Future Challenges of User Modelling for Accessibility

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Abstract. User models are abstract representations of user properties including their needs, preferences, knowledge, as well as physical, cognitive, and behavioral characteristics. These characteristics are usually represented by variables. User models are instantiated by the declaration of these variables for a particular user or group of users. Such instances of user models are called user profiles. A user profile captures the kind of information about an individual user that is considered by an adaptive system to adapt to aspects of a certain situation and preferences of different users.

Complimentarily the process of user modelling can be applied to enhance the accessibility of user interfaces by generating or adapting them according to the particular user needs and preferences represented in the user profiles. In spite of the different approaches in this area, further research and development is necessary, particularly in addressing the need for standards to support the interoperability and portability of user models across implementations. More specifically, one of the main challenges of user modelling is the lack of a common approach for integrating user profiles that support different user models within individual implementations, and for migrating profiles from one implementation to another. This can be attributed to the broad variety of user profiles and the incompatibilities that can occur among them. For example, differences in user profiles can occur due to differences in scope of the modelling, source of information for the modelling, time sensitivity and update methods of the model (static vs. dynamic model). In this paper a thorough review of the latest developments in the area of user modelling for accessibility is presented. Further, in the core of the paper future potentials and challenges that this technology has to face in order to gain significant traction and adoption from wider audiences is analyzed.

Keywords: user model, user profile, adaptivity, simulation, context awareness, interoperability.

1 Introduction

User modeling is a technology used in a variety of domains in order to model specific attributes and characteristics of a system's user. The quantitative values and qualitative properties for such characteristics are stored within user profiles which could refer to a specific user or user group, allowing this way the system to adapt according to the respective users' needs. Obviously accessibility to products and systems could

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benefit largely from such adaptive mechanisms since it would allow for systems to adapt to specific needs that e.g. people with physical and cognitive disabilities possess. In summary, the process of user modelling aims to:

offer different ways to access the content (rights, devices, user agents etc.),
allow for different access to the functionalities provided by the system (roles),
maintain the preferences affecting the results of the user operations,
differentiate the output based on the context of the user.

Recently a number of research programs and standardization actions have emerged in order to exploit the potentials of user modelling for accessibility purposes. However, the usage of the technology in real world scenarios still in its early stages and there are a number of issues and challenges that lie ahead in order for research and development in the area to be taken up into wide adoption [35].

The area of user modelling for accessibility is an active one, so research, development and standardization actions are being carried out. Many user modelling for accessibility projects were funded in the frame of the European research program FP7, e.g.:

The projects VICON (http://vicon-project.eu/) and VERITAS (http://www.veritas-project.eu/index.html) focused mainly on the question: How user modelling is used for simulation purposes in projects that aim to simulate human behavior using virtual user models

The projects
GUIDE (http://www.guide-project.eu/) ,
MyUI (http://www.myui.eu/),
CLOUD4ALL (http://cloud4all.info/)

focused on how user modeling is used for adaptations of user interfaces at runtime. The project I2Web (http://i2web.eu) developed user models based upon existing accessibility standards combined with an analysis of user requirements for people with special needs and older people in relation to ubiquitous Web 2.0 applications. As a result of the above mentioned projects Table 1 summarizes the areas and challenges that lie ahead in the future of user modelling for accessibility technology.

Table 1. Areas and challenges of user modelling

Area	Challenges
User needs research	For which groups of people with disabilities is more research required, so that their specific needs can be better understood and covered by user modeling technology?
Privacy issues	What has to be done in order to ensure privacy of user profiles, secure and transparent exchange of information between sources, control of user over their user profile information?
Modelling approaches	What are the advantages and disadvantages of storing user characteristics or preferences in a user profile and how can these two main apporaches be merged?

Table 1. (*continued*)

design and user experience practices	What kind of user experience and design techniques exist that could help in building more accurate user profiles and get more advanced and sophisticated batter feedback from users?
Standardization	What standards exist in terms of user modeling for accessibility and how could they develop a critical mass of usage so that they enable quicker innovation in the area of design for accessibility?
advanced contextual models	How important is to model contextual information in order to achieve better adaptive systems and what kind of information is currently available for modeling aspects of situations and how could these exploited?

There exist many standards and standardization actions in the area of user modeling for accessibility e.g. "Individualized Adaptability and Accessibility for Learning, Education and specification for the User Modelling software Training" (ISO/IEC 24751 1:2008) (http://www.iso.org/iso/ iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=41521) and its part 2, which specifies a model dividing the personal needs and preferences of the user into three categories (ISO/IEC 24751 2, 2008): (a) Display (b) Control and (c) Content. The IMS Learner Information Package Accessibility for LIP Information Model (ACCLIP) provides a means to describe how learners can interact with an online learning environment based on their preferences and needs (IMS Global Learning Consortium, 2003). The standard is meant to serve the needs and preferences of all users, not only those with a disability. In particular, through its information model, accessibility extends beyond disability to benefit users in learning situations that require alternative modes of use. The user preferences defined aim to aid the user in displaying learning material in the style best suited to their particular needs and in specifying an interface that they can interact with effectively which allows the accessible display and control of the learning material.

Virtual Human Modelling

The purpose of Virtual human modelling (VHM) as well known as (digital human modelling DHM) or VUM (Virtual user Modelling) reduces the need for the production of real prototypes, thus applying these approaches can even make the generation of prototypes partially obsolete [9, 11]. During the past years, research interest in using digital human modelling for ergonomics purposes increased significantly [10]. Lamkull et al (2009) [11] performed a comparative analysis on digital human modelling simulation results and their outcomes in the real world. The results of this study show that ergonomic digital human modelling tools are useful for providing designs of standing and unconstrained working postures.

Researchers worked on modelling various body parts, including face [12][13], neck [14], torso [15], hand [16], and leg [17]. In particular, many researchers [18][19] [20][21][22] concentrated on the biomechanical analysis of the human upper limb. Hingtgen et al (2003) [31] constructed an upper extremity (UE) model for application in stroke rehabilitation to accurately track the three-dimensional orientation of the trunk, shoulder, elbow, and wrist during task performance.

In the area of accessibility a previous case study was presented, the HADRIAN system, based on the SAMMIE CAD [24], which tried to detect accessibility issues during the interaction between users and ATM machines.

Sapin et al (2008) [25] reported a comparison of the gait patterns of trans-femoral amputees using a single-axis prosthetic knee that coordinates ankle and knee flexion's with the gait patterns of patients using other knee joints without a knee–ankle link and the gait patterns of individuals with normal gait. Prince et al (1997) [26], reviewed spatio-temporal, kinematics, kinetics and EMG data as well as the physiological changes associated with gait and aging. Coluccini et al (2007) [27] assessed and analyzed upper limb kinematics of normal and motor disabled children, with the aim to propose a kinematic based framework for the objective assessment of the upper limb, including the evaluation of compensatory movements of both the head and the trunk. Ouerfelli et al (1999)[28] applied two identification methods to study the kinematics of head-neck movements of able-bodied as well as neck-injured subjects. As a result, a spatial three-revolute joint system was employed to model 3D head-neck movements.

In other related areas there are tools and frameworks available, which provide designers with the means for creating virtual humans with different capabilities and use them for simulation purposes. DANCE [29], for instance, is an open framework for computer animation research focusing on the development of simulations and dynamic controllers, unlike many other animation systems, which are oriented towards geometric modelling and kinematic animation. SimTk's OpenSim is also a freely available user extensible software system that lets users develop models of musculoskeletal structures and create dynamic simulations of movement. There are also many tools such as JACK from Siemens, RAMSIS from Human Solutions, or Santos from University of IOWA. Human Builder is the virtual user model for CATIA, Enovia and Delmia from Dassault Systems, offering considerable benefits to designers looking to design for all, as they allow the evaluation of a virtual prototype using virtual users with specific abilities.

As described above significant effort has been made in physical user modelling and many tools use virtual humans for simulation purposes. However, there is no widely accepted formal way for the description of the virtual users, being able to also describe users with special needs and functional limitations, such as the elderly and users with disabilities. This divergence hinders cooperation between research projects and slows down innovation in the area.

2 User Involvement in Product Development

One challenge of recent product development is the inclusion of customer-oriented needs in product design addressing as much user groups of population as possible. Existing methods of user involvement range between „Design for-" and "Design by-" approaches [32].

Kaulio presented a review on selected methods of user involvement and compared 7 different methods [1]. (1) Quality function deployment [4] describes an analytical approach for first design phases with involvement of end users by extraction of consumer demands into quality characteristics. (2) User-oriented product development [4] focuses upon the involvement after first prototype generation. (3) Concept testing [4] uses first sketches in an evaluation with customers. (4) Beta testing [5] refers to prototype evaluation with customers. (5) Customer-idealized design [13] involves customers by transferring product design into a group exercise. (6) Lead user method lets single representatives of a target group solve design problems and issues.(7) Participatory ergonomics involves different groups of product development into the process. Eventually all 7 methods have pros and cons for physical end products, according to the level of involvement (Design for-, with-, and by-) but also to the creativity of design and technological advancement. The challenge for user modeling technologies in this area lays in the question whether user models could be used in combination with some of the aforementioned methods and whether this combination could make some of the methods easier to apply.

3 User Adaptive Systems

Frameworks for the generation of user-adaptive systems [33] are used in different domains and contexts e.g. ergonomics, simulation, e-commerce, e-learning, tourism, cultural heritage, digital libraries, etc. A user-adaptive system adapts its content, structure and interface according to the user features contained in the user model. The user model typically maintains user characteristics such as preferences, interests, behavior, knowledge, goals and other facts that are deemed relevant for a user-adaptive application [7, 8]. As a result, the user model is a key component of an adaptive system. In fact, the quality of personalized services provided to the user largely depends on the characteristics represented in the user model, like its accuracy, the amount of data it stores, whether such data are up to date, etc.

There are many modelling areas and approaches related to the user modelling, so e.g. task modelling and application modelling [30]. Task models describe how to perform activities to reach users' goals. The need for modelling is most acutely felt when the design aims to support system implementation as well. If there are only informal representations (such as scenarios or paper mock-ups) available to developers, they would have to make many design decisions on behalf of their own, likely without the necessary background, to obtain a complete interactive system. Task models represent the intersection between user interface design and more systematic approaches by providing designers with a means of representing and manipulating an abstraction of activities that should be performed to reach user goals.

The application modelling is a multifaceted approach; one can address the topic from different perspectives: architecture design, implementation design or interaction design, part of this research is the area of Model-Based User Interface design (MBUID), which aims at identifying high-level models for the specification and analysis of interactive applications from a semantic perspective. Under this umbrella, the more interesting approach is the CAMELEON Unified Reference Framework [2].

Furthermore the SERENOA project,[1] introduced a semantic container that holds a library of algorithms for advanced adaptation logic. The I2Webproject extended this approach and focused on the research area of Model-Based User Interface design, which aims at identifying high-level models for the specification and analysis of interactive applications from a semantic perspective [34].

4 Conclusions and Future Work

The majority of research projects were so far targeted towards modelling of persons without disabilities. The few projects, which targeted towards disabled people, were concerned with physical disabilities such as visual, hearing and motor. Some of the research efforts are also covering some cognitive disabilities. Sophisticated user models need to cover all aspects of disability to really make a significant difference. Some user models consider visual and motor disabilities and do not involve other disabilities as hearing or cognitive disabilities. The extension of user models to become complete models covering all disabilities implies further work in user studies and statistical analysis.

Having said that, it is obvious that one of the basic challenges for user modelling for accessibility is how can a standard for user models be established so that it covers a wide spectrum of disabilities (physical and cognitive), user needs and preferences. A critical aspect of such a standard would also be the definition of the importance and necessity for each possible adaptation and their prioritization based on each user.

Given the above challenge and the variety of attempts in the area so far a question that rises is how could a user model standard such as the one developed within the VUMS cluster be further extended and matured in order to establish a critical mass of supporters and stimulate adoption. This critical mass is what is missing in most of the attempts so far. Given that, an already existing solution could mature and transform into the standards that the area is missing.

Apart from a common standard however the area of user modelling for accessibility is also split in between two different approaches discussed earlier (characteristics based and preferences based). Therefore, another challenge that is presented is how the strengths of these well-established and recognized user modelling approaches can be integrated in order to establish a seamless link between user characteristics and user preferences. This combination would benefit largely the product development process. One of the possible technologies that could help in that direction is machine learning, thus user modelling should probably invest on that area.

Machine learning could also benefit user modelling helping current VUM to extend in order to evolve to “dynamic virtual user models” which are characterized by dynamic properties in order achieve a concise integration of usage and context data provided e.g. through real-time monitoring of interactions with user interfaces and consumer products.

[1] `http://www.serenoa-fp7.eu/`

Most of the challenges discussed so far are mostly technical but there is a very critical aspect for user modelling technologies in order to reach wider audience adoption. Privacy especially for people with disabilities and elderly is paramount and this is a very complex issue that needs to be addressed. It involves (a) the development of protocols and mechanisms for exchange of user profiles between various sources (b) the control of users on their user profile information and its exposure and (c) the control and awareness of data gathering mechanism (e.g. eye-tracking, mouse-tracking, etc.) so that users feel comfortable and safe when using such technologies.

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