User Actions as a Mediator for Concept Designers

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Abstract

The aim of this paper is to suggest a general approach based on Activity Theory for designing computer systems to support collaboration between creative product concept designers. We will focus on the level of action and examine situated actions in design. The research material consists of design workshops in the domain of electronics industry. Activity Theory, which provides the structure of activity, actions and operation, was used as the framework of video analysis and observation. It appears that concept design activity is mediated through the designers' understanding of user actions. This finding has a fundamental effect on how future computer applications for collaboration should be developed. These systems are seen as mediators of how designers understand user activity, actions and operations. The implications of this for computer systems design are presented with two examples, which demonstrate a technique called shared virtual prototyping.

1. Introduction

Electronics and telecommunication product concept design is about creating new products. At the beginning of the design process, the designers do not know exactly what the new future product will be like or what kind of features it will finally include [1]. Thus, the designers are engaged in a process where they need to discuss their goals, choices and visions, and reflect on their understanding of these goals during the design project. Examples of such descriptions can be found in the literature [2, 3]. This has been the domain of research during two Finnish national projects VIRPI and VIRVE (1996-2001) focusing on the introduction of *virtual prototyping* into electronics and telecommunications industry.

We have been studying product concept design sessions and the product design process by observing actual situations and interviewing people [1, 4]. We observed four successive concept design workshops and videotaped three of them. These workshops lasted for altogether 12 hours. The aim of this work was to find out how a multidisciplinary group creates and works out a new product concept. Also, we interviewed seven relevant stakeholders in the product development process in three companies, designers of mobile telephones, add-ons to mobile telephones, heart rate monitors, etc., people of various backgrounds, such as mechanical engineers, and industrial designers. The interviews lasted for anything from one hour to one working day, including individual work practice descriptions at the desks of 5 interviewees.

Simultaneously, we undertook an effort to study the feasibility of the virtual prototyping tools used to model small handheld electronics devices. One of the main aims was to find out the best techniques for shared virtual prototyping between geographically distributed designers. This technique has been developed jointly at the University of Oulu and at VTT Electronics. We have made several presentations of our software to the group of designers involved in this research and discussed and evaluated the direction of the work. Comments have been invited during the presentations for further elaboration. Several versions of the software have been accomplished with different technical approaches.

CAD and virtual prototyping

The computer systems used by product designers are mainly Computer-Aided Design (CAD) systems, which support an individual's work on a design task. While these systems have been successfully used for this purpose, the vendors have been recently adding features to support cooperative design by geographically distributed product designers. This trend in CAD technology has been enabled by the World Wide Web technology. The most common solution is that the CAD data can be viewed with proprietary "viewers". Such features are used for product data distribution and are helpful in, for instance, communicating the product concept status via a company intranet.

Virtual prototypes for design communication have been used in such domains as aircraft industry, and

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automotive industry. Electronics and telecommunications industry has not seen such applications other than CAD for industrial/mechanical design or simulation tools for user interface design. The goal in our project has been to provide photo-quality, functional virtual prototypes to support geographically distributed cooperative design of electronics devices [5-7]. A virtual prototype simulates product features with a degree of functional realism comparable at least to a physical prototype. A shared virtual prototype allows multiple designers to collaborate on the product concept over time and distance. This work has resulted into an application called VRP application by VTT Electronics in Oulu. For cooperative concept design purposes, University of Oulu has been developing tools for shared virtual prototyping. This set of tools is called WebShaman (for shared manufacturing).

From work practice to software development

It is known that user activity and actions have an important role in product concept design activity. Product designs are tested by users in various ways as soon as the product has a physical form. The way in which designers during collaborative design share and create their understanding of the future product has not been a focal point of discussion. This is rather peculiar, since collaboration in design results in a substantial number of interpretations and transformations (of objects and subjects). To clarify the distinction between designer and user activity:

•Concept designers create new product designs and engage in concept design activity. The goal of concept design activity is to create a new product concept.

•User activity consists of the users' activity that designers are interest in. The goal of the user in his/her activity depends on the context. The understanding of user activity may vary in the context of design activity.

Interdisciplinary concept designers construct the product concept in collaboration. Characteristically, collaborative designers have a general understanding of what they should do together. Thus, although the design team is interdisciplinary and the members have variable motivations to participate in the design process, the ensemble has a certain goal: at the end of their work, they must come up with an outcome, a new product concept. Before appearing as an outcome of the design process, the concept is an object of design. During a design process characterized by situated actions [8], designers reflect and express their understanding of the product concept. Aiming at a shared understanding of the future product concept, they use various representations. One possibility is to use situational artifacts to support an explanation of a perspective or vision. Examples of such artifacts include a pen or a cup, which are used with gestures to show a specific idea [4, 9]. Another example at a later stage is to create visual representations, drawings of ones' vision [10, 11]. An interesting finding was made during the field work with concept designers, which will be explained in more detail later. The relationship between the designer, the design object and the representations is not as simple as it might seem. The research material implies that user actions have an important role in mediating the designers' understanding of the design object.

Actually, the above description sounds reasonable. It may even serve as an important basis when studying how to provide a successful design of computer systems to geographically distributed product designers. If this is true, then it is my belief that this approach has direct implications for the practical design of collaborative computer systems and for product concept design in general.

Structure of the paper

Situated action is first presented as a concept to characterize concept design. Next, a structure is given to situated action based on Activity Theory (AT). Examples of field studies and interviews done in the product concept design domain are given to explain the concept design activity we aim to address and to highlight the importance of user actions in design.

User action refers to the actions of the users as the designers see them. It is shown that user actions are used to mediate the designers' understanding in conjunction with various representations of the design object. Designers also exploit user actions to point out user action breakdowns in order to argue for their designs of new product concepts. The activity-action-operation hierarchy of AT is used in the analysis to show how designers exploit such breakdowns.

We will discuss the WebShaman and WebShaman Digiloop computer systems, which allow product designers to refer to the design object as a shared virtual prototype. The point is to show how these systems represent the design object and to exploit user action as a mediator for geographically distibuted designers, who construct their shared understanding of the future product.

2. Situated actions and design activity

The term 'situated actions' coined by Lucy Suchman [8] underscores the view that every course of action depends essentially upon its material and social circumstances: "Rather than attempting to abstract action away from its circumstances and represent it as a rational plan, the approach is to study how people use the circumstances to achieve intelligent action." Concept design can be characterized as work where designers engage in situated action. Situationality is manifested especially well in the way concept designers use artifacts to mediate their understanding.

An important resource for designers in their situated action is their history and their personal development in the culture they belong to. Everything they do in their actions is related to the culture, whether it be a combination of new techniques or a 'new innovation'. Besides their own history, designers generate, or co-construct, a common history.

From this point of view I got interested in how to involve the context where the actions occur into this study. It is one of the basic presumptions of Activity Theory (AT) that the context should be the focus of study. AT has been suggested and applied as an approach in the fields of Human Computer Interface and Computer Supported Cooperative Work. Accounts of this can be found in the literature [12-15]. To understand what AT is, it is good to note, as Kuutti does, that it can be defined as a framework: "Broadly defined, activity theory is a philosophical and cross-disciplinary framework for studying different forms of human practices as development processes, with both individual and social levels interlinked at the same time"[16]. Activity theorists argue that consciousness is neither a set of discrete disembodied cognitive acts (decision-making, classification, remembering) nor the brain; rather, consciousness is located in everyday practice: you are what you do. AT "provides orienting concepts and perspectives in HCI research while not offering 'ready made techniques and procedures' for research."[17] .

In order to study how AT delineates (situated) action, we will have to discuss the following concepts: activity, action, tool, object and mediation. Due to space limitations, I will not go more deeply into the background of AT, but instead refer to [18, 19] for further reading.

Activity, action, subject, tool, object and mediation

The following list of properties apply to activity:

"-an activity has an *object* and activities can be distinguished according to their objects. The transformation of the object towards some desired state or direction motivates the existence of the activity."[13]

"-an activity has an active subject (actor), who understands the motive of the activity. This subject can be individual or collective. Not all participants involved in an activity necessarily understand the motive of the activity in which they are participating or even recognize the existence of one."[13]

The object of activity differentiates activities from each other. For instance, the activity of product concept design has the product concept as an object of activity, i.e., as the design object. The motive for the activity is to introduce a new product concept and, at the end of the product design process, a new product. An individual subject is the specific designer or group of designers.[13]

AT suggests that collaboration is mediated, and this mediation is carried out through the use of artifacts: a key concept is that the relations within an activity are not direct ones, but are mediated by different artifacts, e.g. instruments, signs, procedures, machines, methods, laws, work organization forms, accepted practices, etc. These artifacts have been created and transformed by people during the development of the activity itself and carry with them a particular culture — historical remnants of that development. Therefore, artifacts are not 'given', and they should never be treated as such. This also implies that our knowledge of the objects of work is not restricted to the body of knowledge only (a special artifact), but is embedded in the whole activity system. Engeström [19] presents the basic structure of activity, but we will here focus on examining the actions involved in the design activity. Figure 1 illustrates the structure of an individual, mediated action. In design action, the designer is the subject of action, and representations are tools used to examine the design object.

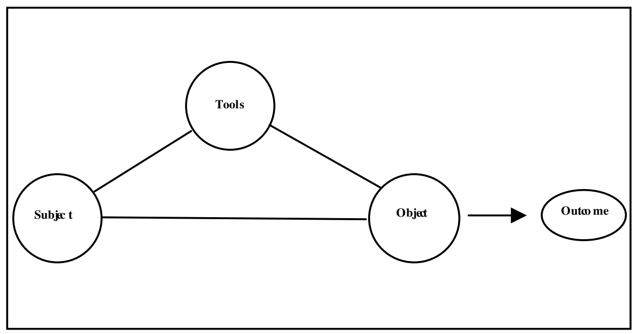

Figure 1: Structure of an individual, mediated action as presented in [20].

Thus, apart from having situated actions, we have now ascribed a structure to these actions: the actions are directed towards an object and mediated by tools. An action is motivated by an outcome.

Three levels of activity

Activities are long-term phenomena; their objects are not transformed into outcomes at once, but through a process that typically consists of several steps or phases [16]. Activities consist of short-term processes, actions or chains of actions, which, in turn, consist of operations. Activities are realized as individual and cooperative actions and chains and networks of actions related to each other by the same overall object and motive. [18] presents a three-level model (Figure 2).

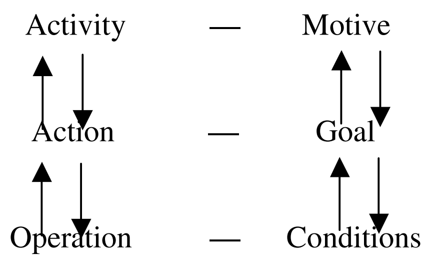

Figure 2: Three levels of activity.[18]

3. Product concept design activity

Product concept design is the part of product development, where new product concepts are introduced. The design of electronic products requires cooperation between representatives of several disciplines, including industrial designers, electrical and mechanical engineers, and software engineers. In the process of creating a new product concept, these designers participate in an activity of design where the object is a new concept that will soon emerge as a new artifact.

Characteristically, concept design is the innovative stage of product design work. It is based on a combination of previous knowledge and novel ideas introduced into the discussion [4]. The activity of concept design is an activity system which has a history. One aspect of this is the past of the designers, i.e. what they have been doing earlier and learnt earlier, and another and broader aspect is the cultural history, i.e. the values of the culture at the time when the concept is being created and the artifacts that have been developed in the culture. These are issues that need to be constantly considered by concept designers.

The designers' argumentation in a design situation draws heavily on hypothetical user activity. Thus, when presenting new ideas and pointing out problems in the old practices, concept designers hypothesize on what will actually be the future user activity.

This can be illustrated with an example of a concept design situation from our field studies. In a series of design sessions, we had several designers, industrial designers, electrical engineers, and mechanical engineers involved in the design of a new mobile telephone concept [1]. The requirements of the concept were presented in a QFD matrix, focusing on women as a possible user group. Thus, no other representation of the concept existed at the baseline. The first discussions stimulated the designers' understanding of what would be culturally a 'woman-like' concept. The group consisted of the designers participating in our research project, and, strangely enough, all were male.

As we found out from the videotape, the discussion followed a certain pattern. When argumenting for a perspective, the designer often referred to the history of previous designs and solutions that had been found useful. They mentioned glasses, hairpins, and a purse as their container. Such seemingly general discussion usually leads to some combination of technologies, which often further lead to an innovation or a new concept. Using glasses as a device-holding technology is probably one of the most popular ideas in the teams designing the next generation (basically video as the media) of mobile telephone technology. In our case, many possibilities of using glasses were discussed, but none of them seriously. The reason for this was that people actually wear contact lenses in order to avoid having to wear glasses and may not, possibly for some other reasons, want to use glasses, which is a cultural aspect. The following pattern was identified: history, innovation, many solutions, serious debate concerning a possible solution. For instance, the idea of a pen-shaped mobile telephone, our final solution, kept popping up during the discussion from time to time, until it was chosen for further consideration.

In terms of AT, the subject of concept design activity is the group of designers. The designers have a shared object, which they are designing together, aiming at a new concept. The motive for their work is to develop the concept to the next stage, where it will be designed for production. During this work, each individual designer has to align his/her own activity toward the common goal, whether it is circuit board design or the shape of the artifact. Thus, concept design activity is polymotivated, which makes concept design a complicated process of combining many domain-specific perspectives in a design situation.

Design object as a shared object

In principle, one could actually talk about a not-shared design object, since most of the work done cooperative by designers consists of communication to find out about the context (activity) they are involved in. Thus, the most conspicuous feature of the shared design object of a group is that it is not at all shared, but cooperatively constructed. The designers recognize the motive to undertake their task (to elaborate the concept for production), but only cooperative construction of the design object helps the group to crystallize their shared objective.

The concept design situation is characterized by uncertainty. Designers make considerable efforts to communicate their visions and perspectives to each other. Decisions and choices must be made, but there is constantly some doubt of whether the decisions are correct. Argumentation skills are useful when presenting a perspective to the issue. There may be periods when argumentation is focused on an ideal design object. Thus, the second feature of the shared design object is that it is ideal in nature. The discussion of the benefits and drawbacks of a tentative idea keeps the shared design object ideal, until it gets a material shape. The ideal is represented by references to objects familiar to everyone in the group, such as glasses, pens, matchboxes, cups, vases. All this time, the designers keep referring to the usability, functionality, and purpose of their ideas. These ideal objects and their surprising representations in the discussions act as a 'boundary object' between the designers [21]. At this point of the design process, the designers' understanding is *mediated* through situationally used artifacts, argumentation, gestures, and the bulk of historically carried conceptual tools, to make a point. For instance, a designer may do an action to demonstrate how a certain antenna design would affect the usability of the device. He may take an artifact, such as his own mobile telephone, and explain step by step why a visible antenna would be a problem. The contradiction is that a good antenna would guarantee a better connection between the telephone and the base station.

Finally, a third feature of the shared design object is that, since the designers are uncertain of what the others (and themselves) mean when explaining their perspectives, the references to known objects change quickly. There are many examples to discuss, ranging from previous antenna designs to seemingly irrelevant suggestions, such as a tooth cavity filling acting as a transmitter for the Global Positioning System. The further the concept design proceeded, the more these examples were crystallized as visual *representations*, i.e., drawings.

Representations as tools to share understanding

Until now, we have pointed out how designers construct cooperatively an ideal shared design object using representations ranging from situational artifacts to drawings, which convey or mediate their understanding of the design object. These representations, or material artifacts, can be written specifications, drawings (sketches), and, at some point, physical models, i.e. wooden or stereolithography models. Various representations, explanations of the use of the concept, and gestures are tools in the effort to co-construct a shared understanding of the design object.

In concept design, the most artistic persons are usually industrial designers, who can quickly outline a sketch of the concept and show it during the session. In doing so, they express their understanding of how they have understood the others and what is their vision of the issue of the moment. Sketches usually work as a common ground for discussion and as a basis for argumentation. There is, however, the danger that good visualization at an early stage may fix the attitudes to a certain vision. Figure 3 shows how the concept of a 'pen-shaped mobile telephone' can be illustrated. The photo-quality image of six possible concepts is rather advanced illustration of what the concept should be like. Now we have an example of polymotivation. It is in the interests of industrial designers to create a visualization of the design object, which is the main objective of industrial design activity. The objective of an individual designer is shared by the group, since a photo works particularly well as a design object representation. Using a photo as a representation then becomes a tool for the transformation of the design object.

Now, imagine a design situation where the photo shown in figure 3 has been brought into the consciousness of all the designers participating in this particular design session. The transformation of the design object occurs through the discussion on these design object representations. If you take a look at the photo, the upper row illustrates yellow product concepts. The material is plastic. Their shape is presumably familiar to everyone, the shape of a pen. Thus, you can compare the understanding of what you have to the dimensions of a pen. All suggestions are small and light-weight.

Figure 3: Six variations of a product concept (Photo courtesy of Metsävainio Design)

The first concept is a mobile telephone (top row left, figure 3). It has all the elements that enable the user to use it as a mobile telephone: dial buttons from 1 to 0, a display to show the dialed number, and a button to place a call. A microphone and a small loudspeaker are embedded in every concept. The next concept is different from the previous philosophy. It is a pen-shaped user interface to a mobile telephone. We can thus see that there are actually two different design philosophies behind the same familiar shape of a pen. The latter concept has only two buttons (or four, as in the next concept, top row right), and their purpose is only to browse the telephone numbers saved in the mobile telephone, which is used through a local wireless connection (8-10 meters range). The concept to be selected for further development was the pivotal point: which design philosophy to use?

All in all, a designer in action uses a representation as a tool to delineate the design object. This object is co-constructed, and representations are used to mediate single designers' understanding, converging towards a shared design object. Thus, all the various representations are *tools* for the designers to manage through the design activity and to mediate between interdisciplinary designers. Figure 4 simplifies the whole presentation.

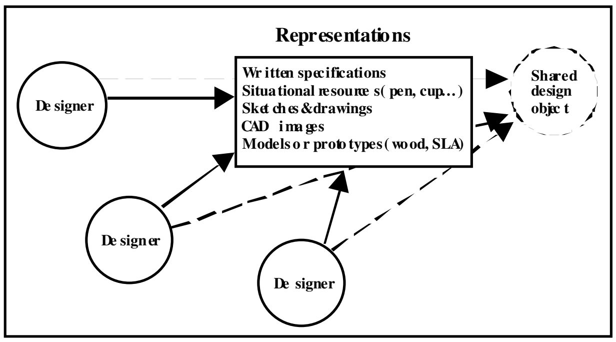

Figure 4: Designers, representations and the shared design object.

4. The role of user actions in concept design

One cannot overemphasize the important role of user actions in innovative product concept development. Many methods have been developed to study the usability of devices and to gather user information of products, but for some reason, designers' vision of user activity or actions has not been a focus of research. I will here point out the importance of user actions for the design activity by presenting an example which also indicates how designers express user actions in order to co-construct a design object. Thus, the importance of user action is that it is used as a mediator between designers.

I will first simplify this idea with a figure (Figure 5) which illustrates user actions as the mediating part of a single design action. A single designer uses tools or representations in order express his understanding of the design object. User action is accomplished with the use of artifacts in order to communicate and co-construct the design object towards a shared understanding of what the design object is. Actions and operations in the user activity are used to argue for breakdowns and contradictions in design, as well as for the functionality and usability of the concept.

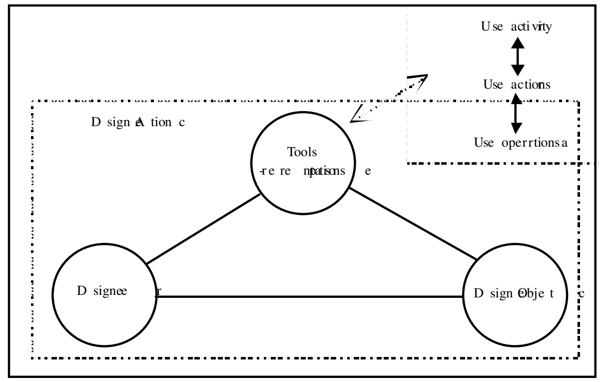

Figure 5: A single design action and its relation to user activity [20].

The designers' vision of a concept depends on their agreement on what the design activity is all about. For example, starting argumentation on the pen-shaped mobile telephone, i.e. the first design philosophy, requires the designers participating in the design session to have a shared history. Otherwise, new designers must be updated with what has been going on. During this joint effort, a vision of the kind of users aimed at and the kind of situations the designer group will face emerges. It also links the understanding of the future use situations to the existing culture as well as the future culture this new concept will generate.

The only way to find out how designers understand user actions is to study their discussion and use of artifacts. As a matter of fact, this is what designers have to do while listening to each other. When a designer makes a point of the use of the concept, the user activity (context) is supposed to be clear. Such a case could be a "woman using a mobile telephone" in a certain environment, i.e. "on the move". The users' motivation to carry such a device would be the need be to be in touch with other people. In this context, the mobile telephone would be a tool to allow any communication by the user (subject) to achieve a certain context-dependent object. Thus, much work is usually done to achieve a shared understanding of user activity, and in order to study the tool itself, designers already assume much of the user activity, environment, and use situation.

The user activity unfolds into actions and operations. The following action could be postulated as an example: make a phone call to your boss to say that you will be late for the meeting since you are visiting a customer. The operations consist of the nitty gritty you never think of, the small things that you do to make a phone call. You open the purse, find the telephone, press some buttons, move the phone next to your ear, and start talking. The operations and usability of the device, on the one hand, are a topic of argumentation for the designers. A supposed breakdown in a use situation, on the other hand, is a tool for argumentation.

A supposed breakdown refers to the relationship between action and operation. Operation may be 'upgraded' to action if a breakdown occurs. Such a breakdown may consist of pressing number buttons which are too close to each other, as someone suggested of the first (Figure 3, upper row left) concept. Since the device itself is small, the buttons are naturally also small. Thus, the user must hold the device in such a position that she (in this case) can focus on the operation of pressing the buttons. When the buttons are too small, erratic presses may increase, thus forcing the user to make correcting maneuvres. This is not good from the usability point of view. One designer highlighted this specific breakdown by picking up a pen and pressing imaginary buttons with his fingers. Actually, everyone agreed on this argument. A *contradiction* thus emerged between the choice of the design philosophy (mobile telephone) and the possibilities of using this concept (all the buttons). This example also highlights the relationship between the use of artifacts (photo and pen), gestures, and the physicality of the design object in the argumentation chain. The designer acts out the users operations as he imagines them to take place.

So much for the usability of the physical (or mechanical) device. What about its logical functionality? Logical functionality here refers to the 'inside' functionality of the telephone, i.e., the user can see the consequences of her actions on the screen or as the responses of the device. This functionality is usually attained with software. The concept presented here is much too simple to demonstrate the full extent of the problems of usability of logical functionality. Actually, a heart rate monitor or a personal digital assistant, which are devices with small screens and lots of functionality, would make far better examples. However, the very same interpretation of users' activity, actions and operation is also useful for this purpose. The user interacts with the logical implementation through the buttons, the pressing order of which is related to the logical sequences of use. Pressing button number 1 means that number 1 is shown on the screen, pressing the next number, 2, will show this number next to the previous one, and so on. The concept 'user interface to the mobile telephone' applies the idea of changing operations into actions. Instead of pressing all the number buttons (a series of operations) to make a phone call, the user can search for a number from the list, moving backward and forward. New design is then on the level of action. Thus, the user must be able to figure out internally or mentally that the phone has a menu-like list to be browsed.

As far as usability is concerned, mechanical and logical functionality go hand in hand. This is shown by the examples used for argumentation. Once again, user action is used to mediate the designers' understanding in order to co-construct the design object. What if the user is left-handed? Taking the imaginary telephone from the pocket (just like a pen) and looking at the device from a left-handed perspective means that the screen and the number buttons will be upside down to the user. This was successfully shown by one of the designers by acting out the user's operations, all the way from putting his hand into his pocket to moving the device into a position where this contradiction in design was evident. Now, the workaround, as ideas were thrown on to the arena, was that the device should have an indicator for its orientation, thus allowing a flip of the screen for the left-handed viewer.

Figure 6 illustrates a photo of the final concept before it went to a mechanical workshop.

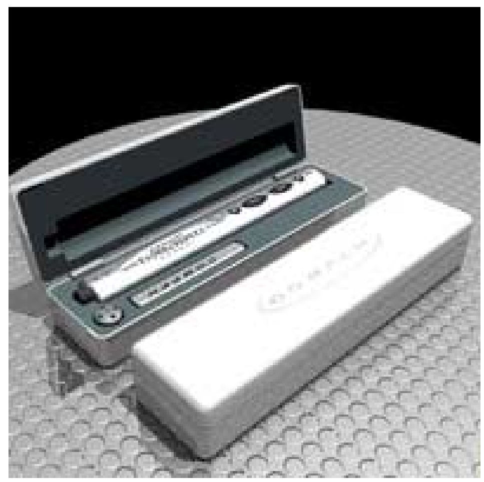

Figure 6: 'Pen-shaped user interface for a mobile telephone' (Photo courtesy of Metsävainio Design).

The photo works as a representation for the management and a sales artifact for the organization. Thus, the designer has included the environment, i.e., the box, of the device as the user (or buyer) would first see it. User activity is therefore also involved in this internal marketing activity, convincing the designers' own organization of the product, as they see it would be tempting for the user to buy.

5. Towards computer support through systems demonstrations

The purpose of our research demonstrations is not to implement all the ideas that can be derived from the field work or interviews, but they have rather served as topics of discussion with our research and industrial partners.

WebShaman

We will not go into the details of application architecture, but will only point out that the graphical presentation of WebShaman is based on the Virtual Reality Modeling Language (VRML 2.0), which is controlled with Java tools. The user interface has a VRML window and a Java applet to control it (Figure 7). This obvious dichotomy is due to technical reasons and leads to an implementation where the virtual prototype is on the left in the figure, while the tools used to control it are on the right. With WebShaman we have introduced a three-dimensional functional virtual prototype as a design object representation for collaborating designers. Since World Wide Web is the platform these designers can inherently be geographically distributed.

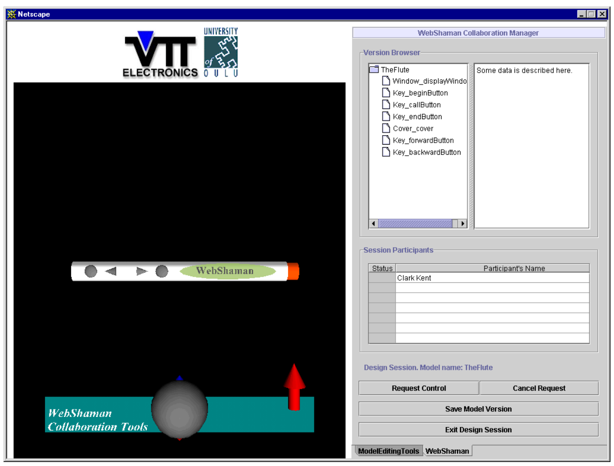

Figure 7. WebShaman

The designer can quickly access the web page and try out the virtual prototype. It is possible to view the virtual prototype in 3D, press the buttons, and see the effect of the user interactions on the screen (Figure 7, left). One can select components to be manipulated (right). The WebShaman tools are a shared cursor (arrow), a virtual trackball for synchronous object manipulation, and (on the right) awareness and control mechanisms to allow the designers to go into synchronous observation or object manipulation. The designer can enter into a design session where a group of designers use the same design object representation. One of the users is in control of the virtual prototype shared by the designers. Other designers can take turns manipulating the prototype, and everyone will see the list of designers updated with a number indicating a request for a turn. All the designers participating in the session can see the interactions of the one who is in control. Thus, rotation, button presses, and functionality are also synchronously shown on the other web pages. When the color or size of a component is changed, the others will see the new color as well.

Although any of the designers may create a virtual prototype, the first version may be part of industrial designers' activity. This is only because the visual representation is important for the group of designers, and industrial designers are usually the most visually competent designers. Therefore, virtual prototyping tools should support the industrial designer in transforming the design object into visible representations. The functionality of the device is accomplished partly by the software designers' activity and partly by the user interface designers' activity. Thus, we should support these activities but also be able to integrate these activities in the virtual prototyping tools. At the moment, modeling of functionality can be used also to produce the software that can be exploited in the final product. These simulation tools have already been built by VTT Electronics, our collaborating research centre in Oulu. The virtual prototype can be characterized as a shared design object for a group of designers, which is easy for everyone to grasp and also serves as an entry point for different disciplines.

User actions as mediators in virtual prototypes

In this demonstration, user activity (context) is an issue which the designers must negotiate and agree upon. Our assumption is that every designer has a telephone available. Any other technology is naturally also possible, such as video or audioconference, etc. What is even more important, however, is that we should demonstrate how the shared virtual prototype can mediate the designers' understanding of user actions.

In this case, in order to simulate users' actions, the designer has to take control of the shared virtual prototype. At some point, we decided to let only one of the designers at a time to control the shared virtual prototype. The reason for this was that, as we noticed, this is what also happens in the group. The designer who is explaining an individual viewpoint does not want to be disturbed until he has made his point. Then, a sequence of user operations can be shown with the shared object. The designer can do the action by using virtual components, i.e., pressing the buttons of the virtual prototype. It is possible to rotate the prototype so that everyone will see it from the same angle, and to use a shared 3D cursor to point out the focus of argumentation. For instance, the argument could focus on a press button too small for the user to press, allowing the designers to point out the button in question. One could argue about the size of the design object by juxtaposing it to some familiar object, such as a match or a ruler. A sequence of user operations can also be recorded and replayed in an appropriate design situation. Thus, argumentation on a certain action can be prepared before a design session starts. The actions in this demonstration are restricted only to the object itself. Thus, it is not possible to show such operations as "take the device from your purse", "move it toward your ear", etc. At any rate, this is the first attempt to use the computer to support user actions, and not only operations, on a virtual device.

In a distributed design session virtual prototyping is only one, although important, medium to convey the understanding of user actions. We assume that the users of shared virtual prototyping techniques also have applications to share documents, make video streams from the output of video cameras, have workstations for CAD information, or a conference telephone.

The demonstration of World Wide Web-based WebShaman is suitable for clearly focused purposes: WWW-based delivery of virtual prototypes and communication support for designers. It could be used as an intermediate tool between CAD applications and users without powerful workstations.

The first criticism we received was that this approach does not support the critical part of concept design, i.e. the quick creation of ideas, where representations change quickly. Second, one should be able to take hold of the object, in order to really understand its dimensions, and one cannot actually use the surrounding physical environment in order argue for a concept. Neither of these arguments, however, conflicts with the basic understanding we presented of how designers do their work. As I see this criticism, these two claims manifest the need of designers for an approach that introduces computer support for user actions, but we should also try to find other possible facilities for them to express what they mean.

WebShaman Digiloop

In reply to the critique, the next step we took in our software design was to examine how to use a data glove and how to introduce the physicality of the object to a virtual prototyping application. Figure 8 depicts a use situation of the WebShaman Digiloop system. In this use situation, the flat screen acts as a window to the virtual design object. While seeing a 3D virtual prototype through the window the user holds a physical object, about the same size as the future device, in his hand. As a matter of fact, a stereolithography model could be used as well.

Bringing the physical object to the virtual prototyping context requires some technical devices. The box on the right is Polhemus Fastrack, which tracks where the hand and the physical mock-up are. The smaller box is the sender, and the two receivers are placed on the dataglove and the mock-up. The (Virtual Technologies) dataglove can be used to recognize finger movements. With all this technology combined, we have a demonstration where the user can interact with the virtual prototype while touching the mock-up. The user sees the virtual prototype wrapped on the physical mock-up. The distance between the mock-up and the virtual prototype can be determined by the system, and the users' mind can therefore connect these two things. The virtual prototype simulates the mechanical movements and functionality.

Figure 8. WebShaman Digiloop in use.

The mock-up, i.e. the design object representation, can now be brought into the designers' environment. It can be used to evaluate concept usability in the designer/user environment and to test its use with other artifacts, such as a purse or a pocket, or the users' physical properties, including the hand or the ear (a pen can be behind the ear). We have not yet designed or implemented the sharing of a virtual prototype in this system, but designers should naturally be able to share these use situations.

The idea of a distributed version of this application is intriguing, and it was the main motivation to carry out the test. The vision is to use this application to help geographically distributed designers to communicate about their work.

6. Lessons learnt

User action as a mediator for concept designers is a new approach to understand how designers cooperatively construct a shared understanding of a new product concept. Furthermore, it is a new way to think about what kind of computer support could be built for geographically distributed designers. An exclusive focus on the representation of the design object as a virtual prototype and the introduction of user action into that context has been a fruitful approach for delineating software prototype designs of shared virtual prototyping. Here we have used this idea to introduce two applications. It is our belief that the inclusion of users' activity will further stimulate application designs that allow communication of concept designers over distance.

Having reached this stage of work, we have, quite understandably, received much critique on these two systems. Following issues reflect the problems we have pointed out through demonstrations in several conferences and sessions with our project partners.

•Situational action means that the designers could use various situational resources or artifacts in order to convey their understanding to the other designers. Our implementations are still very clumsy for such dynamic and creative concept design. Obviously, we will need more solutions to support situational action. As we pointed out earlier, representations may change quickly in the first phases of design activity. A pivotal point for any computer system supporting design would be the need to support multiple representations. The designers should be able to make changes and juxtapose the alternatives quickly. An interesting comment came from an industrial designer who asked me for digital clay: "You know, you should be able to quickly shape the concept, feel it, and make changes on it by using digital wax or digital clay of some sort. Not the way things are done with CAD applications." Certainly, this sort of requirement puts much pressure on software design. Quick sketching could be considered as one approach [22]. From this point of view, too, the process of creating a virtual prototype is critical.

•It was evident that new concepts inherit properties from earlier concept generations. Thus, the history of earlier design objects should be maintained.

•The need to outline a design rationale is an issue that has been on our to-do list. We have been concentrating on the shared virtual prototyping tools and have therefore not introduced any way to save the design rationale. It is obvious, however, from the viewpoint of group dynamics that a newly appointed designer should be able to make a quick analysis of what has taken place in the design sessions earlier.

•We have focused on aspects of concept design and communication on the design object. We are working on further modelling of use situations, which will structure the tools used to create virtual prototypes for these situations. Examples of such domain-specific use situations are web marketing, subcontractor-customer communication, and virtual engineering

•We want to have only the representation of the design object to be distributed. Any effort on using virtual reality would not as such serve our goal.

All in all, in this paper I have suggested that considering user action as a mediator for communication in concept design is a fruitful approach to the design of computer systems supporting collaborative design. It is my understanding that the CAD system vendors and other tool makers for electronics, industrial and mechanical product design have overlooked such features.

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