INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'09
24 - 27 AUGUST 2009, STANFORD UNIVERSITY, STANFORD, CA, USA

USER-DESIGNER COLLABORATION IN THE DESIGN PROCESS OF SURGICAL INSTRUMENTS: NEW ASPECTS FOR ANNOTATION AS A COMMUNICATION TOOL

Onur Hisarciklilar, Rahi Rasoulifar, Jean-François Boujut, Guillaume Thomann and François Villeneuve
G-SCOP Laboratory, Grenoble Institute of Technology, Uni. Joseph Fourier, CNRS

ABSTRACT

Today, collaboration is no more limited to the designers' sphere. In particular, the design of products or systems dedicated to expert users requires the active participation of the users themselves. The aim of this paper is to explore the design collaboration process between designers and expert users in the specific case of new surgical instruments. Two design meetings have been studied; one technical design review without the user, and one design validation meeting with the expert user. Designers were using an annotation tool as a communication support during the design process, before and during the first meeting. Our observations showed that the designers were not able to make decisions about the technical solutions that contained user related issues. Moreover, the expert user's comments during the validation meeting altered the proposed solution. In conclusion, it seemed that the actual design organization should be changed in order to integrate the expert user more actively. Annotation as a communication tool proved to be useful for technical exchanges, but we found important limitations for non technical users, we then propose solutions for further improvement of the tool.

Keywords: collaborative design, user integration, design communication, annotation, design artefacts

1 INTRODUCTION

The increasing interests and needs toward the collaboration between design actors in industry pushed many design research to study and identify the collaboration specification in the design context and to propose new approaches and tools to facilitate the design communication and cooperation. Today, the emergence of new technologies provides many software and extension tools for building a collaboration situation, compatible and complementary for the actual design tools. Such supports should help the designer to satisfy the internal requirements of the design, as well as the external needs from the customer, user and the environment.

Design activity in collaboration encompasses some of the highest cognitive abilities of designers, including creativity, problem identification, proposition evaluation, synthesis and solution proposition. Accordingly, numerous works in the literature point out the importance of communication in engineering design processes [1-3]. We consider here that engineering design is a social activity, where designers need to propose and evaluate solutions in order to collectively negotiate the ongoing design.

Annotations have been used for long time in engineering design as a mean to communicate on specific design artefacts. Distributed participants annotate digital artefacts for synchronous and asynchronous discussion of design issues. So far, research has been focused on annotation methods and functionalities in order to support design communication through design artefacts, especially for the distributed cross-functional teams. Among others, 3D representation annotation functionality seemed to provide a support for the design activity.

In some specific design context, the user plays an important role in the design process for the designer's activity. Expert and complex products and systems are examples of such a design process, including new surgical instruments, flight controlling post, professional sport facilities and so on. Design studies have taken a deep step to determine design collaboration characteristics, activity analysis of designers, and user behaviour dissection, but the user-designer interaction in collaboration context is still overlooked.

In this paper, we investigate a design process of a surgical instrument, which corresponds to the context of user integration. Two situations in this design progression are selected to be analysed. The first is a design meeting in a conceptual design phase using an annotation tool, and the second is an evaluation meeting where the design is finalized with the presence of the user who is a surgeon in this case. The main question of this investigation is whether or not the actual design organization and the employed annotation tool can help the designers to integrate the user requirements. We discuss then the potential development of actual organization (process and tools) aiming to improve the user-designer collaboration.

2 RELATED WORKS

2.1 Communication for user integration

The idea of user involvement in the design process was initiated by the studies in human-computer interactions [4, 5], and widely accepted as a principle in the development of usable products and systems. User-Centred Design (UCD) was introduced in the format of the standard ISO 13407: Human-Centred Design Processes for Interactive Systems [6], and several methods for capturing user requirements during the early design stage have been proposed [7, 8].

The design processes which involve user participation have evolved among several design research and design professions, in both product and software engineering [9, 10]. Some of the specific issues in product engineering are mentioned as low-fidelity mock-ups and prototyping, increased engagement and communication with potential users, and an emphasis on site visits and understanding the work context [11].

The problem in many participatory design projects is that user participation is commonly based on description of current work practices and testing or evaluating of existing products, but users' design-related ideas and decisions are left out [12]. Iterative and adaptive processes in creativity are in conflict with typical design development methods [13]. The absence of a common vocabulary can limit the dialogue between designer and user [8]. Moreover, most of design studies concerning user needs have been based on novices or, at best, accessible users of relatively modest talents. The reason is somehow obvious: it is easier to obtain such people as subjects of study and they seem to provide enough data.

Hence, such a discussion implies that the integration of "special user" in the design process cannot be covered by actual propositions and methods. Olson and Bakke [14] reviewed some experiences of using 'lead user' method. Von Hippel [15] studied the lead users in co-creative activities, and Visser [16] proposed (each) user is a part of the design team as 'expert of their experiences'. The concepts of experts and expertise are debated within the field of epistemology under the general heading of expert knowledge. In contrast, the opposite of a specialist would be a generalist, somebody with expertise in many fields.

While designers design for a usage situation, they usually put themselves in the role of the user [17]. A designer or an engineer can hardly be representative for the user, and this role is almost invalid in case of expert users with professional knowledge [18]. It is also necessary to pay more attention to user cognitive ability as the key element in information processing. According to the studies of user background effect on the evaluation of a medical prototype interface, when more ergonomic factors are included in defining the user background, more design flaws might be detectable and a wide range of error detection could be achieved [19]. Therefore the study presented in this paper considers the surgeon as the expert user, and investigates the surgeon-engineer collaboration through a case study on surgical instrument design.

2.2 Annotation for design communication

Like practitioners in other disciplines such as chemistry or architecture, engineering design actors often use 3D artifacts to communicate complex concepts [20]. 3D artefacts are effective to provide common representations of design solutions to participants from different disciplines (such as between technical and non technical actors). Therefore, these artifacts are more and more set out to support the design communication, specifically the discussion of artefact-centred design issues. Lightweight

versions of CAD representations, such as VRML[1] format, have been proven to be effective to share and manipulate 3D design information over distributed actors. Lightweight representations provide an easy way to share and manipulate versions of CAD models. Their usage becomes common, especially to communicate 3D representations to external partners or users [21].
Several software tools have been proposed in research in order to facilitate annotation practices in lightweight 3D representations across distributed teams. For instance, [22] has developed the Immersive Redliner software for asynchronous communication between designers and users around lightweight representations in architectural design context. [23] proposed Immersive Discussion Tool (IDT) for synchronous annotation of architectural 3D models. IDT allows users to add arrows to designate specific points of the design to point out specific information or evaluate models. In engineering design context, [24] developed a textual annotation tool on 3D lightweight representations with ontology support for increased search functionalities.
In the research presented in this paper, the Annot'Action tool has been used. Annot'Action[2] has been designed to create virtual workgroups for asynchronous annotation of VRML models. Participants in a workgroup are represented by their expertises. The tool allows the annotation of co-constructed argumentation trees to 3D representations. Each node of an argumentation tree contains a textual message and metadata on the content. Main tool functionalities have been presented in the section 3.
The aim of the study presented in this paper is to explore the integration of the expert user in the technical design development of products with a focus on annotation tools as means of communication. A case study on innovative surgical instrument design is presented, in which the surgeon participates actively in problem definition and idea generation as the expert user. We make the hypothesis that communication between expert users and designers is essential during the design artefact development. The research question we ask is: How annotations can help to build-up and support expert user (surgeon) integration in the design process? Our methodology to answer this question is explained in the following section.

3 METHODOLOGY

Studying the design process of healthcare and more specifically surgical instrument is very interesting and also challenging from a research point of view. The design process has to integrate the expert user along the progression of the design process in order to identify the professional requirements and limitations of this very specific domain of expertise.
So far, few researchers explored the design process in this domain and a certain number of models have been proposed [25, 26]. Former studies of the authors of the innovative surgical instrument at Grenoble CHU Hospital indicated the collaborative nature of design process. [27]. Based on this observation, the actual design process is considered as a co-evolution of design object (instrument) and design usage (surgical operation). The iterations take place around the emulation phase, in which the expert user evaluates the design object in the real usage environment (ex. Operating room). (see Figure 1).

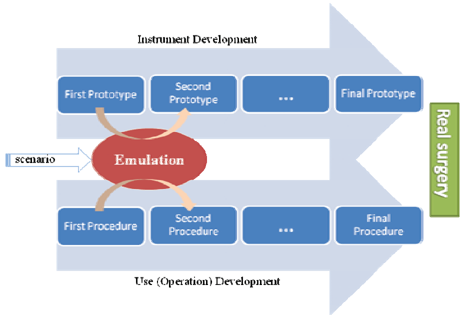

Figure 1. Evolution of the Prototype and the Surgical Procedure versions on the proposed Co-Evolutive model

[1] Virtual Reality Mark-up Language
[2] http://annotaction.g-scop.fr/www/index.php

3.1 New operation-instrument in Spin surgery

For this present study, a design case has been selected in which designers and surgeons collaborate to design a new instrument for a new type of surgery called Minimally Invasive Surgery (MIS).
MIS is a new kind of surgery in which the operation performs through a small incision, which avoids surgeon cutting the muscles, even rarely separating them. So the patient has less pain, less bleeding and will recover quicker. In comparison to the usual, open surgery, MIS operations are better for the patient, but difficult for the surgeon and they need some special instruments.
The specific MIS application studied here is in spine surgery. Conventional spine surgery requires a long incision and a lengthy recovery period. The operation aims to place three pair of screws and two implants (called rod) on three consecutive vertebras, and actually follows the procedure of making a large incision (12-15 cm) to provide enough space for the implementation.
By transforming this procedure to MIS, the incision minimizes the anaesthesia and the recovery time decreases effectively. For this purpose, surgeon should implant the screws by tubular retractor through small incisions and has to deliver the rods percutaneously to the spine. Like the open procedure, the surgeon loses the direct access and direct vision on the operational site. The new procedure is more complex, and requires specific instruments to place the screws and the rods through small incisions.

Figure 2. Left to right: Screw-Rod system on vertebra, emulation on cadaver, x-ray profile image on implanted system

The project originates from an idea that surgeons from Grenoble Hospital have proposed. In order to realize the design of the instrument, a design team was formed. As shown in the design process model chosen for this project, the mechanical development of the instrument has taken two main steps of design and evaluation. The evaluation took place in a real usage situation (operating room) by using a physical prototype. A debriefing session was thus required in order to make a decision and set up strategies for the next step.
At the time of this research, the design has finished the conceptual phases, and the clinical evaluation of a functional prototype instrument has been already realized on cadaver.
Accordingly, two design sessions of this project have been selected for this study. First, the technical detail design of the latest prototype in which the designers were asked to use an asynchronous collaboration tool called Annot'Action for the communication. The second is the session with the expert user, surgeon, to validate new concepts before making final prototype which was meant to be used in a real surgical operation. The Annot'Action tool and the observation are explained in the following.

3.2 Annot'Action tool

Annot`Action is a web 2.0-based annotation tool of VRML representations, developed in University of Grenoble, in 2008 [28]. The tool has been designed to support asynchronous communication of cross-functional design teams. The tool allows designers to create workgroups around specific design tasks (projects). Each project is divided into milestones, which represent a different version of the design solution. A series of VRML objects (views) can be shared within a milestone.
The asynchronous collaboration is achieved through annotations related to the views. The first level of the annotation structure consists of the 3D symbol attached (anchored) to a particular point of the VRML object, pointing to the problematic zone. The second level is a tree consisting of nodes (interventions) and links connecting them to each other. The intervention nodes are connected to each

other, forming a tree-like argumentation structure. Participants communicate through co-constructing these argumentation trees. The objective of this structure is to have a conversational dimension by allowing participants to interact each-others.

Each node on an argumentation tree has a semantic structure, which is represented by a combination of three symbols. This semantic structure aims to enhance the textual core of each node, in order to facilitate the recognition of the textual content and the conversational flow on an argumentation tree. The three symbols consist of:

- The role of the participant in the project,
- The intent of the author (clarification, evaluation or proposition)
- The purpose of the textual content (a project requirement or problem-related constraint, a domain-specific constraint or the current solution)

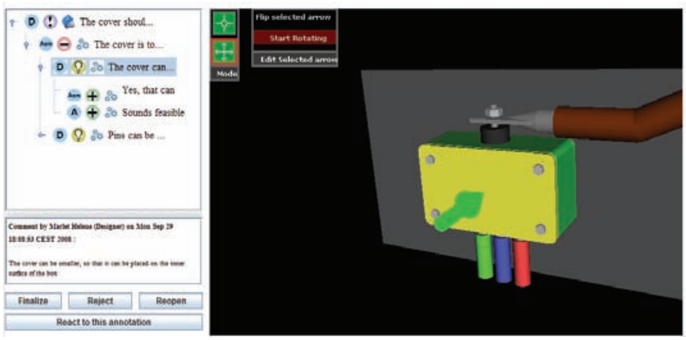

Figure 3. An annotated VRML object in Annot`Action

This structure has been presented in [29]. Figure 3 illustrates an example of an annotated VRML object. The pointing arrow on the VRML object (right side) refers to the argumentation tree (left side). In the following section, our observation on this case study is presented.

4 OBSERVATION

As mentioned earlier, observations for this study have been focused on two successive design meetings. The first one has occurred between the engineering team members, where the participants have validated a series of issues concerning the solution. During the second meeting, the modified solution has been discussed by the surgeon and the engineering team. The Annot`Action tool has been used by the engineering team before and during the first meeting.

Our observations have been focused on two main points. We have investigated whether the early sharing and discussion of the solution through an annotation tool may allow the achievement of more systematic cooperation between the participants. Meanwhile, we observed how engineers have acted when faced with design issues concerning the usage of the product during the solution development phase. We more particularly observed how accurately the usage requirements were perceived by the designers and whether the solutions they produced according to theses perceptions satisfied these requirements.

Through these observations, we tried to find out whether the integration of the user in the development phase facilitates the convergence towards a more satisfying solution, and how an annotation tool could help to fulfil this integration. Our observations related to the process are presented in the following. Annotations functionality for user integration is discussed in the fifth section.

4.1 Asynchronous design phase

Prior to the meeting, the engineering team has shared a lightweight version of the CAD model through the Annot'Action tool. The shared model contained the latest modifications proposed by the designer following the last design meeting.

The participants had the opportunity to review the model first to obtain information on the ongoing design, in order to construct their personal point of view before the meeting. Furthermore, the participants have annotated the model for storing and sharing their comments and proposals initiating a preliminary discussion. Their objective was to acquire further understanding of the respective points of view and to provide a list of issues that should be raised in the next design meeting.

4.2 Example of discussion: body penetration issue

Throughout the rest of this section, the body penetration issue will be presented to illustrate our observations.

From the beginning of the design process, the penetration and guidance functions of the new instrument were one of the main concerns of the engineers. On one hand, design of a part associated to theses functions had two contradictory criteria: First, the body entering part were supposed to be as thin as possible, due to the minimally invasive constraints. Second, this part should also resist the loads that appear during the insertion and the guidance of the implant (rod).Therefore, a compromise should be found to satisfy both criteria (see Figure 4). On the other hand, finding such compromise was requiring expert know-how. The discussion observation showed that engineers had serious difficulties to make decisions about that part.

Figure 4. The penetration and guidance functions of the surgical instrument

4.3 Technical design meeting

Technical design meeting was a face-to-face situation, where engineers have sought to validate the design modifications regarding the mechanical, ergonomic and manufacturing constraints before meeting with the surgeon.

Participants have used the annotated version of the model as the shared artefact during the meeting. The issues raised during the asynchronous annotation session have been reviewed and discussed. When an issue was concluded an agreement or a corrective action, then the participants added further nodes on the argumentation trees to record them. Figure 5 shows a capture of the recorded video (left side) and the shared screen during the meeting (right side).

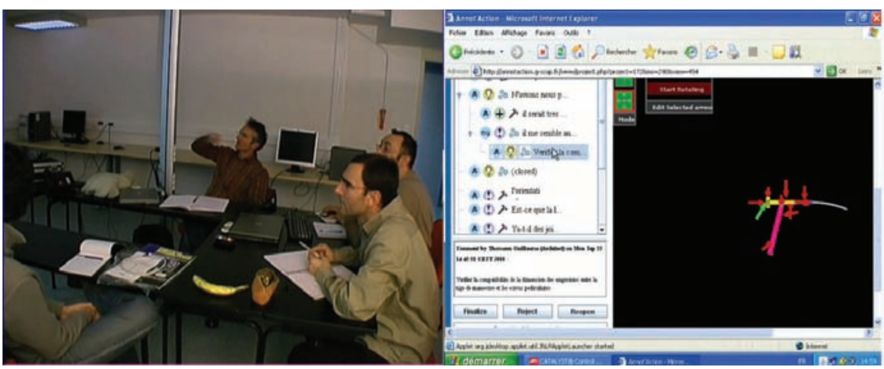

Figure 5. Engineering team discussing on annotated comments

Although a larger number of issues discussed during the meeting were not related to usage (rather related for instance to mechanical or manufacturing constraints), 40% of the issues were directly related to the usage of the product. The amount of time spent for the usage-related issues were approximately equal to the percentage of the total number of issues.
When faced with a usage-related issue, participants followed tree successive strategies. They first tried to back track the previous user feedbacks in order to find a similar case. A decision was made when the participants were convinced of the compatibility between the previous feedback and the current issue. When this strategy failed to bring participants towards a decision, they tried to elaborate usage hypothesis by putting themselves into the user's situation. A decision was made according to the hypothesis when it seemed obvious to participants. When this strategy failed, participants decided to postpone their decisions until a feedback from the use is provided. Data related to usage-centred issues are illustrated in Figure 6.

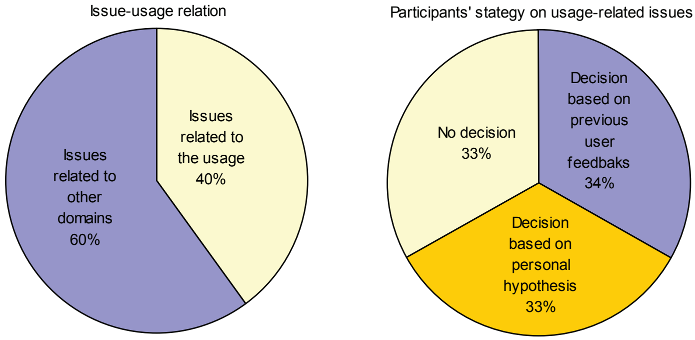

Figure 6. Data related to the usage-based issues during the meeting

The data showed that although the objective of the meeting was to validate technical issues on the solution, designers were needed to consider a large number of usability-related issues. In other words, usability problems have been inevitably involved, even for the technical validation of the design solution.
Furthermore, in the absence of the surgeon, the engineers had serious problems for dealing with these issues. In two third of the cases, they couldn't have a satisfying amount of user feedback upon which to base their decision making. For half of those cases, they weren't able to develop satisfying usage hypothesis, and had to close out the issue without any decision. The engineers therefore concluded that those issues should be rediscussed in the presence of the surgeon.
When the body penetration issue is concerned, although engineers tried to take care of usability issues about this part during the technical meeting, they couldn't make decision about the geometry of the entering part of the tool. Engineers made hypothesis, based on the surgeon's previous feedbacks in emulation, indicating that the new instrument should hold the rod tight enough in order to ensure its manipulation in the body, and placement of the rod in the screws. They adopted a solution which prioritises the tightness of the joint over the thickness of the penetrating part.

4.4 Expert user meeting

Following the design meeting, there was a need to talk to the surgeon to clarify some ambiguities about the usage of the design artifact, and also to validate the new solution proposition in brief before the prototyping. The expert user meeting was also a face-to-face meeting, where the 3D CAD model had been shared. Unlike the technical meeting, where participants communicated only with verbal exchanges, during the expert user meeting participants (especially the user) needed gesture to illustrate specific usage of the tool or the parts (Figure 7). In other words, the CAD representation alone weren't sufficient for participants to achieve a mutual understanding of their respective points of view.

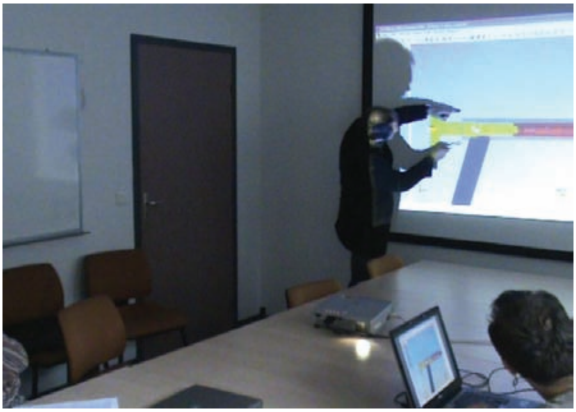

Figure 7. User gesturing to illustrate a specific usage on the CAD model

Before browsing usability-related issues with the user, the engineers presented the new version of the solution in order to have the general feedbacks. The critics of the user have been focused on two main parts of the tool, and they were covering most of the usability related issues detected by the engineers. These critics showed that an important part of the modifications were not satisfying the needs of the user. Furthermore, other usability problems, which appeared through the meeting, had to be considered on these modifications.

In short, we have seen that information considered by the engineers when faced with usability issues (whether a previous feedback or a subjective hypothesis) was either incorrect or incomplete to make the correct decisions. The collective decisions made during the expert user meeting required the rework of parts that were modified according to this information.

In the body penetration issue example, the surgeon has not validated the adopted solution, arguing that the thickness of the entering part cannot be omitted, as the part may fail to properly penetrate in the body with its current shape. Accordingly, the participants had to redesign this part. They have decided not to decrease the diameter of this part, but to taper its shape, so that the wound could gradually stretch without making harm to muscle tissues.

To conclude, these observations confirmed that the surgeon-engineer communication needs to be established in the development phases.

5 DISCUSSION

5.1 Need for a continuous user integration in artefact development

Our observations showed that engineers deal with an important number of usability-related issues in the development phases of the design project. These issues may either relate to existing user requirements for obtaining solutions or to new usability issues that appear as the engineering design process unfolds.

Further, we have also witnessed an important difficulty of the actors to think like the expert users: when faced with a new issue related to the usability, designers often have not enough information to decide on the good corrective action. We point out thus that user must be better integrated in the development phases of the project by appropriate communication mechanisms. Such a mechanism can help the engineers to have a continuous feedback of the user during the whole design process, which can help to avoid design iterations and delays, through the detection of usability-related product failures earlier.

5.2 Benefits of asynchronous annotation on design cooperation

Interviewed engineers have reported the following benefits of the annotation usage. These benefits encourage us to use asynchronous annotation functionality for expert user integration:

- Asynchronous annotation of the proposed solution has allowed engineers to discuss and establish an issues list of the meeting before the session. Moreover, asynchronous discussion on these issues helped them to reach a shared understanding of these issues.

- Sharing the solution before the meeting allowed detecting design failures earlier, and giving designers enough time to search for solutions.
- The annotated solution helped also to ensure a systematic communication during the meeting. The explicit list of issues during the meeting helped participants to achieve a better time management and a better orientation of the discussions towards the decisions.

5.3 Annotation for user integration in development phases

We claim that asynchronous annotations can be used in a similar way to integrate the expert user in the development phases of the design process. The design solutions obtained during the development process can be shared between the engineers and the surgeon. They can preliminary validate the critical points of the developed solution and possibly detect obvious usage-related design failures prior to the technical design meetings. After technical reviews, the modified solution can also be shared between these participants along with the collective decisions, which can help the elaboration of the issues list of the user next meeting session.

However, our observations show that adapting the current annotation functionality to user integration context requires the consideration of following issues:

- As we pointed out earlier, face-to-face communication between the expert user and the engineers involves important usage of gestures for the shared understanding of the intended usage of developed parts. A 3D representation of the solution alone would fail to achieve such shared understanding in asynchronous situations. The representation of the usage thus needs to be represented along with the 3D representation of the product. The integration of the body/operation simulators may be considered to overcome this issue.
- Due to the fact that design issues that are not related to the usage are also considered during the asynchronous annotation practices, the current functionality may be enhanced by annotation filters to provide a specific view of the 3D representation for the expert user. Automatic or semi-automatic mechanisms may be used for the content detection of annotations.
- The tool interface may also need to be evolved to provide simpler ways of 3D manipulation and annotation by the expert user.

6 CONCLUSION

Our findings support the hypothesis that design process in expert-user integrated context is highly collaborative, and the communication through the design artifact needs supportive methods and tools. Moreover, since the experience showed that the presence of the expert user is essential during the design progression, a better organisation and supporting tools should be developed to optimise the collaboration. Improvement in asynchronous annotation tools would possibly help in this matter.

However, reliance on this observation should be tempered, because of the uniqueness of the experience and the lack of experiments on surgeon-engineer interaction through the annotation tool.

In this perspective, we are currently studying the technical possibilities for software developments, as well as developing a new design organisation. Our future work will explore expert user interaction with the technical annotation tools.

REFERENCES

[1] Bodker, S. Scenarios in user-centred design--setting the stage for reflection and action. *Interacting with Computers*, 2000, 13(1), 61-75.

[2] Eckert, C.M., Cross, N. and Johnson, J.H. Intelligent support for communication in design teams: garment shape specifications in the knitwear industry. *Design Studies*, 2000, 21(1), 99-112.

[3] Stempfle, J. and Badke-Schaub, P. Thinking in design teams - an analysis of team communication. *Design Studies*, 2002, 23, 473-496.

[4] Bekker, M.M. and Long, J.B. User involvement in the design of human-computer interactions: some similarities and differences between design approaches. *HCI-2000: People and computers*, XIV - Usability or else!, 2000, 135-147 (Springer Verlag, Sunderland, UK).

[5] Karat, J. Evolving the scope of user-centered design. *Communications of the ACM*, 1997, 40(7), 33-38.

[6] ISO13407. Human-centred Design Processes for Interactive Systems. *International Organization for Standardization*, 1999, Genève, Switzerland).

[7] Jokela, T. Making user-centred design common sense: striving for an unambiguous and communicative UCD process model. *Proceedings of the second Nordic conference on Human-computer interaction*, 2002 (ACM Press, Aarhus, Denmark).
[8] Luck, R. Dialogue in participatory design. *Design Studies*, 2003, 24, 523 - 535.
[9] Battarbee, K. and Koskinen, I. Co-experience: user experience as interaction. *CoDesign*, 2005, 1(1), 5 - 18.
[10] Caelen, J., Jambon, F. and Vidal, A. Participatory Design : "Moments" Theory and Implementation. *Journal of Human-Machine Interaction*, 2005, 6(2).
[11] Grudin, J. and Pruitt, J. Personas, Participatory Design and Product Development: An Infrastructure for Engagement. *PDC 2002*, 2002, 144-161.
[12] Kensing, F. and Blomberg, J. Participatory design: Issues and concerns. *Computer Supported Cooperative Work*, 1998, 7, 167 - 185.
[13] Edmonds, E. New directions in interactive art collaboration. *CoDesign*, 2006, 2(4), 191 - 194.
[14] Olson, E.L. and Bakke, G. Implementing the lead user method in a high technology firm: A longitudinal study of intentions versus actions. *The journal of Product Innovation Management*, 2001, 18(6), 388-395.
[15] von Hippel, E. *Democratizing innovation*. 2005 (MIT Press, Cambridge, MA).
[16] Visser, F.S., Stappers, P.J., van der Lugt, R. and Sanders, E.B.N. Contextmapping: experiences from practice. 2005, 1(2), 119 - 149.
[17] Buur, J. Mechatronics Product Design and Development in Japan In Hewit. *Mechatronics Springer-Verlag Wien*, 1993.
[18] Rasoulifar, R., Thomann, G. and Villeneuve, F. Integrating an expert user in design process: how to make out surgeon needs during a new surgical instrument design. *International Symposium series on Tools and Methods of Competitive Engineering (TMCE)*, 2008 (Izmir, Turkey).
[19] Liu, Y. and Nof, S.Y. Distributed Micro Flow-Sensor Arrays and Networks: Design of Architectures and Communication Protocols. *International Journal of Production Research*, 2004, 42(15), 3101-3115.
[20] Nam, T.-J. and Wright, D. The development and evaluation of Syco3D: a real-time collaborative 3D CAD system. *Design Studies*, 2001, 22(6), 557-582.
[21] Ding, L., Ball, A., Matthews, J., McMahon, C. and Patel, M. Product Representation in Lightweight Formats for Product Lifecycle Management (PLM). *Proceedings of DET2007 4th International Conference on Digital Enterprise Technology*, 2007 (Bath, United Kingdom).
[22] Jung, T., Gross, M.D. and Do, E.Y.-L. Annotating and sketching on 3D web models. *Proceedings of the 7th international conference on Intelligent user interfaces*, 2002 (ACM Press, San Francisco, California, USA).
[23] Craig, D.L. and Zimring, C. Support for collaborative design reasoning in shared virtual spaces. *Automation in Construction*, 2002, 11(2), 249-259.
[24] Aubry, S., Thouvenin, I., Lenne, D. and Okawa, S. Knowledge integration for annotating in virtual environments. *International Journal of Product Development*, 2007, 4, 533-546.
[25] Dankelman, J., Grimbergen, C.A. and Stassen, H.G. Engineering for Patient Safety: The Clinically Driven Approach. *Biomedial Instrumentation & Technology*, 2005, 39(1), 60-63.
[26] Clarkson, P.J., Buckle, P., Coleman, R., Stubbs, D., Ward, J., Jarrett, J., Lane, R. and Bound, J. Design for patient safety: A review of the effectiveness of design in the UK health service. 2004, 15(2), 123 - 140.
[27] Rasoulifar, R., Thomann, G., Villeneuve, F. and Caelen, J. Proposal of a New Design Methodology in the Surgical Domain. *ICED*, 2007 (Paris).
[28] Hisarciklilar, O. *Formes et structures des annotations sémantiques pour supporter la communication en conception collaborative asynchrone*. PhD Thesis, 2008 (Grenoble Institute of Technology).
[29] Hisarciklilar, O. and Boujut, J.-F. An Annotation-Based Approach to Support Design Communication. *International Conference on Engineering Design (ICED)*, 2007 (Paris, France).

Contact: Onur Hisarciklilar
G-SCOP Laboratory
Grenoble Institute of Technology
46 Avenue Felix Viallet
38031 Grenoble
France
Tel: +33 4 76 57 49 13
Fax: +33 4 76 57 46 95
Email: onur.hisarciklilar@grenoble-inp.fr

Onur received his PhD degree in Grenoble Institute of Technology, where he is working as research fellow. Currently, he is also visiting researcher at McGill University, Canada. He has worked in several projects and conducted empirical studies on engineering design communication and informal information structuring. His current research concerns technologies for knowledge capture and reuse in multidisciplinary design collaboration.