INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'07
28 - 31 AUGUST 2007, CITE DES SCIENCES ET DE L'INDUSTRIE, PARIS, FRANCE

TUG TOGETHER – SUPPORTIVE TOOL FOR DISTRIBUTED DESIGN TEAMS

Wolfgang Lauer[1], Alexandra Nißl[2], Henrik Breadt[3], Udo Lindemann[4]
[1,3,4] Technische Universität München
[2] Wallinger & Partner

ABSTRACT
Surveys show that efforts and efficiency of geographically distributed design teams can be improved by an enhancement of the informal communication between product development teams [1]. We developed a tool called *Tug Together* (see figure 1), that allows distributed rope pulling between such teams using a remote connection. Different modes of operation enable tugging against each other, together to reach a common goal, or even alone versus a virtual opponent. *Tug Together* is a force feedback-system that uses the internet for data exchange. First testing revealed a high potential of *Tug Together* for enhancing the exchange of informal information to support the evolution of a distributed team. Further tests will examine the effects of *Tug Together* on the social interaction of the observed people not only in design teams but also in other environments, such as so called *Media Spaces*.

Keywords: Computer supported collaborative play, distributed design, distributed teams, remote interaction, informal communication, haptic interface, media spaces, third places

1 INTRODUCTION
Because of increasing complexity of technical products and product development processes more specific knowledge is needed to face challenges like short time-to-market and high cost efficiency. Nowadays, the required knowledge is mostly collected through cooperation and outsourcing [2]. The consequence is a higher need for distributed and collaborative design teams, especially geographically distributed teams. This special kind of an engineering design team is supported by modern information and communication technology, which enables distributed teamwork to achieve more efficient work processes, reduced travelling needs and increased opportunities for personal interaction [1]. Engineering design fundamentally requires social interaction; hence it is important to provide tools and methods to facilitate this interaction in distributed teams. Another important aspect is informal communication, which plays a major role in the design process. It can even have a greater influence on work processes than formal communication [3]. A lack of informal communication can handicap distributed teamwork or even prevent collaboration [4]. Therefore it is the key to success to adequately support informal communication processes and social interaction [1].

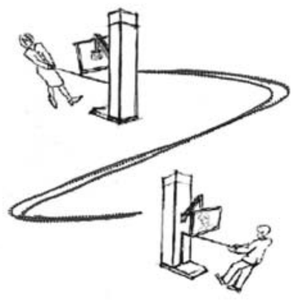

Figure 1. Distributed Rope-Pulling

So far only information and communication technology tools, such as broadband conferencing, shared applications and whiteboards are used to support communication in the field of collaborative work. Also phone, email and instant messaging contribute to the exchange of information between groups.

However, these tools only appeal to the senses of hearing and sight. To include the sense of touch, tangible user interfaces (TUI) can extend the range of tools, which facilitate social interaction [5]. This improves personal interaction by giving the persons a sense of physical proximity as if they were in the same room [4].

Providing the haptic dimension is expected not only to help establishing informal communication in distributed design teams but also extending possibilities in computer supported collaborative play (CSCP). Prior research addressed the potential of computational technologies in public spaces and stated their usefulness for supporting social interaction [6, 7]. So called *Media Spaces* or *Third Places* [8] seize the suggestion of the proximity of people by implementing videoconferencing systems extended by haptic interfaces.

For the realisation of the haptic between the geographically distributed persons the idea has been born to develop a rope-pulling tool named *Tug Together*. It links distributed persons by force feedback to each other. Rope-Pulling also known as Tug-of-War creates new possibilities to improve the exchange of informal information. It can be used to loosen stringent meetings or to give space for social interaction in any field of application. A schematic view of distributed rope-pulling is shown in figure 1. Though the effect of Tug Together is considered to contribute positively to the teambuilding process, it has to be kept in mind that this research concentrates on the support of informal communication and social interaction. Other influencing factors on successful teambuilding are not addressed in this paper.

2 CONCEPT

For the appropriate design of *Tug Together*, various influences of the environment of distributed teams are considered during development, e.g. competitiveness and team spirit. For example different play modes, such as a team mode and an opponent mode, have been realised to attend different aspects of the evolution of a team. While the opponent mode should enhance competitiveness between the team members to generate more productivity, the team mode should improve the togetherness of the team to facilitate communication which leads to better performance [9].

In addition to collaborative work, the diversity of play modes makes it more interesting for collaborative play especially in *Media Spaces*. *Tug Together* attends the play instinct and encourages interaction with distant people and even strangers. The goal is to lower the inhibition threshold at first contact and to use a TUI like *Tug Together* for the creation of a free play atmosphere in an adult domain. This is expected to enhance the attitude of easily establishing interpersonal communication [10], which is important for distributed teams as well as for Computer Supported Collaborative Play.

3 DESIGN

The whole system consists of two stations called Tug-Together-Points (TT-Points), which are outlined schematically in figure 1. An abstract view on the system`s components is shown in figure 2. It shows the set up of one TT-Point. While the user pulls the rope data exchange to the other TT-Point is provided by the internet. It consists of a videoconferencing system and force feedback system. The videoconferencing system provides the visual and auditory information to the users, while the force feedback system enables the haptic connection. The TT-Points represent the force feedback system and are the main focus of this paper. The following overview gives information to the setup and functionalities of the TT-Points.

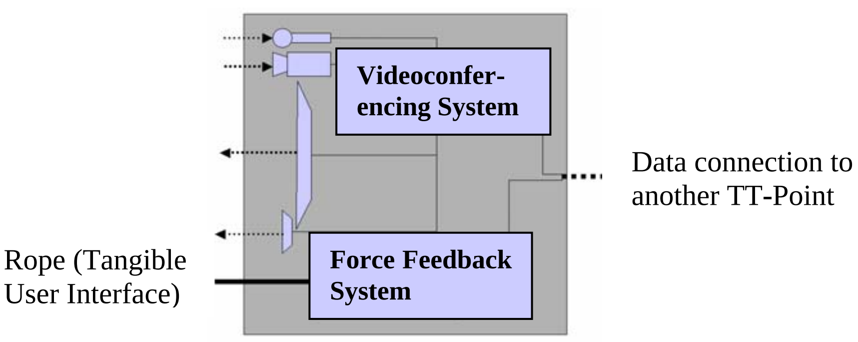

Figure 2. Conceptual view on the Tug Together system

3.1. Overview

Tug Together is a force feedback-system that connects two persons who are geographically separated. A 3-D computer model of *Tug Together* is shown in figure 3 and will be described in the following sections. An important goal for the design of this device is to provide high mobility, so Tug-Together can easily be installed at companies. Thus the housing is designed with a special contact surface. This surface ensures the force closure between the user and the device. Hence, the Tug-Together-Device does not have to be mounted to the floor or wall. Furthermore alternating current (230VAC) and basic internet connection over PC is required for operation.

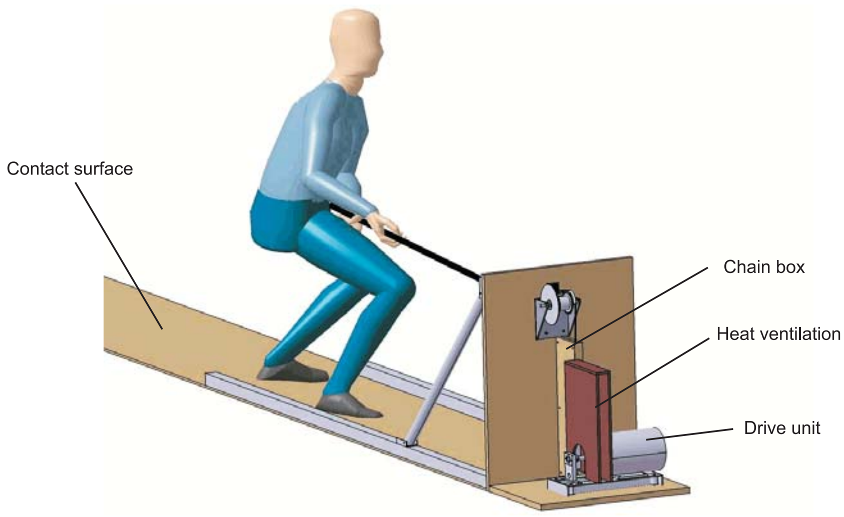

Figure 3. View of the 3-D computer model of a Tug Together Point (TT-Point)

3.1. Hardware

The force at the rope is generated by a combination of an asynchronous motor and a magnetic clutch (including control components) (see figure 3, Drive unit). The clutch allows transmission of the force independently of the speed of the rope (slip). This means that the force at the rope can even be provided properly if the rope does not move, which is essential for the application of Tug-Of-War, see figure 4.

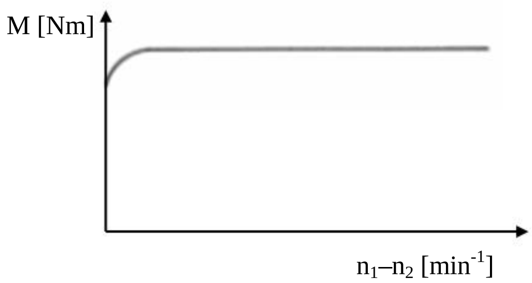

Figure 4. Graph of momentum independent from revolutions per minute of the slip

The clutch transmits the force by a powder consisting of magnetic particles, which are controlled by voltage respectively a magnetic field. The stronger the magnetic field the stronger the connection of particles is. In consequence, the particles cause high friction at high momentum and high difference of the revolutions per minute of the drive end and the output end. Since this application (Tug-of-War) causes long periods of no significant movement of the rope, the temperature of the drive system reaches the limits of temperature very fast. In consequence, a heat ventilation system is built around the clutch using a bimetallic switch to control heat regulation and cooling (see figure 3). The system starts cooling as soon as the temperature rises above 75°C. The ventilation itself is realised by a fan with constant revolutions per minute, which is turned on and of by the bimetallic switch. The heated air flow is lead through a pipe to the outside of the housing. Other openings in the housing provide the exchange of hot and cool air, which is needed to protect the sensitive electronics inside.

The control of the output force at the rope is implemented in a microcontroller system called C-Control II. The working principle of the control is presented in section 3.2., and is called *Virtual Spring*. The maximum force provided at the rope is 900 N at a maximum speed of the rope of 0.83 m/s.
By using a chain drive and a transmission hub in serial connection, the transmission ratio can be increased. Therefore the drive unit can be designed compact and low weight (15kg). The chain drive is connected to the drive end of the transmission hub. A second chain is wrapped around the output end by 90° and attached to the rope (see figure 5). It is possible to pull the chain back and forth without a rope drum, because the loose part of the chain folds itself into a box by its self-weight and gravity. The length of the second chain provides 4 m of movement of the rope.

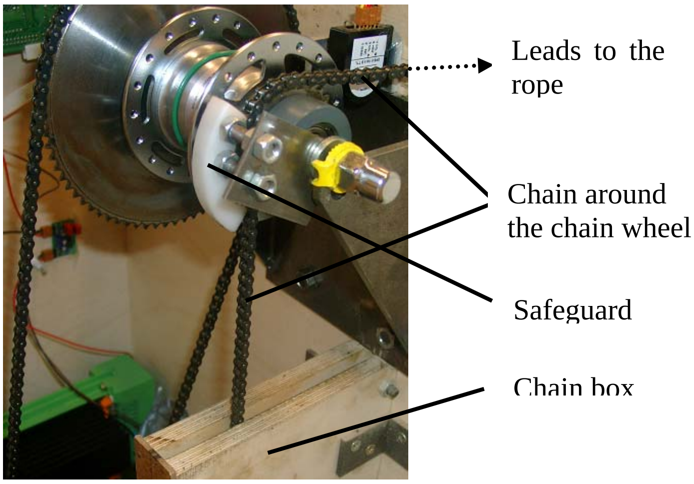

Figure 5. Chain wrapped around the chain wheel by about 90°

Because of the single phase operation of the asynchronous motor, reduction of vibration and noise is needed. Thus the asynchronous motor is mounted on shock-absorbers. Furthermore a control panel is installed to choose different application modes and adjust required parameters like the spring constant or the resolution of increments, also see section 4.
The contact surface where the user stands on is attached to the wooden housing and assures force closure. The length of the contact surface is 4.5 m and can be folded to provide even faster installation of the device. The folding mechanism is designed like an accordion. Once the contact surface is folded, it can be attached to the housing in a compact package. Rolls on the lower side of the housing facilitate the movement of the device. No additional device for transportation of Tug-Together is required. This guarantees high flexibility in transportation means.
The visual and auditory data is transmitted by conventional videoconferencing systems or by low data rate web cams apart from the TT-System. It supports the feeling of proximity and also gives visual feedback of the counterpart.

3.2. Control

The C-Control II, the core element of the control, is a microcontroller based platform. It is programmed in C2, a language similar to C++. The software controls force at the clutch and data exchange of the two connected *Tug Together* stations (TT-Points). The connection and force feedback is realized by a so called virtual spring, which is programmed and implemented in the microcontroller (see figure 6).

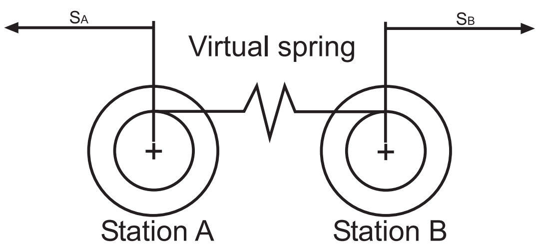

Figure 6. Principle of the virtual spring

Basis of the virtual spring is the spring formula $F = c * x$ (F: Force, c: spring constant, x: expansion), which allows calculating the force by only measuring the incremental path of the ropes (s_a, s_b). The use of expensive force sensors and the need for high bandwidths can be avoided. The programmed virtual spring changes its length dependent on the position of the ropes and calculates the correspondent force. Then the force is created at the TT-Points by the automatic software control which adjusts the magnetic clutch to given values. Because of the high value of the spring constant the expansion of the virtual spring is just barely sensible at the rope by the users. So it seems to be like a real rope between the users. Since nothing but incremental values of the path have to be exchanged between the TT-Points, only a small data rate has to be transmitted. Transmission of data is performed using TCP over the internet.

4. APPLICATION

Tug Together supports informal communication using different play modes. There are an Opponent Mode, a Virtual Opponent Mode, a Single Player Mode and a Multi Player Mode. The Single Player Mode and the Multi Player Mode are used in connection with a dexterity game. The goal of the dexterity game is to collect falling virtual balls with a cursor that is controlled by the movement of the rope. Generally, special parameters, such as spring constant, length of rope and basic force can also be adjusted at the control panel before starting the session. This influences the created force at the ropes, e.g. that the small force of a weak user can be enforced at the other TT-Point.

4.1. Opponent Mode

The basic idea of rope pulling is to compete with an opponent for the win. This competition is addressed by the Opponent Mode. To start a session, the rope has to be pulled out slowly for about 2 m. That way the users increase the tension of the rope until it is spanned. It is comparable with real Tug-Of-War, when the rope lies on the ground and has to be picked up and spanned for the initial position. At this position, the users feel each other’s force and start to pull for the win. When the loser’s rope has been pulled in to the block at the *Tug Together Point* the session is over.

The goal of the Opponent Mode is to stress the physical aspect. It releases competitiveness, supports sportive activity and creates a communicative atmosphere between the users. In addition, the installed videoconferencing system provides visual and auditory information.

4.2. Virtual Opponent Mode

If there is no partner to play with, an opponent is simulated in the Virtual Opponent Mode. A computer-generated behaviour and an animated graphical representation of the virtual opponent helps to create a realistic environment. The graphics include information of the current relative position of the virtual and real user, see figure 7. It is indicated by the height of the bars, which change according to the positions of the cursors/rope. The more the user pulls out the rope the higher is his/her bar. The user has to pull until his/her bar reaches the top to win.

Figure 7. Graphics of the Virtual Opponent Mode

4.3. Dexterity Game

In the dexterity game the user has to collect falling virtual balls in a virtual environment. The graphics of the game are projected onto the screen in front of the TT-Point (see figure 8).

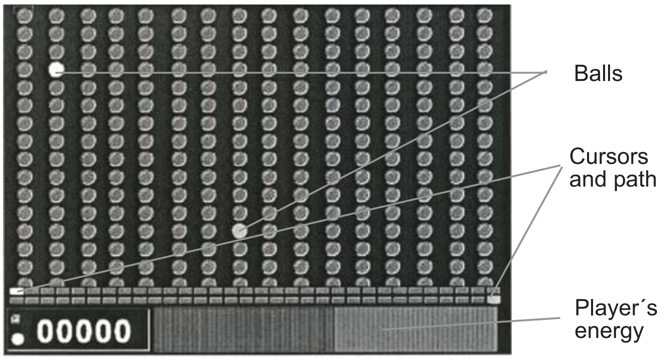

Figure 8. Screenshot of the game

Virtual balls drop from the top of the screen and can be collected by directing a cursor right underneath the ball until it hits the cursor. The cursor is controlled by the movement of the rope and slides horizontally in both directions. Its path (two cursors and two paths in Multi Player Mode) is indicated on the bottom of the screen. Underneath the cursor a bar indicates the player's current energy and score. While every collected ball increases the energy and the score, every missed ball turns into a virtual bomb and reduces player energy. In addition to energy reduction, the virtual bomb causes a shock of force and a sudden movement of the cursor. When the player's energy is spent totally the game is over. The dexterity game can be played either in Single Player Mode or Multi Player Mode as described in the following subsections.

4.3.1. Single Player Mode

The dexterity game can be played in a Single Player Mode. It allows playing without another user and works as it is described above. The rope has to be pulled long ways to collect the balls and the user needs to move faster than in other modes to reach a high score.

4.3.2. Multi Player Mode

In comparison to the Single Player Mode, in Multi Player Mode there are two cursors, one for each user. The cursors are connected to each other by the *Virtual Spring* (see section 3.3) to create dependency. In the beginning the rope has to be pulled out until it is spanned. While both users pull the rope the cursors move in each other's direction until they cross over. At this point, the crossed cursors indicate visually that the rope is spanned. Pulling further leads to a higher tension of the rope since the virtual spring is stretched more. The force between the users allows to move back and forth, which is also indicated by the horizontal movement of the cursors. That way, users can collect falling balls like in Single Player Mode, except for the fact that their movement depends on each other. If the team wants to catch a ball, they have to move coordinated and can not act independently. Since the force is calculated using the virtual spring, the distance between the cursors/users changes the force at the rope. The longer the distance the stronger the force is. The tension of the rope decreases, if the cursors/users come too close. If the cursors even cross back, no force is created by the TT-Point. The lack of force from the TT-Point prevents the user to move towards the TT-Point with appropriate velocity and thus moving the cursor in both directions. Though there is a basic force of the TT-Point and the game could still be played, no balls can be collected, if the rope is in loose condition in relation to the other user. To overcome this situation, both users pull back like in the beginning until the cursors are crossed over and the force is built up again. In case of any violations to these restrictions the already described consequences take effect.

In relation to collaborative work, the Opponent Mode and the Virtual Opponent Mode support competitiveness while the Multi Player Mode improves togetherness. The fixed connection between the users forces them to act coordinated and fulfil a common goal. It teaches team work and loosens the reserved atmosphere in the first phase of a team building process. This leads to the conclusion that the inhibition threshold of interaction can be lowered using *Tug Together* in the beginning of interpersonal contact.

5. EVALUATION

First evaluation of *Tug Together* was not empiric, but proved the creation of competitiveness of Tug Together since most of the test persons pulled the rope harder to win the competition. The selection of different test persons was randomly. The spectrum of persons included infants, young people and adults, who showed big differences according to strength and weight. Specific information was not acquired from the people, because it was not the objective to give empiric evidence. The goal has been to identify possible resonance of spontaneous users to the concept of Tug Together. The positive feedback supports the investment of future work. Though empiric experiments have yet to be done for statistical evidence (see section 7), the experiences with first test rounds proved the quality of the Tug Together concept. Further evaluation will concentrate on scientific issues like the effect of *Tug Together* on the human behaviour in the beginning of interpersonal contact between locally distributed persons.

From the technical point of view, an endurance test has been arranged. 35 test persons used the device for 5 consecutive hours. During the tests no fatigue or malfunctions have been recorded. The reliability of the system has been assured. Additionally the characteristics of the system's temperature under long term load with only short shutdowns have been observed. The cooling system works sufficiently and keeps temperature under the critical limit (< 85°C). The redundancy of intercontinental data exchange between *TT-Points* has not been examined yet and is planned to be arranged as soon as possible.

6. FUTURE WORK

Our special interest is the placement of Tug Together in the field of Media Spaces, computer supported collaborative play (CSCP), and a prognosis of chances in industrial product development processes. Business contacts are to be established to promote the system as well as to improve design and operator convenience. It is also aimed on the improvement of the remote connection and higher failure resistance of the data communication. The system can be improved by easier installation of the peripheral computers and integration of a module for internet communication. Further features of the game play and play modes as well as a higher level of graphics will be added to the dexterity game. An empiric evaluation has not been done yet, but is planned for the near future. The approach for such an evaluation will include a set of test persons, who are representative for a great bandwidth of users. The percentile will be considered as well as the behaviour of the users. Several scenarios will also be included e.g. one task of the test persons will be to pull as fast as possible. Another scenario will give the task to pull for the longest time possible. These two exemplary scenarios give clues to the endurance and the maximal power of the Tug Together system. Furthermore the behaviour of the test persons influences the working of the machine directly and has been addressed in the design of the system from the start. Further evaluation of the effect and acceptance of Tug Together lies in the focus of future examination.

7. CONCLUSION

The Tug Together is an innovative tool that creates new possibilities to interact with distant people. It allows physical contact between physically distributed people based on the game *Tug-Of-War*. The Tug Together consists of two single identical stations, which are connected over the internet. The software control connects the two stations by a virtual spring (software), which allows damping latencies of data exchange. The application itself attends the play instinct, loosens stringent environments and overcomes inhibitions of first interpersonal contact. Mainly developed for the support of the team building process in distributed design teams, other applications like fitness, spare time activities and training of dexterity can be considered. Especially *Media Spaces* reveal high potential, where *Tug Together* could be added to support social interaction. It could be used occasionally by locally distributed people to facilitate their interaction. The range of play modes reaches from Single Player to Multi Player, which covers the support of competitiveness and team work. First evaluation of the feedback in the public has been done. However, empiric evaluation and studies have to be done to test functionalities and to identify the effect of Tug Together on the team building process in the design process.

8. ACKNOWLEDGMENTS

Special thanks to all who have contributed to the development of *Tug Together* and especially Professor Lindemann for supporting the project.

REFERENCES

[1] Johanson, M., Törlind, P. Mobility Support for Distributed Collaborative Teamwork. *Electronic Journal of Information Technology in Construction*, Aug. 2004.

[2] Gaul, H.-D., *Verteilte Produktentwicklung-Perspektiven und Modell zur Optimierung.* PhD-Thesis, Technische Universität München, Germany, 2001.

[3] Preece J., *Human-Computer Interaction*, Addision Wesley, 1994.

[4] Kraut, R. E., Fish, R. S., Root, R. W., and Chalfonte, B. L. Informal Communication in Organizations: Form, Function, and Technology. *Human Reactions to Technology: The Claremont Symposium on Applies Social Psychology,* Beverly Hills, CA, 1990 (Sage Publications).

[5] Ishii, H., Wisneski, C., Chun, B., Orbanes, J., Paradiso, J. PingPongPlus: Design of an Athletic-Tangible Interface for Computer-supported Cooperative Play. *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Chicago, Il, 1999,* pp. 394-401.

[6] Rogers, Y., Brignull, H. Subtle ice-breaking: encouraging socializing and interaction around a large public display. *In Public, community and situated displays: Design use and interaction around shared information displays*, *CSCW '02 Workshop Proceedings*, New Orleans, Louisiana, USA, November 2002.

[7] Yoon, J., Oishi, J., Nawyn, J., Kobayashi, K., Gupta, N. FishPong: Encouraging Human-to-Human Interaction in Informal Social Environments, CSCW 2004, November 6-10, 2004, Chicago, Illinois, USA.

[8] Oldenburg, R. (ed). *Celebrating the Third Place: Inspiring stories about the "Great Good Places" at the Heart of Our Communities.* Marlowe & Company, New York, NY, 2000.

[9] Scholl, W. Grundprobleme der Teamarbeit und ihre Bewältigung. *In Management von Teams. Theoretische Konzepte und empirische Befunde (3rd edition).* Germany, Wiesbaden, 2004.

[10] Mandryk, R.L., Maranan, D.S., and Inkpen, K.M. (2002). False Prophets: Exploring Hybrid Board/Video Games. *In Conference Supplement to Conference on Human Factors in Computing Systems (CCI '02)*, ACM Press, New York, NY, 2002, pp. 640-641.

Contact: Wolfgang Lauer
Technische Universität München
Institute for Product Development
Boltzmannstraße 15
85748, Garching
Germany
+49(0)89/289-15136
+49(0)89/289-15144
WolfgangLauer@pe.mw.tum.de
http://www.pe.mw.tum.de