THE VIRTUAL PROTOTYPE AS AN EVALUATION TOOL IN THE INTELLIGENT-CLOTHING DESIGN PROCESS

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Abstract

This paper describes a study of the implementation of virtual prototyping as part of the process of designing intelligent clothing. Virtual prototyping is used to visualize the results of the concept-design phase for the end-user. Thus, the end-user is involved in the design throughout the process, from studying the context and users' needs to the evaluation phase before production of the physical prototype. The goal is to find new models and methods for design, and to use virtual prototyping to reduce the number of expensive, time-consuming physical prototypes. The virtual prototype has to be a usable instrument for data collection by researchers and for evaluation by end-users.

1. Introduction

This paper outlines the role of the virtual prototype as an evaluation tool and the challenges it must meet. As background to the development of the tool, there is a brief introduction to how the usability of intelligent clothing is understood and why certain methods are chosen for evaluating intelligent clothing. The goal of the Methods and Models for Intelligent Garment Design (MeMoGa) research project was to carry out a user-centred concept-design process (see Säde, 2001) for intelligent clothing, from the background research to the concept-design phase. A virtual prototype and an interactive multimedia presentation were then developed from the material from the concept-design phase and used in a usability evaluation of the concept. The evaluation is structured so as to provide more information about the usability and acceptability of the intelligent-clothing concept, and to study ways of conducting evaluations of clothing concepts in general. Usability evaluation using a virtual prototype will enable researchers and designers to analyze concepts in an early phase of product development and to eliminate design errors and shortcomings. (Mäyrä, Matala & Falin, 2005) Virtual prototyping is also used to gather material for studying how informative, communicative and usable the virtual prototype and presentation are in general in this context. This study is part of the Facilitating Social Creativity through Collaborative Designing (CoDes) research project, one aim of which is to explore how new media and design technologies can improve design communication.

2. Usability evaluation of intelligent clothing

The term 'usability' is rarely used in the context of clothing, even if numerous trials are conducted during the design process, including fit testing and field testing to investigate how the clothing works in practice, usually accompanied by observations of functionality and aesthetics. (See Choi & Ashdown, 2002) Determining usability is important when designing intelligent clothing that may take a long route from idea to end product. Intelligent clothing often consists of electronics, e.g., mobile-phone technology, embedded using conductive fibres and more traditional electronic components. This makes the process more complex, time-consuming and expensive than 'traditional' clothing design. That is why usability evaluations using a virtual prototype can be an important stage in the presentation of the concept to the end-user and for minimizing faults in the physical prototype.

2.1 Towards usability evaluation of intelligent clothing

Usability can be seen as indicating how easy a product is to use. A more formal approach to usability is the description by the International Standards Organisation, which defined usability as the effectiveness and efficiency of a product. The former refers to the extent to which the goal is achieved and the latter to the amount of effort required to accomplish the goal. (Jordan, 2001) The usability of intelligent clothing can be based on these definitions, but when usability is researched using a virtual prototype, and carrying out real tasks with the clothing is impossible, usability should be understood differently. That is why the usability of clothing should be analysed using clothing theories. (See Uotila & al., 2002)

To define the usability of clothing, the FEA model was chosen, which has been developed by Lamb & Kallal in a framework called the ‘Consumer Needs Model’. This provides a basis for the intelligent- clothing design process, from the background research and design phase to production of a virtual prototype and of a questionnaire to conduct the evaluation. The FEA model suggests that the (F)unctional, (E)xpressive and (A)esthetic properties of a garment are inseparable parts of a whole, and there is no reason to distinguish between functional-apparel design and fashion design. All three elements should somehow be present in the design process, as well as in the final product. The emphasis on the three elements can vary according to the garment’s primary intended use. Functional properties are clearly emphasized in workwear, but expressive and aesthetic properties are still relevant to some extent. (Lamb & Kallal, 1992) The FEA model is expanded into a framework called ‘Apparel Product Appearance Factors’ using the FEM model. This takes the user’s body into account in three different ways: (F)orm, (E)xpression and (M)otion, which are incorporated into the analysis of the appearance of the clothed body. **(**Kallal, Keiser, MacDonald & Stefan, 2002)

2.2. Materials and methods of usability evaluation

The evaluation of the usability of the intelligent clothing concept is based on two previous versions used in projects in 2001-2003. (University of Lapland website; Uotila, M. & al., 2002) Both evaluations were conducted using qualitative methods, with the discussion guided by a semi-structured data-gathering framework. To find out how quantitative and more independently executed methods might help conduct the evaluation in a faster, more economical way, this third version tried out three different methods.

The three methods were chosen according to Jordan’s (2001) guidelines on conducting empirical usability evaluations. Earlier versions of the evaluation used individual semi-structured interview and co-discovery methods, both time-consuming, qualitative methods. These experiences prompted the idea of developing quantitative and more independent methods using interactive multimedia and virtual prototyping. These more independent methods use a web-based ‘kiosk’ and a laptop-based ‘kiosk’. Participants get a website address where they can make their evaluation at any time, e.g., using their home computer. The same multimedia presentation is run on a laptop-based kiosk for semi-independent use. This is set up at workplaces for a given time, with technical support provided for end-users taking part in the evaluation. To ensure that the evaluation provides sufficient information about the concept, the co-discovery method was also used. The advantage of this method is that there is no interviewer in a traditional sense in the evaluation situation, so the discussion can flow quite spontaneously. This makes it possible to get data that cannot be obtained using, e.g., a structured questionnaire or a strictly structured interview. The disadvantage of this method is the analysis of the qualitative data, which provides no concrete information and is time-consuming. (Kemp &Van Gelderen, 1996)

The concept evaluation was carried out among workers who use workwear either daily or periodically in their work, or when visiting heavy-industry factories. The laptop-based kiosk produced less than 30 evaluations and the web-based kiosk less than 20. Fifteen people were invited to conduct the evaluation during a working day using the co-discovery method.

3. The role of the virtual prototype in evaluating intelligent clothing

In our case the virtual prototype was intended to assist users in assessing the applicability of the proposed solutions. We focus on three main roles played by the virtual prototype in the evaluation process. These are: 1) to present the designed concept to the end-user; 2) to guide the communication and evaluation process, and to arouse discussion; and 3) to be a usable instrument for data collection from the researcher's viewpoint, and for evaluation from the end-user's viewpoint.

3.1. The informative aims of the virtual prototype

The virtual prototype is defined to give a degree of realism and functionality comparable to that of the real object and to provide a multi-dimensional view of the product. Its purpose is to allow designers or users to examine the quality of the product through impressions given by the virtual prototype. (Leppälä & al., 2003) Our study involved two vital questions about how to simulate features of the clothing concept: 1) What key features are required for a virtual prototype to provide a sufficiently versatile view of the concept?; and 2) What degree of realism and functionality is required? It is essential to use concrete models when users are involved in the process, since they cannot deal with abstract specifications. Thus, the level of abstraction must be decreased and the amount of context around the product increased when the viewer is the end-user. (Säde, 2001) Although our presentation of the concept does not include tangible models, our objective has been to use virtual prototyping to produce models that are concrete enough for evaluation purposes.

In defining the informative aims of the content of the prototype, we have used the model shown in figure 1. Each aspect: garment, body and context, is divided into three subcategories. In defining the subcategories for the garment aspect, we used the same FEA model as in the concept-design process, and this was expanded with the FEM model when defining the body aspect. From the prototyping viewpoint, this framework is used to define the elements for visualizing the virtual clothing and virtual user. A context aspect is also needed to define the simulation features for the context of use. The main purpose of the virtual prototype is to present the functional, expressive and aesthetic properties (FEA) of the concept in as informative a manner as possible. Visualization of the body, i.e. the potential user, is crucial when presenting the garment with regard to bodily proportions and to facilitating the end-user's self-identification as a prospective user. In visualizing the body to give sufficient information we considered the form, expression and motion attributes (FEM) for an avatar model of the employee. Another important aspect is visualization of the physical, cultural and social context of use, since simulating the role of the concept for the user, environment and situation of use is vital especially for evaluating the properties of complex intelligent clothing.

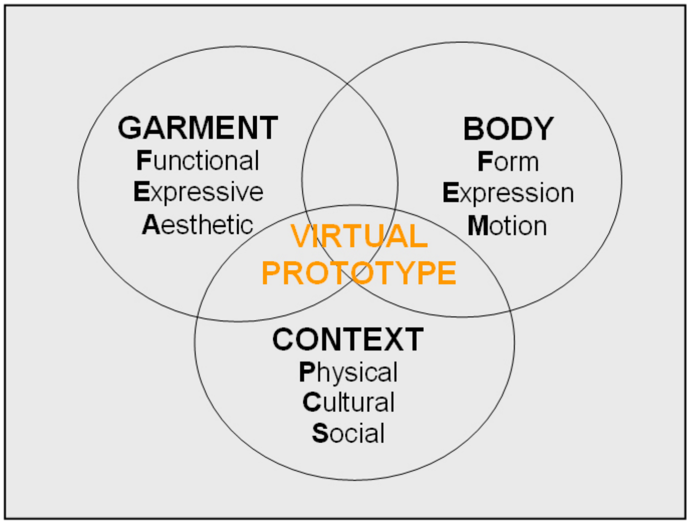

FIGURE 1. The informative aspects of the virtual clothing prototype. (Pursiainen, 2003)

In defining the informative aims of the means used to express the virtual prototype's contentual elements, it is useful to examine the Houde & Hills model of what prototypes prototype. They emphasize that it is more productive to examine prototypes through their purpose than through such attributes as the tools used to create them or how refined-looking or refined-behaving they are. Their model consists of three perspectives for analyzing the essence of the prototype: role; look & feel; and implementation. Role refers to questions about the function, such as usefulness, that an artefact performs in a user's life. Look & feel denotes what the user looks at, feels and hears while using the artefact. Implementation refers to the techniques and components via which an artefact performs its function. A fourth aspect is also introduced: the integration prototype, which explores the balance between all three main dimensions. The actual prototype can be any representation of a designed idea, regardless of the medium. (Houde & Hill, 1997) In our case the purpose of the prototype is to be an 'integration prototype'. This prototype concentrates on the role and look aspects. It is known to be difficult to simulate the feel aspect in the virtual prototyping of clothing, thus the feel aspect was expressed by visualizing the look and structure of the fabric. Implementation of the concept was less important than the other factors, because the prototype was not used to evaluate a production-ready design.

In our case the virtual prototype consists of several elements: pictures and explanatory texts, 3-D animations and interactive 3-D models. These materials are included in the interactive multimedia presentation. A narrative 3-D introductory animation (ca. 4 minutes) including a mobile, dressed avatar figure of the end-user with dialogue and an environment with audio, simulates features of the physical, cultural and social context in which the clothing would be worn and used. The introduction animation also shows the functional, expressive and aesthetic features of the concept including the form, and the expressive and motion features of the end-user avatar. The introductory animation was the most versatile presentation medium in terms of its ability to simulate the different features of concept 'horizontally', but not in great depth. The presentation also uses close-up 3-D animations, including the item of clothing under review worn by a walking avatar figure, primarily simulating the aesthetic properties of the clothing, especially the interaction with the mobile body and showing the clothing from every angle. In addition, the presentation includes interactive 3-D models displaying each item of clothing, simulating the individual aesthetic properties of the single garment. The purpose of these models was to give the viewer the possibility of examining the garment by rotating it with the mouse and choosing the colour of the clothing. It also displays each item as a three-dimensional clothing object. The presentation also includes pictures rendered from the 3-D models and explanatory texts, giving more detailed information about the functional, expressive and aesthetic properties of the concept. (See Figure 2.)

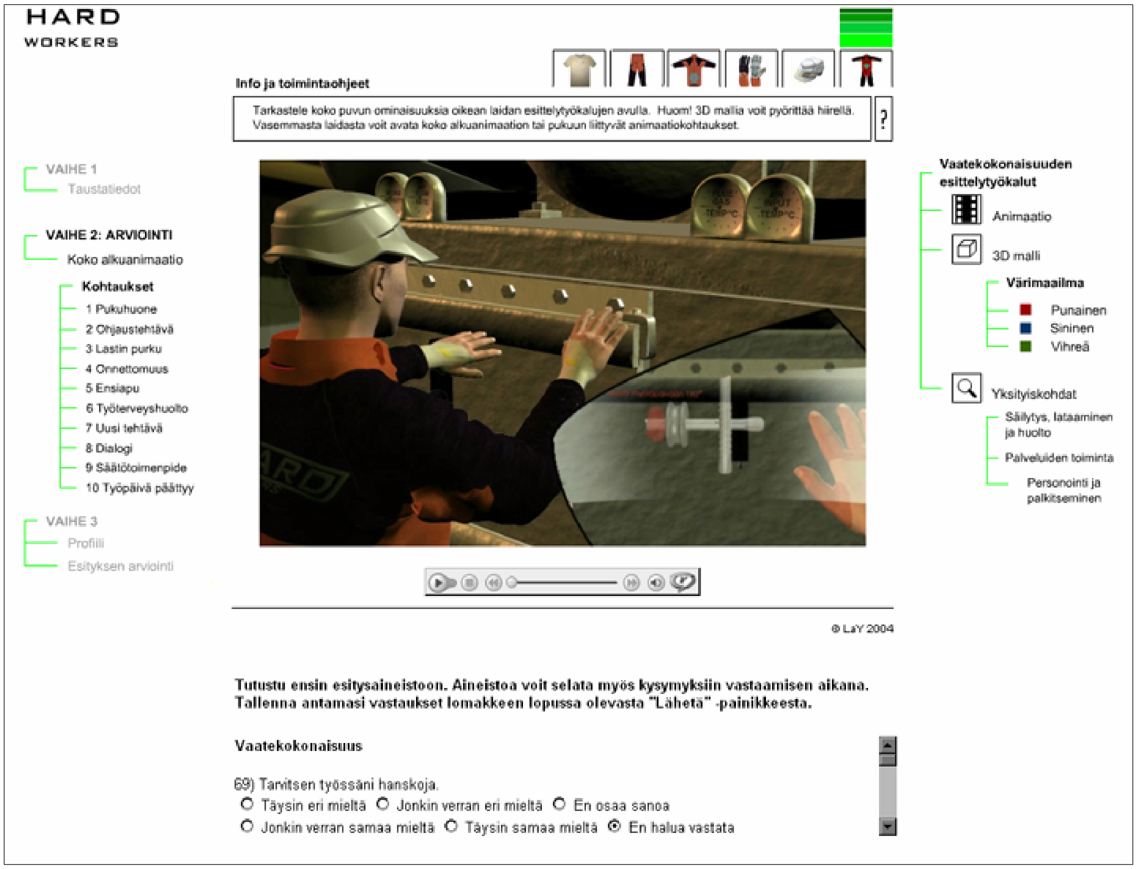

FIGURE 2. Screenshot from the multimedia-presentation interface (Pursiainen et al. 2005).

3.2. The communicative aims of the virtual prototype

In addition, the virtual prototype was intended to facilitate and initiate the communication between researcher and end-users. Representations of designs aid communication, making abstract ideas tangible and providing a common language. Evaluative communication with end-users is possible when the abstract ideas are represented in an explicit, understandable form. The reasons for prototyping can be put into three broad categories: idea generation; communication; and testing. They are all intended to be a basis for decision-making. (Säde 2001) Our study does not adopt the perspective of using virtual prototyping for decision-making during the idea-generation phase. In our study the main goal of virtual prototypes is to provide a basis for decision-making in the usability evaluation. We examined three different usability-evaluation methods, each requiring ways of communicating with the end-user, with only the methods of interaction being different.

The usability evaluation was conducted using web and laptop-based kiosks. Thus, one aim of the interactive multimedia presentation and the prototype was to enable as independent an evaluation process as possible. Using the virtual prototype further allowed us to look for less time-consuming methods than co-discovery. That is why the multimedia presentation includes questionnaire forms for the collection of quantitative data for the web and laptop databases. This Likert-scale questionnaire includes evaluation of the concept, evaluation of the multimedia presentation and virtual prototype, and a few profile questions. In these two methods, communication between end-users and researcher was limited solely to interaction through the questionnaire; so the presentation acted as an intermediary for the evaluative communication. However, the laptop-based kiosk allowed technical support from a member of the research group if needed, while the web-based evaluation was wholly independent, with no possibility of direct interaction with the researcher.

The advantage of gathering quantitative data with a questionnaire is that it is a quick, cheap method conducted totally independently, since the investigator need not be present and the participant is also free of any investigator's influence. In addition, the informant can take as much time as necessary without feeling any pressure to go forward. On the other hand, independence also makes it impossible to ensure that enough participants fill in the questionnaire, and those who complete the questionnaire will most likely be those with comparatively extreme opinions about the issue in question. (Jordan, 2001)

The test method used in our study that was most demanding from a communication viewpoint was co-discovery. In the co-discovery method the virtual prototype was intended to initiate spontaneous discussion between two end-users. In addition, the aim of the entire multimedia presentation was to steer the test situation and the evaluation process forward. The evaluation process started with the introductory animation, its goal being to prompt interest and ideas that would form a basis for the evaluative discussion. The presentation showed the concept starting from the underwear and ending with the whole outfit. The discussion was facilitated by a structured questionnaire, which was included as a fixed part of the graphical user interface. In the co-discovery situation the questionnaire form was not used to save answers to a database, since the situation was recorded on audio and video.

3.3. The usability aims of the virtual prototype

It was important to consider the usability features of the prototype materials and the interactive multimedia presentation, since they would affect the entire evaluation experience. The aims of the usability features take both the end-user's and the researcher's viewpoint into account.

In the first place, the aim was to make the various kinds of virtual-prototype materials available within the same presentation platform, so as to make it easy to view all the concept materials independently. The second aim was to design the graphical user interface to make it as easy as possible to use, since viewers are not assumed to be habitual computer or multimedia users. Therefore, the multimedia presentation started with instructions that were especially important for the web and laptop-based kiosk evaluations. We also considered usability aspects of the graphical user interface such as visual and typographic appearance and layout, navigation and structure. One of the usability goals of the presentation was to show the viewer how the evaluation process progresses. The presentation's primary purpose was to be accessible to as many employees of the selected companies as possible via the Internet. Thirdly, the aim was to design the easiest possible way of collecting the evaluative data for the database, where the data would be easy to collate for analysis. The goal was to incorporate the structured questionnaire form into the interface in such a way that it would be generally easy for end-users to answer the evaluative questions, and at the same time to view the materials for the intelligent-clothing concept. It was extremely important to produce a reliable method for saving the given answers properly in a web-based database.

4. Perspectives on using the virtual prototype as an evaluation tool

When using the co-discovery method, the multimedia presentation worked very well in directing the progress of the situation, and the informative features of the virtual prototype worked sufficiently well to prompt discussion. Some key features of the concept were not credible enough to end-users, they thus speculated about whether the feature in question would be at all useful to them. In this situation a more functional presentation of these features might have made a difference to the resultant evaluation. The co-discovery method is reliable in that it requires that participants be personally invited to participate, and it provides rich material for analysis. The transcription and conducting of the evaluation situation are, however, time-consuming.

The web and laptop-based kiosk methods appeared similar at first, but in the end the laptop-based kiosk seemed to be a more reliable tool, because technical support was provided and problems were minimized using a pre-configured laptop. The laptop-based kiosk was, however, a disappointment, because even if the employees were given permission to take part in the evaluation during certain working days, for some reasons, maybe shyness about doing the evaluation in public, lack of information, or hectic work schedules, they did not participate in such numbers as we had anticipated. Thus, in order to get enough data from this method, it was decided to carry out the evaluation at a fourth company using only the laptop-based kiosk version of the evaluation. This time, employees were told to take part two at a time. These end-users worked on separate computers and had the support of a technical adviser, who also made notes on the situation and on possible problems. So, in the end, this method was almost as time-consuming as the co-discovery method, in which participants needed to be assembled in advance. Working this way there were hardly any technical problems, because support was available.

The web-based kiosk was intended to collect more evaluation data than the co-discovery and laptop-based kiosk methods did. In this respect the web-based kiosk was a disappointment, since participation was much lower than expected. The web-based kiosk was the most challenging method, especially in terms of the tool's usability, since the biggest challenge was to make the tool available to employees through the Internet and to get it working correctly on the participating companies' networks. There was some feedback that confirmed our speculation that inadequate user rights and skills prevented installation of all the required software plug-ins. The other challenge with this method was simply that employees had neither personal computers nor the skills to use them. Another factor could be the lack of motivation to participate, due to the evaluation relying on a wholly independent process.

Both the web and laptop-based kiosks reliably saved the answers to the database, and the gathering of the quantitative material for analysis was quite rapid. Still, the questionnaire needs to be developed to get the gathered data into an appropriate form before analysis. The web-based version needed to make it possible to continue the evaluation without having to start from the beginning after logging off the website, since the evaluation process overall involves a considerable number of questions to be answered and materials to acquaint oneself with. Reducing the number of quantitative questions and focusing them is one of the challenges of developing the evaluation method to make it work faster with the clothing concept, the presentation and the virtual prototype. The virtual prototypes involve the same informative challenges in both web and laptop-based evaluations, since both methods are based on independent observation without further explanation from the researchers. It seems that the low participation in the web evaluation could not be due to insufficient informative features in the virtual prototypes, since in the laptop-based evaluation end-users only asked a few discursive questions, in which the technical support staff were not allowed to take part or explain, and yet it was still possible to conduct the evaluation. With the web-based method, the most challenging and, at the same time, the most crucial features are the technical and accessible usability aspects of the interactive multimedia presentation and the virtual-prototype materials.

5. Conclusion

While a number of experts may participate in the intelligent-clothing design process, it is the end-user who ultimately decides whether the features of the product are appropriate. It is thus important to obtain feedback from end-users, including during the design process proper, to ensure that the users' perspectives and expertise are not overlooked. One approach is to engage in a dialogue with end-users to ascertain their experience of evaluating designed concepts from visualizations and virtual prototypes.

The usability of clothing can be developed using a clothing-theory FEA model. The focus can then be on the usability of the garments, rather than on following guidelines to the usability of technological devices - a subject that has been studied more, but which does not offer an adequate way to analyze the usability of the clothing. The FEA model can also be used to developing the virtual prototype for the usability-evaluation tool. This confirms that the model is useful throughout the design process and that it seems to clarify the design process in general. Using a virtual prototype and an interactive multimedia presentation allows usability evaluations of intelligent clothing to be conducted in several ways. Nevertheless, the aimed-for independence requires more than just the successful development of the tool. It also involves inspiring high motivation and making the evaluation as easy as possible for participants to take part, both with assistance and independently.

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