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SEMANTIC WEB SERVICES FOR THE KNOWLEDGE-BASED DESIGN OF MECHATRONIC SYSTEMS

Christian Bludau and Ewald G. Welp

Abstract

This paper summarizes results of work that has been done in the field of knowledge-based design of mechatronic systems. Because of the complexity of mechatronic systems their design process can be characterized as knowledge-intensive. In contrast to this fact, today available methods and tools poorly support context-sensitive retrieval and processing of relevant information. Therefore, the objective of this paper is to improve the understanding of Semantic Web technology as a basis for offering high-quality information services to interdisciplinary design teams. A central intention is to present a generic platform containing methods and tools for configuration and providing of such "intelligent" Semantic Web Services. These services are realized by a software agent using the Semantic Web as a dynamic and natural language knowledge-base.

Keywords: knowledge-based design, mechatronic systems, Semantic Web, services

1. Introduction

Globalization of the markets entails growing competition in industry. In order to remain in business it is necessary to handle time, costs and innovation pressure by optimizing products as well as processes. Considering these facts, it is insufficient to optimize solely the costs of existing products. New innovation strategies have to be established, which either extend known product functionalities in conjunction with increasing quality or lead to new product functionalities and products.

Mechatronic systems play a decisive role in this context. They have the ability to measure physical values by sensors, process these values and respond to occurring events via actuators [1]. Therefore mechatronic systems are often considered as "intelligent". Their development process comes along with multidisciplinarity, complexity as well as wide solution spaces. To cope with these challenges and to realize integrated systems with optimal behaviour, suitable methods and tools have to be established.

In this context knowledge-based product development gives new opportunities regarding to reduce knowledge deficiencies and to strengthen engineering creativity.

Solutions like Enterprise Information Portals, implemented by the software industry, promise information access anytime and anywhere. But noticeable limits can be found in the field of reasonable and context sensitive retrieval and processing of information. Inquiries are leading to a broad variety of answers, which have to be analyzed, reviewed and exploited regarding to each problem context. Searching for information about "beetles" is leading to answers related to motor vehicles as well as their natural archetype. In addition to that searching for "powerful motors" can not be answered by documents describing "300 KW aggregates". These and other deficits can primarily be traced back on insufficient comprehension of information meaning (semantics) by today's software solutions.

A noticeable improvement in this context is offered by Semantic Web Technology. In contrast to today's situation, where textual information can only be understood by human beings, the new approach allows analyzing and interpreting of documents by computers. This is realized by machine readable, meta-information, which can be integrated in the background of (technical) documents.

Nucleus of the Semantic Web and its technologies has been a contribution of the World Wide Web inventor Tim Berners-Lee "The Semantic Web" [2]. He describes an internet to come, where "WWW"-content can be enriched by semantics. This makes computer-supported discovering, exploiting and processing of data, information and knowledge much easier.

The Semantic Web relies on technologies, like Unicode[1], URI[2], XML[3], RDF[4] as well as OWL[5], which are arranged in a seven-layer-structure. XML builds the basis for storing information in web-documents. Besides the human readable and interpretable part, these documents contain machine readable semantic information founded on RDF standards. It can contain simple statements as well as complex rules.

Software systems - like agents - can utilize this approach to answer natural language queries as well as work on complex tasks autonomously. Technical descriptions of a product, found on a company website, can be the starting point of a software agent, which searches for similar, but much cheaper solutions in the World Wide Web.

2. Characteristics of Knowledge-Based Product Development

During the development of mechatronic systems engineers are confronted with manifold tasks and problems. To find appropriate solutions it is necessary to make use of creativity as well as factual and methodological knowledge. Therefore it is essential to offer methods and tools, which facilitates efficient and effective access to these resources.

As a result of an investigation in natural science literature, a well-defined specification of the term "knowledge" could not be found. However the interpretation of most definitions can hardly be distinguished from each other. According to these definitions knowledge is an accumulation of know-how, experiences and problem solution methods, which is useful to solve problems and cope with tasks in specific fields.

Knowledge-based product development means conscious and purposeful handling of development knowledge. Objective is to provide context-sensitive information, which e.g. helps to cope with design and simulation tasks or solve integration problems.

Starting from such a task or problem, the ambition is to make developers as fast as possible capable of acting. Therefore it is necessary to provide high quality data and information, which can directly be understood and applied by the engineers.

This is a major difference to information providing, which is often realized on the basis of inter- or intranet search engines. Information delivered by these engines is unstructured and of heterogeneous quality. Utilization requires time-consuming processing.

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[1] Unicode: standard for coding of symbols

[2] URI: **U**niform **R**esource **I**dentifier; unequivocal marking of information sources

[3] XML: E**x**tensible **M**arkup **L**anguage; description language for structured documents

[4] RDF: **R**esource **D**escription **F**ramework; description language for specification of metadata

[5] OWL: **O**ntology **W**eb **L**anguage; description language for specification of ontologies

Therefore acquiring, archiving and providing of knowledge are central challenges of knowledge-based product development. Main demands on methods and tools are:

- little effort for acquisition of knowledge,
- generic archiving of knowledge,
- context sensitive providing of knowledge,
- integration of methods and tools into existing working and software environments.

Considering these facts, knowledge-based product development has the potential of enhancing creative and iterative working and revealing useful innovation potentials.

3. Related Work

In this section central insights and results of relevant research areas are presented and classified. Relevant research areas are

- Mechatronics,
- Knowledge Management and Knowledge Based Product Development as well as
- Semantic Web, Semantic Web Technology and Agents.

3.1 Mechatronics

Because of the complexity of mechatronic systems, their development process is knowledge intensive. This fact neither is considered in available methods nor in tools provided by research institutes or companies.

Current research activities focus on methods regarding to engineering processes and domain integration [e.g. 3]. But enhancing efficient and effective development processes by active and systematic use of the resource knowledge is not discussed. In the field of software tools, research activities concentrate on supporting integrated development processes as well as domain independent product model interchange [4, 5]. Especially libraries containing approved solution elements are proposed as a basis for knowledge-based design [6]. But as a passive information source (time-consuming analysis by the engineers) their benefit is smaller than the benefit of an active, computer-supported and context-sensitive providing of knowledge.

An approach of active knowledge providing is considered in the knowledge-based system WISENT [5] as well as Schemebuilder Mechatronics [7]. Both are equipped with knowledge processing systems. But also these solutions have some major limits: high knowledge formalization effort, use of proprietary archiving formats and encapsulated knowledge bases.

3.2 Knowledge Management and Knowledge Based Product Development

Knowledge management and knowledge-based product development play a key role in ruling increasing complexity of products and processes.

Knowledge management, particularly formed by economic sciences, offers a framework for establishing such an approach in industry [8]. But methods and tools developed by research institutes or offered by software companies often concentrate only on one aspect of knowledge management (e.g. acquisition, archiving, providing, …). Thinking about a platform of methods and tools for establishing knowledge processes must be characterized as underrepresented. The diverse software solutions are based on classic technologies and their outputs can not be integrated.

Knowledge-based product development, particularly formed by engineering sciences, made some important improvements by strengthening methodical approaches and better integration of tools in the work environment of developers [e.g. 9, 10, 11].

Knowledge processing systems, which are often a core component of offered software solutions, can be characterized as a valuable contribution to knowledge management. Indeed the formal design as well as the implementation and maintenance of knowledge bases are accompanied by high efforts and costs. From this proprietary knowledge archiving mechanisms and formats are often not profitable. PDM/PLM-systems, which are established in industry, granulate knowledge only up to the level of documents [12, 13]. So information included into the documents is not used for further computer-supported analysis and has to be read and interpreted by developers. Representation of information and knowledge by solution elements, like Gadgets or Features [e.g. 14, 15], are limited to special application areas (e.g. consistency check).

3.3 Semantic Web, Semantic Web Services and Agents

Semantic Web, Semantic Web Services and agents are research areas with high innovation potentials. This is true for each of these disciplines but especially for their interaction. Improvement of technology is leading to new application fields and vice versa.

Central parts of Semantic Web technology have already been standardized [e.g. 16]. Hence a certain degree of ripeness as well as constancy of the technical approaches can be assumed.

Applications are developed for domain specific and domain independent tasks [17, 18]. Solutions for engineering design are clearly underrepresented. In particular potentials of coupling Semantic Web, Semantic Web Services and agents are not used in the field of mechatronic design. Besides a lack of consequent service orientation, there is no work on methodical or tool fundamentals.

In particular potentials arising from an integrated view on Semantic Web, Semantic Web Services as well as agents in connection with mechatronic design are not utilized. Besides a consequent service orientation above all basic research on service methods and tools is still missing.

3.4 Conclusions

The analysis of existing solutions concerning knowledge-based design of mechatronic systems reveals some central insights and deficits.

Mechatronic design is a complex and knowledge-intensive process. Neither today available methods nor software tools consider this fact in an adequate way. Knowledge management and knowledge based development are suitable approaches to cope with product- and process-complexity. However methods and tools for knowledge-acquisition, -archiving and -providing barely attract interest as a solution to handle complexity in mechatronic design. Semantic Web technology, which allows processing of semantics by computers, is getting more and more sophisticated and standardized. This fact makes it very attractive in the field of knowledge based development. Nevertheless, synergies and potentials, which arise from coupling Semantic Web, Semantic Web Services and software agents, are not used in mechatronic design up to now.

4. SEMEC - A Platform for Generation, Linking and Execution of Knowledge Providing Services

Considering the described deficits, the institute for engineering design started research in the field of Semantic Web technology and applications.

Main focus is the realization of a platform, which enables engineers to configure and use knowledge providing services supporting the design of mechatronic systems. These services are realized by a software agent and use the Semantic Web as a dynamic and natural language knowledge base.

4.1 Overview

The Semantic Web Service platform SEMEC (SEMantic and MEChatronics, Figure 1) contains methods and tools for generation and execution of high quality knowledge providing services.

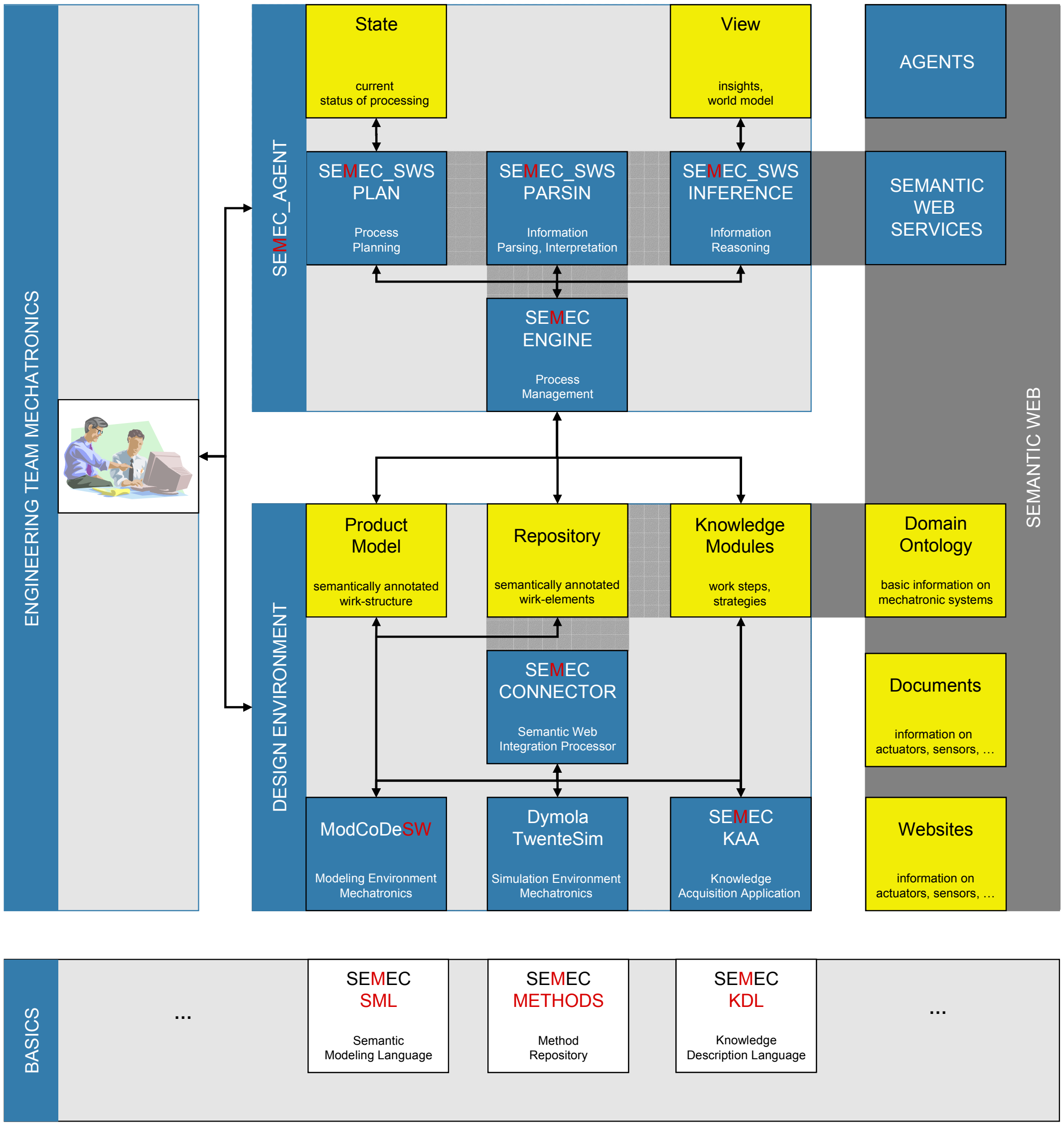


Figure 1. Semantic Web Service Platform SEMEC

These services support interdisciplinary design teams during the concretization of mechatronic concepts by providing context-sensitive knowledge. Knowledge means e.g. results of an inquiry regarding hydraulic actuators and appropriate alternatives, cheap sensors and their characteristics, integrated electronics and latest innovations, but also first dimensioning of a shape memory alloy wire, visualization of kinematics as well as calculation of dynamic behaviour and performance of a mechatronic system.

Main components of the platform are

- a semantic software agent,
- a semantic design environment as well as
- a method library and two description languages.

In addition to that

- a domain ontology mechatronics and
- a repository containing semantic descriptions of representative mechatronic wirk-elements

have been developed.

The software agent supports engineering teams during the conceptual design of mechatronic systems. It provides information and services considering the actual problem context. The semantic design environment offers tools for the creation of product and simulation models as well as acquisition of knowledge. The library contains methods for generation of new services, wirk-elements and ontologies. Beyond this there is a semantic modeling language for mechatronic systems and a knowledge description language for action strategies.

4.2 Semantic Web - A Natural Language Knowledge Base

In the last ten years the World Wide Web grew immensely. This is the reason why retrieving of relevant information becomes more and more complicated. Nowadays web searches are imprecise and yield to thousands of matches. Hence engineers face the task of reading each document retrieved in order to extract the desired information.

Semantic Web is the key to rule these problems. This new generation of World Wide Web will provide a wide range of intelligent services. Documents and Websites, which were mainly read and analyzed by humans until now, will be interpretable and processable by computers. Main contents of the Semantic Web are websites, documents, ontologies, Semantic Web services and agents.

Technical **Websites and documents** e.g. contain information and data about actuators, sensors, new materials etc. Besides information, which can be read and interpreted by human beings, there are so called “semantic annotations” hidden in the background of the document. These annotations contain object meta-information, like “DC_Motor hasInterface ElectricalToRotational” (Figure 2). This object-attribute-value triple is a statement, according to the Resource Description Framework (RDF). The W3C defines RDF as a foundation for processing metadata; it provides interoperability between applications that exchange machine-understandable information on the Web.

The **Domain Ontology Mechatronics** provides a shared and common understanding of mechatronic basics that can be communicated between people and heterogeneous and widely spread application systems. This ontology provides explicit conceptualizations that describe the semantics of technical information. Figure 2 shows a segment of the domain ontology, which describes the relations between MechatronicEntity, Wirk-Element and Interface. Basis for this description is the Ontology Web Language (OWL).

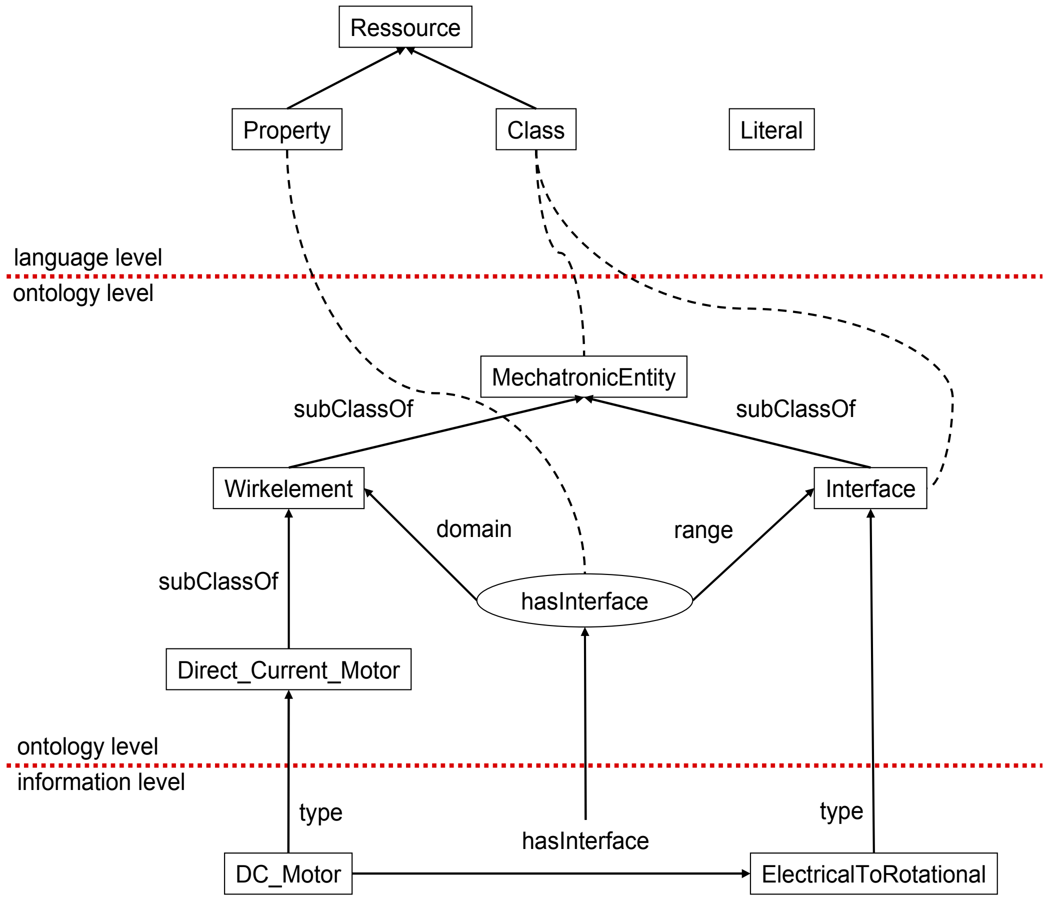


Figure 2. Relations between information, ontology and language level of the Semantic Web

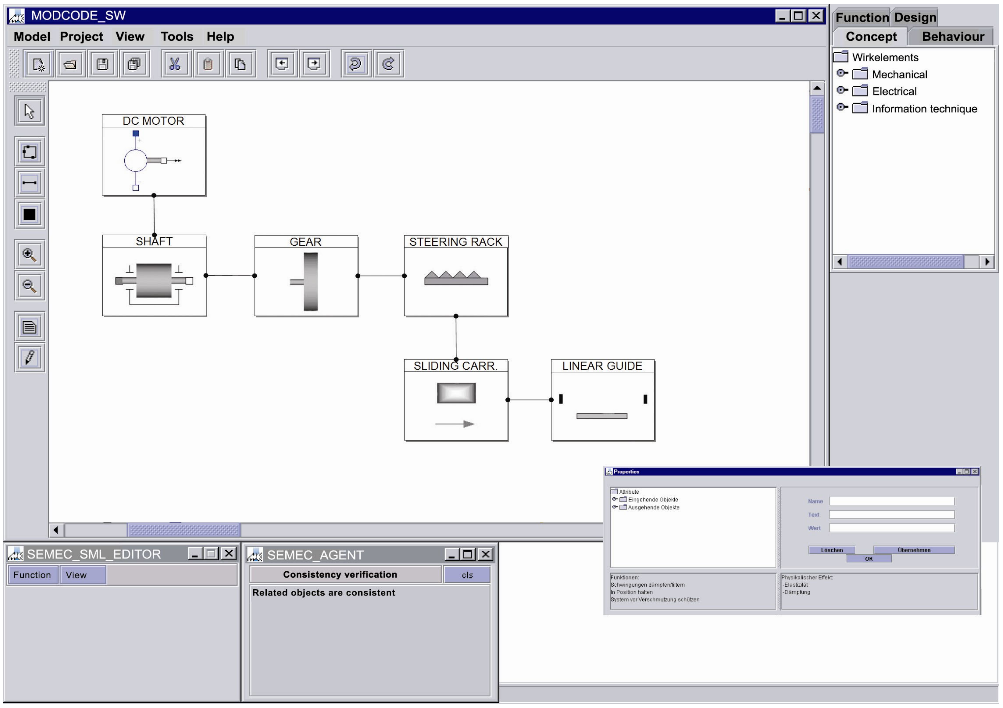
According to the W3C recommendation, “OWL is intended to provide a language that can be used to describe classes and relations between them”. OWL descriptions mainly consist of classes and properties, but also of cardinality and constraint definitions.

Semantic Web Services are web applications, which can be published, located, and invoked across the Web. Web Services perform functions, which can be anything from simple requests to complicated processes. Once a Web Service is deployed, other applications, like agents or other Web services, can discover and invoke the deployed services. Hence they have a key role in the evolution of the World Wide Web from a publishing medium to a genral service fabric. Examples are dimensioning or procurement services for shape memory alloy wires. Among others Semantic Web Services can be realized by software agents.

Due to IBM, **Agents** are software entities that carry out some set of operations on behalf of a user or another program with some degree of independence or autonomy. In this way they employ some knowledge or representation of the user’s goals or desires. Hence they can be characterized as mediators between the **Engineering Team Mechatronics** and the Semantic Web. They enable engineers to find, analyze and process the needed information and services and to concentrate on the design process.

4.3 Design Environment - Integrated conceptualization and evaluation of Mechatronic Systems by Semantic Development Tools

The development of mechatronic systems, which are composed of mechanical and non mechanical elements and components, is a special challenge for interdisciplinary engineering teams. Efficiency and quality of such development processes can significantly be increased by methods and tools, which help to cope with the different tasks of early design stages and rule the occurring complexity. Being aware of these facts **ModCoDe_SW** (Semantic Modeling System for Conceptual Design, Figure 3) has been developed at the institute of engineering design. It enables engineers of different disciplines to create a comprehensive mechatronic concept, based on so called "wirk-elements" fulfilling the required product functionalities.



Funktionen:
Schwingungen dämpfen/filtern
In Position halten
System vor Verschmutzung schützen

Physikalischer Effekt:
-Elastizität
-Dämpfung

Related objects are consistent

Figure 3. Semantic Modeling System for Conceptual Design - ModCoDe_SW

Configuration of a new concept is supported by a wirk-element **Repository** containing approved mechanic, electronic and software solutions for different tasks and problems. Results of the design process, the so called wirk-structures, are represented by a machine-processable **Product Model**.

Wirk-elements and -structures are being described by the **Semantic Modeling Language** (SML), a central part of the SEMEC platform. Founded on Semantic Web standards, this language enables any Semantic Web application to analyze and interpret the archived mechatronic concept.

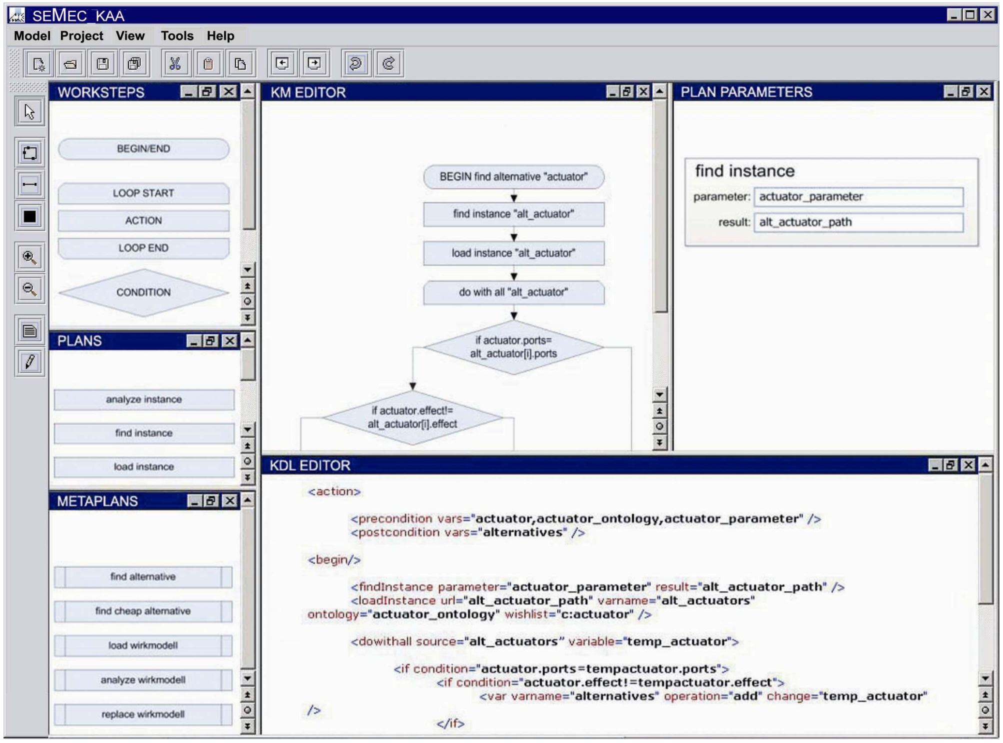
An example of such a description can be seen in Figure 4. *DC_motor* is an instance of *Direct_current-motor* described in the Domain Ontology Mechatronics. It has an *ElectricalToRotational* interface, which means that it has electrical values (e.g. current, voltage) as inputs and rotational values (e.g. angle, angular velocity, torque) as outputs. In this case behaviour of the system is described by three equations, which are associated with the *DC_motor*. Details of the equations are described in another instance.

```
<?xml version="1.0" ?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#" xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xmlns:owl="http://www.w3.org/2002/07/owl#" xmlns="http://www.owl-ontologies.com/unnamed.owl#" xml:base="http:….owl">

    <Direct_current_motor rdf:ID="DC_motor">

      <hasName rdf:datatype="http://www.w3.org/2001/XMLSchema#string">DC_motor</hasName>

      <hasInterface rdf:datatype="http://www.w3.org/2001/XMLSchema#string">ElectricalToRotationalInterface</hasInterface>

      <hasCurrentValue rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0.02</hasCurrentValue>
      <hasTorqueValue rdf:datatype="http://www.w3.org/2001/XMLSchema#string">0.016</hasTorqueValue>
      <hasVoltageValue rdf:datatype="http://www.w3.org/2001/XMLSchema#string">12</hasVoltageValue>
      <hasDegree_of_efficiency rdf:datatype="http://www.w3.org/2001/XMLSchema#string">80</hasDegree_of_efficiency>

      <hasBehavior_describedby rdf:datatype="http://www.w3.org/2001/XMLSchema#string">EquationA</hasBehavior_describedby>
      <hasBehavior_describedby rdf:datatype="http://www.w3.org/2001/XMLSchema#string">EquationB</hasBehavior_describedby>
      <hasBehavior_describedby rdf:datatype="http://www.w3.org/2001/XMLSchema#string">EquationC</hasBehavior_describedby>

    </Direct_current_motor>

</rdf:RDF>
```

Figure 4. Description of a Wirk-Element based on the Semantic Modeling language SEMEC_SML

Coupling of commercial software with the Semantic Web can be realized by using **SEMEC_CONNECTOR**. In a first step it has been equipped with functionalities for annotation of simulation models described in Modelica language. Hence these models e.g. generated with **TwenteSim** or **Dymola** can be processed by any Semantic Web Application and be used for further operations.

In addition to that, there is the Knowledge Acquisition Application **SEMEC_KAA** (Figure 5). It enables engineers to make their strategies for finding alternative solutions, latest innovations, reliable actuators or cheapest sensors explicit. These strategies can be configured by defining new or using approved worksteps, plans and metaplans in the KM Editor window.



find instance

parameter: actuator_parameter

result: alt_actuator_path

```
<action>

      <precondition vars="actuator,actuator_ontology,actuator_parameter" />
      <postcondition vars="alternatives" />

<begin/>

      <findInstance parameter="actuator_parameter" result="alt_actuator_path" />
      <loadInstance url="alt_actuator_path" varname="alt_actuators"
ontology="actuator_ontology" wishlist="c:actuator" />

      <dowithall source="alt_actuators” variable="temp_actuator">

            <if condition="actuator.ports=tempactuator.ports">
                  <if condition="actuator.effect!=tempactuator.effect">
                        <var varname="alternatives" operation="add" change="temp_actuator"
/>
                  </if>
```

Figure 5. Description of an action strategy by using the Knowledge Acquisition Application - SEMEC_KAA

Result of the knowledge acquisition process is a **Knowledge Module**, which determines proceedings of the software agent SEMEC_AGENT according to specific tasks or missions. The **Knowledge Description Language** SEMEC_KDL builds the basis for all strategy descriptions (Figure 5, KDL Editor Window). This language has been developed with the objective of easy handling by engineers and being processable by Semantic Web applications and agents.

4.4 SEMEC_AGENT - Assisting Development Processes by realizing Knowledge Providing Services

Semantic Web technology builds the basis for the service functionality realized by the software agent **SEMEC_AGENT**, which can be encapsulated in a Semantic Web Service. In this way the agent is able to understand the meaning of different information sources describing wirk- and solution-elements of mechatronic systems. Examples for such sources are product models, web sites, documents, ontologies as well as other agents and Semantic Web Services. Depending on the actual task or problem the agent uses different action strategies and is able to take preferences of different developers into consideration.

As shown in Figure 1, SEMEC_AGENT consists of four functional and two memory modules. Three of the four functional modules are Semantic Web Services, which means that the agent can configure itself dynamically depending on the actual task or mission.

SEMEC_ENGINE realizes the process management of the agent. It coordinates the planning, communication, and reasoning activities.

The Semantic Web Service **SWS_PARSIN** is responsible for the communication of the agent. It contains a parser, which analyzes incoming information (documents, websites, product models, knowledge modules, etc.) regarding to structure and content and an interpreter, which class information regarding to meaning and starts appropriate actions.

Often an agent mission cannot directly be completed by an action strategy described in one single knowledge module. But in many cases there is a particular combination of knowledge modules, Semantic Web Services or agent functionalities that would make the needed information or results available. Finding such a combination of knowledge modules (work steps, plans, meta plans), agents and web services is the task of the Semantic Web Service **SWS_PLAN**. With the help of planning techniques it can generate a complete action strategy automatically. Starting from the mission goal, the planning service uses a back-chaining and depth-first search strategy. If the proposed strategy is accepted by the engineering design team, it is executed by the agent.

Main task of the Semantic Web Service **SWS_INFERENCE** is the reasoning about information represented in product models, websites, documents and ontologies. It has the ability of drawing conclusions and to develop new insights by discovering of implicit knowledge. The service functionalities mainly base on first order predicate logic and transitivity as well as operations founded on set theory. For example the statement *“all technical systems base on physical effects”* combined with the statement *“all actuators are technical systems”* leads to the statement *“all actuators base on physical effects”*. Thus the agent gets powerful instruments for dealing with new tasks, where relevant knowledge must be derived from existing statements.

The agent has two “memories”. The **View** memory remembers insights gained during task processing and can be characterized as the agents’ view on the world. The **State** memory saves provisional results of task processing building the basis for next steps.

5. Case Study

During the design and realization of the Semantic Web Service Platform SEMEC, different case studies have been developed with the objective of getting valuable hints and impulses for the optimization of this approach.

One of these case studies is a Semantic Web Service providing suggestions for alternative concepts during the knowledge-based design of a DVD-ROM reading head drive. Starting point is a roughly described first idea (Figure 6). It is configured in the ModCoDe_SW modeling environment by using a repository of approved wirk-elements. Examples for such wirk-elements are actuators, sensors or basic elements, like linear guides. Result of the design process is a product model containing the semantically annotated wirk-structure. This wirk-structure builds the basis for next steps executed by the agent.

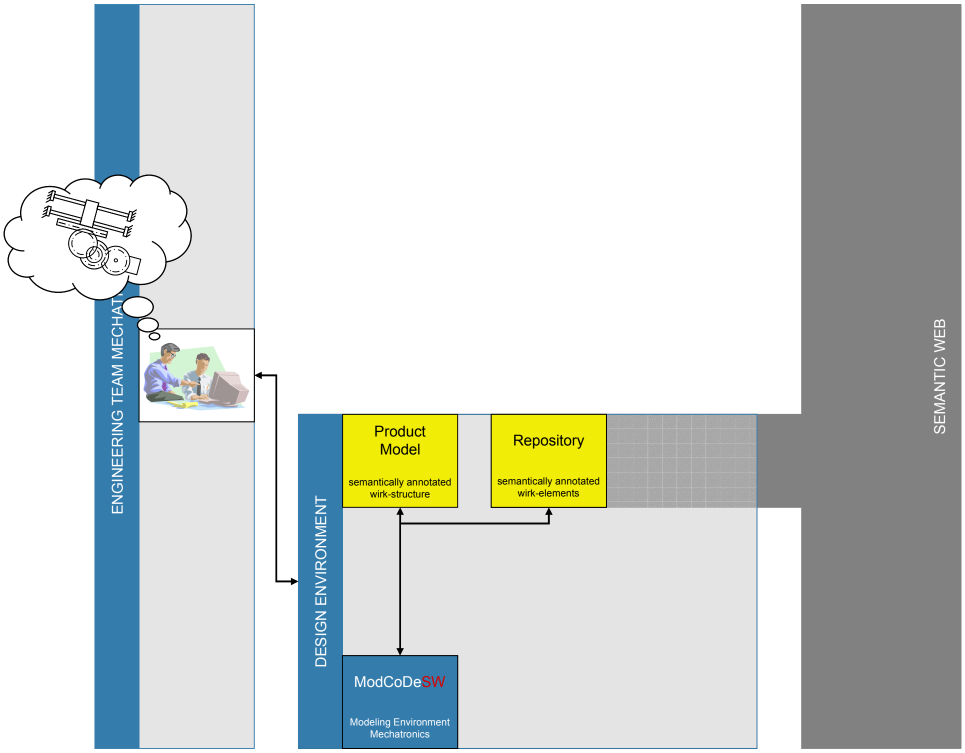


Figure 6. Case Study: Knowledge Based Design of a DVD-ROM Reading Head Drive

In a first step SEMEC_AGENT analyzes the semantically annotated product model (Figure 7). Simultaneously it focuses on relevant sections of the domain ontology and acquires basic information on mechatronics, like

- mechatronic systems consist of actuators, sensors and information-processing components,
- actuators consist of positioner, transformer and converter,
- components realize one ore more function(s),
- functions base on physical effects,
- components have characteristics and properties,
- characteristics of a component are (besides others) physical in- and output values.

Strategies described by work-steps, plans and meta-plans in knowledge modules build the basis for the proceeding of the agent. It considers important restrictions and constraints e.g. given by the product model or named by the engineering team.

After that it analyzes and interprets documents and web sites of the Semantic Web regarding to the enclosed data and information. It rates retrieved components and solutions using criteria described in the knowledge modules. A simple criterion may be the equivalence of the physical in- and output values of the components.

If no appropriate solution can be found, the agent falls back on basic knowledge explained by the ontology. For example it does not search for actuators only; it also searches for alternative actuator sub-components, like positioner or transformer, to realize a needed output value.

Besides information and components offered in websites and documents, the agent can also consider approved wirk-elements archived in the repository.

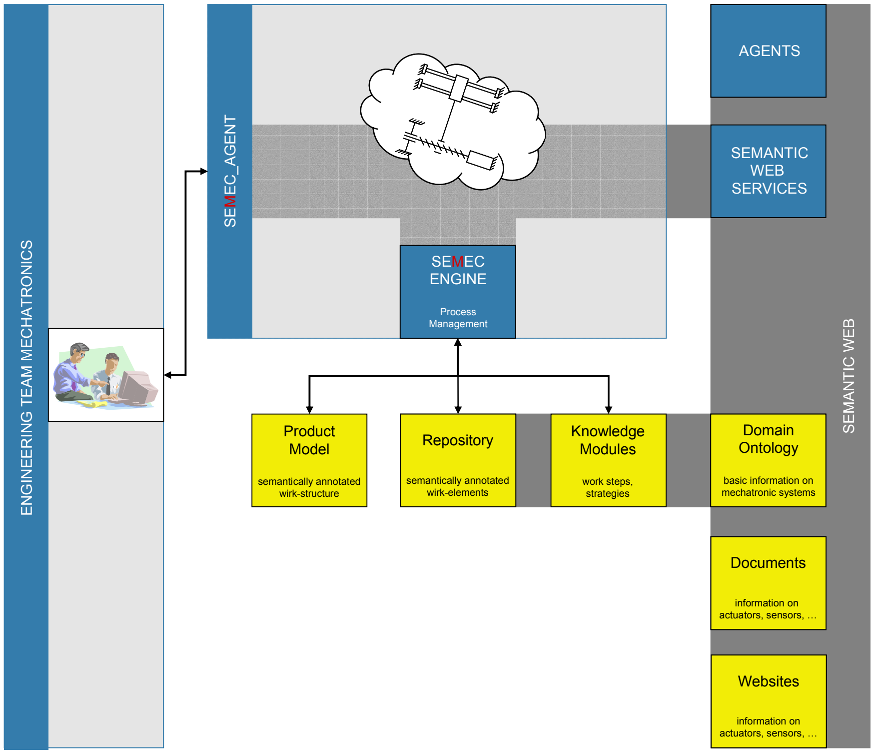


Figure 7. Case Study: Knowledge Providing Service

At the end the agent configures the alternative conceptual design by instantiating a new product model. This model can be visualized in the ModCoDe_SW environment.

In addition to that the services realized by the software agent can be complemented by other Semantic Web Services. For example it can be supported by a service, which provides efficiency or cost calculations. Also it can communicate with other agents, which e.g. realize monitoring of websites regarding to latest innovations realized by research institutes or companies.

Furthermore the agent has the ability to optimize its strategies regarding to priorities of the engineering team. Depending on given feedback it is able to prefer e.g. special classes of actuators or component materials.

6. Conclusions

Semantic Web technology is a suitable approach for the knowledge-based design of mechatronic systems. It provides a wide range of possibilities and new potentials.

First tests of SEMEC show, that already a small stock of semantically annotated web sites, documents and product models in combination with an agent and domain ontology is able to deliver very interesting and helpful information for developers. In this way Semantic Web Services open useful views on different information sources considering the context of a design task.

However not only providing of higher information quality is interesting. Especially design services using processed semantics for performing complex tasks lead to a significant improvement compared to today's solutions. This approach allows dealing effectively and efficiently with the resource knowledge. It helps to focus on innovation potentials of mechatronic systems and to strengthen creative, iterative and interdisciplinary design.

7. Outlook

The institute of engineering design is already working on some remarkable improvements, extensions and applications of the Semantic Web Service platform SEMEC.

At first there is the development of methods and tools supporting semantically annotation of technical websites and documents. Herewith it is possible to push fast growing natural language knowledge bases.

In addition to that the Semantic Modeling Language SML is being extended by SWRL language elements. SWRL (Semantic Web Rule Language) enables users to formulate rules, which can be analyzed and processed by Semantic Web applications. With that for example it is possible to describe the behaviour of a mechatronic component by rules. Also different states of a system and their transitions can be formulated.

SEMEC_CONNECTOR will be improved by realizing bi-directional coupling of applications. In that way a Semantic Web document can be the basis for a Modelica simulation model.

Furthermore the institute is working on a repository of generic work steps, plans and meta-plans (knowledge modules) to simplify knowledge acquisition for agent strategies. This repository will be founded on Knowledge Description Language KDL.

Also first steps have been done in the field of realizing a set of helpful Semantic Web Services. These services will base on methods developed at the institute of engineering design. An example is cost estimation in early design phases.

Discussions with and tests in industry are delivering valuable hints and impulses for the optimization of SEMEC.

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Christian Bludau Ruhr-University Bochum Institute of Engineering Design 44780 Bochum Germany
Tel: +49 (0)234 / 32-22011 Fax: +49 (0)234 / 32-14159 E-mail: bludau@lmk.ruhr-uni-bochum.de
URL: http://www.lmk.ruhr-uni-bochum.de/