured Literature Review

Christian Tollestrup, Linda Nhu Laursen, Helle Nødskou Vesti, Aalborg University

Today research has come far in explaining distinct aspects of design expertise at different skill levels. However, with the increasing number of studies, we argue there is a need to assimilate present knowledge. In this paper we advance the field of design expertise by conducting a structured literature review. Through a systematic search of papers, from 1970 to today, we identify 110 papers concerning design expertise. We then analyze the accumulated research, and map how design expertise research has evolved, in terms of what we know and what remains unexplored. Through the review, we contribute with a distinction of skills acquisition at increasing levels of design expertise.

Location: Building H - ground floor: Conference room ASSELAIN

2:45pm
3:45pm

Design Methods and Teams

Session Chair: Petra Badke-Schaub, Delft University of Technology, The Netherlands

A Boundary Object for Mapping, Comparing, and Integrating Product Design Methods

Jesse Velleu, Diann Brei, Richard Gonzalez, Jonathan Luntz, University of Michigan

There are innumerable design methods that exist across a wide spectrum of disciplines, ranging from engineering, to marketing, to psychology. However, the organic, multidisciplinary nature of methodological development in design leads to challenges in comparing or combining methods. Disciplinary perspectives can create conceptual 'boundaries' that may not align with the fluidity of the problems that designers may need to address. It is challenging to work between the boundaries of these design methods due to the unclear delimitation of exactly where and how methods may be integrated. Nomenclature is unstandardized and different terminologies may describe similar phenomena. To address this, a boundary object—the Actor-Abstraction matrix—is developed to recontextualize each of these divergent methods onto a common scale so they may be better understood in reference to their peers. A meta-analysis of four established design methods is performed to demonstrate the flexibility of this conceptual device. With this tool, existing design methods may be more easily examined to identify points of compatibility and gaps in their coverage, and could also serve as a powerful platform for the creation of new design methods in the future.

The situatedness of design concepts: empirical evidence from design teams in engineering

John Gero, Julie Milovanovic, University of North Carolina at Charlotte

Situatedness in design suggest that designing is situated within the design process or the cognitive actions taken by the designer, the designer's expertise and know-how, the designer's experience generally and the interactions in the specific design task being undertaken as well as the interactions with the design artefact generated. In this paper, we analyzed the situatedness of design concepts generated by teams of professional engineers during a design task. The method combines protocol analysis, Natural Language Processing and network theory to provide a representation and a measurement of design situatedness overtime. Providing empirical evidence of the situatedness of concepts has been overlooked in design research. The method and results presented in this paper outlines the foundation to empirically explore design situatedness.

Location: Building A - ground floor: Conference room BERNARD

2:45pm
3:45pm

Applications of Sustainable Design 2

Session Chair: Nadege Troussier, Arts et Métiers, France

Sustainable Design Evaluation - Integration of Sustainability in Product Development Processes

Julian Johannes Reichard 1,2, Alex Martin 2
1 S2 Health GmbH; 2 IPEK - Institut for Product Devolpement at Karlsruher Institut of Technology (KIT)

To develop sustainable products, product developers must be able to incorporate sustainability into individual decision processes during product development. In doing so, they are faced with the conflicting demands of time and cost pressure and the growing complexity caused by the many requirements and (sustainability) criteria.

The Sustainable Design Evaluation, which is presented in this publication, is a method to enable product developers to estimate the impact of their product-related decisions along the three dimensions of sustainability across all phases of the product life cycle. The core of the Sustainable Design Evaluation is a two-stage assessment technique enabling a relative and comparable quantification of ecological, economic, and social criteria. Furthermore, an aggregation scheme for those criteria is introduced. Based on the two-stage assessment technique and the system of aggregation, the results of the Sustainable Design Evaluation can be displayed clearly and interpreted easily by product developers to assess the impacts of their product-related decisions.

Thus, in contrast to existing methods, the SDE combines ease of use and interpretation with a sufficiently holistic sustainability assessment.

Design optimization for environmental sustainability: a framework to select the best eco-design strategy

Federica Cappelletti, Luca Manuguerra, Marta Rossi, Michele Germani, Mikhailo Sartini, Università Politecnica delle Marche

Environmental sustainability represents an unavoidable design driver. The consciousness of the importance of tackle the topic of environmental sustainability since the first stages of the product lifecycle is slowly spreading through enterprises. However, although they reach this grade of awareness, it is hard to introduce additional considerations to the traditional drivers of functionality, manufacturability, assembly, cost, etc. Therefore, it is crucial to identify methods and tools to support companies in efficiently integrating environmental sustainability issues in their design process. This paper proposes an approach to identify the inputs, functionality and outputs suitable to each industrial reality. Its core is the eco-design tool matrix, that estimates the tool implementation time and suggests proper outputs; from this the necessary inputs and functional blocks are derived. The approach is applied to the cases of two Italian industries, very different one another. This proves the wide applicability of the approach. The definition of a validation procedure represents the next steps to identify the benefits of the approach.

Location: Building A - ground floor: Conference room BERNARD

2:45pm
3:45pm

Applications of Sustainable Design 2

Session Chair: Nadege Troussier, Arts et Métiers, France

A Sustainable Computational Design Concept using Web Service Methods

James Gopsil l1,2, Ben Hicks 1, Oliver Schiffmann 1, Adam McClenaghan 1
1 University of Bristol, UK; 2 Centre for Modelling and Simulation, UK

Simulation is fundamental to many engineering design processes and powers the field of computational design. Simulation inherently consumes energy resulting in CO_2 emissions that impact our environment. While one can source energy from renewable sources and use energy efficient hardware, efforts need to also be made in how we can use simulation in a sustainable manner.
This paper presents a sustainable simulation framework that borrows concepts from web services. The framework makes it easy for engineering firms to adopt and embed sustainable simulation practices thereby removing the burden from the designer tin thinking about how to design sustainably. An illustrative example reveals a 25% reduction in computational effort can be achieved by adopting the framework.

Effects of Embodied and Self-reflected Virtual Reality on Engineering Students' Design Cognition about Nature

Josh Trump, Tripp Shealy, Virginia Tech

The study presented in this paper investigated the impact of embodied and self-reflected virtual reality (VR) experiences on engineering design students' cognition and perception of nature-relatedness during the early conceptual design phase. Results showed that students who explored the design environment as a bird (embodied) or human (self) avatar were significantly more likely to explore a larger design space indicated by more semantically unique design concepts compared to students without the VR experience. Network graphs of the syntactic connection of design concepts revealed notable differences among the three groups. The bird avatar group showed more connections to nature-related and social concepts, while more technical concepts were central for the human avatar group, and concepts about money were more central to the control group. Finally, students who embodied the bird avatar had a significantly stronger perception of connection to nature compared to the human avatar and control group, with a small to medium effect size. The results suggest that embodied (as a bird) and self-reflected (as a human) VR experiences can enhance engineering students' design thinking and perception of connection to nature.

Location: Building A - ground floor: Conference room BENZACAR

2:45pm
3:45pm

Ecodesign & Circular Design Methods

Session Chair: Harrison Kim, University of Illinois at Urbana-Champaign, United States of America

Guidelines from literature to practice: First key to implement eco-innovation in an innovation laboratory

Lili Coustillac 1,2,3, Florence Bazzaro 2, Yann Meyer 3,4, Justine Lobbé 1, Patrick Guillaud-Vallée 1
1 Forvia Clean Mobility, France; 2 Université Bourgogne Franche-Comté, France; 3 Université de Technologie de Compiègne, France; 4 Université Savoie Mont Blanc, France

Today, eco-innovation is a major challenge for companies. This new innovation approach requires to renew current practices to meet new societal and environmental issues. To do this, more and more companies create innovation laboratories to support them in this process, by providing different tools and methods adapted to their needs. To integrate eco-innovation in these new spaces, tools must answer to differents criteria. The only tool proposed by the literature is the guidelines tool but by confronting it with current practices, limits of this tool and of the innovation laboratory practices were defined. In this paper we will question and deconstruct guidelines tool in order to propose a new vision of it through identification of eco-innovation attributes.

Classification of Methodologies for Design for Circular Economy based on a literature study

Merlin Gerald Stölzle, Daniel Roth, Matthias Kreimeyer, University of Stuttgart

Global resource consumption is steadily rising. One option for stopping this upward trend is to reduce material consumption in general. With economics built for growth, this is not a practical path to pursue. Another recently explored alternative is the paradigm shift from a linear economy to a circular economy. The most common concept among practitioners and academics comprises the 6R's: Reuse, Repair, Refurbish, Remanufacture, Repurpose, and Recycle. In addition to business cases and supply chains that have been adapted to the circular economy, the products themselves must be circular. Developers face the challenge of developing novel products without appropriate experience from previous tasks. This paper takes up the challenge of gathering relevant methods in the context of circular product development. A classification with regard to the required input data and use case shall help users effectively and efficiently find development methods suitable for their given development task. With the categorization via a product development framework it is pointed out in which phase existing methods support users and where a lack of support occurs.

Design in a complex world

Location: Building A - ground floor: Conference room BENZACAR

2:45pm
3:45pm

Ecodesign & Circular Design Methods

Session Chair: Harrison Kim, University of Illinois at Urbana-Champaign, United States of America

Adapting a dashboard-based approach for feasibility analysis to circular PSS business models

Tobias Mahl, Michelle Petry, Christian Köhler, htw saar - Saarland University of Applied Sciences

Sustainability and circular economy are currently some of the strongest trends in industry as well as in politics. They are seen as the best chance to tackle emissions, pollution and climate change while maintaining the prosperity of society. Product-Service System (PSS) business models are seen as an enabler of the circular economy. However, the development of such business models is a major challenge, especially for SMEs. Therefore, there is a need for support through a methodical approach in the development and decision-making. This paper combines and extends an existing approach for assessing the feasibility of PSS-driven business models and a decision-support matrix for recirculation strategies to provide support to practitioners in the early development phases of circular PSS business models. The existing approach for feasibility analysis was focused on PSS only. To include the perspective of circularity and sustainability a systematic literature review was conducted to identify necessary criteria. Combined with the decision-support matrix the improved method aims to be a lean method to support feasibility analysis and decision-making in circular PSS business model development.

A circular product design toolkit: methodological background, basic principles and building blocks

Tetiana Shevchenko 1,2, Francois Cluzel 1
1 Scientific Department, Sumy National Agrarian University; 2 Laboratoire Genie Industriel, CentraleSupélec, Université Paris-Saclay

Circular product design has been recognised in the academia as a foundational step for companies to make circular business models functional and viable. In this regards, it is vital to have a quick-and-easy practical toolkit providing diagnostics and specific guidelines on product design in terms of circularity performance. The present paper announces a Circular Product Design Toolkit (CPD Toolkit) under development now, which aims at enhancing the circularity potential of an existing product by redesign. The following objectives are addressed. First, a brief review of existing approaches in the field of product-level circularity metrics and also available circular product design tools to clarify their purpose and practical value is conducted. Second, the scientific approach to assess a product circularity performance, previously developed, as a methodological background of the CPD Toolkit is outlined. Third, the basic principles and building blocks of the CPD Toolkit are briefly set out with further discussion in terms of possible presentation of information block as actual product circularity dataset and guideline part dealing with specific instructions for a company on how to progress in the circularity of the product produced.

Industry Design Challenges

Session Chair: Markus Zimmermann, Technische Universität München, Germany

Evaluation of e-scooter tyre performance using dynamometer-based coast-down tests

George Stilwell, Shayne Gooch, Max Goodwin, Harry Zarifeh, University of Canterbury

E-scooters have become a popular form of personal transport with millions of E-scooters used worldwide. This paper details an initial investigation into the relative differences in rolling resistance for a range of e-scooter tyres. Tyre performance was measured using dynamometer-based coast-down tests to determine the coast-down distance and coefficient of rolling resistance of each tyre. Insights from testing showed that e-scooter tyres had coefficients of rolling resistance that were 3.5 to 6 times the coefficient of rolling resistance of a 700x32C bike tyre. Comparisons between tyres of similar specification showed the tyres with solid inserts had more rolling resistance than a pneumatic tyre at the rated pressure. Comparisons of equivalent airless and pneumatic tyres the rated pressure indicated airless tyres had slightly better performance in terms of coast-down distance. The results also show how a decrease in tyre pressure increases rolling resistance, highlighting the importance of maintaining rated tyre pressure to improve e-scooter efficiency. The results from this study provide useful insights into the performance of tyres that can be used on low-powered vehicles.

Method for reference-based manufacturing cost estimation – evaluation study using a prototype

Fynn Hellweg 1,2, Ardian Cacaj 1, Simon Haneke 1, Albert Albers 2
1 Robert Bosch GmbH, Robert-Bosch-Campus 1, 71272 Renningen, Germany; 2 IPEK - Insitute of Product Engineering at Karlsruhe Institute of Technology (KIT), Kaiserstraße 10, 76131 Karlsruhe, Germany

Within product development, manufacturing cost estimation provides a sound basis for design and management decisions. This secures companies profitability, but the effort is high and deep knowledge at the interface of design, manufacturing and costs is needed. These issues can be eased with automation enabled by semantic technologies. Therefore, the authors developed a method for reference-based manufacturing cost estimation and created a prototype. This research evaluates the method and the prototype. Observation, interview and questionnaire were conducted with ten experienced cost engineers at a large German manufacturing company.

Based on its results, the study shows the methods contribution to lower estimation effort, while the impact on transparency and the knowledge base was only partly verified. The method steps show different automation potential, so an incremental automation should be considered. Even though semantic technologies show high potential for identifying reference system elements in this study, the limiting factor for automation in manufacturing cost estimation remains the low availability of product and manufacturing information and missing knowledge of its connection within product development.

Location: Building C - ground floor: Salle C3 – 001

2:45pm
3:45pm

Industry Design Challenges

Session Chair: Markus Zimmermann, Technische Universität München, Germany

Eco-innovation method in a Research and Technology Organisation: need analysis and identification of the main functions of the method (Judais 2023)

Pierre Judais 1,2, Elise Monnier 1, Helmi Ben Rejeb 2, Peggy Zwolinski 2
1 Univ. Grenoble Alpes, CEA, Liten, 38000, Grenoble, France; 2 Grenoble INP, CNRS University of Grenoble Alpes, G-SCOP, 38000 Grenoble, Franc

Research and Technology Organisations (RTOs) develop and transfer new technologies to industry. Considering environnemental and social challenges in their activities is becoming more and more important. Integrating these challenges within an organization requires a global and coherent method, but also flexibility to adapt to the various activities of the organisationz. Eco-innovation is an approach that can meet these goals. However, literature has already shown that the main obstacles for the integration of eco-innovation come from the lack of global approaches adapted to companies' practices. In this paper, we characterise the specific activities of RTOs. Then, we specified the need for an eco innovation approach for RTOs. We carried out a functional analysis to formalise the need and identify the main functions that the eco-innovation approach must fulfil. We conducted exploratory interviews with various stakholders from an RTO in order to validate the identified needs and functions.

Analysis of the correlation between agile team maturity and standardised key performance indicators in automotive development

Franziska Scharold 1, Julian Schrof 2, Kristin Paetzold-Byhain 1
1 Technical University Dresden; 2 Bundeswehr University Munich

The application of agile development methods in response to increasing market dynamics and product complexity is a key lever in the automotive industry. Agile methods originally come from the software industry and enable fast, flexible and customer-oriented product development. These methods are also increasingly being used in hardware development. However, the evaluation of the benefits of agile methods in the context of automotive development has been primarily subjective. The publication aims to present a first data-based approach to objectify the benefits of agile methods in automotive development by highlighting the effects in the quality of collaboration within teams. A standardised procedure is therefore designed and presented. On the one hand, a model for measuring the agile maturity of teams is described. On the other hand, the quality of collaboration within a team is examined in different aspects using standardised key performance indicators. Based on the proposed procedure, a strong positive correlation was found between the considered key performance indicators of the quality of collaboration and the agile maturity of the development teams within the investigated organisation.

Design for X - Applications and Examples

Session Chair: Dietmar Göhlich, Technische Universität Berlin, Germany

Design for X: enabling the reuse of space hardware ?

Bernd Michael Weiss, Anna Öhrwall Rönnbäck, René Laufer, Margot Clauss, Luleå University of Technology

With a growing number of objects in space, the pressure to be sustainable and more efficient with resources is increasing. Driven by technological advancements, the reuse of space hardware becomes feasible and viable as alternative to spacecraft end-of-life disposal. Reuse of space hardware promises benefits in areas like mitigating space debris risks, cost reductions, and environmental sustainability on Earth and in space. However, challenges related to the space environment, like micro gravity, unknown changes due to radiation, and the energy requirements to perform maneuvers in space must be addressed in order to enable spacecraft reusability. Nonetheless, reuse of space hardware is an important objective related to long-term space exploration with implications on the human expansion into space. This paper investigates the requirements for reusability of spacecraft and if circular economy strategies can support implementing reusability for spacecraft. Based on the finding of expert interviews, it argues for design as a key enabler. It introduces design for X, design for circularity, and design for reusability, and explores how reusability of space hardware implies the need to include the space environment in design decisions.

Reconstruction of Topology Optimized Geometry with Casting Constraints in a Feature-Based Approach

Johannes Mayer, Martin Denk, Sandro Wartzack, Friedrich-Alexander-Universität Erlangen-Nürnberg, Engineering Design

Topology Optimization (TO) is an established method for the development of high strength and lightweight structural components. However, its results have to be geometrically revised to obtain a computational model that meets product development requirements. Design has to be in accordance with manufacturing constraints. Geometry reconstruction therefore still is a typically manual and tedious task, but increasingly supported by computational and automated approaches. In this paper, the inclusion of a casting constraint in an automated Medial Axis based reconstruction method is presented. Since the Medial Axis provides cross-section values by the computation of maximally inscribed spheres, this information is used for geometry reconstruction and even further for the purposeful adaption of the cross-section to match Heuver's circle method. Thereby, the directed solidification of molten material is considered. With a predefined feeder position, the demonstrator of a suspension control arm is used to show the application of the method. Resulting CAD-models are also structurally evaluated for their stiffness characteristics.

Design for X - Applications and Examples

Session Chair: Dietmar Göhlich, Technische Universität Berlin, Germany

An SE Based Maritime Vessel Development Framework for Changeable Propulsion Systems

Brendan Sullivan, Monica Rossi, Politecnico di Milano

Reducing Greenhouse Gas Emissions from vessels is one of the greatest challenges the maritime industry is currently facing. International Maritime Organization has set the goal of reducing CO2 emissions from international shipping by at least 40% by 2030, compared to 2008. Emissions regulations are also leading to a progressive reduction of ships life span, together with a decrease in economic value. To cope with these challenges, the preferred strategy suggested by IMO for new vessels -Energy Efficiency Design Index- aims at increasing the energy efficiency over time by stimulating innovation and continuous development of technical elements. In this context, ship builders are indirectly led to develop vessels that will be "changeable" in terms of propulsion systems over time. This paper presents a conceptual framework to maritime vessels for propulsion system changeability, which integrates contributions from literature review with the knowledge of design thinking experts and precious insights of maritime industry professionals. The aim of this framework is support the integration of renewable fuel sources for vessel propulsion systems through an extended value approach, while improving propulsion efficiency over time.

IDEA - Towards an interactive tool that supports creativity sessions in automotive product development

Verena Lisa Kaschub 1, Reto Wechner 2, Lara Krautmacher 4, Daniel Diers 2, Matthias Bues 3, Ralf Lossack 5, Uwe Kloos 4, Oliver Riedel 3
1 Graduate School of Excellence advanced Manufacturing Engineering GSaME - University of Stuttgart; 2 Institute of Human Factors and Technology Management IAT - University of Stuttgart; 3 Fraunhofer IAO; 4 Reutlingen University; 5 Siemens Industry Software GmbH

The basis for developing future products in the automotive industry is finding creative and innovative solutions. Ideas can be found by means of creativity methods that support product developers throughout the creative process. Product developers are provided with a variety of different and new methods. This leads to a "method jungle" in which it is difficult for product developers to find the most suitable path. The successful use of methods in product development goes hand in hand with the acceptance and implementation of the methods. Despite the added value, only a low use is observed in the development process. The field of Creativity Support Tools also offers a wide variety of different tools that support the creativity process. Although a chasm exists between the many CSTs that are developed and what creative practitioners actually use. Therefore, previous studies iteratively developed a user-centered tool called "IDEA" that tries to provide a tool that responds to users' needs. The question arises how the developed tool IDEA performs in "real life setting" regarding its UX and usability as well as the creativity method acceptance and level of mental workload.

THURSDAY 27th July 2023

PROGRAM
&
ABSTRACTS

24th International Conference on Engineering Design
Bordeaux, France, 24 - 28 July 2023

9:00am - 9:45am

KN 05: Keynote: Design for circular economy: application to outdoor sports products
Location: Bât D - RDC: Amphi AUBY
Chair: Tim McAloone

Design for circular economy: application to outdoor sports products

Benoît Jeulin, DECATHLON

9:45am - 10:45am

D - DW 09: AI Applications for Requirements	D - DW 10: Digital Support for Design Application	D - H&W 05: Intangible Aspects of Wellbeing	D - M&P 05: Design Methods	D - M&P 06: Designer Cognitive Loads	D - S&R 09: Stakeholder Value in Circular Systems	D - SC 04: Design Practice and Empathy	D - SC 05: Understanding Design and Experience	D - SD 09: Product Architecture Design 3 - Configurable Products
Location: Bât C - RDC: Salle C3 - 002 Chair: Beshoy Morkos	Location: Bât C - 1er étage: Salle C2 - 114 Chair: Shigeru Wesugi	Location: Bât C - RDC: Salle C2 - 004 Chair: Beate Bender	Location: Bât A - RDC: Amphi BERNARD Chair: Stanko Škec	Location: Bât A - RDC: Amphi BENZACAR Chair: Hideyoshi Yanagisawa	Location: Bât H - RDC: Amphi ASSELAIN Chair: Bernard Yannou	Location: Bât G - Rez de jardin: Amphi MANON CORMIER Chair: Francesca Montagna	Location: Bât C - 1er étage: Salle C2 - 106 Chair: Andy Dong	Location: Bât C - RDC: Salle C3 - 001 Chair: Matthias Kreimeyer

10:45am - 11:15am

CB 05: Marketplace and Coffee Break

11:15am - 12:45pm

P - DE 07: Project Planning and Execution	P - DW 11: AI / VR for CAD applications	P - HB 06: Design of Intangible Aspects in Health and Wellbeing	P - HB 07: Prototyping in Design	P - IBM 05: Knowledge Management	P - M&P 07: Examples in Design Optimization	P - S&R 10: Designing the Sustainable Transition - Strategy & Policy	P - SC 06: User Behaviour and Sustainability	P - SD 10: Design Theories and Approaches 2	P - SD 11: Product and System Modelling 1
Location: Bât C - 3ème étage: Salle C2 - 308 Chair: Kilian Gericke	Location: Bât C - RDC: Salle C3 - 002 Chair: Matthias Guertler	Location: Bât C - 2ème étage: Salle C2 - 216 Chair: Anna Öhrwall Rönnbäck	Location: Bât G - Rez de jardin: Amphi MANON CORMIER Chair: Wendy Zhang	Location: Bât C - RDC: Salle C3 - 001 Chair: Saeema Ahmed-Kristensen	Location: Bât C - 1er étage: Salle C2 - 106 Chair: Felician Campean	Location: Bât H - RDC: Amphi ASSELAIN Chair: Akane Matsumae	Location: Bât A - RDC: Amphi BENZACAR Chair: Tua A. Björklund	Location: Bât A - RDC: Amphi BERNARD Chair: Shuichi Fukuda	Location: Bât C - 1er étage: Salle C2 - 114 Chair: Ali Yassine

12:45pm - 2:00pm

LB 04: Marketplace and Lunch Break

2:00pm - 3:00pm

D - DC 03: Creativity in Context	D - DE 08: Challenges in Design Education	D - DW 12: AI and Business Processes	D - HB 08: Teamwork in Design	D - I&S 04: Model-Based Systems Engineering	D - S&R 11: Managing Uncertainty in Design	D - SD 12: Digital Interfaces and Interaction	PS 01: Panel Sessions 01
Location: Bât C - RDC: Salle C3 - 001 Chair: Philip Cash	Location: Bât G - Rez de jardin: Amphi MANON CORMIER Chair: Carlye Anne Lauff	Location: Bât C - 1er étage: Salle C2 - 106 Chair: Johan Malmqvist	Location: Bât C - 1er étage: Salle C2 - 114 Chair: Ben Hicks	Location: Bât C - 2ème étage: Salle C2 - 216 Chair: Michael Kokkolaras	Location: Bât C - RDC: Salle C3 - 002 Chair: Ian Whitfield	Location: Bât H - RDC: Amphi ASSELAIN Chair: Josef Oehmen	

3:00pm - 3:30pm

CB 06: Marketplace and Coffee Break

3:30pm - 4:30pm

D - DE 09: Collaboration, Ideation and Sustainability	D - DW 13: Machine Learning in Design	D - H&W 06: Enhancing Wellbeing in Specific Contexts	D - I&S 05: Advancements in Systems Engineering 2	D - IBM 06: Understanding Customers	D - S&R 12: Sustainability and Resilience - Life Cycle Assessment	D - SD 13: Product and System Modelling 2	PS 02: Panel Sessions 02
Location: Bât H - RDC: Amphi ASSELAIN Chair: Niccolo Becattini	Location: Bât A - RDC: Amphi BERNARD Chair: Ji Han	Location: Bât C - 1er étage: Salle C2 - 106 Chair: Monica Bordegoni	Location: Bât C - RDC: Salle C3 - 001 Chair: Eswaran Subrahmanian	Location: Bât C - 1er étage: Salle C2 - 114 Chair: Philip Farrugia	Location: Bât C - 2ème étage: Salle C2 - 216 Chair: Clement Fortin	Location: Bât C - RDC: Salle C3 - 002 Chair: Boris Eisenbart	

4:30pm - 5:15pm

KN 06: Keynote: The Importance of Computing and Making in Design Research
Location: Bât D - RDC: Amphi AUBY
Chair: Benoit Eynard

The Importance of Computing and Making in Design Research

Kristina Shea, ETH Zürich

5:15pm - 6:00pm

CC: Closing Ceremony
Location: Bât D - RDC: Amphi AUBY

7:00pm - 8:30pm

FW: Farewell Party

Design in a complex world

KN 05 - Keynote : Design for circular economy : application to outdoor sports products

THU
27 JUL

Benoît Jeulin, Decathlon, France
Session Chair: Tim McAloone, Technical University of Denmark, Denmark

Climate and economic issues (inflation, access to raw materials, etc.) will lead to major changes in our societies. In particular, the transition, more or less rapidly and under pressure, from a linear economy to a circular economy.

New elements must be taken into account in the design of our products to drastically limit their environmental impact and respond to these new uses.

Design is becoming an essential element in the success of a company's change of business model. How does this change the "classic" design methods? How can we quantify and take into account these new elements in the design process?

We will detail this through an example of a sports product: the 2 second tent (from 2005 to 2023)

BIO

Benoît JEULIN is Degree in Industrial Engineering - INP Grenoble

Joined Decathlon on leaving school as a project engineer on purchasing and sales forecasting tools. Then Supply Chain career, in the animation of a European then World supplier panel on «big sewn» products (punching bags, riding equipment, sleeping bags...).

With these Digital and Operational experiences, I lead for 5 years the project teams in the transformation of the Supply Chain business and tools.

On my return from parental leave, I reoriented myself towards the theme that had attracted me for many years. I joined the electronic product design teams at Decathlon to build the sustainable development project for this entity. I lead projects on environmental assessment, the implementation of a «universal» reparability index, and the consideration of end-of-life through recycling channels.

Since 2022, I have joined the Decathlon Mountain Sports teams (Quechua, Forclaz, Simond) to build the sustainable development project. I lead the environmental and circular themes (carbon budget, reparability & repair, recyclability & recycling,...) for the teams of Conceptions, Offer, Design, Communication,... on all types of products (tents, backpacks, textiles,...)

Passionate about outdoor sports, I regularly practice trail, mountain bike, ski touring,

DW 09

THU
27 JUL

AI Applications for Requirements

Session Chair: Beshoy Morkos, University of Georgia, United States of America

A method to capture and share production requirements supporting a collaborative production preparation process

Rohith Areth Koroth, Fredrik Elgh, Martin Lennartsson, Dag Raudberget, School of Engineering, Jönköping University

The production preparation process (3P) enables collaboration between design and production engineers during product development but its efficiency is limited by the abundance of documentation of manufacturing constraints and capabilities. Empirical studies showed that use of production requirements can increase the efficiency of 3P, however, the support for production engineers to capture and share production requirements is scarce. A method to support production engineers in identifying, defining, structuring and sharing production requirements and collaborating with design engineers is presented. The method has three major parts - focus areas and requirement categories, a worksheet for production requirements capturing and prioritization, and a workflow for using the worksheet. The method was developed in collaboration with practitioners and contributes to the existing knowledge by providing production engineers with a structured way of working with production requirements. Evaluation of the method in the case company showed its usability when developing product variants and that additional work is needed to support the development of new product families and assembly lines.

Efficient Formalisation of Technical Requirements for Generative Engineering

Iris Gräßler 1, Daniel Preuß 1, Lukas Brandt 2, Michael Mohr 3
1 Heinx Nixdorf Institute / Paderborn University; 2 Atos Information Technology GmbH; 3 EDAG Engineering GmbH

Currently, engineers need to manually analyse requirement specifications for determining parameters to create geometries in generative engineering. This analysis is time-consuming, error-prone and causes high costs. Generative engineering tools (e.g. Synera) cannot interpret natural language requirements directly. The requirements need to be formalised in a machine-readable format. AI algorithms have the potential to automatically transform natural language requirements into such a formal, machine-readable representation. In this work, a method for formalising requirements for generative engineering is developed and implemented as a prototype in Python. The method is validated in a case example using three products of an automotive engineering service provider. Requirements to be formalised are identified in the specifications of these three products, which are used as a test set to evaluate the performance of the method. The results show that requirements for generative engineering are formalised with high performance (F1 of 86.55 %). By applying the method, efforts and therefore costs for manually analysing requirements regarding parameters for generative engineering are reduced.

Location: Building C - ground floor: Room C3 – 002

9:45am
10:45am

AI Applications for Requirements

Session Chair: Beshoy Morkos, University of Georgia, United States of America

Natural Language Processing in Requirements Engineering and its Challenges for Requirements Modelling in the Engineering Design Domain

Judith Sophie van Remmen 1, Dennis Horber 1, Adriana Lungu 2, Fan Chang 2, Sebastiaan van Putten 2, Stefan Goetz 1, Sandro Wartzack 1
1 Friedrich-Alexander-Universität Erlangen-Nürnberg; 2 AUDI AG

Requirements represent a central element in product development. The large number of requirements inevitably results in an increased susceptibility to errors, an expenditure of time and development costs. The associated problems motivate the application of Artificial Intelligence in the form of Natural Language Processing (NLP). In Requirements Engineering one main task is the classification of requirements which serves as the input in architectural models e.g. in SysML. In mechanical engineering there is still little overview regarding the interface between requirements classification and modelling. This paper provides an overview of the requirement classes and entities used in the literature and analyses their utilisation in modelling. Existing requirements classes usually do not offer the flexibility to be transferred to other domains. However, basic structures can be adopted from those classifications. This enables a clear assignment of existing classes to object classes in modelling. Resulting from the conducted literature study the observed predominant focus of research on the software industry requires an extension of the existing requirement classes and entities to enable further use and transfer to mechanical engineering.

Automated Condition Detection in Requirements Engineering

Alexander Elenga Gärtner 1,2, Dietmar Göhlich 1, Tu-Anh Fay 1
1 TU-Berlin; 2 IAV GmbH

In product development, it is of great importance that a complete, unambiguous, and, as far as possible, contradiction-free target system is defined. Requirements documents of complex systems can contain several thousand individual requirements, derived in an interdisciplinary manner and written in natural language by many different stakeholders. Hence, errors, in the form of contradictions, cannot be completely avoided in these documents and today they must be corrected manually with high effort. This paper presents an important building block for automated contradiction detection and quality analysis of requirements documents. We discuss the necessary identification of conditions in requirements and the extraction of the verbal expressions associated with condition and effect, respectively. We applied and analyzed natural language processing methods based on grammatical versus machine learning models. The models have been applied to 1,861 real-world requirements. Both approaches generate promising results, with an accuracy partly over 98%. However, in structured specification texts, a grammatical model is preferable due to lower effort in preprocessing and better usability.

Design in a complex world

Location: Building C – 1st floor: Room C2 – 114

9:45am
10:45am

Digital Support for Design Application

Session Chair: Shigeru Wesugi, Waseda University, Japan

A Digital Twin Business Modelling Approach

Jakob Trauer, Duc Phat Mac, Markus Mörtl, Markus Zimmermann, Technical University of Munich, TUM School of Engineering and Design, Department of Mechanical Engineering, Laboratory for Product Development and Lightweight Design

Digital Twins are one of the most trending topics. However, there are still open issues in the development of Digital Twins. One of these impediments is formulating a clear and valid value proposition of a Digital Twin. Therefore, this paper presents a novel business modelling approach for Digital Twins. Based on a literature review and an academic case study, different business modelling approaches and techniques were systematically compared, selected and adjusted in order to develop a new framework suitable for describing the value of Digital Twins. It consists of 10 steps – (1) describe a basic development concept of the DT, (2) identify the customer segments, needs and pain points, (3) derive a value proposition (4) identify revenue streams and values created, (5) identify key activities, (6) resources needed, and (7) necessary partners. (8) Adapt the organization to fit the business model and (9) evaluate the cost structure of the project. In the end, document and communicate the new business model (10). Each step is supported by auxiliary methods, tools and procedures. The approach was applied to a scientific case study. In an initial evaluation the overall applicability and usefulness of the approach were confirmed.

Managing Smart Systems for the Net Zero Agenda - How can Digital Twin Technologies and Smart Products deliver Customer Value ?

Charlotte Lucinda Markey, Saeema Ahmed-Kristensen, University of Exeter

Using the case study of a smart green blue roof pilot project in Greater Manchester, the authors have coded and analysed a series of semi structured interviews. We present our findings which are specifically focused on how 'smart' was understood by the multiple stakeholders involved in the project and how product complexity is managed when digital technologies are integrated into nature based solutions that are becoming more popularised in the construction sector. This integration of digital twin and sensor technologies with physical drainage products to create the next generation of smart green blue infrastructure, presents numerous challenges for organisations in the construction sector. We conclude that the need for smart systems of systems in this sector necessitates organisational change and new methods of knowledge transfer across organisations who work together to deliver the holistic physical and digital services to the client.

Location: Building C – 1st floor: Room C2 – 114

9:45am
10:45am

Digital Support for Design Application

Session Chair: Shigeru Wesugi, Waseda University, Japan

Project-Based Learning in Engineering Education – Developing Digital Twins in a case study

Lisa Hagedorn 1, Theresa Riedelsheimer 2, Rainer Stark 1
1 Technische Universität Berlin; 2 Fraunhofer IPK

The current engineering environment demands for an increasing level of interdisciplinarity, innovation, creativity and cross-domain thinking as well as the consideration of sustainability aspects. New concepts, such as Digital Twins and complex product systems lead to the need for integrated product development approaches and new methods that put the user perspective in focus. This also needs to be an integral part in today's teaching concepts of the next generation of engineers.
At the Department of Industrial Information Technology of the Technical University of Berlin, a case study was conducted by applying a concept of project-based learning in the engineering domain to address these challenges. In this paper, the case study as well as the method and its validation are presented. Students from different engineering disciplines had the task of developing virtual and physical proto-types for a sustainable, complex product system with a digital twin and respective sustainable business models. Within a structured survey, the teaching concept and the applied method were validated and lessons learned as well as further improvement measures are derived.

Identification and Retrieval of Relevant Information for Instantiating Digital Twins during the Construction of Process Plants

Max Layer 1, Sebastian Neubert 1, Lea Tiemann 1, Ralph Stelzer 2
1 Siemens Energy Global GmbH & Co.KG; 2 Technische Universität Dresden

While volume-driven industries such as automotive are characterized by a high degree of data backflow across all production cycles, there is still a certain residue in the planning and construction of process plants. This is firstly due to the high proportion of customer-specific requirements and secondly to the significant amount of value added on site during construction. To handle recurring project-specific process plants as time- and cost-efficiently as possible, optimal information exchange among contractors of various disciplines and the plant developer is a prerequisite. For this purpose, a holistic digital representation of the plant is created, which consolidates all relevant information in one place serving as a foundation of multiple digital twins. An approach to identify and define relevant information depending on their subsequent use is developed. On this basis, a framework is proposed to enable a multipliable BOM-based automatic definition of information backflow to instantiate digital representations in parallel to the planning and construction process. Furthermore, project-specific contextual information will be captured and referenced in a structured form preventing their loss for subsequent similar projects.

Location: Building C - ground floor: Room C2 – 004

9:45am
10:45am

Intangible Aspects of Wellbeing

Session Chair: Beate Bender, Ruhr University Bochum, Germany

Visualizing the Complex Problem of Children's Digital Wellbeing in South Korea: a Systems Thinking Approach

Shannen Patricia Widjaja, Joon Sang Baek, Yonsei University

Considering the prevalence of digital interaction within the Generation Alpha, this study focuses on the digital wellbeing of elementary school-aged children in South Korea. By taking into account the multi-faceted nature, this study frames the issue that exists within children's digital wellbeing as a complex problem and aims to have a better comprehensive understanding of the system using a designerly and systems thinking approach. Thus, this study conducts a Systematic literature review and thematic analysis to get grasp of the current situation which then is translated using a systems thinking-based visualization tool to convey the causal relationships that exist within the system. Therefore, the outcome of this study presents a concept map that consolidates the findings to communicate a holistic perspective of children's digital wellbeing which can be used in design activities and decision-making processes which contribute to future design solutions and conversations.

Application of anamorphism in product design

Calum Kettley, Andrew Wodehouse, University of Strathclyde

This research aims to investigate the incorporation of anamorphism into product design and has resulted in the creation of a series of handheld objects with embedded anamorphic information. Anamorphism is a phenomenon typically applied to images, where it appears distorted from all but one angle. Often associated with optical illusions, its history and viability for application to product design are reviewed. This includes an assessment of different designs' impact on the overall recognition of hidden anamorphic objects, focusing on their design attributes to determine the best at concealment. With the creation of 3D anamorphic objects, experiments were conducted to allow correlations between object visibility and design features to be identified. Analysis of the results showed that objects with vertically stretched text and wider cuts within the characters were hardest to recognise and therefore more secure. Objects with the least material made it more difficult to interpret the hidden information from positions that were not the "privileged viewing zone". The creation of these anamorphic objects highlighted that this function of anamorphism is possible and could be incorporated within products in future.

Location: Building C - ground floor: Room C2 – 004

9:45am
10:45am

Intangible Aspects of Wellbeing

Session Chair: Beate Bender, Ruhr University Bochum, Germany

Using Pleasurability to Compare Wristwatches and IoT Smartwatches: Providing Novel Insights into UX Design

Zidong Lin 1, Saeema Ahmed-Kristensen 2, Ashley Hall 1, Bjorn Sommer 1
1 Royal College of Art, London, UK; 2 INDEX, Department of Science, Innovation, Technology, Entrepreneurship, University of Exeter, London, UK

The emergence of the Internet of Things (IoT) has brought more challenges for designers to fully understand networked objects and develop pleasurable user experiences (UXs). Due to the radical change of products when they are connected, traditional experience design theories may not be applicable in this new context. Based on two well-established UX design theories, this paper presents a survey study that investigated the pleasurability of IoT devices by comparing a representative IoT device (i.e., the smartwatch) and its conventional form (i.e., the wristwatch). An online questionnaire was deployed to gather feedback from parallel wristwatch and smartwatch users. Their experiences using both types of watches were quantitatively and qualitatively compared by data analysis. The results highlighted the differences in UXs between smartwatches and wristwatches in three types of pleasure and five psychological needs. The study revealed design opportunities to improve the pleasurability of smartwatches and provides novel design insights informing the development of pleasurable UXs for future IoT devices.

Designing with Self-Determination Theory: Home-Based Digital Exercise Interventions Creating Positive Change

Bahar Şener, Owain Pedgley, Middle East Technical University

The well-thought implementation of technology within the product-service system (PSS) will undoubtedly contribute to the increase of healthy life expectancy and to the improvement of the wellbeing of society. The 'Exercise-Well' project, explored the problem and solution areas related to home-based exercise through digital interventions. Students worked in pairs and expected to propose a PSS solution providing a type of sports/physical activities for individuals to support their wellbeing. The proposed solutions were encouraged to create positive change especially through the integration of self-determination theory (SDT), but also be functionality suited to the persona. The project had the goals of directing students: i) to learn how digital technologies can be best tailored to assist people to exercise; ii) to consider engineering and healthcare domain constraints for utilizing convenient technological methods and integrating relevant hardware and software components; and iii) to motivate people by integrating autonomy, competence, relatedness into their design proposals. The paper demonstrated how SDT can be integrated into the design process, and how home-based digital exercise interventions can lead to creative solutions.

Location: Building A - ground floor: Conference room BERNARD

9:45am
10:45am

Design Methods

Session Chair: Stanko Škec, University of Zagreb, Croatia

A follow-up on the methodical framework for the identification, analysis and consideration of uncertainty in the context of the integration of sensory functions by means of sensing machine elements

Peter Welzbacher, Anja Geipl, Benjamin Kraus, Steffen Puchtler, Eckhard Kirchner, Institute for Product Development and Machine Elements (pmd), Technical University of Darmstadt

When integrating sensing machine elements for in-situ measurements in technical systems, special attention must be paid to uncertainty to ensure the reliability of the provided information. Therefore, a methodical framework for the identification, analysis and consideration of uncertainty was already developed in prior research, which still offers room for improvement regarding the included methods and tools. Therefore, in this contribution, the initially proposed methods and tools are adapted and extended to enhance their efficiency and applicability and to reduce their error proneness in order to increase the acceptance of the framework in practice. First, the identification of uncertainty is improved by means of an extended effect graph for an automated identification of disturbance factor induced data and model uncertainty. Second, the significance of the subsequent evaluation of uncertainty is enhanced by replacing the initially proposed local sensitivity analysis with a global sensitivity analysis. Finally, a flowchart is proposed that supports the identification of applicable and promising strategies for the development of measures to consider critical disturbance factor induced uncertainty.

Linking digital B2B platform business models and product development: A bibliometric analysis and literature review

Patrick Brecht 1, Daniel Hendriks 1, Manuel Niever 1, Carsten Hahn 1, Felix Pfaff 2, Simon Rapp 2, Albert Albers 2
1 Karlsruher University of Applied Sciences; 2 Karlsruher Institute of Technology (KIT)

Developing digital platform business models, especially in business-to-business (B2B) markets, has a high potential for companies who successfully develop their products in generations. The model of SGE - System Generation Engineering describes the development of mechatronic systems on subsystem level. The authors investigate to what extent a comprehensive and unified methodology can be identified, connecting the research areas of product development and digital B2B platform business models. Therefore, this study conducted a bibliometric analysis of scientific data to identify a research gap and a qualitative literature review to affirm the relevance of future research in this research area. The results show a gap between the research areas of digital B2B platform business models and product development. Essentially, several renowned platform researchers suggested performing future research with a methodology that fulfils the following purposes: (1) improve the general understanding of digital platforms, (2) understand their success factors and development, and (3) deal with challenges (e.g., monetization) and loss of valued personal relations in B2B markets through digitization.

Design Methods

Session Chair: Stanko Škec, University of Zagreb, Croatia

M&P 05

THU
27 JUL

A Method to Support the Improvement of Knowledge Transfers in Product and Production Engineering

Albert Albers, Monika Klippert, Moritz von Klitzing, Simon Rapp, Karlsruhe Institute of Technology (KIT)

The product engineering process as part of the product life cycle includes product and production system development as well as production. In integrated product and production engineering (PPE), knowledge transfer is an important success factor. Optimizing the efficiency and effectiveness of knowledge transfers can, for example, support the avoidance of costly, production-related changes to the product design. The current state of research describes different models of knowledge transfer as well as factors that influence it. Some results show how the speed and quality of knowledge transfer can be improved by implementing so-called interventions. However, those models either represent abstract contexts of knowledge transfer or focus only on product engineering. Therefore, a literature analysis is conducted to identify the system of objectives for a method, that supports the improvement of knowledge transfer in PPE. Subsequently, the system of objectives is operationalized to provide the basis for the InKTI – Interdepartmental Knowledge Transfer Improvement Method, which is applicable, supports the user in improving knowledge transfers in PPE, and aims to increase the quality and speed of knowledge transfers.

Derivation Of a Method DNA for The Unified Description Of Methodical Procedures In Product Development

Florian Reichelt 1, Dietmar Traub 2, Thomas Maier 1
1 University of Stuttgart - Institute for Engineering Design and Industrial Design; 2 PPM – Unternehmensberatung

The number of publications on methods in product development is increasing constantly. In addition to scientific models, method guidelines exist in practice to support the selection of suitable methods. When looking more closely, it is noticeable that new methods are not new developments of methodical principles, but rather adaptations and summaries of known methods to specific application areas. Although approaches to standardize methods exist, they are usually formulated too abstractly to be useful to project managers as a support for method decision making.In our contribution, we analyse common methods of technical product development regarding similarities in content and time. In doing so, we were able to derive a method DNA on the basis of which all methods can be described and, above all, distinguished in a verifiable manner. In addition to essential activity blocks, the DNA also includes the description of temporal sequences, which in particular enables a differentiation between agile and classic methods. Ultimately, the method DNA not only offers the chance to make methodical work comprehensible, but also the possibility to select methods specifically for upcoming development steps arises through the classification option.

Location: Building A - ground floor: Conference room BENZACAR

9:45am
10:45am

Designer Cognitive Loads

Session Chair: Hideyoshi Yanagisawa, The University of Tokyo, Japan

EEG-based cognitive load indicators in CAD modelling tasks of varying complexity

Fanika Lukačević 1,2, Niccolò Becattini 2, Stanko Škec 1
1 University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture; 2 Politecnico di Milano, Department of Mechanical Engineering

As an initial step towards a better understanding of cognitive load in computer-aided design (CAD), the herein presented study investigated cognitive load imposed on 24 mechanical engineers during two CAD modelling tasks of intentionally different complexity levels. The cognitive load has been rarely studied in the CAD context, which resulted in the lack of understanding if and how the EEG-based indicators available from the literature reflect the changes in cognitive load imposed on engineering designers in CAD activities. Therefore, cognitive load was measured and analysed using three EEG-based indicators to explore insights that might be obtained from them. The initial analysis revealed different cognitive load results from the employed indicators for the same EEG data. In addition, the study implies that the cognitive load results obtained through the used indicators are only partially coherent with the CAD modelling task complexity. Hence, the results imply that the chosen EEG-based indicator matters when measuring and analysing cognitive load in CAD modelling tasks and that its adjustment for CAD context might be needed.

A Study of the Early-Stage Engineering Design Activities in Practice

Chijioke C. Obieke 1, Jelena Milisavljevic-Syed 2, Ji Han 3
1 University of Liverpool; 2 Cranfield University; 3 University of Exeter

The early-stage engineering design activities include conceptualising, identifying, and solving an engineering design problem. These activities are essential and standard roles of a design engineer. However, they seem to lack comprehensive practice within the engineering design community. In this study, semi-structured interviews conducted with 18 participants having engineering design backgrounds are presented. The aim of the interviews is to investigate the awareness and practice of the early stage engineering design activities. The participants interviewed practice in countries including France, the United Kingdom, and the United States. Contrary to standard expectations, the results of the interviews show that the early-stage engineering design activities are not comprehensively practised. The results suggest that design engineers' crucial role in identifying unknown problems lacks practice. Also, the data from the interviews provide empirical evidence on the determinants for the lack of comprehensive practice of early-stage engineering design activities. Recommendations on possible interventions to support the practice are presented to expedite innovations and inventions.

Design in a complex world

9:45am
10:45am

Designer Cognitive Loads

Session Chair: Hideyoshi Yanagisawa, The University of Tokyo, Japan

M&P 06

THU
27 JUL

Looking Beyond Self-Reported Cognitive Load: Investigating the Use of Eye Tracking in the Study of Design Representations in Engineering Design

Madison Cass 1, Rohan Prabhu 2
1 Neuroscience Program, Lafayette College; 2 Department of Mechanical Engineering, Lafayette College

Designers are experiencing greater mental demands given the complexity of design tools, necessitating the study of cognitive load in design. Researchers have identified task- and designer-related factors that affect cognitive load; however, these studies primarily use self-reported measures that could be inaccurate and incomplete. Little research has tested the accuracy and completeness of self-reported measures and we aim to explore this gap. Towards this aim, we seek to answer the question: How does cognitive load vary based on the different design representations used, and do these differences depend on the measure of cognitive load? From our results, we see that the design representations vary in the range of cognitive load experienced by designers when using them. Moreover, this role of the range of cognitive load variance was observed given our use of pupil diameter. These findings call for the use of a multi-modal approach for measuring cognitive load with the combined use of subjective (e.g., self-report) and objective measures (e.g., physiological measures), as well as the use of both retrospective (e.g., self-report) and concurrent measures (e.g., physiological measures).

EEG Variations as a Proxy of the Quality of the Design Outcome

Shumin Li, Niccolò Becattini, Gaetano Cascini, Politecnico di Milano

This paper presents an EEG (Electroencephalography) study that explores the correlation between the EEG variation across design stages and the quality of the design outcomes. The brain activations of 33 volunteers with engineering backgrounds were recorded while performing a design task using a morphological table to develop an Conference roombious bike. The EEG variations from the analysing/ selecting stage to the illustrating stage were analysed based on the EEG frequency band and channel sets. A significant correlation between the detail level of the design outcome and the power variation mode was observed in theta, alpha and gamma bands, each involving different channel sets. Compared to the assessment results from two evaluators, using EEG variations as a proxy of the detail level of the design outcome could reach a maximum accuracy of 0.727, precision of 0.765, and recall of 0.889. These results also provide suggestions on the selection of the frequency bands and channel sets to achieve better prediction performance according to each metric.

Location: Building H - ground floor: Conference room ASSELAIN

9:45am
10:45am

Stakeholder Value in Circular Systems

Session Chair: Bernard Yannou, CentraleSupélec, Université Paris-Saclay, France

Motivations behind actors' cooperation in circular ecosystems: a systematic literature review and a Brazilian case study

Sophia Barquete, Adriana Hofmann Trevisan, Camila Gonçalves Castro, Janaina Mascarenhas, Department of Production Engineering, São Carlos School of Engineering, University of São Paulo

The circular economy (CE) aims at the cycling of resources through restorative and regenerative strategies. To achieve circularity, coordination of several actors is necessary. The interaction among actors allows the connection between the CE and ecosystem research fields. Although fundamental, the relationships, mainly cooperation, among actors within an ecosystem to foster circularity is not deeply explored in the literature. The objective of this study was to identify the possibilities of cooperation within circular ecosystems, in particular, the motivations that make the actors interact to achieve a CE. A systematic literature review (SLR) and a case study of a Brazilian ecosystem specialized in the recycling of carton packages to manufacture ecological tiles were conducted. The goal was to identify the motivations through the SLR and the case study so the theoretical and the empirical results could be compared. As a result, 28 motivations for actors to engage in ecosystems driven by circularity were identified. In order to achieve a complete and circular solution, actors must be able to clearly understand their roles and relationships so that they can establish new partnerships or reframe those already established.

Demand-driven design strategy for inter-organizational circular system - the valorization of expanded polystyrene in Brazil

João Jaeger 1, Istefani Carisio de Paula 1, Madalena Heinen 2, Aline Cafruni Gularte 1, Ghissia Hauser 1, Victor Calcanhoto Phanebecker 1
1 Federal University of Rio Grande do Sul; 2 Trashin

The valorization of plastic wastes in the Circular Economy poses the challenge of developing inter-organizational systems. Concerning the implementation, the inter-organizational level consists of a set of companies from the same segment acting in different roles in the circular system. This research aims to demonstrate a structured method designed to develop a demand-driven inter-organizational closed-loop circular system for the valorization of packaging waste.

The five-step method includes (i) Contextualization/problematization, (ii) Closed-loop system mapping, (iii) Closed-loop system consolidation, (iv) Building Commitment,(v) Pilot system implementation and operation. A real case illustrates the method. As the unit of analysis we have chosen the supply chain and reverse channels of expanded and extruded polystyrene packaging in Brazil. The project was developed from December 2021 to March 2022.

The contribution to the literature is to validate the premises and to provide insight into the challenges of developing real circular economy closed loop systems. The practical contribution is to support the development of a recycling system of packaging in a developing country.

Stakeholder Value in Circular Systems

Session Chair: Bernard Yannou, CentraleSupélec, Université Paris-Saclay, France

Multi-internal actors diagnosis of Circular Economy in an industrial SME

Gabrielle Gentric 1,2, François Cluzel 1, Vincent Boccara 3, Hakim Boudaoud 4, Julien Gonzalo 2
1 Laboratoire Genie Industriel, CentraleSupélec, Université Paris-Saclay; 2 Style & Design; 3 Laboratoire Interdisciplinaire des Sciences du Numérique (LISN), Université Paris-Saclay; 4 Equipe de Recherche sur les Processus Innovatifs (ERPI), Université de Lorraine

In big companies, Circular Economy (CE) is being explored, nevertheless, Small and Medium-sized Enterprises (SMEs) struggle to follow because of particular barriers and a lack of practical guide. Here, we use Style & Design, a French industrial SME, as a case study to explore how SMEs can perform a successful CE integration. This article aims at proposing a multi-internal actor circularity diagnosis method. It focuses on building an inclusive and co-constructed therefore well-accepted and persistent integration of CE for SMEs, which is lacking today in the existing literature. This work relies on a mixed qualitative and quantitative data analysis applied on a corpus of 42 one-hour-long semi-structured interviews, with 37 different professions. We capture the view of the current and desired situation and identify CE barriers unique to each interviewed worker. We also connect with each worker and open the dialog for the rest of the CE deployment. The final goal is to assemble this worker-oriented diagnosis with quantitative diagnosis, like Life Cycle Analysis of the products and Material Flow Analysis of the factory, to diagnose a complete picture of an industrial SME circularity.

Solving tomorrow's design challenges requires new tools for large world decision-making

Scott Ferguson 1, Kye Drobac 1, Kenneth M. Bryden 2
1 North Carolina State University; 2 Iowa State University

Engineering design research has largely focused on normative models of decision analysis based on small world causal frames where uncertainty can be resolved as probabilities or probability distributions. However, today we need to design solutions for our built environment that are sustainable, just, and able to adapt. Because of the scale and complexity of our world, designs that address sustainability, justice, and adaptability are dominated by unresolvable uncertainty. This requires large world frames and new engineering design frameworks and tools that provide a much broader and nuanced understanding of the impact of our engineering decisions. In this paper we propose that these tools will need to link quantitative and qualitative data and engineering judgment using narrative decision-making processes. To support this, we provide two examples where engineering decision-making is based in part on narrative processes. We then identify five research areas that require additional research to support large-world frames including (1) how can we create microcosms that enable transition between large- and small-world frames and (2) how engineers develop conviction to act using the narratives they create.

S&R 09

THU
27 JUL

Design Practice and Empathy

SC 04

THU
27 JUL

Session Chair: Francesca Montagna, Politecnico di Torino, Italy

Studying the design process in constrained environment: an empirical approach to analyzing informal metal working enterprises in Tanzania

Sonal Keshwani 1, Santosh Jagtap 2, Eliab Z. Opiyo 3
1 Dayananda Sagar University, Bengaluru India; 2 Indian Institute of Technology, Guwahati, India; 3 St. Joseph University, Tanzania

Product design is one of the key features of intellectual and creative abilities of humans.
Activities of product design have attracted not only experts, but also those without any design training. Many people - working in metalworking microenterprises in the informal sector of developing countries - engage in the activities of designing and manufacturing products. However, since extant design research is mainly undertaken in developed countries, there is scarce knowledge about design activities in informal metalworking microenterprises in developing countries. This paper aims to address this issue by uncovering some aspects of design processes in such microenterprises. In particular, we explored: various product attributes that these microenterprises consider in designing products, the process steps they follow in requirements identification and solution generation, and resources (e.g., design methods, training, etc.) available to them. To explore these aspects, we conducted semi-structured interviews in 24 informal metalworking microenterprises in Tanzania. The findings have important implications for supporting their design activities.

The Role of Design In Interdisciplinary Product Development - Challenges, Research Approaches and Further Research Needs

Bernd Stöhr, Christian Koldewey, Roman Dumitrescu, University Paderborn, Heinz Nixdorf Institute

In global competition, companies are continuously searching for a competitive advantage. A growing number of companies have identified the design of their products as a major success factor. The promises for companies associated with outstanding design are extremely attractive, ranging from better customer experience to higher sales growth. But even though the advantages of design seem to be compelling, companies are still having difficulties in leveraging the benefits of design.
In this paper, we want to identify the underlying challenges that explain this gap. We are especially interested in the role and challenges of design in interdisciplinary product development. Therefore, we perform a literature review that clarifies terminology, analyses research approaches and identifies challenges. We determine seven key challenges for design in interdisciplinary product development. Furthermore, we observe a limited scope of research approaches in the reviewed literature. Based on these findings, we propose three further research directions to strengthen the role of design in interdisciplinary product development in the future.

Design in a complex world

Location: Building G - Ground floor: Conference room MANON CORMIER

9:45am
10:45am

Design Practice and Empathy

Session Chair: Francesca Montagna, Politecnico di Torino, Italy

The Study of Cognitive Differences between Designers and Users based on Schema Theory

Su Guo 1,2, Shengxi Fan 1, Yichen Meng 2
1 Tongji University; 2 Zhengzhou University of Aeronautics

This study is grounded upon the cognitive process and knowledge representation, analyzes the differences in perceptions between designers and users by applying schema theory. Per design process, we disassembled the semantic words that represent the design concept, and re-construct the representative visual imagery library. We experimented the imagery library with selective designers and users, and through their selections of the images, we uncovered: 1. The differences largely exist in concept interpretation and imagery selection between designers and users, which has strong relationship with their different schema; 2. The experiment revealed the fact that designers are inclined to understand the concept by disassembling the elements, and have obvious tendency of professionalism, while users' interpretation prefers complete forms and life-oriented; 3. As compared with users, designers relatively prefer brand-new, creative elements in selecting visualized representation.

Black Mirror: A Novel Application of Speculative Design to Facilitate Context-Aware Design Thinking

Kyung seo Jung 1, Neharika Makam 2, Summer Dahyang Jung 3, Seoyoung Kim 1, Sohyeong Kim 3
1 Stanford Center at the Incheon Global Campus, Stanford University; 2 University of California, San Diego; 3 Stanford University

As design thinking became popularized, practitioners in the field pointed out that design thinking rarely takes stakeholders and contexts into account as a result of focusing solely on end-users. We believe such a limitation can be complemented with speculative design, which critiques the future that an idea depicts and interrogates relationships with social, cultural, economical, and political systems. This paper, through pilot interviews with 10 participants and a thematic analysis on interviews with 12 participants, explores possible interaction between design thinking and speculative and critical depiction of the future. Speculative and critical inquiries allowed the participants to consider various social contexts and stakeholders, and further helped them shape and brainstorm the ideas' potential values and challenges faced during adoption. The overall critical speculation influenced various steps of the design thinking process. The paper contributes to the literature by reporting a novel application of speculative design to the conventional design thinking process. In the future, we hope to further explore other elements of speculative design and their impact on design outcomes.

Design in a complex world

Location: Building C – 1st floor: Room C2 – 106

9:45am
10:45am

Understanding Design and Experience

Session Chair: Andy Dong, Oregon State University, United States of America

A Framework for Smart Experience Design based on Zero-Party Customer Experience Data

Yong Se Kim, University of Turku

Data about customer experiences would be critical in smart product-service systems. Research is desired on how to establish a framework for Smart Experience Design based on customer experience data so that determining what kinds of customer data are needed and how these data are acquired effectively can be supported. This paper presents a framework and a method to design customer experience personalization services based on customer experience evaluation data obtained in real time and accumulated together with context data. Two illustrative cases are provided to demonstrate the validity of the framework of smart experience design based on customer experience data.

A Method for Prescribing Psychological Ownership: A Project Handover Case Study

Michelle Rose Cedeno 1, Weston Baxter 1, Tayla Porat 1, Joann Peck 2
1 Imperial College London; 2 University of Wisconsin Madison

Among the topics of psychological ownership (PO) within current literature, a significant gap exists in understanding PO within a prescriptive lens. This study will examine how instigating the PO mapping method will help us understand how the PO mapping method can support an ownership journey. In addition, we want to see how we can create a prescriptive ownership structure that one follows rather than using the tool as a descriptive method. To do this we will follow a Research Through Design methodology and test the PO mapping method in an organisational case study. We believe that the PO mapping method can help frame and guide organisational project handovers. We want to examine the factors that influence the parties (project teams) emergence and relinquishment of ownership, and how that affects the feeling of ownership of a project over time. Based on this understanding we will derive prescriptive phases to integrate into our PO mapping method. Thus this study demonstrates how the PO mapping method can be used in different contexts to support and provide prescriptive guidance for ownership journeys.

Design in a complex world

SC 05

THU
27 JUL

Understanding Design and Experience

Session Chair: Andy Dong, Oregon State University, United States of America

Retrospective coding of the UX design process for UX design enhancement in design agencies

Benoît Dabouis 1,2,3, Vincent Boccara 2, Bernard Yannou 1
1 Université Paris-Saclay, CentraleSupélec, Laboratoire Genie Industriel, Gif-sur-Yvette, France; 2 Université Paris-Saclay, CNRS, Laboratoire Interdisciplinaire des Sciences du Numérique, Orsay, France; 3 Style & Design, Maurepas, France

User Experience is becoming an increasing centre of interest both in the academic and industrial worlds. Design agencies are no strangers to this phenomenon and are willing to shift from product-oriented design toward user experience design. However, their design process is often loose which may explain a lack of final UX quality or proof of quality, and does not allow to diagnose misuses and improvement opportunities due to a lack of UX formulation and traceability. We propose in this paper to retrospectively represent a design project and its specified, designed and validated UX, in the perspective to conduct a posterior collective diagnosis of UX design in a design agency. The proposed representation model is used to analyse one design project. Results show that only a few UX traces are found in the presented project, and that many dimensions are not considered (like perceptions or affects). Finally, we discuss the next steps of this tool's deployment to create a shared mental model of the design process among the design players.

Understanding audiences for immersive and interactive museum and gallery experiences and cultural exchanges

Hyejin Kwon 1, Youngok Choi 1, Xiaoyang Zhao 3, Min Hua 2, Wei Wang 2, Vanja Garaj 1, Busayawan Lam 1
1 Brunel University London; 2 Shanghai Jiaotong University; 3 Imperial College London

The advent of immersive and interactive technologies has facilitated the growth of the museum and gallery sector by offering a variety of new experiences. In the UK and China, in particular, the museum and gallery sector lies at the heart of the creative industries and makes a significant contribution to cultural growth. Both countries have recognised the impact of such technologies on the growth of the sector and have actively sought opportunities to use them for bilateral collaboration. However, the interest in immersive and interactive technologies among museum and gallery audiences remains underexplored, as do their preferences and behavioural patterns with respect to such technologies. This study discusses the key findings of user research, exploring the awareness, experiences and preferences of current museum and gallery audiences regarding (i) immersive and interactive museum and gallery experiences and (ii) the cultural exchange between the UK and China.

Product Architecture Design 3
Configurable Products

Session Chair: Matthias Kreimeyer, Universität Stuttgart, Germany

SD 09

THU
27 JUL

The relationship between Product Architecture and Innovation: A Study through Design of Motorcycles

Sushil Chandra, BML Munjal University

How does the quantity and quality of innovation in an organization vary with the architecture of the product that the organization produces is a recurring theme in literature. This paper attempts to answer this question in quantitative terms and establishes an empirical relationship. While establishing this relationship, this paper also finds objective and quantitative expressions both for the product architecture and innovation in such a way that both the qualitative and quantitative aspects of innovation are accounted for. In this process three new formulations, which can be calculated using the data available in public domain, have been established for architectural modularity, architectural complexity and innovativeness of an idea respectively.These formulations have been verified by collecting innovation data in an automobile manufacturing company and analyzing it from the perspective of architecture and innovation. Finally, the relatioships between architectural parameters and innovativeness have been explored. Implications include the type of architecture more amenable to innovation, the impact of innovation on architectural complexity and a methodological contribution to operationalizing innovation.

Types of partly configurable products in high-variety, low-volume context

Teuvo Heikkinen, Tero Juuti, Tampere University

Research on partly configurable products is emerging. Key concepts of these types of products have been scarcely synthetized, as definitions of partly configurable products in high-variety, low-volume industrial context are limited. These products incorporate modular and integral designs, which calls for an overview on the relations of key concepts defining them. The problem is approached through an exploratory literature review, which allowed an overview of the key concepts over product modularity and partly configurable products. Those were synthetized further define partly configurable products. As a result, four types of partly configurable products are given. This review supports vantage over the key concepts and their relations for reuse with partly configurable products in academia. For practitioners the presented attributes and given examples support in understanding of concepts and their relations with partly configurable products.

Product Architecture Design 3
Configurable Products

9:45am
10:45am

SD 09

THU
27 JUL

Session Chair: Matthias Kreimeyer, Universität Stuttgart, Germany

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Product Architecture Design 3
Configurable Products

9:45am
10:45am

Session Chair: Matthias Kreimeyer, Universität Stuttgart, Germany

SD 09

THU
27 JUL

The interior design challenges of a Hyperloop pod How to enhance the passenger experience

Gisela Zita Cerron, Andre Liem, NTNU

Although still in its infancy, the Hyperloop project aims to develop a new type of public transport. The concept is to send a capsule, called "pod", at about 1000km/h in a vacuum tube that would connect two places separated by 500km. One issue is that the pod will be windowless and travel inside a tube made of steel which will influence passenger comfort. This article brings together various domains to explore the different characteristics that can influence the travel experience. As the Hyperloop concept is still in an early stage of development, methods for analyzing the interior design of transportation vehicles, such as Kansei Engineering, Mayr's circle, and the comfort model by Looze have been proposed. Moreover, typical characteristics, such as "Environment", "Running Factors" and "Service & Installation" have been discussed with respect to "passengers" experience, comfort and safety.

Considering engineering activities and product characteristics to achieve material circularity by design

Iris Gräßler, Philipp Hesse, Paderbron University

To select design guidelines engineers have to identify relevant from a bewildering amount of design guidelines. In this paper, a rule-based method for selecting design guidelines for material circularity selection is presented. For this purpose, a generic Product Life Cycle model is detailed with regard to Multi Material cycles (gPLC-MM). The presented method is divided into four steps. Core of the presented method is the comparison of circular product strategies with product life phases and material recovery processes. Engineering activities and increments of the product architecture are used to identify design guidelines. The results show that through the material circularity-oriented design guideline identification method, the product architecture is designed for different processes and technologies, to recover materials. The method allows engineers to select guidelines in a more targeted and consolidated way in sustainability-friendly product engineering.

Design in a complex world

Location: Building C – 3rd floor: Room C2 – 308

11:15am
12:45am

Project Planning and Execution

Session Chair: Kilian Gericke, University of Rostock, Germany

Design sprint: Use of design methods and technologies

Iris Huić, Nikola Horvat, Stanko Škec, University of Zagreb

This paper analyses the use of design methods and information and communication technology (ICTs) tools in design sprint (DS) activities. Team members, team leaders, and coaches of five international student teams were interviewed (40 interviews in total) regarding their use of design methods and ICT tools during three DS activities: problem definition, conceptual design, and embodiment design. The results show that teams utilise various methods through three approaches: one method for the task, several methods for the task, or adjusting methods. Teams considered several aspects when deciding which method to utilise: the possibility of work distribution, the time needed to execute the method and their prior experience in using the method. The results on using ICT tools suggest that teams mainly use the collaborative whiteboard and Computer-aided design (CAD). In this context, tools that enable continuous sharing of the work in progress (e.g., cloud-based tools) show great potential for DS activities. Finally, the results show a potential to integrate various tools in order to enable easy transition between tasks (e.g., a transition from collaborative whiteboard to CAD modelling).

A Data Driven Tool to Support Design Team Composition Measuring Skills Diversity

*Filippo Chiarello 1,5, Irene Spada 3,5, Simone Barandoni 4,5, Vito Giordano 1,5, Gualtiero Fantoni 2,5
1 School of Engineering, Department of Energy, Systems, Land and Construction Engineering, University of Pisa, Italy; 2 School of Engineering, Department of Civil and Industrial Engineering, University of Pisa, Italy; 3 School of Engineering, Department of Engineering Informatics, University of Pisa, Italy; 4 Department of Informatics, University of Pisa, Italy; 5 B4DS - Business Engineering for Data Science lab, University of Pisa, Italy*

Team composition in Project Based Learning is the first task for the class and has a great impact on the learning experience. Anyway, little space is dedicated in literature about team composition, considering their personal inclinations towards design tasks.

For these reasons we propose a tool that aims to map the design skills of students to optimise team composition. The tool is based on a questionnaire grounded in the design theory and aims at measuring the willingness of students at performing certain design tasks. The results of the questionnaires are analysed using Principal Component Analysis to normalise each students' answers to the whole class, and to show the distribution of students in the space of engineering design skills.

We present the design process of the tool, and a first experimentation on two classes of master's degree students in Management Engineering and Data Science, testing the tool on a total of 72 students. The results are promising and demonstrate the robusteness of the questionnaire and of the analytical method. Also, we propose next steps for our research activity, calling for other researchers to test our method in different contexts.

Design in a complex world

Location: Building C – 3rd floor: Room C2 – 308

11:15am
12:45am

Project Planning and Execution

Session Chair: Kilian Gericke, University of Rostock, Germany

A study on the potential of game based learning for sustainability education

Giulia Wally Scurati 1, Sze Yin Kwok 2, Francesco Ferrise 3, Marco Bertoni 1
1 Blekinge Tekniska Högskola, Department of Mechanical Engineering; 2 Blekinge Tekniska Högskola, Department of Strategic Sustainable Development; 3 Politecnico di Milano, Department of Mechanical Engineering

Academic institutions are increasingly required to prepare future practitioners to face complex sustainability challenges. The need to foster the development of different skills, attitudes, and multidisciplinary collaboration raised the interest in alternative learning approaches. Game-based learning can be a tool to achieve a variety of desirable learning outcomes, including sustainability and collaborative attitudes change. We present a pilot study investigating the potential of a board game on sustainability risks and opportunities in product development and life cycle, performing a test with different student audiences. The paper discusses our results of the experiment, including a survey following the game, qualitative analysis of students' feedback, and observations during the game sessions. Additionally, we relate insights from students' reflections to CDIO learning objectives. We then illustrate lessons learned and the potential advantages of using the game compared to other teaching approaches and as a complementary tool. Finally, we propose future directions and recommendations for the use of the board game and game-based learning in sustainability education with different student audiences.

Project-based learning for engineering students in the context of industry 4.0: application to automotive assembly system

Ahmad Al khatib 1,2, Jean-Marie Malhaire 1,2, Stéphane Dauvé 1,2, Alain-Jérôme Fougères 1,3
1 ECAM Rennes - Louis de Broglie, Bruz, France; 2 Dept. of Mechanical and Industrial Engineering; 3 Dept. of Informatics & Telecommunications

Fourth industrial revolution called Industry 4.0 has radically transformed production systems in manufacturing companies by the integration of emerging technologies. However, manufacturers must overcome several barriers, such as the lack of qualified talent to develop and manage various high-technology systems. Assembly system design aims to define proper assembly line configurations with the optimal performances to overcome increased competitiveness in the market. Nowadays, assembly system design should consider industry 4.0 concepts integration beyond traditional aspects like system balancing and sequencing. In this paper, we introduce a project-based learning approach to teach engineering students assembly system design taking into account industry 4.0 dimension. This project is carried out in collaboration with an industrial partner to design and implement car doors assembly line. The project demonstrated students interest and prepared them better for industry 4.0 era.

AI / VR for CAD applications

Session Chair: Matthias Guertler, University of Technology Sydney, Australia

Is it better ? Exploring the effect of transition goal and virtual reality on team performance

Nikola Horvat, Tomislav Martinec, Marko Brnčić, Stanko Škec, University of Zagreb

Transition activities, such as design reviews, are often utilised in product development to evaluate the conducted work and plan future actions. While key decisions are made during these activities, they are still underexplored. This paper studies the effect of transition goals and virtual reality (VR) on transition team performance. In an experimental study, four-member teams conducted two transition-related experimental tasks (validation and verification) working in one of the two conditions (VR or desktop interface). The results show that transition goals and VR affect performance. More specifically, the validation-oriented transition was more efficient but less effective than the verification one. Furthermore, the performance of the validation-oriented transition compared to the verification one was increased in VR and decreased in a desktop interface. Finally, the high-performing teams consistently discussed new issues, while low-performing teams had prolonged moments of not discussing anything new. These findings suggest that desktop interface and VR are not substitutable but rather complementary technologies.

Comparing collaborative CAD modelling patterns of high-performing and low-performing teams

Robert Celjak, Nikola Horvat, Stanko Škec, University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture

The development of cloud-based Computer-aided design (CAD) enabled real-time CAD collaboration between multiple designers. While this technology has great potential to change the way CAD work is done, it is still little explored. This paper presents a case with two high-performing and two low-performing three-member teams monitored with non-invasive methods (log data) during a six-week design project. The results show that high-performing teams focused more on the editing of assembly, while low-performing teams focused on creating and editing a part. Furthermore, high-performing teams tended to perform consecutive deleting actions and to transition to creating and editing classes of CAD actions after performing viewing actions. Two modelling approaches which lead to high-quality CAD models were identified. One approach is characterized by frequent use of transitions between editing and Organizing-Design (collaborative actions) classes, while the other between creating, editing and reversing classes. Presented results allow design teams to gain insight into sequential patterns which led to the generation of a high-quality CAD model and to better understand the CAD modelling process.

Location: Building C - ground floor: Room C3 – 002

11:15am
12:45am

AI / VR for CAD applications

Session Chair: Matthias Guertler, University of Technology Sydney, Australia

Clustering of sequential CAD modelling data

Jelena Šklebar, Tomislav Martinec, Marija Majda Perišić, Mario Štorga, University of Zagreb

Automating modelling activities in computer-aided design (CAD) systems is no exception within design automation, one of the current research endeavours aiming to use and transform design-related data in design decision-making processes and the generation and evaluation facilitation of new design solutions. The paper explores the differences between CAD models based on their feature-based CAD modelling sequences that lead to the final models' design. The dataset collected and structured for the study contains more than 1400 CAD models clustered on two levels by using an unsupervised K-means clustering algorithm. The algorithm is performed on the number (total and unique) and the first-order Markov model transition matrices of the CAD modelling operations and their sequential order, respectively. Therefore, three and ten groups (clusters) of CAD models are obtained regarding the level of clustering. The results show that most of the obtained groups are specified by the dominant transition between particular modelling operations. In addition, the study also provides insight into the potential of using feature-based CAD modelling operations' sequences as a first step toward automating the user interaction with the CAD system.

Crowdsourcing Engineering Design Problems: Learning from Experiences

Chijioke C. Obieke 1, Jelena Milisavljevic-Syed 2, Ji Han 3
1 University of Liverpool; 2 Cranfield University; 3 University of Exeter

The availability of digital data in the fourth industrial revolution brings different trends with new opportunities and challenges for the engineering design community. As an opportunity, these trends would impact engineering design. However, the challenge is finding applications for these trends in engineering design. Crowdsourcing is one of the trends inspired by digital data. It is outsourcing an individually performed task to be mass-performed. This paper explores the application of crowdsourcing in identifying engineering design problems. Identifying an engineering design problem is an aspect of engineering design considered challenging but necessary for inventions. Secondary data from 63 invention-related cases and an interview with a renowned UK inventor are presented. The data contains scenarios on how the engineering design problems solved to qualify for a UK patent grant or application are identified. Lessons from the case studies are presented and discussed, especially regarding crowdsourcing engineering design problems. These seem to be promising ways of supporting the identification of new engineering design problems with inventive benefits once solved.

Design in a complex world

Location: Building C – 2nd floor: Room C2 – 216

11:15am
12:45am

Design of Intangible Aspects in Health and Wellbeing

Session Chair: Anna Öhrwall Rönnbäck, Luleå University of Technology, Sweden

Knowledge-driven Design for Additive Manufacturing: A framework for design adaptation

Paul Schaechtl 1, Stefan Goetz 1, Benjamin Schleich 2, Sandro Wartzack 1
1 Friedrich-Alexander-Universität Erlangen-Nürnberg; 2 Technische Universität Darmstadt

Due to the high freedom of design, additive manufacturing (AM) is increasingly substituting conventional manufacturing technology in several sectors. However, the knowledge and the awareness for the suitable design of additively manufactured components or assemblies ensuring manufacturability and fully realizing its potential is still lacking. In recent years, approaches and tools have emerged that allow the incorporation of existing knowledge of Design for Additive Manufacturing (DfAM) into the design process. Nevertheless, these applications mostly do not consider the formalisation of both restrictive and opportunistic DfAM guidelines for their integration in design tools.

Therefore, the following article presents a framework for the knowledge-driven adaptation of existing designs in the context of DfAM within an expert system. The novelty of the presented approach lies in the interdisciplinarity between the formalization of design guidelines and their integration and consideration within computeraided design for the semi-automated adaptation of functional non-assembly mechanisms. The application of the presented framework to a case study manufactured via Fused Layer Modeling (FLM) illustrates the applicability and benefits.

Function integration in additive manufacturing: A review of approaches

Gregory-Jamie Tüzün, Daniel Roth, Matthias Kreimeyer, University of Stuttgart

This paper provides an overview of established approaches for function integration in additive manufacturing and critically compares their capabilities. One of the decisive factors is how functions and structures are addressed. This is necessary because function integration - among many others - affects material decisions and the manufacturing process chain. It is one of many reasons to rethink the product architecture and a way to support the design of resource-efficient products. Various strategies for function integration exist. However, there are currently no approaches in additive manufacturing that provide systematic support for early function integration.

A systematic literature review identified 21 unique approaches. All approaches were categorized according to their abstraction level within a product architecture and their design type to be supported. They were then compared on the basis of their categorization, design objective and strategy for function integration to allow for a better understanding of when to use the approaches in research and practice. Key findings and considerations for adapting function integration approaches to early design stages are presented. In addition, several research gaps were identified.

Design of Intangible Aspects in Health and Wellbeing

Session Chair: Anna Öhrwall Rönnbäck, Luleå University of Technology, Sweden

Visual Behaviour in The Evaluation of Physical and Virtual Prototypes

Aurora Berni, Chiara Nezzi, Nadia Piazzolla, Yuri Borgianni, Free University of Bozen-Bolzano

Product development stages are typically characterized by different forms of representations and degrees of specification, which potentially affect user's perception and evaluation. These effects are worth investigating more closely also because of the growing relevance of new technologies such as Virtual Reality (VR) in the design field. The objective of this paper is to elucidate the mutual relations between forms of representation, visual behaviour, and people's evaluations. The focus is on differences between virtual and physical prototypes. In the illustrated experiment, participants visited a tiny house in an immersive VR (360° images acquisition). The results were compared with a past experiment where the physical prototype of the same product was similarly evaluated. The dwell times on Areas of Interest (AOIs) pertaining to the tiny house were compared and correlated to variables concerning subjective evaluations. The results show just a few similarities of visual exploration in terms of gazed AOIs. Substantial differences in terms of how the duration of gazing affects evaluations have been found too. The larger number of significant correlations between observations and evaluations in the virtual exploration emerged.

A multi-criteria decision-making approach to optimize the part build orientation in additive manufacturing

Mikhailo Sartini 1, Manuguerra Luca 1, Favi Claudio 2, Mandolini Marco 1
1 Università Politecnica delle Marche; 2 Università Politecnica delle Marche

The part build orientation is a manufacturing variable that must be considered when designing a product to maximise AM opportunities. There are several approaches to selecting the best print direction in the scientific literature by considering different criteria. However, most of the studies are focused on specific AM technologies. It is missing a general method that evaluates a widespread number of criteria. Furthermore, such approaches expect designers establish weights for technical criteria that are too specific, especially during the preliminary design steps. Designers are familiar with criteria like cost-effectiveness, productiveness, quality and mechanical strength.

The paper presents a multi-criteria decision-making approach to optimise the build part orientation in additive manufacturing. The method considers five decision-making criteria (cost-effectiveness, rapidity, productiveness, quality and mechanical strength) and seventeen specific technical criteria. TOPSIS is the method used to optimise the build part orientation. A case study of three components exemplifies the five steps of the procedure.

Design of Intangible Aspects in Health and Wellbeing

Session Chair: Anna Öhrwall Rönnbäck, Luleå University of Technology, Sweden

How do prototypes change? Characterising quantitative and qualitative changes between prototype iterations

Ricardo Real, Chris Snider, Mark Goudswaard, Ben Hicks, University of Bristol

Prototyping strategies and technology often focus on reducing the fabrication time and cost between design iterations, however, there is limited knowledge about the specific characteristics of change that prototyping strategies aim to impact. To investigate, and better understand these characteristics, this study curates and systematically analyses a representative dataset of 50 'real-world' prototype samples. The study aims to explore the various elements that constitute a design change and to determine their impact on the scale of volumetric change detected. The results highlight emergent patterns and correlations between study metrics to better understand the reasons for design change and the frequency and scale of changes detected in the sample dataset. Findings reveal that the purpose of a design change is, in certain cases, highly correlated to the scale of change affected, and that some changes are more prevalent in the dataset than others, with an average volumetric difference of 4.2% between sample versions detected. The study provides an initial characterisation of prototype change to guide iterative prototyping processes and improve the efficiency and effectiveness of design iterations.

Design in a complex world

Location: Building G - Ground floor: Conference room MANON CORMIER

11:15am
12:45am

Prototyping In Design

Session Chair: Wendy Zhang, University of Canterbury, New Zealand

Prototyping for Children: Understanding how fidelity affects children's comprehension of prototypes

Andria Carolynn Codner, Carlye Anne Lauff, University of Minnesota-Twin Cities

Testing prototypes with intended end users is critical to the design process. There is limited research on testing prototypes with certain types of end users, specifically children for toy products. Additionally, prototypes evolve in fidelity throughout a project, adding to the complexity in developing best practices for prototype testing. This paper analyzes children's understanding of physical prototypes at various levels of fidelity throughout a university semester-long design project developing wooden toys. Through analyzing students' feedback on their prototype testing sessions, aspects of the prototypes that aid or inhibit children from understanding both form and function are uncovered. These aspects relate to Norman's principles of interaction and their inclusion in prototypes, specifically mental models, signifiers, and affordances. This paper suggests to include these principles in prototypes early in development to guide the user during testing. The goal of this research is to be a resource for those developing products for children, as well as adding knowledge around prototyping testing at various levels of fidelity.

How Should We Prototype? Establishing the Affordances of Prototyping Media and Approaches

Chris Snider 1, Mark Goudswaard 1, Charlie Ranscombe 2, Chaunpeng Hao 1, James Gopsill 1, Ben Hicks 1
1 University of Bristol, UK; 2 Swinburne University of Technology, Australia

The breadth of media and approaches used when prototyping are vast, with each holding inherent properties that vary their suitability for a given prototyping activity.
While several have established classifications of types and purposes of prototypes, there is little by way of guidance for designers on how select and strategise prototyping given their activity needs, or how the prototype chosen may influence their process, success or efficiency.
This paper presents nine affordances of prototypes derived from literature, together characterising the properties of prototyping media or approaches that affect their suitability across prototyping activities. The affordances are illustrated through application to physical and digital classes of prototypes and four real prototype cases, showing descriptive capability, inherent differences between the media, and enabling direct and consistent comparison.
By mapping affordances across many media and approaches, this work enables better method selection to align with activity needs, better description and comparison of media and approaches, and the ability the broadly interrogate and direct future development of prototyping technologies.

Design in a complex world

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11:15am
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Investigating the process, design outputs and neurocognitive differences between prototyping activities with physical and digital Lego

Adam McClenaghan, Mark Goudswaard, Ben Hicks, University of Bristol

Design neurocognition is an emerging research area that can provide insights into the black box of designers' cognitive processes. However, work to date has focused on neurocognition on its own, without integrating this with other design measures.

This paper presents the results of a pilot study which brings together designer neurocognition with design output and assessment of the design process followed in a constrained prototyping activity comparing use of physical and digital Lego. This was achieved via EEG data capture, a TLX survey and measures of design output variance.

Differences between physical and digital prototyping methods were found with respect to Task Related Powers of EEG signals and the design process followed with digital prototyping methods found to take longer, require more effort and cause more frustration. No differences were found with regard to design output.

Whilst the sample size used (n=12) was small, future studies will use large sample sizes to increase their statistical power and will consider alternative EEG or fNIRS to capture brain activity due to challenges with the headset used in this study

Location: Building G - Ground floor: Conference room MANON CORMIER

11:15am
12:45am

Prototyping In Design

Session Chair: Wendy Zhang, University of Canterbury, New Zealand

Current and potential applications of 3D printing in a general hospital

Sayfeddine Eddous 1,2, Guillaume Lamé 2, Benoît Decante 1, Bernard Yannou 2, Antoine Agathon 1, Laure Aubrège 1, Valérie Talon 1, Éléonore Dacosta-Noble 1
1 Groupe Hospitalier Paris Saint-Joseph; 2 Laboratoire Genie Industriel, CentraleSupélec, Université Paris-Saclay

3D printing is widely touted as a game changer in medicine and surgery, paving the way for point-of-care production of personalised medical devices. Nonetheless, to date, most reported applications of 3D printing in healthcare are restricted to specific scenarios in a few surgical disciplines, and little research exists on how 3D printing can be deployed more systematically beyond pioneer surgical departments. To understand the potential for 3D printing at a hospital level, we report the results of an interview study in a French general hospital. We analyse the current use of 3D printing and estimate the potential for new applications. We explore what share of these applications could be internalised, and what would be the organisational implications and the key success factors for an internal 3D printing unit. We find a large untapped potential for internal production of 3D printed products, spanning a much broader range of applications and hospital departments than what currently exists in the hospital. We then discuss important criteria to develop in-house 3D printing.

Knowledge Management

Session Chair: Saeema Ahmed-Kristensen, Royal College of Art, United Kingdom

IBM 05

THU
27 JUL

Improving Knowledge Transfers at Protektorwerk Florenz Maisch GmbH & Co. KG through the Application of the InKTI – Interdepartmental Knowledge Transfer Improvement Method

Monika Klippert 1, Luisa Schäfer 1, Jörg Böllhoff 2, Heiner Willerscheid 2, Simon Rapp 1, Albert Albers 1
1 Karlsruhe Institute of Technology (KIT); 2 Protektorwerk Florenz Maisch GmbH & Co KG

In the development and production of new products, interdepartmental knowledge transfer is essential. Successful knowledge transfer faces several challenges, such as a lack of willingness to transfer knowledge or an inappropriate selection of tools. These can lead to the reduction of efficiency and effectiveness of knowledge transfers. Therefore, the InKTI – Interdepartmental Knowledge Transfer Improvement Method is developed to support the improvement (in terms of speed and quality) of knowledge transfers, particularly in product and production engineering.

This paper presents the first validation of the InKTI Method through a field study at the company Protektorwerk Florenz Maisch GmbH & Co. KG, which is a leading European company in the construction industry, to support the successful knowledge transfer into practice. Therefore, the research need is pointed out, and a concept for validation is developed and implemented. Afterward, the InKTI Method is evaluated based on its success, support as well as applicability.

Decision Support Framework using Knowledge Based Digital Twin for Sustainable Product Development and End of Life

Chorouk Mouflih 1, Raoudha Gaha 1, Alexandre Durupt 1, Magali Bosch-Mauchand 1, Kristian Martinsen 2, Benoit Eynard 1
1 Université de Technologie de Compiègne; 2 Norwegian University of Science and Technology

In order to have a sustainable disassembly process, a successful decision-making based on reliable and up-to-date information should be made while taking into consideration sustainability indicators. In this context, The aim of this paper is to introduce a decision support system based on knowledge based and digital twin in order to help stakeholders to choose the most sustainable disassembly scenario .In this research, firstly, we presented the state of art of disassembly process, digital twin, knowledge based system and the merging of knowledge based system and digital twin for disassembly. Secondly, we presented the knowledge based digital twin (KBDTw) system framework for a sustainable disassembly process. Thirdly, a case study is presented about the use of KBDTw in the end-of-life of internet boxes. Finally, a conclusion and future work are conducted.

Knowledge Management

Session Chair: Saeema Ahmed-Kristensen, Royal College of Art, United Kingdom

Sheafification as a design technique for creative preservation - principles, illustrations, and first applications

Pascal Le Masson, Armand Hatchuel, Benoit Weil, Mines Paris-PSL

In times of 'grand challenges', design theorists dealing with complex systems are facing a dilemma: grand challenges require rule breaking, but they also require the preservation, as much as possible, of existing resources, systems, know-how and societal values. Design for transition calls not for 'creative destruction', but for 'creative preservation'. How do we model a design process that involves 'creative preservation'?

Today, it is recognized that category/topos theory provides a solid foundation for modelling complex systems and their evolution in design processes. Category theory can account for a design process inside a given 'theory of the object', while topos theory and design theory can account for the phenomena whereby a design process is innovative to preserve the knowledge structure. At the heart of this creative preservation is sheafification.

In this study, we analyse the sheafification process using design theory. First, we characterize sheafification from a design perspective. Next, we propose a very simple illustration involving the sheafification of an ordinal 2 category presheaf. Finally, we show how sheafification can be used to enable 'creative preservation' in specific complex systems.

An exploration of knowledge management activities in multidisciplinary service design organizations

MohammadReza Mirafzal 1, Piyush Wadhera 2, Julie Stal-Le Cardinal 1
1 CentraleSupelec University; 2 Sibylone

This study aims at revising the history of knowledge management in service design organizations to discover what sources, technologies, tools, and users have been used and how knowledge management may thus help to improve consultants' performance. Also, this study sheds light on the importance of decomposing knowledge (knowledge-leveling being said in this article) before tackling knowledge management. Moreover, this study provides a real case study investigation of knowledge management in a service design organization. Through this investigation, the authors propose their knowledge-leveling classification model and how knowledge management activities satisfy each class. Thus, the authors showcase the essentiality of knowledge leveling in knowledge management.

Examples in Design Optimization

Session Chair: Felician Campean, University of Bradford, United Kingdom

M&P 07

THU
27 JUL

Vibration reduction by tuned mass dampers inside cavities of topology optimized lattice structures

Marc Konrad Bernd Janousek, Duo Xu, Anand Vazhapilli Sureshbabu, Markus Zimmermann, Techische Universität München

Tuned mass dampers may be used to improve vibrational behavior of structures. However, they require space to move. This paper presents an approach to incorporate tuned mass dampers into a light-weight-optimized structure without extra space requirement. It is based on (1) topology optimization (TopOpt) with unit cells and (2) vibration reduction with multiple tuned mass dampers (m-TMD) within the unit cells. The topology optimization is performed with a physics-informed penalty factor, unique to the chosen unit cell. Subsequently, the weight optimal density distribution is realized by populating the design domain with unit cells of ten different densities. To reduce the induced vibration, m-TMDs are placed inside the cavities of the unit cells in the grey scale regions. The effectiveness of the approach is demonstrated for the design of a 2-segment robot arm. The resulting unit cell robotic arm (UC-Arm) is 3.6% lighter than the reference model, maintains the same static performance, and shows a 60% smaller dynamic displacement in the observed frequency range. No extra space is required for the motion of the m-TMD.

Implementation of a design guideline for aluminum foam sandwich based on industrial demands

Patrick Hommel, Daniel Roth, Hansgeorg Binz, Matthias Kreimeyer, University of Stuttgart

Aluminum foam sandwich (AFS) is an innovative material for lightweight structures, consisting of an aluminum foam core surrounded by two face sheets of aluminum. The advantages of AFS are a low density combined with a high bending stiffness, good energy absorption properties, and high recyclability, meaning it can be used for many different applications. However, the number of realized series applications with AFS is low caused by a lack of design knowledge, as shown in various studies. In order to address this lack of design knowledge, a design guideline is to be developed. This paper focuses on the development of such a design guideline based on requirements and demands from the industry and presents a structure. In addition, the individual contents of the design guideline are explained in more detail in order to clarify how designers can be supported in the future when designing products with AFS, so that the full potential of this material can be realized. Finally, a survey in an industrial context evaluates the extent to which this design guideline is a useful form of support, in order to check whether its application can improve the design process with AFS.

11:15am
12:45am

Examples in Design Optimization

Session Chair: Felician Campean, University of Bradford, United Kingdom

M&P 07

THU
27 JUL

Exploring the potential for a FEA-based Design of Experiments to develop design tools for bulk-metal joining processes

Jacob Hatherell 1, Arnaud Marmier 1, Grant Dennis 2, Will Curry 2, Jason Matthews 1
1 University of the West of England; 2 SKF (U.K) Ltd

Over the last 20 years, finite element analysis (FEA) has become a standard analysis tool for metal joining processes. When FEA tools are combined with design of experiments (DOE) methodologies, academic research has shown the potential for virtual DOE to allow for the rapid analysis of manufacturing parameters and their influence on final formed products. However, within the domain of bulk-metal joining, FEA tools are rarely used in industrial applications and limit DOE trails to physical testing which are therefore constrained by financial costs and time.

This research explores the suitability of an FEA-based DOE to predict the complex behaviour during bulk-metal joining processes through a case study on the staking of spherical bearings. For the two DOE outputs of pushout strength and post-stake torque, the FEA-based DOE error did not exceed ±1.2% and ± 1.5 Nm respectively which far surpasses what was previously capable from analytically derived closed-form solutions. The outcomes of this case study demonstration the potential for FEA-based DOE to provide an inexpensive, methodical, and scalable solution for modelling bulk-metal joining process.

Parametric Modelling of the Exterior Design of Autonomous Shuttles

Philipp Hafemann, Manuel Daumoser, Markus Lienkamp, Technical University of Munich

Autonomous vehicles for the last mile are a promising use case for advancing autonomous driving in real-world traffic. For this purpose, traditional car manufacturers and newcomer companies develop a new vehicle concept: the autonomous shuttle. During the development, components from the automation domain, such as the sensors, must be placed and integrated into the vehicle body. The trade-offs between the functional performance of the perception and the exterior design must be evaluated early in the design process. For this purpose, a model of the vehicle exterior is needed. In this contribution, we present a method for parametric modeling of the vehicle exterior of autonomous shuttles. We define 17 input parameters and use computer-aided design to create a virtual model of the body and the wheelhouses. In the results, we validate our method by ensuring that existing shuttles can be modeled with our approach and also analyze the limitations. The model supports decision-making in the early design phase by enabling quick iterations between sensor placement and exterior design.

Examples in Design Optimization

Session Chair: Felician Campean, University of Bradford, United Kingdom

M&P 07

THU
27 JUL

On the treatment of requirements in DfAM: Three industrial use cases

Felix Endress, Jasper Rieser, Markus Zimmermann, Laboratory for Product Development and Lightweight Design, TUM School of Engineering and Design, Technical University of Munich, Germany

Optimization-driven design offers advantages over traditional experience-based mechanical design. As an example, topology optimization can be a powerful tool to generate body shapes for Additive Manufacturing (AM). This is helpful, when (1) load paths are non-intuitive due to complex design domains or boundary conditions, or (2) the design process is to be automated to minimize effort associated with experience-based design. However, practically relevant boundary conditions are often difficult to put into a formal mathematical language to, for example, either feed it into a topology optimization algorithm, or provide precise quantitative criteria for CAE-supported manual design. This paper presents a survey of three industry use cases and identifies three types of requirements: the first can be directly cast into parts of an optimization problem statement (40%), the second is considered indirectly by adapting the optimization problem without explicit reference to the requirement (20%), and the third is only assessed after the design is finalized (40%). For categories 2 and 3 we propose directions of improvement to support formulating complex design tasks as unambiguous design problems.

S&R 10

THU
27 JUL

Designing the Sustainable Transition Strategy & Policy

11:15am
12:45am

Session Chair: Akane Matsumae, Kyushu University, Japan

Assessing systemic drivers and barriers to sustainable design transitions: relationship strengths and research gaps

Hossein Basereh Taramsari 1, John McFarren 1, Matilda Watz 2, Sophie I. Hallstedt 2,3, Steven Hoffenson 1
1 Stevens Institute of Technology, U.S.A.; 2 Blekinge Institute of Technology, Sweden; 3 Chalmers University of Technology, Sweden

The sustainable design transition has proven to be a challenging process, in part due to the diverse set of stakeholders, which includes the general public, policymakers, scientific researchers, and businesses. In prior work, the interconnected relationships among systematic drivers and barriers for sustainable design were identified and mapped using a causal loop diagram at a relatively abstract level. To further understand and characterize this complex system, this research aims to identify the relationship strength levels among the variables in the system, as indicated by previous research identified in the literature. In addition, the knowledge maturity levels of these identified relationships are specified to illustrate strengths and gaps in the literature. The findings are used to create a refined system representation that illustrates the power dynamics between systemic driving forces to sustainable design transitions. The results of this work reveal valuable insights about the linkages among the driving forces of sustainable design transitions that can be used as a foundation for further investigation, such as experiments and data analytics that can better quantify these relationships.

Implications of EU instruments on company capabilities to design more sustainable solutions–Product Environmental Footprint and Digital Product Passport

Josefin Lövdahl 1, Sophie I. Hallstedt 1,2, Jesko Schulte 1
1 Blekinge Institute of Technology, Sweden; 2 Chalmers University of Technology

In the EU, initiatives with concrete instruments for measuring and storing sustainability-related product data are now introduced in legislation. Based on literature review and semi-structured interviews, this study investigates two EU instruments, the Product Environmental Footprint method and Digital Product Passports, and their potential implications for company capabilities to design and select more sustainable solutions in a strategic way. The results show that these instruments can lead to increased transparency and traceability in the design and comparison of solutions, allowing for more effective collaboration across the value chain. By applying a strategic sustainability perspective, it was found that these EU instruments have major limitations as they lack a systems perspective, do not include a full socio-ecological sustainability perspective, and do not support strategic decision-making. This results in risks for suboptimization and the design of solutions that turn out to be costly dead-ends on the way towards a sustainable society. Research is therefore recommended to investigate how these instruments can facilitate a strategic development of sustainable solutions.

S&R 10

THU
27 JUL

Designing the Sustainable Transition Strategy & Policy

11:15am
12:45am

Session Chair: Akane Matsumae, Kyushu University, Japan

Uncertainty management in product development portfolios: the impact of global sustainability agendas

Andy Mattulat Filipovic 1,2, Torgeir Welo 1, Pelle Lundquist Willumsen 2, Josef Oehmen 2
1 Department of Mechanical and Industrial Engineering, Norwegian University of Science and Technology; 2 Department of Technology, Management and Economics, Technical University of Denmark

Increased focus on sustainability significantly impacts product development portfolio management in organizations. This paper focuses on the significant unaccommodated uncertainty caused by the green transition for current mid- and long-term portfolio management processes. These uncertainties arise in areas such as the regulatory environment, market demands, and technical capabilities. This paper makes four contributions: First, current product portfolio management literature is mostly employing deterministic practices. Uncertainties are incompletely addressed, and current methods fail to address the deep uncertainties of the green transition. Second, building a literature-based conceptual framework of the sources of uncertainty in 6 areas: Business Models, Technology, Regulation and Legislation, Finance and Insurance, Market and Consumer, and Organizational Context. Third, preliminary empirical evidence supports the usefulness of our model for product development portfolio management. Fourth, concluding with a suggested empirical research agenda to develop a deeper understanding of challenges towards method and theory development to support the green transition on the portfolio management level.

Towards the design of sustainable mobility systems: objectives and barriers from the French local authorities' perspective

Julien Baltazar 1, Ghada Bouillass 1, Flore Vallet 1,2, Jakob Puchinger 3,1, Nicolas Perry 4
1 Université Paris-Saclay, CentraleSupélec, Laboratoire Génie Industriel, 3 rue Joliot-Curie, 91190 Gif-sur-Yvette, France; 2 IRT SystemX, Paris-Saclay, Avenue de la Vauve, 91127 Palaiseau, France; 3 EM Normandie Business School, Métis Lab, 92110 Clichy, France; 4 Arts et Metiers Institute of Technology, University of Bordeaux, CNRS, Bordeaux INP, INRAE, I2M Bordeaux, F-33400 Talence, France

Within the on-going ecological transition, mobility systems are considered as sociotechnical systems that raise several challenges for local authorities due to the different levels of decision, a complex stakeholder network and the numerous objectives to be dealt with. Designers are therefore seeking to develop new frameworks to support local authorities moving towards more sustainable mobility systems. Based on the French context, this study relies on an analysis of the regulation and an interview-based survey that depict the mobility design from the local authorities' perspective. First, it investigates the objectives defined in the law and the difficulties met by local authorities. Then, it highlights the main political, organisational, and knowledge barriers for sustainable mobility. Finally, it proposes a set of recommendations to create a framework to better define and prioritise the objectives, ensure efficient planning and monitoring, clarify the interactions between actors, and enhance mobility plans.

Designing the Sustainable Transition Strategy & Policy

11:15am
12:45am

Session Chair: Akane Matsumae, Kyushu University, Japan

Barriers And Drivers for An Efficient Integration of Eco-Design of Complex Systems: A Case Study in The French Military Industry

Elise Dupont, François Cluzel, Bernard Yannou, Laboratoire Génie Industriel, CentraleSupélec, Université Paris-Saclay, Gif-sur-Yvette, France

The defense industry tends to anticipate environmental issues through eco-design integration in the overall design process. This leads to focus on the impact of technological and design choices of complex systems while maximizing operational performance. Such development involves long and complex processes and is constrained in a project owner and industrial project manager context. In this context poorly described in the literature, the objective of this paper is to identify barriers and drivers to achieve an efficient application of eco-design. A comprehensive analysis of the interactions and the current design processes is performed in the context of the French defense industry. Through internal documentation and semi-structured interviews with the key actors, the generic design process of a project owner is analysed (including relationships with industrial project manager). The failure modes that currently limit the integration of eco-design in projects are also identified.

Design in a complex world

Location: Building A - ground floor: Conference room BENZACAR

11:15am
12:45am

User Behaviour and Sustainability

Session Chair: Tua A. Björklund, Aalto University, Finland

Designing Serious Games to Understand the Challenges of the Anthropocene

Mathilde Boissier 1, Vincent Jost 2,1, Mathieu Mangeot 1, Léa Viénot 1
1 INRIA / Laboratoire Jean Kuntzmann, équipe STEEP; 2 Laboratoire G-Scop

The challenges of the Anthropocene require a deep transformation of the world's economic organization. In order to manage such a change, it is necessary to have a systemic vision of the resources, processes at stake and their interdependencies. One possible approach to modeling part of this complexity is biophysical flow accounting. One of the challenges is to involve populations in participatory processes. It is therefore important to understand the systemic effects. However, biophysical accounting tools remain too complicated.

This is why we have designed serious games to present the issues in a simple way, to articulate them with concrete experiences already lived by citizens and to take a step back, by mobilizing their participation, their emotions and the discussions.

The first game was designed to show the geographical transfer of pressure through the description of the steps leading to the purchase of a chicken, starting with the vegetable culture allowing to feed it.

The second game was designed to show the competition of use between resources. Designed as a board game, it also involves reflection on the cooperative and competitive aspects of many societal situations.

Preventing the overconsumption and disposal of refill at home fast-moving consumer goods - interventions that support circular consumer journeys

Catriona Tassell, Marco Aurisicchio, Imperial College London

Context and problem: Reuse is positioned as a strategy capable of countering single-use overconsumption and disposal. For refill at home FMCGs, consumers are responsible for carrying out behaviours that enable this, such as keeping and using products for a prolonged period. However, it is not known if consumers actually fulfil these responsibilities. Aim: This research aims to understand the extent to which consumer reuse behaviours supports the intended reduction in impact and, if not, consider how best to improve it. Method: In-depth interviews with 15 consumers were conducted where the behaviour chain method was used to map resource journeys for 31 refill at home offerings. Results: Five models of consumer behaviour increased the impact of reuse. The critical moments which led consumers to carry out these behaviours were identified, uncovering intervention areas. Conclusions: The behaviour models and critical moments offer a first attempt to systematically analyse how and where actual consumer behaviour can increase the impact of refill at home FMCGs. The results call for focussed interventions across the consumer journey that support reuse components as part of a system.

User Behaviour and Sustainability

Session Chair: Tua A. Björklund, Aalto University, Finland

SC 06

THU
27 JUL

Green Product Personality: Developing a Product Concept Made of Recycled Ocean Plastic Based on the Collection of Context-Related Personality Traits

Katharina Kohllöffel 1, Martin Luccarelli 1, Claus-Christian Carbon 2
1 Reutlingen University; 2 University of Bamberg

The replacement of conventional material with recyclates affects product personality, particularly regarding sustainability aspects influencing consumer behaviour. A definition of personality for products made of recyclates is missing in literature. As these products require appropriate aesthetics based on material origin to communicate the advantage concerning sustainability, there is a need for research in this regard. This paper aims to develop an adequate personality of a reusable water bottle made of ocean plastic by collecting personality traits that evoke associations related to the material's origin and sustainability. We conducted two quantitative field studies. Study 1 collected associated visual perceived attributes and context-related personality traits in order to develop and visualize a preliminary design. Study 2 evaluated the design regarding associated personality traits. The overall outcome was a product personality scale consisting of 23 items plus a concrete design recommendation for a water bottle made of recycled ocean plastic. The assessment of degree of sustainability was strongly influenced by participants' associations with personal use, familiarity with usage and the factor of stability and resilience.

Trash talk: who uses which reusable product? User insights and design opportunities for single-use alternatives

Laure Herweyers, Els Du Bois, Ingrid Moons, University of Antwerp

Single-use products often end up in the environment as waste, threatening ecosystems and human life. This indicates a need to transition towards sustainable reuse routines. In this study, we investigate to what extent reusable products are already established in society and what design properties users require. We compare the results between user clusters and countries. To create a meaningful list of reusable products to investigate, we distinguish four categories based on typical barriers by means of focus groups (n=3) and interviews (n=32). Next, we did a survey (n=3000) in three countries (Belgium, Russia, U.S.) to define user clusters and investigate product usage and design requirements. Most established products are hard-material products such as lunch boxes, while intimate hygiene products, such as menstrual cups, are not established yet. Multifunctionality and compactness are the most indicated product requirements. There are significant differences between countries and clusters for both research questions. We conclude that different types of users have different needs: while a sharing system might work for one group, a customizable option would be more suitable for others.

SD 10

THU
27 JUL

Design Theories and Approaches 2

Session Chair: Shuichi Fukuda, Keio University, Japan

Modelling the design of models: An example using CRISP-DM

Udo Kannengiesser 1, John S. Gero 2
1 Johannes Kepler University Linz; 2 University of North Carolina at Charlotte, USA

Design is widely understood as a domain-independent notion, comprising any activity concerned with creating artefacts. This paper shows that models can be viewed as artefacts, and that the design of models resembles the design of artefacts in other domains. The function-behaviour-structure (FBS) ontology of design is applied to models, mapping generic characteristics of models derived from literature on modelling onto basic, design-ontological categories. An example of model design, namely the CRISP-DM model for designing data mining models, is analysed and compared with models of designing in other domains (systems engineering, mechanical engineering, software engineering, and service design). The results show that there are fundamental commonalities but also differences, revealing the need for further research in developing a theory of model design.

The Aristotelian causalities in localised distributed manufacturing

Esben Bala Skouboe, Mário Barros, Aalborg University

Half of the total greenhouse gas emissions and 90% of biodiversity loss come from resource extraction and processing. (EC 2020). To counter this, we must switch to sustainable, long-lasting products and slow down the use of resources. It is clear that these systems will not be fixed by incremental changes but by a series of disruptions. This article uses the Aristotelian causalities as a vehicle to break down the concept of "why" industrial design and discuss the underlying value propositions of distributed manufacturing. This critical perspective allows designers and engineers to bridge the knowledge-siloes and rewire the way a product is designed, sourced, built and consumed in relation to the four Aristotelian causalities. The paper discusses the limitations and potentialities for each causality in relation to a distributed manufacturing paradigm and argues for a new sustainable design concept: The Local Limited Edition. A site-specific product design, realised by brands to enrich brand value on local markets, improve market fit and increase attachment, ultimately improving the products' longevity and value of the products.

Location: Building A - ground floor: Conference room BERNARD

11:15am
12:45am

Design Theories and Approaches 2

Session Chair: Shuichi Fukuda, Keio University, Japan

Combining Exploration/Exploitation with Domain Theory: A two-dimensional categorization of design research and product development.

Chris McMahon 1, Claudia Eckert 2
1 University of Bristol; 2 The Open University

This viewpoint paper uses two established classifications – March's distinction between exploration and exploitation and Andreasen's Domain Theory – to develop a classification matrix to map industrial challenges and design research topics. Exploration/exploitation and the organ, part and activity domains of Domain Theory are respectively the two dimensions of this classification matrix. Examples are given of the fit of design research and industrial innovation topics into each cell of this matrix, and the need for change in industrial emphasis towards exploration across the range of domains to meet current challenges is discussed. We show how design research covers all categories in the matrix, and argue that using a simple classification may assist the research community in explaining its activities to a wider world, and in organising and directing these activities. We conclude by making suggestions for topics for debate in the design research community.

Towards a better understanding of the influence of visual references on consumer aesthetic perception

Chukwuma M Asuzu, Alison Olechowski, University of Toronto

When viewing a product for the first time, a consumer's aesthetic perception is based on their knowledge of other products, artefacts, and concepts. These mental images function as visual references for consumers and affect the processing fluency of the new product. Designers frequently use visual references as inspiration during the research stage of the design process. It has been documented, however, that there is a gap between designer intent and consumer response; Consumers do not always realize the intent of designers nor draw on the same visual references when perceiving a product, which can reduce their processing fluency of new products.
Visual references differ from one consumer to the other which make them difficult to study. In this paper, we argue for a new way of studying visual references: by analyzing the cognitive process that occurs when consumers view a new product and recognize aspects of that product that are similar to visual references in their memory. We present a framework of three approaches for recognizing this similarity and implications for design practice.

SD 11

THU
27 JUL

Product and System Modelling 1

Session Chair: Ali Yassine, Stevens Institute of Technology, United States of America

Mapping stakeholder engagement needs in early-stage system development process

Man Hang Yip, Institute for Manufacturing, University of Cambridge

Companies design, develop, and market new systems of products and services, through the process of translating beneficiaries' needs into design specifications, where beneficiaries are those who generate value when using the new product or experiencing the new service enabled by the product. Successful new systems of products and services attract potential beneficiaries. This study explores how to identify the stakeholder engagement requirements of a new system at its early stage of development.
The study proposes a procedure and a tool - a new visual representation called the stakeholder-value map - to show the system development team how stakeholders are to interact with the system's key elements, and hence inform the timing of stakeholder involvement, for realising the value proposition of the new system. A working theoretical construct is also emerged from the study: for a new system to have a higher chance of market adoption, one can first visualise the 'route' of value-creation, from the lowest value-level product/service elements to the highest value-level service elements; then, identify the requirements for stakeholder engagement in the new system development.

A hierarchical exploration of how design margins enable adaptability

Lindsey Jacobson, Scott Ferguson, North Carolina State University

Our society is built on engineered systems. Engineers are becoming increasingly concerned with the sustainability of systems, particularly their ability to adapt to a changing world. Recently, there has been increased interest in exploring how design margins provide opportunities for a system change. There have been great developments in determining how design margins can absorb change at a system level, but it is still not clear how design margins might provide change opportunities at a decision variable level. In this paper, we show how system-level margins could be deconstructed to explore what change opportunities they may provide at a decision variable level. We also investigate how the coupling of functional requirements limits how system-level margins can be operationalized. Our analysis suggests that design margins can provide meaningful change opportunities at the decision variable level, but the mechanisms that produce these opportunities are complex. These insights lay the groundwork for future research on mapping and representing design margins in the context of system adaptability.

Product and System Modelling 1

Session Chair: Ali Yassine, Stevens Institute of Technology, United States of America

SD 11

THU
27 JUL

Managing functional trade-offs in the mechanical design of integrated products using Multiobjective Monotonicity analysis

Nökkvi S. Sigurdarson 1, Panos Y. Papalambros 2, Tobias Eifler 3
1 Device Delivery Systems, Novo Nordisk A/S; 2 University of Michigan; 3 Technical University of Denmark

With the continuously increasing integration of (mechanical) products, the identification and management of trade-offs becomes a major task in product synthesis, with substantial effect on optimality and robustness of the final solution. At the same time, a rigorous and comprehensive study of trade-offs through mathematical design optimisation is often impractical in design, as efforts spent on modeling and optimizing are likely wasted if a chosen design is changed. Extending research on configuration redesign based on a multiobjective monotonicty analysis (MOMA), this paper presents three levels of evaluation for early design or redesign: (I) informal evaluation, (II) opportunistic evaluation, and (III) exhaustive evaluation. The chosen level depends on what knowledge the designer wants to gain, and the higher the level, the larger the analysis effort, the lesser the re-use of the information gained from the initial MOMA analysis respectively. The approach is illustrated using a novel drug delivery device, the Self-Orienting Millimeter-Scale Applicator (SOMA), for the oral delivery of protein compounds such as insulin.

A review on real vehicle usage modelling of driverless multipurpose vehicles in vehicle routing problems

Raphael Andreolli 1,2,3,5, Mikael Nybacka 1,2, Ciarán J. O'Reilly 1,3, Erik Jenelius 4, Eric Falkgrim 5
1 KTH Royal Institute of Technology, Division of Vehicle Engineering and Solid Mechanics, Department of Engineering Mechanics, Stockholm, Sweden; 2Integrated Transport Research Lab (ITRL), KTH Royal Institute of Technology, Stockholm, Sweden; 3 Centre for ECO2 Vehicle Design, KTH Royal Institute of Technology, Stockholm, Sweden; 4 KTH Royal Institute of Technology, Department of Civil and Architectural Engineering, Stockholm, Sweden; 5 Scania CV AB, Södertälje, Sweden

Real vehicle usage rarely matches the predictions made during early phases of vehicle development and sales processes at commercial road vehicle manufacturers. The automotive industry needs multidisciplinary vehicle design methods to predict real-world vehicle operations by considering the vehicle level and the transport system level simultaneously, in a more holistic approach. The aim of this study was to analyse how realistic vehicle usage of driverless multipurpose vehicles can be modelled in Vehicle Routing Problems (VRPs) by conducting a systematic literature review. We found that real vehicle usage modelling of driverless multipurpose vehicles in VRPs mainly depended on the following elements: VRP variant, energy consumption model, energy consumption rate class, number of vehicle-specific design variables and transport system-level factors. Furthermore, we identified in the literature five classes of energy consumption rate edge behaviour in VRPs. These findings can support decision-making in the modelling process to select the most suitable combination of elements, and their level of detail for the overall modelling aim and purpose.

SD 11

THU
27 JUL

Product and System Modelling 1

Session Chair: Ali Yassine, Stevens Institute of Technology, United States of America

Linking cross-domain information to support the development of complex systems

Julian Baschin 1, Ronald Schmidt 2, David Schneider 1, Thomas Vietor 1, Umut Volkan Kizgin 1
1 TU Braunschweig; 2 fme AG

Due to an expanding number of mechatronic functionalities in modern technical products, the proportion of software and electronic components is also increasing. As a result, the products are developed by different engineering domains in complex development processes. To handle the growing complexity, Systems Engineering (SE) is increasingly important for development organizations of enterprises. System Engineering (SE) is understood as an approach to network the individual engineering domains and shall lead to a collaborative development of complex systems. Model-Based System Engineering (MBSE) expands SE by using common models and software tools to describe und visualize the systems. However, MBSE is not widely established in enterprises today. On the one hand, the introduction requires a distinct and consistent system understanding and collaborative way of working. On the other hand, the application of the existing tools requires extensive tool competencies due to many possible functions and features. Therefore, this paper presents a concept and a software based tool for a lean implementation of SE/MBSE to support the collaborative development of complex technical systems in small and medium-sized enterprises.

Design in a complex world

Location: Building C - ground floor: Room C3 – 001

2:00pm
3:00pm

Creativity in Context

Session Chair: Philip Cash, University of Northumbria, United Kingdom

Experience of creativity and individual cultural values in ideation

Zhengya Gong, Vijayakumar Nanjappan, Georgi V. Georgiev, Center for Ubiquitous Computing, University of Oulu, Finland

The influence of culture on design is reflected in many aspects, such as design creativity, communication within design groups, and individuals' creative performance. Culture has a profound impact on design. For example, studies have identified the positive effect of a higher individualism-collectivism value on design team performance. To examine the influence of individual cultural values on the experience of creativity in ideation, we experimented by recruiting participants from different counties to complete two ideation tasks. Moreover, we collected their cultural values and experiences of creativity through two questionnaires. We also examined the connections between individuals' cultural values and their experiences of creativity in ideation. The results show five correlations between individuals' cultural values and their experiences of creativity when the country setting was a control variable. Recommendations based on the findings include that explorations of cultural influence and the relationship between culture and design or other fields irrelated to the country or society level have to measure individual cultural values (with the country setting as a control variable) instead of adopting country cultural scores.

Enhancing Engineering Creativity with Automated Formulation of Elementary Solution Principles

Pavel Livotov, Offenburg University of Applied Sciences

Several researchers have reported on the effectiveness of knowledge-based inventive stimuli, known in the Theory of Inventive Problem Solving (TRIZ), in enhancing engineering creativity, but few authors have focused on the comparative analysis of structured ideation in engineering design in terms of quantitative and qualitative outcomes. Previous studies have mainly concentrated on the investigation of exemplary selected single stimuli rather than on a critical assessment of the relationship between the structured application of inventive stimuli and their contribution to engineering design. The paper describes a method for the automated formulation of elementary creative stimuli for product or process design at different levels of abstraction and in different engineering domains. The experimental study evaluates the impact of structured automated idea generation on inventive thinking in engineering design and compares it with previous experimental studies in educational and industrial settings. The outlook highlights the benefits of using automated ideation in the context of AI-assisted invention and innovation.

Design in a complex world

DC 03

THU
27 JUL

Creativity in Context

Session Chair: Philip Cash, University of Northumbria, United Kingdom

Relations Between Cognitive Ability and Creative Design Quality

Yuan Yin, Peter Childs, Dyson School of Design Engieering, Imperial College London

The study aims to identify the relations between creative design quality and content of the memorising precedents, association, and combination of information processes in a design context. 71 participants were recruited to finish a creative design task. Think aloud and interview were conducted during and after the creative design task to understand the content of the memorising precedents, association, and combination of information processes. The 71 creative designs were then assessed by five experts in creative design. The results from this study revealed that participants who generated high-creativity design tend to memorize various topic-related precedents, associate items based on topic-related information, and combine topic-related information with products. Participants who generated low-creativity design tend to memorize characteristics of a specific space of the design topic, associate items based on specific topic-related information, and add the topic-related pattern to a product.

Visualising and reverging: Understanding the intersection between creativity and visual thinking

Alix Jansen 1,2, Katrina Heijne 1, Iren van Oosterom 2, Milene Gonçalves 1
1 Delft University of Technology, Industrial Design Engineering Faculty; 2 Flatland Agency

We investigate reverging - the phase between the diverging and converging steps in a creative process - in the context of a visual thinking agency. Creative facilitation literature advocates for such a phase, aimed at revisiting and rearranging ideas generated during diverging, to prepare for converging. However, in practice this step is often neglected or not performed well, resulting into a sense of increased complexity or lack of client ownership.

Two studies were used to investigate reverging in context: a preliminary study consisted of interviews and observations to better understand reverging in current visual thinking practices. The follow-up study focused on co-creating a tool to solve the problem identified in the preliminary study.

While the preliminary study revealed the need to involve clients in both diverging and reverging phases, the follow-up study resulted in the creation of the Whiteboard Canvas. The tool was tested in practice and several benefits of reverging in visual thinking practices emerged.

The tool empowers visual thinking practitioners to involve their clients more actively in reverging, resulting into a more deliberate creative process and an increased sense of client ownership.

Design in a complex world

Location: Building G - Ground floor: Conference room MANON CORMIER

2:00pm
3:00pm

Challenges in Design Education

Session Chair: Carlye Anne Lauff, University of Minnesota, United States of America

Strong sustainability aspects in the ideation process: a pedagogical experiment

Melissa Escobar 1,2,3, Valérie Laforest 1, Nadège Troussier 3, Jenny Faucheu 2
1 Mines Saint-Etienne, Univ Lyon, CNRS, Univ Jean Monnet, Univ Lumière Lyon 2, Univ Lyon 3 Jean Moulin, ENS Lyon, ENTPE, ENSA Lyon, UMR 5600 EVS, F-42023 Saint-Etienne, France; 2 Mines Saint-Etienne, Univ Lyon, CNRS, UMR 5307 LGF, F-42023 Saint-Etienne, France; 3ICD, CREIDD, Université de Technologie de Troyes, 12 rue Marie Curie, 10 0 04 Troyes, France

The progress of science and technology has considerably increased the quality of life - especially the material standard of living - (e.g. disappearance of famines, increase in life expectancy) On the other hand, climate change, reduction of biodiversity, decrease of natural resources, and increase of environmental risks are some of the consequences of this human activities. Addressing these new challenges will require holistic comprehension and actionable approaches. The mitigation of these consequences requires effective responses in terms of transition. In this context, engineering and design students need time but also adapted curricula focused on sustainability and eco design concepts to support evolution of their skills, their knowledge and their culture. This article discusses the integration of a strong sustainability knowledge within the ideation process through a pedagogical experience, in order to develop new knowledge-based approaches, methodologies and tools

A Kansei-Engineering-based active learning module for familiarizing middle-school students with basics of product design

Sotiris Papantonopoulos, Democritus University of Thrace

The paper proposes a methodology for developing an active learning module adapted from the Kansei Engineering methodology that intends to engage and familiarize middle school students with basics of product design and the Kansei product design and culture, and develop design skills. The module includes an identification of the design elements of a selected product, the creation of an items/categories matrix, product clustering according to different criteria (shape, material, principle of operation), an analysis of product functions and main product characteristics, and an evaluation of products with a Kansei scale created by the students. This series of activities lead to a design-thinking-based product-design project culminating in the construction and evaluation of prototypes. It carefully considers how students can gradually learn by going from activity to activity leading to a design project. In doing so, important skills such as, among others, analytical thinking, divergent thinking, and critical thinking are intended to be practiced.

Design in a complex world

Location: Building G - Ground floor: Conference room MANON CORMIER

2:00pm
3:00pm

Challenges in Design Education

Session Chair: Carlye Anne Lauff, University of Minnesota, United States of America

The T-Shaped Design Engineer – using cohorts to explore how skills profiles differ through career stages

Elies Dekoninck, Liam Bridge, University of Bath

The T-Shaped designer has previously been identified as a design engineer with the desirable set of skills for a successful career. Twelve design engineers ranging from novice to expert, were interviewed to gain an understanding of their skill set, how it has evolved and how it needs to evolve in order to be futureproofed. With the use of qualitative, quantitative data and the development of a novel engineering skills profiling method, this paper found that 75% of design engineers did not exhibit a T-shaped skill profile, but a skill shape that has been termed 'M-shaped' or 'Comb-shaped'. The majority of participants exhibited a great depth of specialist skills in multiple disciplines, not limited to their immediate field of work. All participants exhibited a wide knowledge of skills that allowed them to work across different disciplines, which included electronics, management or manufacturing, and so the wide vertical bar of the T-Shape design predicted by previous literature has been supported.

Location: Building C – 1st floor: Room C2 – 106

2:00pm
3:00pm

AI and Business Processes

Session Chair: Johan Malmqvist, Chalmers University of Technology, Sweden

Engineering Graph as an approach to support Design Decisions in Product Development

Gregor Schweitzer 1, Michael Bitzer 1, Michael Vielhaber 2
1 Fresenius Medical Care; 2 Saarland University

The requirements space is increasing due to non-functional areas such as security, resilience and sustainability gaining in importance. This creates a complex and dynamic space which makes it hard for engineers to take good data driven design decisions. Increasing the quality of design decisions allows to better set up development projects and develop more successful products and services. The design can most heavily be influenced in the early design phases, where design flexibility is high and resource commitment is low. Unfortunately, the system knowledge is also low in early phases. The Engineering Graph is a concept that connects data from different internal and external sources. It allows to connect product data stored in Product Lifecycle Management systems with system models and also add external sources from the Wikimedia Knowledge Graph, World Health Organization and World Bank. This interconnected data allows the support of engineers in managing the complex and dynamic requirement space and provide high system knowledge in the early design phases to support design decisions.

Knowledge-based data identification for machine learning use cases

Helena Ebel, Sahar Ben Hassine, Rainer Stark, Technische Universität Berlin

The number of digital solutions based on machine learning has increased in recent years. In many industrial sectors, they try to enhance automation in manual or repetitive tasks or provide decision support for complex problems. Data plays an essential role in the selection and implementation of ML algorithms, as it determines the quality of the training and the results. As data drive ML models, selecting the correct data with the suitable ML algorithm for a given use case is crucial but challenging. This paper reviews the application of machine learning in the embodiment design phase addressing the challenge. The work focuses on ML applications in conventional product development and non-conventional additive manufacturing processes. Based on the literature review, the required knowledge to implement the ML algorithms has been derived and presented in a systematic approach. This work highlights the importance of an initial analysis of the existing knowledge in the engineering and additive manufacturing processes in order to implement the proper ML algorithms.

Design in a complex world

DW 12

THU
27 JUL

AI and Business Processes

Session Chair: Johan Malmqvist, Chalmers University of Technology, Sweden

Methodical Approach to cluster Configurations of Product Variants of Complex Product Portfolios

Jan Mehlstäubl 1, Christoph Pfeiffer 1, Ralf Kraul 2, Felix Braun 2, Kristin Paetzold-Byhain 1
1 Technische Universität Dresden; 2 MAN Truck & Bus SE

Companies are increasingly struggling to manage their complex product portfolios. Since they do not fully understand the complexity, intelligent solutions are required. Emerging technologies and tools offer new ways to deal with existing problems. With the help of clustering, similarities between product variants can be identified automatically, and complexity can be systematically reduced. This article aims to develop a methodological approach to identify correlations between product variants in complex product portfolios automatically by using clustering algorithms. The approach includes the systematic cleaning and transformation of product portfolio data. In addition, a guide for algorithm selection and evaluation of clustering results is presented. As the last step, the results are systematically analysed and visualised. To validate the methodical approach, it is applied to a real-world data set of a commercial vehicle manufacturer and the usefulness of the results is confirmed in an expert workshop.

A Value-Driven Design approach for the virtual verification and validation of autonomous vehicle solutions

Marco Bertoni 1, Stefan Thorn 2
1 Blekinge Institute of Technology; 2 Volvo Autonomous Solutions

Autonomous vehicle solutions (AVS) are regarded as a major enabling technology to support the realization of 'total site solutions' in the construction equipment industry. Their full-scale deployment is hindered today by the need to test autonomous driving capabilities against the varying conditions an AVS is expected to be exposed to during its lifetime. Therefore, using virtual simulation environments is common to overcome the cost and time limitations of physical testing. A caveat in this virtual verification and validation (V&V) work is how to trade off the 'realism' of the V&V output (using high-fidelity models across many scenarios) against computational time. This research investigates expectations and needs for value-driven decision support in the virtual V&V process, proposing an approach and a tool to raise awareness among decision-makers about the value associated with using selected simulation models/ components in the virtual verification and validation task for AVS. Verification activities performed on the initial prototype show that its main benefit lies in facilitating cross-domain negotiations and knowledge sharing when negotiating the desired features of the virtual simulation environment.

Teamwork in Design

Session Chair: Ben Hicks, University of Bristol, United Kingdom

HB 08

THU
27 JUL

The emergence and impact of synchrony in design teams: A computational study

Marija Majda Perišić 1, Mario Štorga 1,2, John Gero 3
1 University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia; 2 Luleå University of Technology, Sweden; 3 UNC Charlotte, USA

Studies revealed that, while collaborating, humans tend to synchronise on multiple levels (e.g., neurocognitive or physiological). Inter-brain synchrony has been linked to improved problem-solving, decision-making, and creativity. Nevertheless, studies on synchrony in design teams started to emerge only recently. This study contributes to this stream of research by utilising a computational model of a design team to explore the relationships between team cohesion, synchrony, and team performance. The experiments revealed a positive link between team cohesion level and the emergence of (cognitive) synchrony. Furthermore, cohesive teams were found to be more efficient, converging quicker and producing solutions at a higher rate. In addition, the diversity of the solutions generated by highly cohesive teams tends to increase over time. Teams in medium- and low-cohesive settings initially generate highly diverse solutions, but such diversity decreases as the simulation progresses. Finally, highly-cohesive teams were found to be prone to premature convergence.

The Importance of Individual Work in Collaborative Design Meeting: Impact on Design Tools and Methodologies

Izabella Chartres 1, Thierry Gidel 2, Claude Moulin 3
1 Université de Lille, CIREL, Centre interuniversitaire de recherche en éducation de Lille, URL 4354; 2 Sorbonne Universités, Université de technologie Compiègne, COSTECH, Connaissance, Organisation et Systèmes Techniques, EA 2223; 3 Sorbonne Universités, Université de technologie de Compiègne, Heudiasyc, UMR 7253

This paper demonstrates the importance of individual work in collaborative design meetings based on Granger' causality and discusses how this impacts design tools and methodologies.
Based on Tucker's et al. CIAO model of globally collaborative work which allows distinguishing the main modes of interaction during a meeting, our research identifies the patterns or sequences of those interaction modes according to the Granger causality concept. Granger causality makes it possible to identify a temporal precedence of events without necessarily implying causality.
The results show that individual work plays a key role in achieving collaborative work. However, other factors such as the nature of the meetings and the objectives pursued also influence the sequences of interaction of the different modes.
These first results allow making recommendations on collaborative work methodologies and support mechanisms for collaboration. For instance, the ability of digital devices to facilitate the simultaneous individual work of participants in a collective space is a key factor and the ability to preserve sequences for individual work during a design meeting should be monitored to keep global efficiency.

Location: Building C – 1st floor: Room C2 – 114

2:00pm
3:00pm

Teamwork in Design

Session Chair: Ben Hicks, University of Bristol, United Kingdom

Active Engagement in Collaborative Engineering Design: How to Measure and Use It in a Feedback System?

Sabah Farshad, Clement Fortin, Skolkovo Institute of Science and Technology (Skoltech)

Engineering design is typically a collaborative process, and in the era of digital engineering, online collaboration platforms are increasingly being used to perform the work. Despite the development of e-collaboration technologies, there is a significant gap between actual collaboration and what is really needed. However, improving collaboration requires a proper measurement system. Yet, the common methods to measure and improve collaboration are challenging, usually not compatible with digitalized collaboration, and have limited scalability. This paper presents a new data-driven method for measuring, visualizing, and monitoring Active Engagement (AE) in web-based teamwork, which is a key element of effective collaboration. We applied the method in a case study of four engineering teams during a Technology Planning and Road-mapping course. The results suggest that measuring AE in web-based teams, with an available history log, is technically feasible and can meaningfully represent the team's collaboration. The presented approach can be used to upgrade e-collaboration platforms as a toolkit or for further investigation on improving web-based collaborative design and learning through monitoring dashboards and feedback systems.

A Multilayer Graph Network-Based Tool for Identifying Key Project Actors

Shlomi Efrati, Yoram Reich, Tel-Aviv University

As the demands for new complex products/services increase, leading to strict constraints on budget and time-to-market, it is hard to learn from experience and improve practice. Improvement can be exercised in all aspects contributing to project management: the skill set of project personnel, the project structure, and the development process. People are the key asset of the project. Identifying the key participants in a project whose role is influential is important for improving the project's success. These people can receive support, remove their burdens, make sure their communication channels work well, etc. This paper offers a multilayer network-based method to examine an actor's influence in a project while combining two additional organizational key aspects: products and processes. Considering these three aspects together allows for a more informed evaluation of the actors' influence on the project. Using the insight from graph theory, we gain indicators related to each network actor. The influence of the actors in a multidimensional network makes it possible to present a clearer picture to decision-makers in the organization to make better decisions related to increasing the effectiveness of the development project.

Model-Based Systems Engineering

Session Chair: Michael Kokkolaras, McGill University, Canada

Model-Based Systems Engineering using Security Design Patterns in the context of ISO/SAE 21434

Sergej Japs 1, Faizan Faheem 2, Harald Anacker 1, Stephan Husung 2, Roman Dumitrescu 3
1 Fraunhofer Research Institute for Mechatronic Systems Design IEM; 2 Technische Universität Ilmenau;
3 Universität Paderborn

The development of modern vehicles is complex, especially regarding compliance with security and safety. ISO/SAE 21434 considers security and safety along the entire product life cycle. According to the standard, a system architecture, a risk analysis, and the application of countermeasures are carried out in the early system design.
Design patterns are solutions to known design problems. Security Design Patterns (SDP) describe countermeasures and are used to reduce risk. After our literature review, we did not find a suitable approach that presents SDPs that would be applicable in early system design.
In this paper, we present 10 SDPs for early system design, which we evaluated during an 11-week student project with 28 teams. We present the results of the quantitative analysis and the evaluation of the feedback.

MBSE incorporating time-dependent behavior for the design of robot-like systems

Klara Ziegler, Marcus Volpert, Maximilian Amm, Birgit Vogel-Heuser, Karsten Stahl, Markus Zimmermann, Technical University of Munich

Complex systems typically consist of many components and are subject to many requirements. Approaches like the V-Model support complex systems design by providing guidelines on how to break down large systems into smaller pieces. Models built with SysML provide documentation on an abstract level. However, neither incoporates detailed information on components that may be relevant for design decisions. In robot-like systems, e.g., the choice of transmissions will depend on the system dynamics of the robot. This is modeled in the time domain, where detailed time-dependent component interaction is considered. The design perspective, however, is best represented in the property domain. Here, requirements on static component properties are formulated.
This paper presents a generic approach that connects the property and time domains to enable early-stage design decisions. The approach is applied to a 1-link robot system with a simple demonstrator transmission model, including properties that are typically not considered in the early design phase, like a nonlinear stiffness characteristic with backlash.

Model-Based Systems Engineering

Session Chair: Michael Kokkolaras, McGill University, Canada

MBSE within the engineering design community - an exploratory study

Markus Christian Berschik 1, Thomas Schumacher 2, Fabian Niklas Laukotka 1, Dieter Krause 1, David Inkermann 2
1 Hamburg University of Technology; 2 TU Clausthal

Objective of this contribution is to present the use of Model-based Systems Engineering within the engineering design community. Based on a differentiation between SE and MBSE, the definition of three core MBSE elements, namely modelling method, modelling language, and modelling tool as well as the three major aspects of a consistent system model (requirements, behaviour, and structure) a structured review is conducted, focussing on the understanding and motivation as well as the modelling of systems. The review includes 93 publications from Design Society library and proceedings of the CIRP Design conferences during the period from 2011 to 2022. The review points out, that there is an increasing application of MBSE within the engineering design community, mainly focussing on architecture definition or combined engineering activities. Only a small portion of works (16 publications) are providing a consistent approach as these publications link all aspects of the system model and consider all three MBSE elements. It can be concluded, that there is a diffuse understanding of MBSE and different motivations are given to apply more formal system models as well as modelling tools.

From Text to Images: Linking System Requirements to Images Using Joint Embedding

Cheng Chen, Cody Carroll, Beshoy Morkos, University of Georgia

Smart manufacturing enterprises rely on adapting to rapid engineering changes while minimizing the generated risk. Making informed decisions related to engineering changes and managing risks against unexpected costs requires more information to be extracted from limited data. However, limited information in early-stage design can come in many forms, namely text and images. The development of innovative design tools and processes to link multisource data together is essential to assist designers in building model-based engineering (MBE) systems. However, the formal computational linking of multisource data is yet to be realized in MBE. We propose a framework to implement transfer learning and integrate domain specific knowledge to bridge this information gap. A synthetic dataset is created using web scraping techniques based on keywords extracted from the requirements. Requirement-image pairs are used to fine tune a contrastive language-image pretraining model to acquire domain knowledge. The results demonstrate how the content of images can be used to indicate all affected requirements for tracing engineering changes in a complex system.

S&R 11

THU
27 JUL

Managing Uncertainty in Design

Session Chair: Ian Whitfield, University of Strathclyde, United Kingdom

Sustainable and resilient system development in a VUCA-world: An empirical study to develop a process orientated method of risk and technical change management in automotive industry

Jennifer Lechner, Nadine Schlüter, Bergische Universität Wuppertal

Revolutionary changes of a VUCA-world are effecting more and more industries. Focusing the automotive industry, this is caused by several new trends in technology or market. This situation is requiring high flexibility and is questioning for sustainability as well as resilience in system development projects. This publication represents results out of a survey, part of a wider research. The objective is the development of a process orientated method for risk and technical change management. The survey is conducted by participants of transdisciplinary system development in automotive industry. Topics questioned are VUCA, complexity, (re-)action, quality and module interfaces of Generic Systems Engineering. The results demonstrate the participants' experience and demands for sustainable and resilient system development projects. In conclusion, this report provides information on the considering elements to develop a process orientated method for risk and technical change management in automotive industry.

Text mining of resilient objects absorbing change and uncertainty

Massimo Panarotto 1, Vito Giordano 2, Filippo Chiarello 2, Arindam Brahma1, Inigo Alonso Fernández 1, Gualtiero Fantoni 2
1 Chalmers University of Technology; 2 University of Pisa

The current ways of coping with uncertainty such as changes during product design or use have been through methods such as easy restructuring (e.g., modularity with buffer in interface definition), by overdesign and so on. The present investments on maintaining products in the economy for "as long as possible" is challenging these strategies from a cost and environmental perspective. Moreover, these strategies often lead to highly overdesigned products. An alternative strategy is to introduce features in a design, called "resilient objects", which are able to absorb such uncertainties without wasteful overdesign of other parts. By applying a 'text-mining' approach on patents, this paper has identified 5,552 candidates for such resilient objects that can be recombined and inserted in regions of the product that are likely to be most affected by current and future uncertainties. The application of resilient objects is demonstrated on a case study (a cooling system for battery electric vehicles). The case study highlights the ability of these objects to 1) significantly increase protection against uncertainties without the need for restructuring, 2) reduce the risk for overdesign and 3) dampen effects of change propagation.

Managing Uncertainty in Design

Session Chair: Ian Whitfield, University of Strathclyde, United Kingdom

Understanding Resilience of Agricultural Systems: A Systematic Literature Review

Samuel Boahen 1,2, Peter Ozaveshe Oviroh 2,3, Jesse Austin-Breneman 2, Emmanuel W. Miyingo 2,4, Panos Y. Papalambros 2
1 Department of Mechanical Engineering, Kwame Nkrumah University of Science and Technology, PMB, Kumasi, Ghana; 2 Department of Mechanical Engineering, University of Michigan, Ann Arbor, USA; 3 Department of Mechanical Engineering Science, University of Johannesburg, South Africa; 4 Department of Electrical and Computer Engineering, Makerere University, Kampala, Uganda

Resilience is a widely studied concept that is a key objective in the design and development of sustainable systems. This is especially true for the agricultural systems critical to food production, economic viability, and sustainability of our communities, as farmers seek to meet increasing demand in the face of shocks such as climate change and natural disasters. Although there is a rich body of work examining resilience, there is limited understanding of how the concept of resilience should be tailored for agricultural systems. This study seeks to address this gap by performing a systematic literature review of 50 papers selected from SCOPUS using the PRISMA protocol. A summary of research topics and characteristics by geographical region is presented. The paper also categorizes the types of shocks studied and the corresponding response methods. Results suggest that the focus of resilience research changes by region, which may indicate that design strategies and objectives should also differ by region. Furthermore, the work identifies a need for more simulation-based quantitative research into the impact of resilience.

Designing solutions for uncertain futures: A checklist for choosing suitable scenarios

Tjark Gall 1,2, Flore Vallet 1,2, Malek Ben Ammar 1, Bernard Yannou 1
1 LGI, CentraleSupeléc; 2 Anthropolis Chair, IRT SystemX

Future scenarios are intermediary artefacts for mid- and long-term design of complex solutions, e.g., to improve urban mobility systems. They allow designers to explore possible alternatives and incorporate uncertainty in the process. While their making is widely studied and implemented in scenario planning, their assessment got little attention. To find out which characteristics of scenarios we can assess, we conducted interviews and an expert workshop. This results in a scenario assessment framework of 3 levels: Assessment of system impact, evaluation of impact on practitioners and quality assurance. We focus on the latter as it represents the key gap and established a checklist for it. We distinguish between the level of engagement, i.e., scenario makers and users who adapt existing sets (or archetypes). Finally, we provide a checklist to aid ensuring that when choosing existing scenario sets, key criteria are fulfilled. This shall enable designers to better integrate scenarios in their workflows. We provide examples of designing mobility solutions. Yet, the findings can be applied to all disciplines where scenarios can aid design processes but are so far limited due to the resources needed for creating meaningful scenarios.

Location: Building H - ground floor: Conference room ASSELAIN

2:00pm
3:00pm

Digital Interfaces and Interaction

Session Chair: Josef Oehmen, Technical University of Denmark, Denmark

Design of a teleoperation user interface for shared control of highly automated agricultural machines

Sebastian Lorenz, Technische Universität Dresden

This paper presents a focused examination of critical performance and design issues for the introduction of highly automated tractors and their user interfaces in agriculture. An industry that as of today mainly uses direct-controlled machines that at least to some extent have partly automated functionalities. Issues include out-of-the-loop unfamiliarity, interface complexity, automation transparency, and changing information modalities in teleoperation scenarios for former cabin-based operated machines. Selected evidence and accompanying concepts and findings from literature are put in context to each issue, informing a systematic design process that utilizes the frameworks of knowledge engineering and ecological interface design. The resulting user interface prototype is built upon the identified requirements in analysis and collected design guidelines, stemming from various research areas. The documentation of the consideration of these in context with additional requirements, such as complexity reduction, information interactivity, and users' existing experiences is meant to provide insights into the often opaque and art-like design space.

Conceptual Framework to Study Team Cohesion in Human-Robot Teams

Sreeja Sri Ramoji, Vishal Singh, Indian Institute of Science, Bengaluru

Social Robots, part of current advanced technology, will be integrated into our daily lives across diverse use-case scenarios, including homes, hospitals, workplaces, and recreation. Though the area of Social Robotics has gained traction in recent years, the majority of the studies so far have studied single-human and single-robot interaction. In comparison, Social Robots are increasingly being placed in human teams, likely affecting team dynamics. On the other hand, Engineering teams work together to deliver outstanding results and the processes in these teams are social. We propose that Social robot can be added to engineering human team to enhance team cohesion and performance. Therefore, this paper presents a preliminary framework towards developing a conceptual framework to study team cohesion in Human-Robot Teams (HRTs) in engineering context, looks at different roles of social robot and how the responses, behaviours, emotions of social robots shape outcomes in the engineering team. The research specifically focuses on team cohesion because team cohesion is reportedly one of the most critical concepts in team dynamics. The paper outlines the research objectives, framework and concept workflow.

Location: Building H - ground floor: Conference room ASSELAIN

2:00pm
3:00pm

Digital Interfaces and Interaction

Session Chair: Josef Oehmen, Technical University of Denmark, Denmark

Computer-Aided Design of Fault-Tolerant Hardware Architectures for Autonomous Driving Systems

Tim Maurice Julitz, Antoine Tordeux, Manuel Löwer, University of Wuppertal

Fault-tolerant hardware architectures for autonomous vehicles can be implemented through redundancy, diversity, separation, self-diagnosis, and reconfiguration. These approaches can be coupled with majority redundancy through M-out-of-N independent system architectures. The development of fault-tolerant systems is of central importance in the launch of autonomous driving systems from level 4. The increasing complexity of electrical and electronic systems is challenging for the design of safety-critical systems. This work aims to develop a method to manage this complexity in product development and to use it to compare different types of architectures. The basis is a system consisting of sensors and microcontrollers. The reliability of all possible MooN configurations of the system is calculated automatically by numerically solving the master equation of the corresponding Markov chain. Subsequently, a software-based fault tree analysis enables more detailed modeling of the component structure. The results show that four-line architectures can provide suitable results and that the development effort for 2-ECU systems is higher than for 1-ECU systems with respect to the ISO 26262 target values.

Defining permaengineering: new practices for strong sustainable contexts of design

Lou Grimal 1, Inès di Loreto 2, Nadège Troussier 1
1 CREIDD, INSYTE, Université de Technologie de Troyes; 2 Tech-CICO, LIST3N, Université de Technologie de Troyes

Designers can project their vision of the world into reality and share it. They have, in short, the capability to transmit values and points of view through their products. We believe that engineering culture and tools need to shift from a culture of control to a culture of care. The aim of this paper is to propose and test new engineering practices for strong sustainability. We argue that the role and the shape of engineering in strong sustainability contexts are not explored enough in the scientific literature. We propose therefore a form of strong sustainability practice that we call permaengineering. Permaengineering practices are conceived to be in line with strong sustainability contexts. In other words, permaengineering practices should allow achieving activities upper the social floor and within the planetary boundaries. 4 elements will be studied in permaengineering: the ethics of permaengineering, the goal of the practice, the approach to sustainability, and the expertise needed. Those 4 elements will be tested through an interactive tool embedding perma-engineering principles. A seven-month study was conducted to test this tool.

Location: Building H - ground floor: Conference room ASSELAIN

3:30pm
4:30pm

Collaboration, Ideation and Sustainability

Session Chair: Niccolo Becattini, Politecnico di Milano, Italy

Toward a Framework for Sustainable Experience Design Education and an Illustrative Case of a Service Design Thinking Course

Yong Se Kim, Rida Kamal, University of Turku

In sustainable experience design education, experience activities of consumers and users, design activities of student designers, and education activities of instructors should be addressed. It would be meaningful to compare various sustainable experience design education efforts considering regional and cultural context. This paper describes a framework where experience, design and education activities are systematically represented with diverse contexts also represented in a structured manner. Student design projects in a service design thinking course are illustrated where sustainability is gently introduced.

Understanding upcycling and circular economy and their interrelationships through literature review for design education

Kyungeun Sung, De Montfort University, UK

Design and engineering are fundamental activities in shaping the world we live in. Educating new generations in design and engineering, therefore, is crucial to build a better and more sustainable world. The changes in education for the transition from a linear economy to a circular economy, in particular, has become a priority for many educators. Aligned with the circular economy, a promising umbrella concept and practice called 'upcycling' is emerging. The concepts and practices in the circular economy and upcycling overlap depending on the definitions of the terms in various disciplines and sectors in different parts of the world. This has caused some confusion and misunderstanding. For educators aiming to teach students about sustainable design, production and consumption, it is beneficial to distinguish between these two concepts. Understanding the relationships (or interrelationships) between them in theory and practice is important for the educators to offer clear guidance and recommendations to future designers and engineers. This paper provides literature review on upcycling and circular economy, compares these two concepts, and visualises their interrelationship as draft teaching materials for design education.

Location: Building H - ground floor: Conference room ASSELAIN

3:30pm
4:30pm

Collaboration, Ideation and Sustainability

Session Chair: Niccolo Becattini, Politecnico di Milano, Italy

Assessment of Product Design and Engineering students essential skills' for tomorrow

Viviane Gallindo, Melissa Lim, Aasish Boora, Gabriela Castro, Monikuntala Das, Arlindo Silva, SUTD

This paper explores the assessment of Critical and Creative Thinking skills among Product Design and Engineering (PDE) students, whose profession holds significant potential for addressing the complex challenges facing global societies. In today's globalized world, higher education institutions must equip students to solve both local and global problems. The lack of emphasis on assessing critical problem-solving skills has led to growing concerns among employers and organizations that graduates may not be adequately prepared to meet the demands of the 21st-century workplace, including PDE.
This paper uses a case study approach to evaluate the performance of final-year PDE students, specifically their Critical and Creative Thinking abilities. The study assesses two groups, Group A and Group B, which produce solutions focused on the marketplace and design sustainable solutions, respectively. The study concludes that solving wicked problems that require sustainable solutions demands a higher level of these skills. The study's findings are consistent with the Organization for Economic Co-operation and Development's 2022 report, which also highlighted low levels of CriT and CreT in students at the same level studied for this paper.

Immersive Gaze Sharing for Enhancing Communication in Design Education: an Initial User Study in the Context of Architectural Design Critiques

Yuval Kahlon 1, Santosh Maurya 2, Haruyuki Fujii 1
1 Tokyo Institute of Technology; 2 Hitachi Ltd.

Gaze sharing is an emerging technology which can enhance human communication and collaboration. As such, it is expected to play an important role in future educational practices. To date, its application was not explored in the context of design education. Additionally, it was mainly implemented in non-immersive environments, which are limited in their potential for engaging learners. Acknowledging the growing interest in immersive learning, as well as the promise made by gaze sharing technology, we strive to develop an immersive gaze sharing environment, to support design education. As a first step, we have implemented and tested an immersive gaze sharing system for supporting design learners. The system was then tested by focusing on a scenario of architectural design, with the aim of collecting valuable user feedback regarding its usability and potential. Our initial user study informs developers of such systems regarding potential issues that may be encountered during deployment in a real-world setting and proposes concrete ways to address these. These insights can help to pave the way for integrating gaze sharing system into design education practices in the near future.

Machine Learning in Design

Session Chair: Ji Han, University of Exeter, United Kingdom

A Knowledge Graph and Rule based Reasoning Method for Extracting SAPPhIRE Information from Text

Kausik Bhattacharya, Amaresh Chakrabarti, Indian Institute of Science Bangalore

Representation of design information using causal ontologies is very effective for creative ideation in product design. Hence researchers created databases with models of engineering and biological systems using causal ontologies. Manually building many models using technical documents requires significant effort by specialists. Researchers worked on the automatic extraction of design information leveraging the computational techniques of Machine Learning. But these methods are data intensive, have manual touch points and have not yet reported the end-to-end performance of the process. In this paper, we present the results of a new method inspired by the cognitive process followed by specialists. This method uses the Knowledge Graph with Rule based reasoning for information extraction for the SAPPhIRE causality model from natural language texts. Unlike the supervised learning methods, this new method does not require data intensive modelling. We report the performance of the end-to-end information extraction process, which is found to be a promising alternative.

Machine Learning-based Virtual Sensors for guiding user behaviour: a case study on household appliances

Dennis Ilare 1,2, Gaetano Cascini 1, Stefano Manzoni 1, Alessandro Mansutti 2
1 Politecnico di Milano; 2 ROLD

The Agenda 2030 calls for collective awareness, starting with individuals. The interaction between users and household appliances produces a relevant amount of data that can be elaborated through Machine Learning algorithms to guide users towards sustainable behaviours. In particular, the data already available on household appliances can be conveniently used to create Virtual Sensors, increasing the overall information about the system. This paper focuses on the description of the pipeline for the creation of Virtual Sensors and applies it to a no-frost refrigerator. The Data Acquisition phase is described and feeds the Model Creation phase. For the case study, the data have been discretized and labelled to train a Random Forest algorithm. The validation of the model has been done on an independent dataset. An analysis of the minimum prediction accuracy required for the model is reported. Furthermore, experimental data shows the effect of hot load positioning on the compressor's working time rate.

Location: Building A - ground floor: Conference room BERNARD

3:30pm
4:30pm

Machine Learning in Design

Session Chair: Ji Han, University of Exeter, United Kingdom

Descriptive attributes of analysis use cases in the data-driven validation of elements in the system of objectives

Steffen Wagenmann 1,2, Felicia Weidinger 1, Moritz Schöck 2, Albert Albers 2, Nikola Bursac 3
1 TRUMPF Machine Tools SE+Co.KG; 2 IPEK, Karlsruher Institute of Technology; 3 Technical University of Hamburg

Usage data of reference systems can be analyzed in the development process for the validation of system elements. The process model for data-driven validation of elements in the system of objectives aids developers in performing such data analyses. The conducted studies show that the basis for an efficient analysis process is a common understanding of the system and the goal of the analysis. Therefore, a template was derived over the course of case studies describing the elements in the system of objectives. The template covers the three descriptive dimensions general information, technical system and data. It allows a comprehensive description of analysis use cases. On average it takes 11 minutes for developers to aggregate all necessary information and consequently fill out the template. An A/B-Test confirmed the comprehensibility and applicability of the template even for developers of different domain knowledge. Through its contribution to a sustainable knowledge management the template provides an added value for the developers for conducting analysis.

A pattern language approach to identify appropriate machine learning algorithms in the context of product development

Sebastian Sonntag, Janosch Luttmer, Robin Pluhnau, Arun Nagarajah, University of Duisburg-Essen

The product development process faces several challenges, such as an increasing and differentiated number of customer requirements, increasing product complexity, and shortened time-to-market. To address these challenges, the implementation of automation approaches in form of machine learning (ML) algorithms appears promising. However, companies lack the implementation of these approaches in their processes, inter alia due to inadequate knowledge and experience in this field. Therefore, the aim of this paper is to develop a structured formulized way of characterising ML algorithms, which can support non-experts in identifying the optimal algorithm to solve a given problem. First, existing approaches covering the determination of appropriate ML algorithms for a given task are examined. Based on this, a pattern language approach is introduced to characterise ML algorithms and problems, allowing matching to be performed to identify the most suitable one for a given task. Due to their broad application, the concept is demonstrated by creating patterns for decision trees and artificial neural networks. A study is conducted to prove that the proposed concept is appropriate to support the ML algorithm selection.

Enhancing Wellbeing in Specific Contexts

Session Chair: Monica Bordegoni, Politecnico di Milano, Italy

H&W 06

THU
27 JUL

Social earplugs: a case study on integrating human augmentation in hearing protection

Muriel De Boeck, Jill Sempels, Kristof Vaes, University of Antwerp

Social augmentation refers to a human-computer integration technology that aims to enhance the user's social skills by supporting empathy, interaction and communication. This study investigated the implementation of social augmentation in hearing protection within the context of entertainment. Through a user-centred analysis, potential social augmentation functions for earplugs were conceived. Three innovative conceptual prototypes were then developed, each enriched with three social functions. Accordingly, each of these concepts should ensure that social skill is enhanced, facilitated or improved. To assess whether the concepts were successful, the social impact of the prototypes on the user and bystanders was evaluated and compared through questionnaires and focus groups using video footage. The results provided promising conclusions regarding the applied methodology and the potential for optimizing the iteration process of innovative human augmentation concepts.

Analysis of the Application of Synaesthesia Concept in Modern Product Design

Yang RuiKun 1,2, Shahriman Zainal Abidin 1, Verly Veto Vermol 1
1 Universiti Teknologi Mara (Uitm); 2 School Of Arts,Lanzhou Technology And Business College

Objective To analyze and discuss the application of synaesthesia theory in modern product design and emphasize the important position and necessity of synaesthesia in modern product design. Methods Based on the concept of synesthesia, the value, significance and design principles of synesthesia in modern product design were further analyzed and summarized through the study of concrete examples of shape, color, material and using methods. Conclusion When the concept of synesthesia is applied to product design, it can enhance the expressive force of products, realize users' synesthetic perception, mobilize users' senses to give psychological suggestions, meet users' various psychological needs, and bring users a richer physical and mental experience.

Enhancing Wellbeing in Specific Contexts

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Enhancing Wellbeing in Specific Contexts

Session Chair: Monica Bordegoni, Politecnico di Milano, Italy

H&W 06

THU
27 JUL

A new design method for generating surrogate kinematic truss orthoses to support pathological gait patterns in human model simulations

Patrick Steck, David Scherb, Johannes Mayer, Michael Jäger, Jörg Miehling, Harald Völkl, Sandro Wartzack, Friedrich-Alexander-Universität Erlangen-Nürnberg

With increasing life expectancy, the risk of diseases of the central nervous system, such as cancer, strokes, etc., also increases. Strokes often result in injury to the sciatic nerve, which is responsible for controlling the calf muscles (plantar and dorsal flexors). A so-called ankle joint orthosis (AFO) helps to support the pathological gait and to avoid foot drop during gait. Passive orthoses are of particular importance for research, as they do not require additional incoming energy from outside to the orthotic system. However, current passive orthoses are often not personalized. On the one hand, because they usually have only a temporary muscle-building function and, on the other hand, because the individual design process is computationally time consuming and thus expensive. This paper presents a possibility to pre-dimension and pre-design passive orthoses fast and cost-efficiently by reducing the complexity of the model based on volume-optimized truss elements. Therefor a traditional high calculation intensive design procedure is compared with the complexity reduced model to show its effectiviness and the similarity of the results.

Design of Wearable Tensegrity Structures Focusing on the Tension Propagation Function throughout the Body

Hiroki Wakashima, Kodai Kishino, Shinpei Iizuka, Masahiro Tamachi, Shigeru Wesugi, Waseda University

Humans are able to perform skilful movements by coordinating muscles throughout the body. It has been revealed that not only neural mechanisms but also direct and dynamic interactions between body parts contribute to muscular coordination. Tensegrity, accurately biotensegrity, can be considered to the basic mechanism for the interactions. Tensegrity structures are composed of tensile and compressive components, and are lighter and more flexible than existing rigid structures. The authors investigated designing wearable tensegrity structures for extending human motor ability, especially assisting in carrying heavy objects. Based on Flemons' spine model, we devised a columnar tensegrity structure that can be expanded to the size of the whole body, and connected each of four columns to the front and back of the body on right and left side. The wearable tensegrity structures can deform flexibly due to tension distribution when external force is applied, and follow the human motions in twisting trunk and walking. Experimental results in carrying heavy objects showed that some muscle activities around hip and knee tended to decrease by using the structures when those joints extended.

3:30pm
4:30pm

Advancements in Systems Engineering 2

Session Chair: Eswaran Subrahmanian, Carnegie Mellon University, United States of America

Designing emergence in systems of systems using information streams

Uriel Hochmann, Yoram Reich, Tel Aviv University

Systems complexity is increasing, in particular, when systems become systems of systems (SoS). SoS are composed of constituent systems (CS), have unique goals for the CS and the SoS as a whole, and present new SoS-level properties called emergent properties. Emergent properties are unique because they only appear at the system level. Current research has only revealed some tools focusing on simple emergence for engineers aiming to design emergence at the SoS level. However, forming design tools for the creation or modification of strong emergence will enable engineers to create systematic changes in the SoS. This article proposes a connection between emergence and information streams with the latter being a model of the transfer of information between the different CS in the SoS. A methodology for designing SoS information streams is demonstrated, with encouraging results, using a multi-agent simulation of the propagation of the COVID-19 virus through citizens. By testing several information stream configurations, an SoS with a decrease of 47% in sick agents was found. These results show that by changing the information stream better SoS performance is attained, supporting designing in a complex world.

A Framework for Analysis and Design of Dynamic Ad Hoc Socio-Technical Systems

Sergey Tozik, Yoram Reich, Tel Aviv University

Ad-hoc systems are socio-technical systems emerging in response to dynamic problematic situations. These systems form when situation systems interact with respondent systems organized by human agents using elements available in the situation and assets brought in from outside the situation. The immediacy of formation, fast evolution, and short lifecycles of ad-hoc systems intertwine design, implementation, and operation activities in complex ways not addressed by current approaches to Systems Engineering focusing on more sedate environments.

The proposed framework presents a language for classifying fundamental building blocks of ad-hoc systems – single-agent intervention, staging, readiness, and development systems. Further classification according to the physical location of agents and assets relative to situations generates 16 system classes on the 4x4 matrix of Ad-hoc Systems Gameboard, which is a helpful tool for managing the evolution of system portfolios. Combining the Gameboard with mapping the systems onto the PSI matrix reveals additional relationships and evolution patterns, opening up promising directions to address the challenge of designing, planning, and implementing interventions in complex situations.

I&S 05

THU
27 JUL

Advancements in Systems Engineering 2

Session Chair: Eswaran Subrahmanian, Carnegie Mellon University, United States of America

Adjusting Scaled Agile for Systems Engineering

Jake Farlon Drutchas, Steven Eppinger, Massachusetts Institute of Technology

Scaled agile development of large systems has primarily followed the approach used in traditional systems engineering – system decomposition and static teams assigned to subsystems. However, this arrangement may result in an inefficient allocation of resources and uneven progress. This paper presents an alternative approach in which problem-based decomposition replaces system-architecture-based decomposition, and resources are flexibly allocated to problems for each sprint using ad hoc teams. Using a field study approach, we examine a mechatronic system development project utilizing these agile adjustments and discuss situations in which these methods may be successfully utilized in other projects and organizations.

Supporting Systems Engineering activities by artifact-oriented description and selection of methods

Theresa Ammersdörfer 1, David Inkermann 1, Johannes Müller 2, Constantin Mandel 2, Albert Albers 2, Julian Tekaat 3, Anja Schierbaum 3, Harald Anacker 3, Michael Bitzer 4, Sven Kleiner 5, Jan-Phillip Herrmann 6, Patrik Krause 7
1 Technische Universität Clausthal, Institute of Mechanical Engineering (IMW), Robert-Koch-Str. 32, 38678 Clausthal-Zellerfeld, Germany; 2 Karlsruhe Institute of Technology, Institute of Product Enginee-ring (IPEK), Kaiserstraße 10, 76131 Karlsruhe, Germany; 3 Fraunhofer Research Institute for Mechatro-nic Systems Design IEM, Zukunftsmeile 1, 33102 Paderborn; 4 Fresenius Medical Care Deutschland GmbH, Daimlerstr. 15, 61352 Bad Homburg, Germany; 5 em engineering methods AG, Model Based Engineering, Rheinstr. 97, 64295 Darmstadt, Germany; 6 OWL University of Applied Sciences and Arts, CampuRoome 12, 32657 Lemgo, Germany; 7 3DSE Management Consultants GmbH, Seidlstraße 18a, 80335 München, Germany

Systems Engineering (SE) is becoming increasingly relevant in industrial application since more stake-holders are involved in engineering activities. To implement SE, companies have to adapt existing en-gineering processes and methods. This adaption requires knowledge about new methods as well as their integration into the engineering activities. In order to ensure goal-oriented identification of methods for different SE activities in this contribution an action field profile and the Systems Engineering Method Matrix are proposed. The development of both tools is driven by the assumption that most SE activities and methods can be described based on the artefacts the deliver. In order to get feedback about the proposed tools, semi-structured interviews with two industry partners were conducted, focussing on the tool's usability. These interviews underline the basic usability of the tools and their support to identify SE activities to be supported by (new) methods. Moreover, requirements for further development and adaption are derived from the interviews.

Location: Building C – 1st floor: Room C2 – 114

3:30pm
4:30pm

Understanding Customers

Session Chair: Tobias Larsson, Blekinge Institute of Technology, Sweden

Evolution of Innovation in Industry Life cycles: A Complex Network Perspective

Soumyakant Padhee, Babak Heydari, Northeastern University

Technological life cycles are driven by the changes in the shape and level of innovation, yet innovation rate is not directly observable and is difficult to trace. Innovation measured by patent-citation networks (PCN) cannot be estimated solely by quantity, whereas quality-adjusted quantity measurements are still prone to bias. Our paper complement PCN data analysis with an agent-based simulation (ABS) on networks to uncover the latent innovation that automatically accounts for the quality and quantity components instead of decoupling them. We build dynamic PCN for radio frequency 'CMOS' technology and subsequently develop ABS to replicate underlying innovation network formation. Comparing the real and synthetic data, we isolate latent innovation rate in PCN and by mapping pivotal patent assignees — innovators, we calculate the diversity of innovators in the technology market. Identifying innovation patterns, we show that, early on, innovation structures are less diverse and exploratory, but this grows and matures eventually until value creation become an expensive endeavor. Contrary to what is observed, we show how the abundance that appears are less significant publications mostly driven by exploitation in the technology market.

Tech to Market. Finding and designing suitable technology applications with design thinking

Nicolò Cocchi, Clio Dosi, Matteo Vignoli, University of Bologna

Although it's human centered focus, design thinking has proven to be effective also in technology-driven projects, both in education and business. Yet, scant research has investigated whether and how design thinking might be leveraged to find new opportunities based on emerging technologies and design new innovation concepts accordingly. To address this gap, we employed an Action Innovation Management Research framework and co-designed a program called Tech to Market with Oper.Space, the design factory for Open Innovation of the University of Bologna. We ran 5 iterations of the program from October 2018 to December 2022, in which we conducted 52 interviews, observed 10 presentations, and held 10 meetings with the main stakeholders involved. Our results show how to apply design thinking to find and design a suitable application for a given technology, contributing to the ongoing conversation about the implementation of design thinking in technology-driven projects.

Understanding Customers

Session Chair: Tobias Larsson, Blekinge Institute of Technology, Sweden

IBM 06

**THU
27 JUL**

Investigation of Customer Preference Changes Following COVID-19 Market Disruption Using Online Review Analysis

Seyoung Park 1, Kangcheng Lin 1, Junegak Joung 2, Harrison Kim 1
1 University of Illinois at Urbana-Champaign; 2 Hanyang University

COVID-19 pandemic has continued to pose a challenge to the society for almost three years, adversely affecting all segments of population in a scale unseen in the recent decades. Over the course of COVID-19 pandemic, many people have lost their jobs and income. These social and economic impacts have disrupted the market, potentially altering people's attitudes towards different product features. Therefore, this paper investigates the changes in customer preferences on various features of different products, before and after COVID-19 pandemic, using online review analysis. The proposed framework consists of four stages. Firstly, product review data is collected and preprocessed. Secondly, customer interest in product features is explored using latent Dirichlet allocation. Thirdly, customer sentiment for these features is analyzed with Valence Aware Dictionary and sEntiment Reasoner. Finally, the importance of each feature is calculated based on interpretable machine learning. The proposed method is tested on two real-world datasets – smartphone and laptop reviews. The result reveals the changes in customer sentiments and preferences for product features, thus helping companies quickly establish strategies in rapidly changing market environments.

The sharing economy's success: advantages, drawbacks, and applications

Vedran Simic, André Liem, Department of Design NTNU, Norwegian University of Science and Technology

Department of Design NTNU, Norwegian University of Science and Technology
The emergence of intermediary platforms created networks that facilitate peer-to-peer interactions, as well as encourage the sharing of goods and services within the context of collaborative consumption and cost saving. This article sets out to inspect "why the sharing economy is so successful" and provide a critical viewpoint on the topic's essential ideas, while also taking a perspective on the advantages and disadvantages that affect the end users. A literature review paired with case studies of Airbnb, Uber, and other applications of the shared economy, looks upon how despite their rapid market growth in the past decade and public approval, such platforms caused disruptions to the markets they operate in. Results indicate that by being involved as a part of the collaborative consumption ecosystem, either as a provider or a user, the absence of personal ownership is key, while the utilisation of the product needs to be maximised to result in a pleasant experience. However, it is critical that the development of these platforms which thrive on connecting people stays closely monitored by regulatory bodies, and that the legislation needed for prevention of unethical practices follows quickly enough to ensure rightful operation.

Location: Building C – 2nd floor: Room C2 – 216

3:30pm
4:30pm

Sustainability and Resilience - Life Cycle Assessment

Session Chair: Clement Fortin, Skolkovo Institute of Science and Technology (Skoltech), Russian Federation

A dynamic approach for life cycle assessment. The case of domestic refrigerators.

Federica Cappelletti, Marta Rossi, Michele Germani, Università Politecnica delle Marche

The Life Cycle Assessment is a well-stated methodology whose application has recently spread over a multitude of sectors. Thus the need for very accurate and reliable analysis. The present work investigates how to achieve reliable and faithful results while still maintaining a micro-systemic approach and how to handle the evolution of the real cases through commercial solutions available. The works present an innovative dynamic approach that aims at filling the discrepancy between the attributional Life Cycle Assessment which is focused on the product at the point to appear short-sighted and isolated from the surrounding evolving system and the consequential, which is willing to include the consequences of the evolution of the surrounding system, with increased complexity. The approach is applied to the case of a domestic refrigerator; the application reveals a discrepancy of 16% between the results of the dynamic and attributional analysis and registered doubled environmental impacts than the consequential, carried out with the support of commercial datasets. The approach respects the 5 main criteria for methods in environmental systems analysis, namely feasibility, accuracy, easiness in communication, inspiration, robustness.

Challenges in Extracting Insights from Life Cycle Assessment Documents During Early Stage Design

Nicole Goridkov 1, Kelly Ye 1, Ye Wang 2, Kosa Goucher-Lambert 1
1 University of California, Berkeley; 2 Autodesk Research

Life cycle assessment (LCA) has been established as a benchmark for design for sustainability practices. LCA provides detailed technical documents regarding a product's environmental impact, but its use is often limited to trained experts who share the knowledge with designers. Life cycle experts are highly specialized, and the typical designer faces technical barriers and time constraints in extracting information from LCA documents. This work uses knowledge transfer principles to replicate expert practices in LCA information retrieval to support designers. Life-cycle experts (n=4) were interviewed to understand practices and challenges in information retrieval for LCA documents. Interview findings were used to create a set of guidelines for effectively navigating LCA documents and then tested in a follow-up task where designers (n=16) annotated an electric toothbrush LCA using the identified guidelines. Results find designers can effectively extract information from LCA documents given provided guidelines, but need detailed support interpreting complex visual entities like charts and figures. This work is the first step toward enabling knowledge transfer from LCA documents and building a structured sustainability knowledge base.

Sustainability and Resilience - Life Cycle Assessment

Session Chair: Clement Fortin, Skolkovo Institute of Science and Technology (Skoltech), Russian Federation

The Doughnut as a support of the «Sustainable Value Engineering»

Alexis Lalevée 1,2,3, Nadège Troussier 1,4, Eric Blanco 2,5
1 UR InSyTE, Université de Technologie de Troyes, 12 rue Marie Curie, 10010 Troyes, France; 2 Univ. Grenoble Alpes, CNRS, Grenoble INP1, G-SCOP, 38000 Grenoble, France; 3 Euro Contrôle Projet (ECP) Company, 13000 Aix-en-Provence, France; 4 Arts et Métiers - campus de Paris - ENSAM, 151 Boulevard de l'Hôpital, 75013 Paris, France; 5 Ecole de l'Air BA 701 13661 Salon Air, France

Societies are faced to ecological crises and widening disparities. This has to be integrated in the management of complex projects as they are increasingly complex and impactful. Value Analysis can serve assessing the value of a project i.e. knowing how the project will be perceived by the Stakeholders. It is a collaborative approach that helps make decisions in the early stages of a complex project.
This paper aims at demonstrating that a new "Sustainable Value Analysis" (SVA) provides a decision-making support toward sustainability. SVA uses a new definition of Value and a set of indicators based on the Doughnut.
Methods for the introduction of sustainability in the upstream design phases have limitations, which are highlighted in the literature review. Yet, the potentials of value approaches can be shown. Based on this analysis, an illustrative case is proposed to demonstrate how to integrate the ecological and social dimensions in a classical Value Engineering approach to determine SVA. The article concludes that the SVA allows identifying and characterizing the sustainable dimensions of Value, through a collective approach based on Stakeholders.

Framework for Comparison of Product Carbon Footprints of Different Manufacturing Scenarios

Sven Winter, Niklas Quernheim, Lars Arnemann, Reiner Anderl, Benjamin Schleich, Product Life Cycle Management (PLCM), TU Darmstadt

The Product Carbon Footprint (PCF) has been established over the last few years as a new control variable in product design to quantify the sustainable impact of a product. However, the calculation of the PCF is subject to numerous uncertainties and assumptions, which are no longer represented in the stand-alone value. The uncertainties and assumptions arise at different stages of the calculation of the PCF and consequently create a multidimensional problem, which means that the PCF does not provide a trustworthy basis for comparing different production scenarios. To face this multidimensional issue, in this paper, a methodology for categorization of the different issues and, therefore, of the final PCF is presented. Through this methodology, which is divided into five levels mainly based on the origin, the quality, and the uncertainty of the data, an assessment can be made as to whether the values of the PCFs are comparable in different scenarios. The methodology can therefore help to improve decisions in product development with regard to environmental sustainability.

Design in a complex world

Location: Building C - ground floor: Room C3 – 002

3:30pm
4:30pm

Product and System Modelling 2

Session Chair: Boris Eisenbart, Swinburne University of Technology, Australia

Challenges of Product Modularization Methods in SMEs: Lessons Learned from a Manufacturer of Rigid Inflatable Boats

Tiago Silva, Cláudio Santos, INEGI - Instituto de Ciência e Inovação em Engenharia Mecânica e Engenharia Industrial

Nowadays, Western rigid inflatable boat (RIB) manufacturers are facing increased competition from Asian and Middle East producers and the need to push the modularization of their product architecture. Many modularization techniques have been developed to support this effort, being the Modular Function Deployment a well-established multi-stage modularization technique with applications in several industries. Despite the reported literature, the challenges and learnings from the application of modularization techniques have focused on large organizations and complex product systems. In this paper, a case study is presented with the objective of analysing the MFD process implementation in the context of an SME manufacturer of RIB. A learning framework focused on the project and process perspectives is used to facilitate the systematic extraction of lessons from the experience of the MFD implementation. This paper contributes to the modularization techniques literature by observing a modularization method as a learning process and makes it evident the call for more investigation on the implementation process of modularization methods.

Combining function modelling and requirements modelling with the IFM framework

Merlin Frederik Krüger, Stefan Zorn, Kilian Gericke, University of Rostock

The transmission of information between requirements modelling and function modelling in the product development process often appears challenging because of multiple used models and different terminology of specific disciplines. The integrated function modelling (IFM) framework is used for functional analysis of technical moderate complex systems and supports cross-disciplinary modelling and communication in the design team. To improve the applicability of this method and its supporting purpose in the modelling process, the authors combined requirements as an additional entity with the existing entities of this method. Furthermore, the extended framework has been used to visualise the procedure with this approach as an example. The outlook provides the potential for further development of the method.

Product and System Modelling 2

Session Chair: Boris Eisenbart, Swinburne University of Technology, Australia

Towards a Configuration Management integration to Feature Models in Model-Based Product Line Engineering

José Lameh 1,2, Alexandra Dubray 2, Marija Jankovic1
1 Université Paris Saclay - CentraleSupélec, Laboratoire Genie Industriel, Gif-sur-Yvette, France; 2 Renault, Technocentre, 1 Av. du Golf 78288 Guyancourt, France

In parallel with the industry 4.0 revolution, customers' demand and number of product requirements are increasing, inducing increased product variability. System complexity is growing with the new technologies and system architectures. Hence, maintaining a system consistent and in the desired state becomes crucial. This paper tackles two problems: a product's variability and its temporal evolution. Regarding variability, Model Based Systems Engineering (MBSE) methods and Product Line Engineering (PLE) techniques become essential to configuring products by selecting and arranging features in a combination. In parallel, versioning and temporal evolution are managed with the configuration management (CM) principles. A versioned feature model (FM) is proposed. In PLE methodology, the first step is to model variability through traditional FM. This research presents an extension of the FM by integrating CM into it. The versioned FM includes not only features' variants but also their versions, making it evolve in time. This work is presented as a base for a work that will study the application of CM for PLE. This study is done in an automotive industry context at Renault Group, and the model proposed is applied to Renault's systems.

Robust Product Design – Influencing Factors on Upgradeable Modular Products

Maximilian Stephan Kübler, Frederik Beck, Bastian Glasmacher, Simon Rapp, Albert Albers, Karlsruhe Institute of Technology

In today's VUCA-World it is necessary to consider future requirements to develop change- and future-robust future products, especially regarding the increasing demand for sustainable solutions. In order to address this situation, upgradeability of modular products can be a solution. Considering that elements of modular products are used in several different products and over a long period of time, there is a need to act on this challenge. To uncover areas with a need for action, a systematic literature review on upgradeable and modular products was conducted. After resolving four fields of action and under consideration of the need for sustainable products, another systematic literature review examined the solution space of upgradable modular product architecture. In conclusion, several influencing factors on the upgradeable design of modular products could be identified, which are presented in this work.

Design in a complex world

4:30pm
5:15pm

KN 06 - Keynote
The Importance of Computing and Making in Design Research

THU
27 JUL

Kristina Shea, ETH Zürich, Switzerland

Session Chair: Benoit Eynard, Université de Technologie de Compiègne, France

I have always loved the artifact of design, the object that we make when designing and its form, material and function. As such, design, computing and making have always played a large role in my research and are hard for me to separate. In this talk, I will present several research projects we have carried out, the significance that computing and making has had in them, and why I believe they are important to advancing design research. The rise of 3D printing in the last ten years has been a great trigger and opportunity to integrate more computing and fabrication, one form of making, in many areas of design research to both explore more complex design spaces and fabricate designs with unprecedented complexity. The first research project will discuss our work designing with 3D printing and 4D printing, which is the 3D printing of functional materials, to create parts that actively reconfigure themselves in response to environmental stimuli. This creates a new paradigm for the design of novel machines that do not use conventional components and thus require new ways to design. In a second research project, I will present the combination of a complex parametric modeling approach, design automation, 3D printing and traditional fabrication to build accessible, sustainable, Compressed Earth Block (CEB) dwellings in a Low-Resource Setting (LRS). Finally, I will show a recent project where we take a holistic approach to designing a low-cost, mechanical ventilator for LRSs that combines technical efficiency, user-centered design and user training. I will conclude with lessons learned in these projects and thoughts for future research.

BIO

Prof. Kristina Shea is a Full Professor for Engineering Design and Computing in Mechanical and Processing Engineering at ETH Zürich since 2012. Her lab's research combines engineering design, computation and fabrication to design and prototype creative engineering systems with new functionalities that help to achieve sustainable development goals. Current research topics include computational design, design for Additive Manufacturing (AM), multi-material AM and 4D printing as well as new research in development engineering. Her lab investigates a wide variety of application areas across a number of industries including consumer products, space, automotive, built environment and biomedical. Kristina Shea graduated in Mechanical Engineering (BS 1993; MS 1995; PhD 1997) from Carnegie Mellon University. She has held academic positions at EPFL (Switzerland) where she was a post-doc, University of Cambridge (UK) where she was a tenured Lecturer (Assistant Professor) and TU München (Germany) where she was a tenured Associate Professor. She also worked as a Senior Engineer at Arup (London, UK). She is a Fellow of the American Society of Mechanical Engineers (ASME), member of the Design Society, former member of the Board of Management of the Design Society and co-founded the Design for Additive Manufacturing SIG and Computational Design Synthesis SIG in the Design Society.

Location: Building D - ground floor: Espace FORUM

10:45am
6:00pm

Marketplace

Advanced Design Augmentation (ADA) Technologies: Augmenting the Upfront of Product Design with AI

Marion, Tucker (1); Moghaddam, Mohsen (1); Ciuccarelli, Paolo (1); Wang, Lu (2)
1: Northeastern University; 2: University of Michigan

Topics: Usage and integration of supportive technologies, Supporting design creativity, AI and the data driven economy

Approach for the targeted use of data from image-based digitizing processes in virtual product development

Sembdner, Philipp; Paetzold-Byhain, Kristin; Pendzik, Martin, TU Dresden

Topics: Design of medical devices, Design driven innovations in healthcare, User-centred design in health-care, Industry 4.0, Product development models and strategies, Design for Interfaces, Human-Machine Interfaces, Design for X, design to X (quality, sustainability, costs, …), Modelling and simulation methods, Digital Engineering, Additive Manufacturing, 3D/4D Printing, Representation of design information

Utilizing the embodiment function relation and tolerance model for robust concept design

Li, Jiahang (1); Horber, Dennis (2); Keller, Christoph (1); Grauberger, Patric (1); Goetz, Stefan (2); Wartzack, Sandro (2); Matthiesen, Sven (1)
1: Karlsruhe Institute of Technology (KIT); 2: Friedrich-Alexander-Universität Erlangen-Nürnberg

Topics: Robust Design, Tolerance Management

Demonstration of the Hybrid Augmented Reality Computer Workstation for CAD

Harlan, Jakob; Goetz, Stafen; Wartzack, Sandro, Friedrich-Alexander-Universität Erlangen-Nürnberg

Topics: Modelling and simulation methods, Virtual Reality, Augmented Reality

Evaluation of Robustness Indicators for Early Comparison of Design Configurations and Application to a Novel Open-Source Benchmark Case

Juul-Nyholm, Herle Kjemtrup; Højeng-Swensson, Jakob; Eifler, Tobias, Danmarks Tekniske Universitet / Technical University of Denmark

Topic: Evaluation methods

Simulation Games for Systems Engineering Education and Training

Schumacher, Thomas; Ammersdörfer, Theresa; Inkermann, David, TU Clausthal

Topics: Systems Engineering, Complex Systems Design, Training in design (academic and industrial)

Computationally Designed Lightweight Skateboard Truck

Mayer, Johannes; Pfister, Felix; Bartz, Marcel; Wartzack, Sandro, Friedrich-Alexander-Universität Erlangen-Nürnberg, Engineering Design

Topic: Modelling and simulation methods

Design in a complex world

Location: Building D - ground floor: Espace FORUM

10:45am
6:00pm

Marketplace

Application of Bio-Bricks & its benefits

Rautray, Priyabrata (1); Roy, Avik (2); Eisenbart, Boris (3)
1: IIT Hyderabad; 2: KIIT School of Architecture and Planning; 3: Swinburne University
Topics: Eco-design, Design for the environment, Design for cleaner production, Design for a circular economy, Design for sustainable life/consumption

MedTech Combination Product Development in a Complex World

Menshenin, Yaroslav; Pinquié, Romain; Chevrier, Pierre, Univ. Grenoble Alpes, CNRS, Grenoble INP, G-SCOP
Topics: Design of medical devices, User-centred design in healthcare, Systems Engineering, Complex Systems Design, Product development models and strategies

GitHub for product design - An open platform for product design innovation

Hackenberg, Georg; Zehetner, Christian; Frühwirth, Dominik, University of Applied Sciences Upper Austria
Topics: Engineering ontologies, Product development models and strategies, Design process modelling and management, Design of workspaces to manage product development, Product and system modelling, Requirement management, user orientation, user integration, Digital Engineering, Teamwork in design, Collaborative and participatory design, Design communication, Representation of design information, Design information and knowledge

Exploring the impact of different stimuli on the creativity of designers in combinational design

Wang, Da, University of Liverpool
Topics: Design tactics and methods, Creative design processes, Cognitive processes in design creativity, Supporting design creativity, Assessing creativity

Visualisation of a coastal erosion prevention system

Urquhart, Lewis William Robert, University of Strathclyde
Topics: Design for the environment, Infrastructure and support system design

A Purely Mechanical Plantar Pressure Evaluation Device for Diabetic Foot Assessment in Low-Resource Healthcare Settings

Reddie, Madison, Massachusetts Institute of Technology
Topics: Design of medical devices, Design driven innovations in healthcare, User-centred design in healthcare

Design in a complex world

10:45am
6:00pm

Marketplace

AutoVision Demo

Lecomte, Robin (1,2,3); Yannou, Bernard (1); Cahen, Roland (2); Thibaud, Guillaume (3); Etienne, Fabrice (3)
1: Laboratoire Génie Industriel, CentraleSupélec, Université Paris-Saclay; 2: Centre de Recherche en Design, ENSCi Les Ateliers / ENS Paris-Saclay, Université Paris-Saclay; 3: Stellantis, Centre Technique Vélizy, France

Topics: Product innovation engineering,Innovation strategies and innovation management, Modelling and simulation methods, Designers' thinking and skills, Supporting design creativity, Training in design (academic and industrial), Awareness of societal consequences

International Summer School on Product Architecture Design PAD2024 – PAD feat. SiME

Kuechenhof, Jan; Krause, Dieter, Hamburg University of Technology

Topics: Designing of Cyber-Physical Systems, Product architectures, structural complexity, Platform design, modularization, product family design, Design for X, design to X (quality, sustainability, costs, …), Teaching examples and experiments, Education experiences, plans, and visions, Training in design (academic and industrial)

The Micro-Processes Involved in Searching Complex Design Landscapes: An Exploratory Case Study Using A Bridge-Building Game

Vrolijk, Ademir-Paolo (1); Paravizo, Esdras (2); Crilly, Nathan (2); Olechowski, Alison (1)
1: University of Toronto; 2: University of Cambridge

Topics: Design theories and approaches, Product development models and strategies, Design process modelling and management, Design tactics and methods, Decision Making

Digital Sustainability Implementation Package

Mallalieu, Adam Mattias (1); Hallstedt, Sophie I. (1,2); Isaksson, Ola (1); Watz, Matilda (2)
1: Chalmers University of Technology; 2: Blekinge Institute of Technology

Topics: Eco-design, Design for cleaner production, Environmental and sustainability assessment, Design for a circular economy, Design practice: Best practice, industry practice (cases), Digital Engineering

Studying the mind and brain in engineering design: situating community research and aspirations on a representational framework

McTeague, Chris, Technical University of Munich
Topics: Designers' thinking and skills, Cognitive processes in design creativity

What makes a space a work-space? Participatory design activity   "Design for mental health and wellbeing

Canizares, Claudia, Technical University of Munich (TUM)
Topics: Researching of designs and design methods, Requirement management, user orientation, user integration

Design in a complex world

Marketplace

Location: Building D - ground floor: Espace FORUM

10:45am
6:00pm

Generative AI and its Impact on Design: Towards an "Atlas of AI in Design

Thoring, Katja; Diefenthaler, Annette, Technical University of Munich

Topics: Artificial Intelligence and Awareness, Designers' thinking and skills, Creative design processes, AI and the data driven economy

Collaborative Ideation with the Internet of Things within Industry 5.0

Aranda Muñoz, Álvaro, Mälardalen University

Topic: Collaborative and participatory design

CHRONOSPEDIA: First On-line Antiquarian Horology 3D-Encyclopaedia

Simon-Fustier, François (1); Protassov, Konstantin (2); Laroche, Florent (3)
1: Horloger de la Croix-Rousse; 2: Université Grenoble Alpes; 3: Centrale Nantes

Topics: Modelling and simulation methods, Virtual Reality, Augmented Reality, Digital Engineering

Minimize your work suitcase

Dreyer, Susanne, Technical University of Munich

Topics: Design of workspaces to manage product development, Supporting design creativity

21st Century Prototyping Technologies: Powering up prototypes to learn more, faster, with less

Snider, Chris, University of Bristol

Topic: Researching of designs and design methods

Dhwani : A holistic rehabilitation solution for children with hearing impairment

Venkatesh, Kavyashree, Indian Institute of Technology Guwahati

Topics: Human behaviour in design, Biomedical design, Bio-inspired design / biomimetics, Design of medical devices, Design for mental health and wellbeing, Design for patient-centred care, Designing e-health systems"

FRIDAY 28th July 2023

PROGRAM

&

ABSTRACTS

24th International Conference on Engineering Design
Bordeaux, France, 24 - 28 July 2023

8:15am - 12:30pm	IV 01: Industrial Visit - Lectra	IV 02: Industrial Visit - Chaban Delmas Bridge	IV 03: Industrial Visit - Construction Navale Bordeaux
9:30am - 12:30pm	IDA 01: Panel Discussion on Digital Solutions for Design Education Location: Bât H - RDC: Amphi ASSELAIN	IDA 02: Workshop on Sustainable Innovation Location: Bât C - 1er étage: Salle C2 - 106	

IDA 01

IDA 02

FRI
28 JUL

Location: Building H – ground floor: Conference room ASSELAIN

Panel Discussion on Digital Solutions for Design Education

9:30am
12:30am

Session Chair: Ross Brisco, University of Strathclyde, United Kingdom,
Lionel Roucoules, Arts et Métiers Institute of Technology, France

A panel discussion will be lauched by chairpersons on the browde topic of Design, Engineering and Technology Education and the new challenges to Train Students with the next generation of Digital Solutions proposed by Information Technology vendors acting ad panelists i.e. Ansys, Dassault Systèmes and Immersion. They will be invited to contribute to the debates according to their viewpoints on existing challenges for Design Education and on future opportunities to improve Students Training and Learning.

Location: Building C – 1st floor: Room C2 – 106

Sustainable innovation: Make reuse and repair a core industrial process ?

9:30am
12:30am

Session Chair: Flore Vallet IRT SystemX, CentraleSupélec, France,
François Cluzel CentraleSupélec, France, Benjamin Tyl APESA, France

The European economy is surprisingly wasteful and continues to operate a take-make-dispose system. Today, reuse and repair are crucial activities to move toward environmental, economic and social transitions. Recently, the Commission's Circular Economy Action Plan has emphasized the need to develop more sustainable products, promoting a "right to repair" (European commission, 2020), while France has developed a repair index for various electronic products.

Nevertheless, if reuse and repair activities are developing through local initiatives, through reuse and repair workshops which often originate from the social economy, it seems that more conventional companies still experience difficulties to integrate this new paradigm. Through the presentation of good practices, conferences, and collective debates, the goal of this workshop is to discuss how to better support designers and companies – in integrating reuse and repair in industrial processes, with a special emphasis on the circularity challenges for reducing electric and electronic waste.

We propose a three-step workshop:

1. Presentation of the main issues of reuse and repair in industrial processes (30 min)
2. Inspirational talks to present good practices from companies; social and solidarity organizations (1h)
3. Collective workshop (3 to 4 groups) to challenge the strengths and weaknesses to integrate reuse and repair activities in current industrial processes (1h).

Examples of questions to be addressed by teams, in interaction with the guest speakers:
- What business models for reuse and repair activities?
- What are the scaling issues?
- What challenges for designing a refurbished computer?
- …

Guest speakers
- Emmaüs Connect: dedicated to support remanufacturing process of computers, to provide products at a solidarity price and digital education for fragile citizens.
- DOSATRON: Manufacturer of proportional dosing pumps
- Ecosystem: French eco-organism for WEEE ERP's
- …

ICED23 Bordeaux

Industrial day
FRIDAY 28 July

Construction Navale de Bordeaux
From 8:45am at 12:30pm
Transport : Bus journey from University
Meeting point at the University of Bordeaux Montesquieu campus

Travel time: 45 minutes

Opening times for visits: 10:15 - Time visit: 1:30 -01:45

LECTRA company
From 8:30am at 12:30pm
Transport : Bus journey from University
Meeting point at the University of Bordeaux, Montesquieu campus

Travel time: 16 minutes

Opening times for visits: 08:50 - Time visit: 3:00
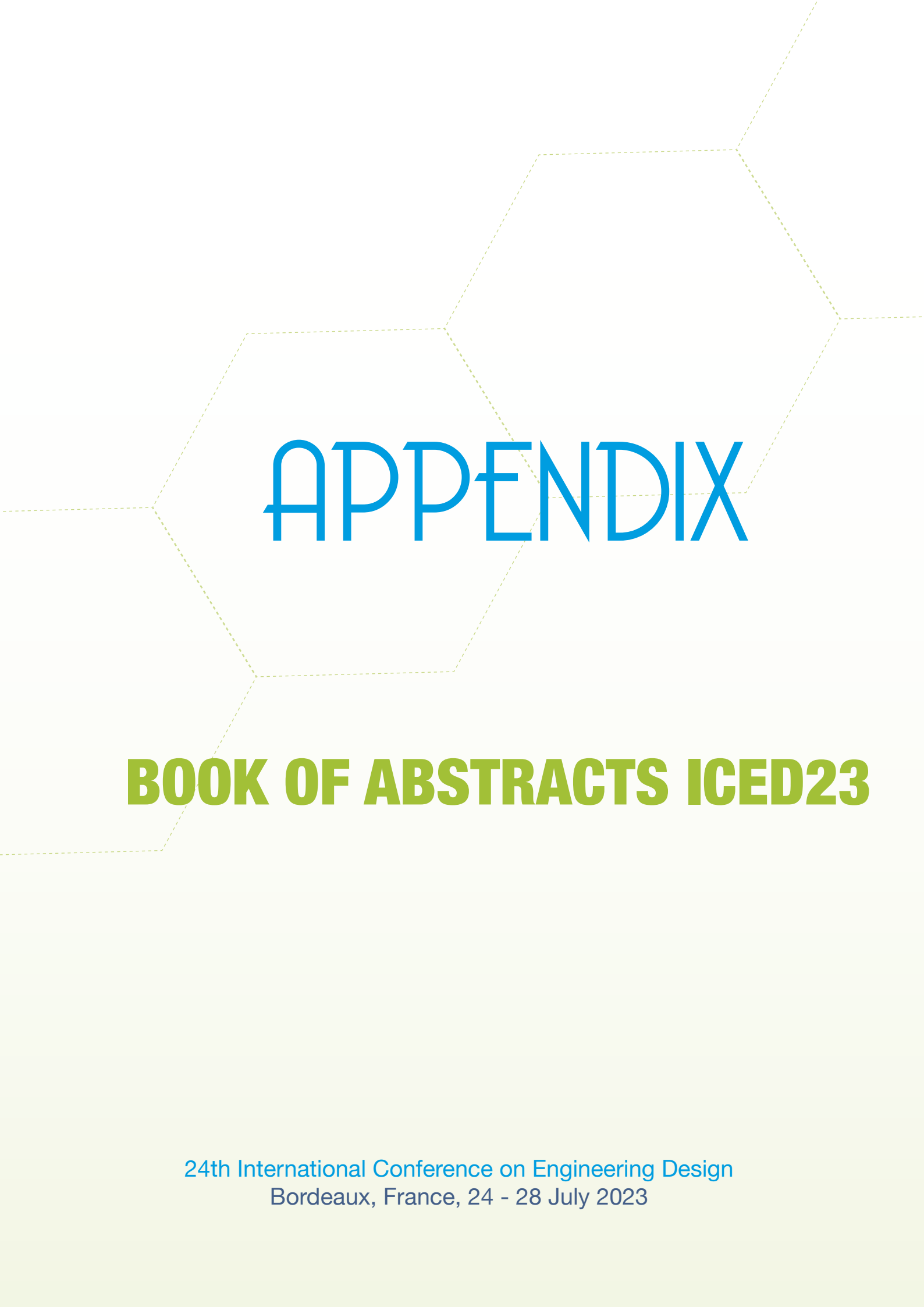
Chaban Delmas bridge
From 9:00pm at 12:30pm
Public Transport : TRAM **B** BORDEAUX Berges de la Garonne / Claveau Stop «*la cité du vin*»

*Meeting point at **10:20am directly to Quai de Brazza***

Opening times for visits: 10:30 visit duration : 1:30

Visit of Chaban Delmas bridge
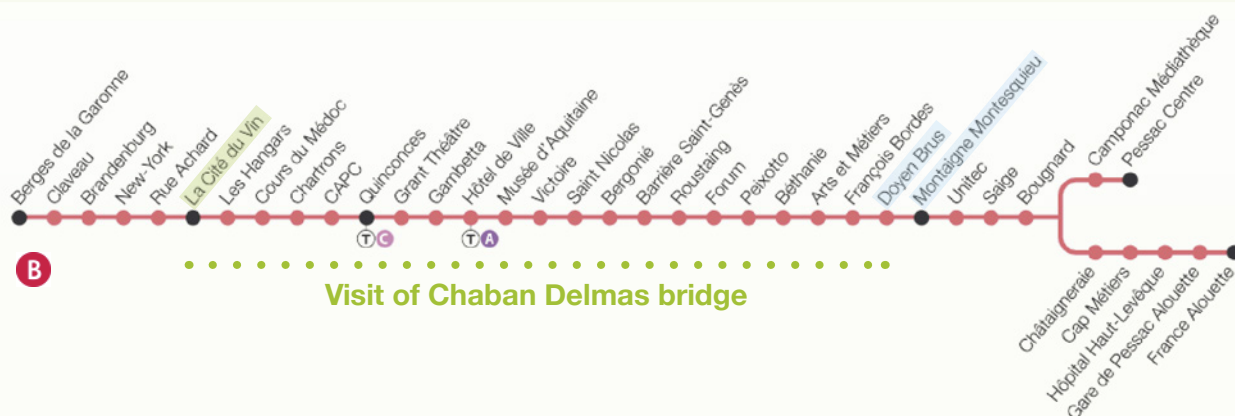
APPENDIX

BOOK OF ABSTRACTS ICED23

24th International Conference on Engineering Design
Bordeaux, France, 24 - 28 July 2023

Groups & labels

Ref.	Theme
SIG 1-01	Data-Informed Design in practice
SIG 1-02	Design Creativity : Encouraging creativity through effective feedback to ideas (Hybrid)
SIG 1-03	Design Practice : AI technology as support in Early Phase Design
SIG 1-04	Decision Making : Supporting the choices of embedded sensors in the product design process
SIG 1-05	Design Processes: Current status and trends in design process modelling and management
SIG 1-06	Health Systems Design : Health Systems Resilience by Design
SIG 1-07	Robust Design: Design Research for achieving product robustness
SIG 1-08	New Initiative : Computational Design Methods
PHD-01	PhD Forum
SIG 2-01	Design Theory : Design Theory to face grand challenges
SIG 2-02	Human Behaviour in Design : Design in a Complex World - Bridging capacities: Supporting exploration and learning from complex systemic challenges
SIG 2-03	Sustainability Design : Investigating and fostering education in sustainable design
SIG 2-04	Design of Product-Service Systems: Extended Reality (XR) - technologies for PSS design
SIG 2-05	Chapter Africa Design : Towards Creating a Design Society African Chapter (Hybrid)
SIG 2-06	Collaborative Design : An interactive experiment to investigate a fundamental concept that defines collaborative design 2.0
SIG 2-07	Design for Additive Manufacturing : Leveraging Data-Driven Design Methods to Support Complex and Multidisciplinary Design Scenarios in Additive Manufacturing
YME-01	Young Member Event
KN 01	Keynote: Complexity and System Design
AM 01	Architecture and New Materials
DE 01	Design Education and Training
DE 02	Gaining Design Experience
DW 01	AI enhanced design processes
I&S 01	Design of Complex Systems
IBM 01	3D Printing Design
S&R 01	Strategy & Sustainable Design
S&R 02	Circular Product Design
SD 01	Systems Engineering
SD 02	Virtual Interface Design
KN 02	Keynote: Towards an integrative approach to the study of a protected natural environment: The Lascaux Cave
DE 03	Empathy and Design Cognition
DW 02	Review of State of the Art of Data Applications
H&W 01	Supporting Patients
HB 01	Prototyping In Design
IBM 02	Applications of Additive Manufacturing
M&P 01	Working with Digital Tools
SC 01	Design for DIY & Repairability
SC 02	Sustainable and Risk Design Evaluations

Design in a complex world

Ref.	Theme
SD 03	Research Design Methods
DC 01	Design Cognition
DW 03	Human Factor and AI
DW 04	Generative Design for Engineering
H&W 02	Methods and Processes for Medical Applications
HB 02	Agile Systems Development
I&S 02	Advancements in Systems Engineering 1
IBM 03	Design Innovation
M&P 02	Design Validation
S&R 03	Addressing Sustainability Challenges in Design
SD 04	Product Architecture Design 1 - Applications
KN 03	Keynote: The challenge of preserving and improving the quality of wines in a changing context
AM 02	Additive Manufacturing
AM 03	Data Driven Manufacturing
DE 04	Hybrid Education
DW 05	Practical Applications of Data Driven Design
H&W 03	Supporting Specific Medical Conditions
HB 03	Design Collaboration Behaviour
IBM 04	The Virtual and the Physical
M&P 03	Applications in Design Modeling
S&R 04	Circular Design of Packaging
S&R 05	Product Lifecycle Management
DE 05	Educating and Learning Design
DW 06	VR-Enhanced Design
H&W 04	Medical Design
HB 04	Cognitive Processes in Design
HB 05	Human in Behaviour in Design
I&S 03	PSS and Service Design
S&R 06	Designing for the Circular Economy
SD 05	Design Theories and Approaches 1
SD 06	Product Architecture Design 2 - Analysing Modularity and Impact Effects
SD 07	Robust Design & Tolerance Management
MIP 01	Mentoring programme Event (Hybrid) - 7 plateaux repas
KN 04	Keynote: The 4th industrial revolution: myth or reality
DC 02	Creativity and Collaboration
DE 06	Teaching Examples & Experiments
DW 07	Specific Applications Of AI
DW 08	Enhancements to CAD
M&P 04	Design Methods and Teams
S&R 07	Applications of Sustainable Design 2
S&R 08	Ecodesign & Circular Design Methods
SC 03	Industry Design Challenges
SD 08	Design for X - Applications and Examples
GM	General Meeting DS

Design in a complex world

Ref.	Theme
KN 05	Keynote: Design for circular economy: application to outdoor sports products
DW 09	AI Applications for Requirements
DW 10	Digital Support for Design Application
H&W 05	Intangible Aspects of Wellbeing
M&P 05	Design Methods
M&P 06	Designer Cognitive Loads
S&R 09	Stakeholder Value in Circular Systems
SC 04	Design Practice and Empathy
SC 05	Understanding Design and Experience
SD 09	Product Architecture Design 3 - Configurable Products
DE 07	Project Planning and Execution
DW 11	AI / VR for CAD applications
HB 06	Design of Intangible Aspects in Health and Wellbeing
HB 07	Prototyping In Design
IBM 05	Knowledge Management
M&P 07	Examples in Design Optimization
S&R 10	Designing the Sustainable Transition - Strategy & Policy
SC 06	User Behaviour and Sustainability
SD 10	Design Theories and Approaches 2
SD 11	Product and System Modelling 1
DC 03	Creativity in Context
DE 08	Challenges in Design Education
DW 12	AI and Business Processes
HB 08	Teamwork in Design
I&S 04	Model-Based Systems Engineering
S&R 11	Managing Uncertainty in Design
SD 12	Digital Interfaces and Interaction
PS 01	Panel Sessions
DE 09	Collaboration, Ideation and Sustainability
DW 13	Machine Learning in Design
H&W 06	Enhancing Wellbeing in Specific Contexts
I&S 05	Advancements in Systems Engineering 2
IBM 06	Understanding Customers
S&R 12	Sustainability and Resilience - Life Cycle Assessment
SD 13	Product and System Modelling 2
PS 02	Pannel Sessions
KN 06	Keynote: The Importance of Computing and Making in Design Research
CC	Closing Ceremony
Workshop	Workshop Sustainable Innovation
Panel	Panel Discussion on Digital

Scientific Committee

Scientific Committee

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Yildirim	Unal	Hubei University of Automotive Technology	China
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Formentini	Giovanni	Aarhus University	Denmark
Guzzo	Daniel	Technical University of Denmark	Denmark
Hansen	Andreas Claus	DTU	Denmark
Hansen	Claus Thorp	Technical University of Denmark	Denmark
Hansen	Zaza Nadja Lee	Danish Police Force	Denmark
Keldmann	Troels	Keldmann Healthcare A/S	Denmark
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Pigosso	Daniela	Technical University of Denmark	Denmark
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Al khatib	Ahmad	ECAM Rennes - Louis de Broglie	France
Anwer	Nabil	University of Paris Saclay	France
Aoussat	Améziane	ENSAM	France

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Pinquié	Romain	Grenoble INP	France

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Troussier	Nadege	Arts et Métiers ENSAM	France
Vallet	Flore	CentraleSupélec-Université Paris-Saclay	France
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Weil	Benoit	MINES Paris PSL Research	France
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Bender	Beate	Ruhr University Bochum	Germany
Beneke	Frank	University of Göttingen	Germany
Bursac	Nikola	Hamburg University of Technology (TUHH)	Germany
Chantzaras	Christos	Technical University of Munich	Germany
Dumitrescu	Roman	Fraunhofer Institute for Mechatronic Systems Design IEM	Germany
Engelhardt	Roland	Continental Teves AG & Co. oHG	Germany
Fay	Tu-Anh	Technische Universität Berlin	Germany
Forte	Sven	University of Kaiserslautern	Germany
Frankenberger	Eckart	Airbus	Germany
Gebhardt	Nicolas	Thyssenkrupp Marine Systems GmbH	Germany
Gericke	Kilian	University of Rostock	Germany
Göbel	Jens Christian	TU Kaiserslautern	Germany
Göhlich	Dietmar	Technische Universität Berlin	Germany
Graessler	Iris	Paderborn University	Germany
Holder	Daniel	University of Stuttgart	Germany
Husung	Stephan	Technische Universität Ilmenau	Germany
Inkermann	David	TU Clausthal	Germany
Jonuschies	Ingo	University of Rostock	Germany
Kiessling	Jonathan Max	University of Stuttgart	Germany
Kirchner	Eckhard	TU Darmstadt	Germany
Köhler	Christian	htw saar - Saarland University of Applied Sciences	Germany
Krause	Dieter	Hamburg University of Technology	Germany
Livotov	Pavel	Offenburg University of Applied Sciences	Germany
Matthiesen	Sven	Karlsruhe Institute of Technology (KIT)	Germany
Mertens	Kai G.	Hamburg University of Technology	Germany

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Paetzold	Kristin	TU Dresden	Germany
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