Prototype of a Virtual User Modeling Software Framework for Inclusive Design of Consumer Products and User Interfaces

Svetlana Matiouk[1], Markus Modzelewski[2], Yehya Mohamad[1], Michael Lawo[2], Pierre Kirisci[2], Patrick Klein[2], and Antoinette Fennell[3]

[1] Fraunhofer Institute for Applied Information Technology FIT,
Schloss Birlinghoven, 53754 Sankt Augustin, Germany
{Svetlana.Matiouk,Yehya.Mohamad}@fit.fraunhofer.de
[2] University of Bremen, Bibliothekstraße 1, 28359 Bremen, Germany
[3] NCBI Centre for Inclusive Technology, Whitworth Road,
Drumcondra, Dublin 9, Ireland

Abstract. The recent developments in technology inspire designers and engineers in creating more and more sophisticated and smart consumer products. However, the most ingenious device in the world will fail, if its users are not able to access the mastermind it provides. How can we best support product creators in the thorny task of inclusive design? In this paper a prototypic realization of a virtual user modeling framework to support designers in creating more inclusive products following the phase-based product development process is presented. A qualitative usability survey evaluated the acceptance of the proposed end-user applications among designers and the effectiveness of the recommendations-driven support – the paper provides insights.

Keywords: Virtual user modeling, digital human model, recommendations-driven design support, virtual usage simulation, user experience, inclusive product design.

1 Introduction

In this day and edge of rapid technological progress and growing economic competition, a lot of industrial effort is put into resource optimization. This can lead to a deterioration of product quality, in particular, as a result of failing to access diverse user requirements and to understanding user abilities and habits.

In this paper we describe a realization of a model-based approach that aims to involve the user's perspective at early phases of the design process. A detailed description of the proposed concept is provided in [1] and [2]. The product designer is therefore supported by appointed software tools throughout the three design phases: the sketch phase, the CAD design and the virtual evaluation phases. The supportive tools are connected to a *Virtual User Model (VUM)* that contains knowledge related to the product usage in the form of models of such entities like user, environment, product component, task, design recommendation and their interrelationships. The form of the support provided by the system depends on the stage of the design process.

C. Stephanidis and M. Antona (Eds.): UAHCI/HCII 2013, Part I, LNCS 8009, pp. 59–66, 2013.

The aim is to provide the industry with a cost efficient way to integrate inclusive design know-how into the existing workflow. We would like to emphasize at this point that the proposed concept does not suggest to replace involving human users into ergonomics evaluation. However, the hypothesis, that it is capable of focusing the development according to the principles of inclusive design and in preventing major design mistakes, has been confirmed by the results of the end-user[1] evaluation. For product manufacturers who still could not commit to the time and cost-intensive product evaluation with real users as an integrated part of their development process, the method can provide a possibility to benefit from inclusive design at least virtually. This might represent a first step towards an overall design improvement.

The concept has been realized in the form of a prototypic virtual user modeling software framework. Hereby inclusive design support has been focused on elderly people with mild to moderate physical and sensory impairments. End-user interfaces of the three supportive applications have been qualitatively evaluated with designers.

After an overview of related work, we describe the main principle, which drives the design support, namely the design recommendations. We then describe the implemented framework prototype, the end-user evaluation and its results. We conclude with a discussion of the key benefits and limitations of the approach we identified as a result of the user studies and our personal experiences.

2 Related Work

User modeling has been an active research topic for more than four decades. Since the beginnings of the 1970s many dedicated and general user modeling systems have been developed to enable user-adaptation in different domains [3], [4], [5].

In the last decade the simulation of virtual humans has been identified as a powerful approach to support engineers in the product development process. Virtual human modeling reduces the need for the production of real prototypes and can even make it obsolete [6]. During recent years, the research interest in using digital human modeling for ergonomics purposes has increased significantly [7]. The use of virtual humans and simulation in the automotive industry showed also great potential. Porter et al. [8] present a summary of applications of digital human models in vehicle ergonomics during the early years of personal computers.

Existing available tools and frameworks provide designers with the means for creating virtual humans with different capabilities and use them for simulation purposes. DANCE [9], for instance, is an open framework for computer animation research focusing on the development of simulations and dynamic controllers. SimTk's OpenSim[2] is also a freely available, user extensible software system that lets users develop models of musculoskeletal structures and create dynamic simulations of

[1] In the following the *end-users* refer to designers. The designers are the end-users of the proposed supportive system.

[2] `https://simtk.org/home/opensim`

movement. There are also many commercial tools such as JACK[3], RAMSIS[4], AnyBody[5] and Santos[6], offering considerable benefits to designers looking to evaluate their designs, as they allow the evaluation of a virtual prototype using virtual users with specific abilities. These tools are mainly based on anthropometric data sets based on measurements taken from healthy and the able-bodied groups.

Even though significant effort has been put into physical user modeling and many tools have been developed using virtual humans for simulation purposes, very little effort has been made to incorporate data for users with impairments or functional limitations, such as older users and users with disabilities. The present paper aims to demonstrate the approach, proposed and realized by VICON project, towards the design and evaluation of consumer products using the VICON simulation model considering the characteristics of older people.

3 Design Recommendations

Design recommendations play a key role in the proposed method for inclusive design support. Several research projects collect and classify guidelines for designers of ICT. The guidelines include advice and recommendations on accessibility issues for all types of disabilities [10]. A number of research projects make the guidelines, they have developed, publicly available online. See e.g. cariac-eu project website[7]. Published international standards, e.g. ISO Guide 71 [12] or CEN Guide 6 [13], provide basis for identifying design recommendations as well.

In terms of our approach, the available design recommendations have been collected and integrated into the VUM as a logical mechanism for relating the different entities of the usage context model to each other. To give a simple example, the recommendation "Avoid the use of glossy material to improve readability" [11] relates the following properties of the entities: user's sensitivity to glare, environment's lighting level and the presence of direct light sources as well as surface glossiness of a product's component. The relation is expressed in form of a logic rule.

The recommendations usually contain qualitative information about the usage aspects, however there is an increasing number of recommendations available, which provide quantitative relational information, based on statistics and measurements. In our framework we differentiate between two types of recommendations:

- Informative (or qualitative) recommendations
- Quantitative recommendations

The framework intends to provide designers with recommendations-driven support throughout the three product development phases. The next section describes how it is realized in software architecture.

---

[3] http://www.plm.automation.siemens.com/en_us/products/tecnomatix
[4] http://www.human-solutions.com/automotive/products_r_auto_en.php
[5] http://www.anybodytech.com/
[6] http://www.santoshumaninc.com/
[7] See http://www.cardiac-eu.org/

4 Framework Prototype

The system has been designed according to the requirements that have been identified for the industrial phase-based product development process. In the following the emerged workflow model and the system architecture are described.

4.1 Workflow Model

Fig. 1 presents all impact areas of the framework by means of the three applications that are used in each phase. For more detailed review, see [16], [17].

Sketch Application. Product development process can be seen as a sequence of phases [14]. Starting in a sketch of a rough idea, the product design is sequentially refined to a number of detailed two-dimensional sketches, showing the product from different perspectives. During this sketch phase, there is a big diversity of tools used by designers. Thus, the prototypic application for support of the design activities at this phase is a standalone application, i.e. independent from any particular sketching tool. Moreover, it can be easily extended to a web-interface.

The Sketch Application provides the designer with design recommendations for a given type of the target product. Selecting a target user profile, an environment profile and a task via the UI of the application enables filtering of the identified recommendations. The selection can be stored for the later use.

CAD Design Application. Based on a created sketch, 3d virtual prototype of the product is then created. In this phase different software solutions for CAD design such as CATIA or Siemens NX [4] can be applyed.

Siemens NX is widely used in the industry. The CAD Design Application has been integrated into it. During the creation of a product prototype in CAD, designer can access the recommendations directly within the CAD environment. Moreover, by importing the data from the sketch phase, the predefined usage context is then accessible.

Now the product can be annotated, i.e. additional product descriptive information that is not contained in the geometrical 3d surface representation can be assigned to the parts of the product model. The product annotation assigns both kinds of information: semantic, e.g. “this product part is a button”, and non-semantic, e.g. color or label size. As soon as the product model is annotated, the designer can constrain the filtering of recommendations by selecting specific product parts, so the presented recommendations will refer only to the selected component. Furthermore, quantitative recommendations can be applied to the selected component, in case the measured properties of the component do not meet the recommended values. Annotated product model can then be virtually evaluated.

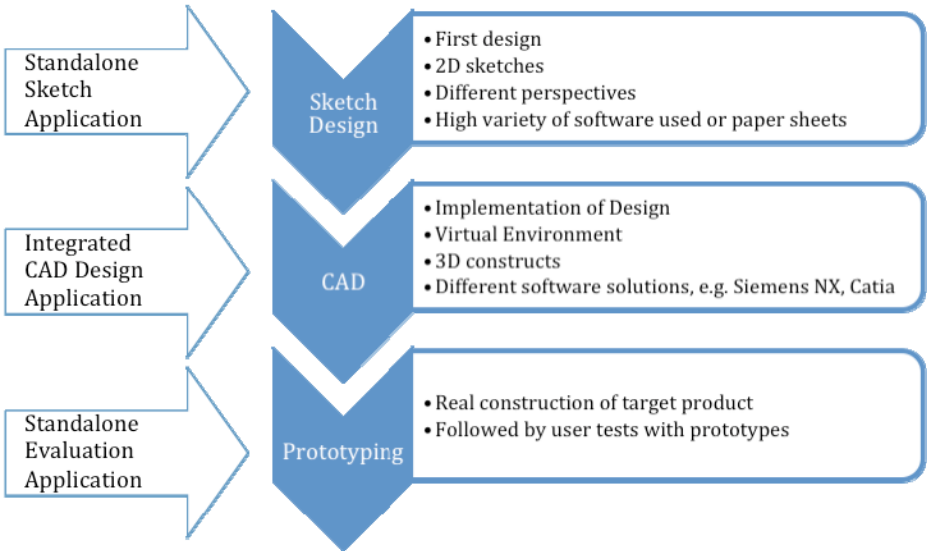

Fig. 1. Phase-based product development workflow (top-down directed arrows in the center) and key characteristics of each design phase (right). For each of the virtual user modeling framework application a target impact phase is depicted (left arrows).

Virtex – the Evaluation Application. Virtex stands for virtual experience. It is a virtual usage simulation platform that enables a designer to test the 3d product prototype virtually by running a set of different task simulations for a selected user and environment. The usage simulation is performed in real-time and is visualized in a virtual 3d environment. Hereby the user has the possibility to run the simulation for different usage context configurations. As confirmed by results of the end-user evaluation, that can help in dealing with changing requirements and provide more flexibility for the use.

Likewise the sketch and CAD design support tools, the product evaluation is driven by recommendations. However, only quantitative recommendations can trigger the system to report potential usage difficulties for a product component. Since informative recommendations do not provide measurable relationships between the component and the usage context, no evidence can be provided whether they are met or not by the product design. Hence an informative recommendation is then reported in the form of a warning, as soon as the recommendation applies to the usage context.

After each simulated task a detailed text report is shown to the designer. The evaluation results report follows the structure of a particular task.

4.2 Framework Architecture

The framework is designed following the service-oriented architecture (SOA) paradigm. The framework offers a number of services – each of them is part of one of the three subsystem tiers: front end, middleware and back end. Fig. 2 presents the software architecture of the framework. The VICON project deliverables [16], [18] describe the architecture in more detail.

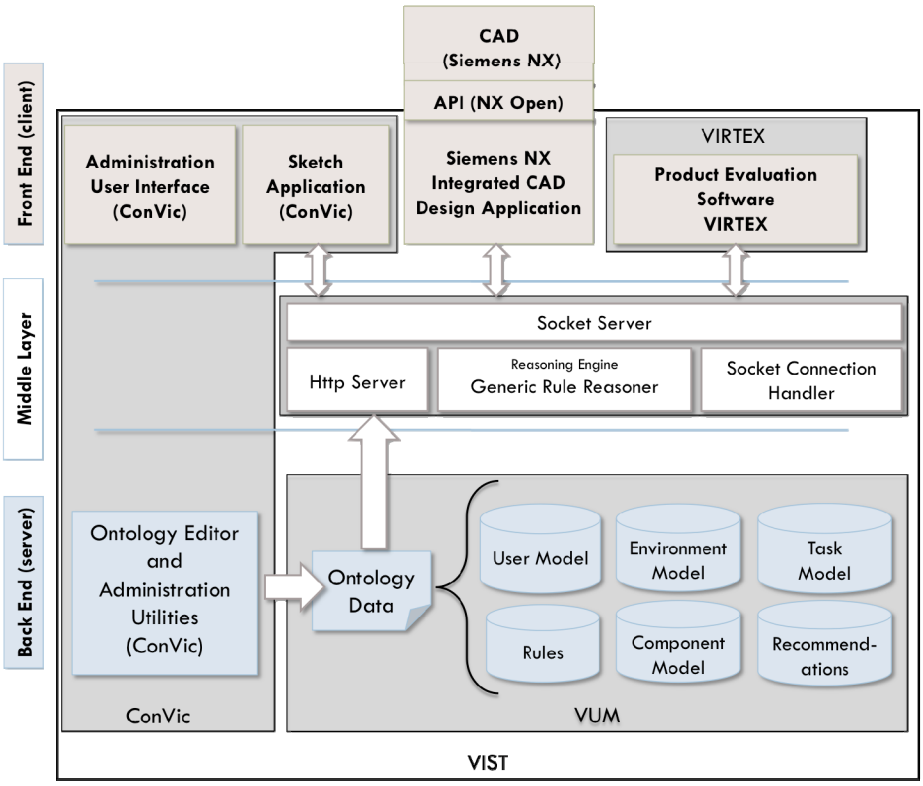

Fig. 2. The three-tier architecture of the virtual user modeling framework called VICON Inclusive design Support Toolset (VIST). The VIST is designed following the service-oriented architecture (SOA) paradigm. The framework offers a number of services, which can be dedicated to three subsystem layers: front end layer, middleware layer and back end layer. The Virtual User Model (VUM) defines the software part, which deals with all ontology data and references, and is used in the back end. The subsystem ConVic provides the configuration center for VIST supporting VUM editing. It also includes the Sketch Application. VIRTEX, the evaluation part of the framework, deals with virtual ergonomic tests using already existing 3d product prototypes and its meta-data coming from the CAD Design phase.

Front End Services. In addition to the services provided by the Sketch, CAD Design and the Evaluation applications, the front end includes the Administration UI. Via this interface a user with administration privileges can access the data stored in the VUM and edit it.

Middleware Services. The middleware services manage the connection between the different front end applications and the ontology data.

Back End Services. Depending on the type of request the back end provides different types of ontology data. In particular it provides the recommendations specific to the service for each of the three phases. For the evaluation application the results of the accessibility tests, which are encapsulated in the recommendations, are provided.

5 End-User Evaluation

The end-user evaluation of the virtual user modeling software prototype has been conducted qualitatively with maximum nine designers. Hereby two questionnaires have been prepared. The questionnaires were designed based on the ISO Norm 9241-110. For detailed evaluation results please refer to [19].

Overall, all designers responded to the workflow proposed by the framework as to a clear and straightforward. The knowledge provided by the recommendations and the references to the appropriate literature were very appreciated. We can say that the concept of such inclusive design support has been generally well accepted. However, some critics regarding the look & feel of the applications have been expressed, and minor usability issues.

The designers in the role of end-users of a system, are not only very sensitive to the system's graphic design, but also have learned specific software they use every day, i.e. they are also used to certain look & feel of their tools. In the case of the framework presented in this paper, no designer were actually actively involved in the design of the application's user interfaces. The feedback regarding the visual appearance of the interfaces suggests that it is indispensable to hire designers for graphic and interaction design of a tool that designers should use.

6 Conclusions and Outlook

In this paper we presented a virtual user modeling framework for the evaluation of virtual prototypes of consumer products throughout the entire design cycle beginning by the sketch, the design and the simulation phase. We presented the architecture of the framework and depicted its components and the workflow approach. We then evaluated the impact upon product development process with different impact strategies and implementations for each phase. We then presented the end-user evaluation process, which provided many encouraging results and entailed many points, which should be considered in future developments e.g.:

- The guidelines leading to recommendations should be added to the system seamlessly
- Quantitative vs. Qualitative recommendations should be studied in more detail under consideration of the needs of designers
- The presented approach did not consider the cognitive abilities in its user model. This lead to independent virtual user modalities. The addition of cognition to the model may lead to improvement of the recommendations and this will need to be resolved before the system truly mimics human-product interaction.

Acknowledgments. We would like to thank Henrike Gappa and Gabriele Nordbrock at the Fraunhofer Institute of Applied Information Technology FIT for their critical review and imaginative suggestions for improvement of the end-user evaluation questionnaires. Special thanks go to all the designers who participated in the end-user survey.

References

1. Kirisci, P.T., et al.: Supporting inclusive design of user interfaces with a virtual user model. In: Stephanidis, C. (ed.) Universal Access in HCI, Part II, HCII 2011. LNCS, vol. 6766, pp. 69–78. Springer, Heidelberg (2011)
2. Mohamad, Y., Velasco, C.A., Pullmann, J., Lawo, M., Kirisci, P.: Virtual user concept for inclusive design of consumer products and user interfaces. In: Stephanidis, C. (ed.) Universal Access in HCI, Part II, HCII 2011. LNCS, vol. 6766, pp. 79–87. Springer, Heidelberg (2011)
3. Kobsa, A.: Generic User Modeling Systems. User Modeling and User-Adapted Interaction 11(1-2), 49–63 (2001)
4. Fischer, G.: User Modeling in Human–Computer Interaction. User Modeling and User-Adapted Interaction 11(1-2), 65–86 (2001)
5. Rojbi, S., Soui, M.: User Modeling and Web-based Customization Techniques: An examination of the published literature. In: 4th International Conference on Logistics (LOGISTIQUA), pp. 83–90 (2011)
6. Cappelli, T.M., Duffy, V.G.: Motion Capture for Job Risk Classifications Incorporating Dynamic Aspects of Work. In: Digital Human Modeling for Design and Engineering Conference, Lyon, July 4-6. SAE International, Warrendale (2006)
7. Laitila, L.: Datormanikinprogram om verktyg vid arbetsplatsutformning – En kritisk studie av programanvändning. Thesis, Luleå Technical University, Luleå (2005)
8. Porter, J., Case, K., Freer, M.T., Bonney, M.C.: Computer-aided ergonomics design of automobiles. In: Peacock, B., Karwowski, W. (eds.) Automotive Ergonomics, pp. 43–77. Taylor and Francis LTD, London (1993)
9. Shapiro, A., Faloutsos, P., Ng-Thow-Hing, V.: Dynamic Animation and Control Environment. In: Proceedings of Graphics Interface, pp. 61–70. Canadian Human-Computer Communications Society, Waterloo (2005)
10. CARDIAC project, Guidelines, `http://www.cardiac-eu.org/guidelines/index.htm`
11. CARDIAC project, Guidelines, Membrane keys, `http://www.cardiac-eu.org/guidelines/membrane_keys.htm`
12. ISO/IEC Guide 71, Guidelines for standards developers to address the needs of older persons and persons with disabilities (2001)
13. CEN Guide 6, Guidelines for standards developers to address the needs of older persons and persons with disabilities (2012)
14. Silva, F.M., Almendra, R.: Inclusive Design: A New Approach to Design Project. In: Pereira, M.S. (ed.) A Portrait of State-of-the-Art Research at the Technical University of Lisbon, pp. 605–621. Springer, Netherlands (2007)
15. VICON Consortium, Deliverable 1.2–Survey of Design Frameworks and Tools (2010)
16. VICON Consortium, Deliverable 3.1–System Architecture and Interface Specification (2012)
17. VICON Consortium, Deliverable 3.4–Final Prototype of the Virtual User Modelling Software Framework (2012)
18. VICON Consortium, Deliverable 2.2–Virtual User Model, Final Release (2012)
19. VICON Consortium, Deliverable 4.3–Evaluation Report on How Convenient it is to use Virtual User Model and Adapted Prototype (2013)