MyUI: Mainstreaming Accessibility through Synergistic User Modelling and Adaptability

FP7-ICT-2009-4-248606

Interim Report on VUMS cluster standardisation

Public Document

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Abstract	This VUMS cluster interim report describes the standardisation activities of the first period of the VUMS cluster and a strategic action plan for further standardisation activities. Moreover, a draft version of potential standardisation input to be fed directly into standardisation bodies is included. This includes common definitions of the most important terminology and a concept for a generic user model, its structure and syntax.		

This is a joint deliverable of the VUMS cluster. In GUIDE, this deliverable is referred to as D2.6

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1. Introduction

This document is a joint deliverable of the VUMS cluster. VUMS stands for "Virtual User Modelling and Simulation Standardisation". The cluster is formed by four projects funded by the European Commission under the Theme "FP7-ICT-2009.7.2 Accessible and Assistive ICT" and is partly based on the results of the VAALID (http://www.vaalid-project.org/).

The cluster member projects are

- GUIDE (Gentle User Interfaces for Disabled and Elderly Citizens, http://www.guide-project.eu/),
- MyUI (Mainstreaming Accessibility through Synergistic User Modelling and Adaptability, http://www.myui.eu/),
- VICON (Virtual User Concept for Inclusive Design of Consumer Products and User Interfaces, http://www.vicon-project.eu/) and
- VERITAS (Virtual and Augmented Environments and Realistic User Interactions To Achieve Embedded Accessibility Designs, http://veritas-project.eu/).

One of the objectives of the cluster is to improve interoperability of the projects' solutions and software. A commonality between the projects is the application of user profiles and user models. In order to be able to exchange these among the projects the VUMS cluster is working on a unified way to describe and communicate such models/profiles.

Future research projects and industrial implementations of the research result would benefit from these results. Therefore the cluster intends to ensure sustainability by making them available within a standard.

The purpose of this white paper is to present results and positions of the VUMS cluster in order to facilitate a wider discussion and in particular to get in contact with working groups related to relevant standardisation activities.

2. Scope and Purpose of the VUMS Cluster

The VUMS cluster has been initiated by the European Commission in beginning of 2010 to synchronize efforts among several on-going research projects. The projects VERITAS, VICON, MyUI, GUIDE and VAALID agreed to co-operate on issues of common interest in order to synergise among them and to disseminate their results to the scientific fora and standardisation bodies. All projects in VUMS follow activities in the area of user modelling/simulation and involve human users in their developments and evaluation processes. Therefore the main objective of the VUMS cluster is to align activities in the area of:

- User modelling
- Standardisation
- Dissemination
- Ethics

User models can be considered explicit representations of the properties of an individual user and can be used to reason about the needs, preferences or future behaviour of that user. Most computer systems providing human-machine interaction already maintain some kind of implicit model of the user (i.e. a specific user profile for an individual user), but there are difficulties when incorporating a user model into the design process of products and services. Usually the main problem is to integrate user profiles supporting different user models in one service/application, or migrating profiles stemming from one user model to a different service. Main reasons for incompatibilities in user profiles are usually to be found in the scope of modelling, source of modelling information, time sensitivity of the model or update methods (Static vs. dynamic model). In some cases physical (mechanics and control) as well as cognitive processes that underlie the user's actions are relevant in user modelling. Also the differences between the user's skills and expert skills, or the user's behavioural patterns or preferences can be reflected in a user model specification. Another important dimension along which it is important to distinguish approaches is with respect to whether they model individual users or whole communities / groups of users. In general one can conclude that user modelling covers many different aspects, including the interaction of the user with interfaces and devices, the analysis of user tasks and the analysis of user characteristics (sensory, physical and cognitive abilities, psychological and behavioural characteristics). Therefore it is necessary to put efforts into finding similarities among modelling approaches and to make the exchange of user profiles possible. A common standard for user model interoperability could be an approach to achieve this.

It is of course necessary to not only involve the VUMS projects in the process of user modelling, but to integrate external institutions as well, especially standardisation bodies and other research projects and experts. Therefore dissemination and networking activities are an important part of VUMS collaboration. The projects will perform joint dissemination activities and organise workshops to promote the ideas of VUMS and collect feedback to initial user model specification drafts. The basic goal of standardisation is to avoid fragmentation among projects (and also external institutions). As described above, application and nature of user models are of course very heterogeneous among different contexts, and this has to be reflected in the standardisation activities. The goal is therefore not to create a new common user model standard, but to make user models interoperable through standardisation of common aspects. This will then support the exchange and sharing of user profiles among different services and contexts.

On the side of ethical management, it is mandatory that all projects perform proper management of ethical issues, and to make sure that national and international regulations apply. The VUMS cluster shall therefore ensure that ethical documentation is shared among the projects, and that the respective ethical coordinators of all projects can maintain regular communication and exchange of information.

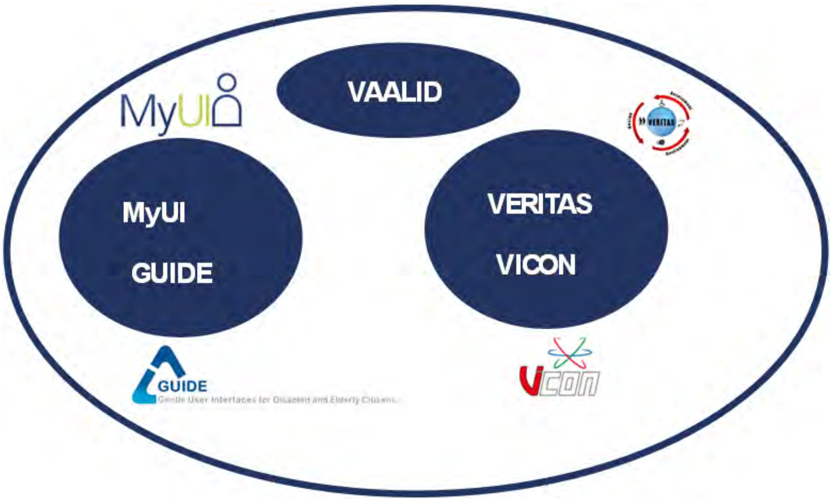


Figure 1 VUMS cluster and involved projects

3. Current Achievements and Standardisation Activities in the VUMS Cluster

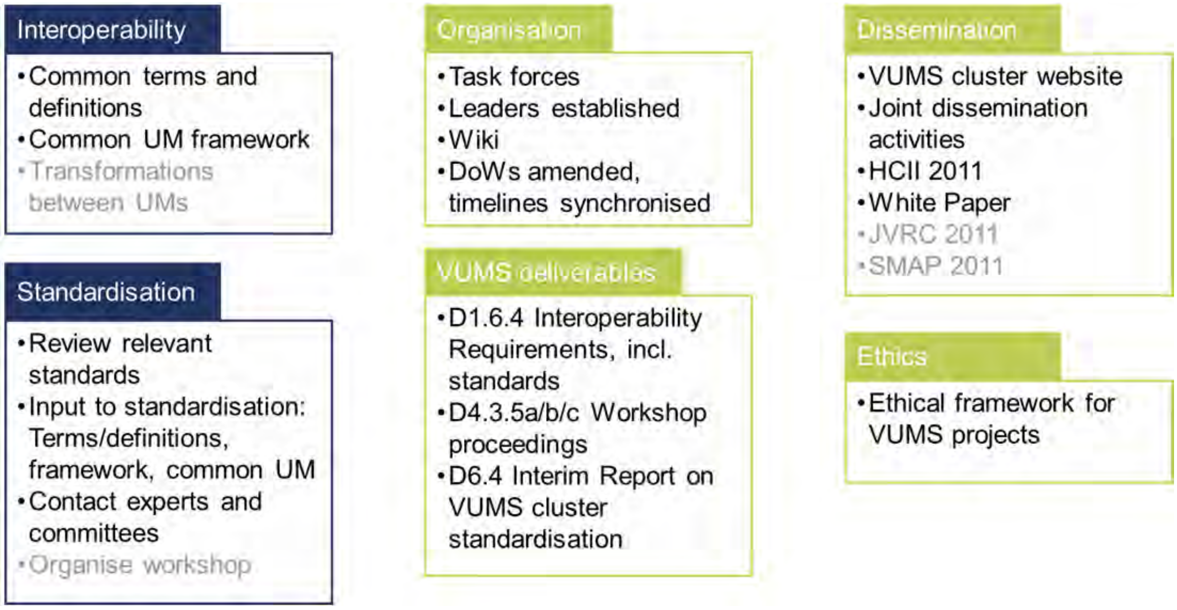


Figure 2 Achievements and activities in the VUMS Cluster

Figure 2 provides an overview of the current VUMS cluster achievements and activities. In order to start the collaboration between the four European projects a couple of **organisational** issues had to be resolved:

- The cluster has established *task forces* with dedicated leaders for standardisation and ethics. These two fields have been defined as the as the main areas for collaboration in the cluster.
  The *standardisation task force* is led by Matthias Peissner (MyUI) and Yehya Mohamad (VICON). Members of the task force include Christoph Jung and Pradipta Biswas (GUIDE), Peter Wolf (MyUI), Manfred Dangelmaier and Dimitrios Tzovaras (VERITAS), Pierre Kirisci (VICON) and Pilar Sala (VAALID).
  The *ethics task force* is led by Mari Feli González (GUIDE) with support from all other projects. Responsible contact persons are Johann Riedel (MyUI), Karel Van Isacker (VERITAS), and Antoinette Fennell (VICON).
- A Wiki has been set up for the internal communication and sharing documents: http://cluster-wiki.vr.iao.fhg.de/index.php/Main_Page
- The tight cooperation in the VUMS cluster required changes in the Descriptions of Work (DoW) of the four projects. Main changes include adding new common VUMS deliverables, shifting budget to VUMS cluster activities and synchronizing the timelines of the four current VUMS projects.

The **VUMS deliverables** document the main technical achievements of the cluster work and report decisions of VUMS cluster meetings.

Common **dissemination** activities include the joint *cluster web site* (http://www.veritas-project.eu/vums/) and presentations and presence at *conferences* and other events. The latest conference with a strong VUMS cluster presence is the *HCI International 2011* Conference in Orlando, USA where the concepts, results and positions of the VUMS cluster have been presented to a large scientific community. Recently, the VUMS cluster dissemination efforts have more and more targeted the development and dissemination of a common position statement for international user model standardisation. A *White Paper* which will be extracted from the document at hand will be sent to relevant experts and organisations in international standardisation.

The **ethics task force** was created with the aim of carrying out together three different tasks:

1. To organize a special session dealing with Ethics in the first scheduled workshop of VERITAS (November 2010), to which all mentioned projects were invited.
   This special session was held as planned. In this session a general overview about the Ethical framework in the VUMS cluster and in each one of the projects belonging to this cluster was presented.
2. Exchange of ethics forms like consent forms, manuals, etc.
   At the beginning of the ethics task force, the different ethics-related materials were exchange between the different projects.
3. To develop an Ethical Guideline or Manual about the general ethical approach to be followed throughout the projects.

Regarding this third point, VERITAS was the first project releasing its Ethical Guideline which was public in the Wiki and it was also reviewed by the other partners. This Manual is now being used in all cluster projects, which work in the same direction, and also it is publicly available on the cluster web-site for other projects to use.

In the roadmap for the next months it is planned to take this Manual as a base for the common VUMS Ethics Manual but improving it in different points. The future work in this manual will be focused on:

- Include aspects related with the involvement of the users in the trials carried out in the different projects, but also aspects related with the interaction of the elderly with the technology in the possible future in live operations.
- Incorporating feedback from other European Projects dealing with ethical issues in the context of ICT for the elderly (e.g. ETICA, DG Research, UserFit projects, etc...).
- Collating a list of European and National (from the countries involved in the ethics task force) legislation related with ethics.

This Manual will be finished by the end of the VUMS Cluster and it will be public so other project can benefit from it.

The **interoperability** of the user model approaches in the four VUMS cluster projects is one of the most important areas of activities. As a first step towards a close collaboration and interoperable project results, *common terms and definitions* have been worked out for the most relevant concepts (cf. section 4 in this document). A *framework for a common VUMS user model* has been developed. The main principles for this user modelling framework can be found in section 7. In section 8, the structure of the VUMS user model is described. Currently on-going activities towards interoperability include the definition of common syntax on the basis of the current VUMS project user model syntaxes (cf. section 9) and the development of a meta user model which shall comprise a superset of all user variables used in the single projects.

As a first step towards international **standardisation**, a profound *state-of-the art review* has been carried out. In the joint cluster deliverable D1.6.4, an overview and evaluation of existing standards in the field of user modelling has been provided. A *White Paper*, which will be extracted from this document, will be used as an initial input to standardisation. After deciding to target the ISO-related standardisation activities, important contacts to relevant experts and representatives of standardisation groups have been established.
Jutta Treviranus and Erlend Overby (responsible editors and ISO-WG7-convenors) have signalled interest in collaborating when continuing their work on ISO 24751 which has been identified as the most relevant and suitable standard for VUMS cluster contributions. In order to get VUMS cluster partners into the respective working groups at ISO and the national levels, contacts to DIN (Germany) and BSI (UK) have been made. Chrsitian Stracke (Convener ISO/IEC JTC1 SC36/WG5) and Nikolaus Kovacs (DIN secretary) would welcome Matthias Peissner (MyUI) as an active member of DIN NIA 36. Next DIN NIA 36 meeting is scheduled for 18 November 2011. Pradipta Biswas (GUIDE) has been inducted to the BSI committee and will attend the ISO/IEC SC36 meeting at Shanghai, China in September. Pradipta has also been appointed as coordinator of a working group in ITU-T Focus group on Audio Visual Media accessibility and this focus group will work with ISO/IEC JTC 1 Special Working Group on Accessibility (SWG-A).

Further experts and standardisation committees will be addressed by sending around the White Paper. A discussion panel with invited experts is planned to be held in September 2011 in the course of JVRC 2011 in Nottingham, UK.

4. Glossary of Terms (WP)

The VUMS cluster has defined a Glossary of Terms for supporting a common language. Its scope and contexts of usage is the adaptation of human-machine interfaces to the needs of the real user or the simulation of the interaction between a human and a product in order to design the product.

==User Model==

An (abstract) user model is a set of user characteristics required to describe the user of a product. The characteristics are represented by variables. The user model is established by the declaration of these variables. It is formally described in a machine-readable and human-readable format. An instantiation of the user model is a user profile.

== User Profile==

A user profile is an instantiation of a user model representing either a specific real user or a representative of a group of real users. It is an instantiation of an (abstract) user model and it is formally described in a machine-readable and human-readable format. A user profile can be employed to generate adaptive user interfaces or simulations.

==Virtual user==

A virtual user is a representation of a user based on a User Profile. It includes components, which are able to interact with other virtual entities e.g. virtual products or software applications. VU's intended for simulation purposes represent the human body as e.g. a kinematic system, a series of links connected by rotational degrees of freedom (DOF) that collectively represent musculoskeletal joints such as the wrist, elbow, vertebra, or shoulder. The basic skeleton of the model is described usually in terms of kinematics. In this sense, a human body is essentially a series of links connected by kinematic revolute joints. Each DOF corresponds to one kinematic revolute joint, and these revolute joints can be combined to model various musculoskeletal joints.

==Environmental Model==

An environmental model is a formal machine-readable set of characteristics used to describe the use environment. It includes all required contextual characteristics besides the user model, the interaction model, the device model, the product and related user tasks.

==Device Model==

A Device Model is a formal machine-readable representation of the features and capabilities of one or several physical components involved in user interaction. It is important to carefully discriminate between user and device model as they are two kinds of models. The device model expresses capabilities of the device. A given device can be used by many different users and a given user could use different devices. By carefully separating the different functionalities of device modelling and user modelling in design scenarios it will be easier to enumerate the attributes for each model and from them develop the matching function and attributes of the adaptation process.

==User Agent==

A User Agent is any end user software (like browser, or other user interface component) that can retrieve and render application content and invoke requests to the User Agent Capabilities Model to modify the application content

==User Agent Capabilities Model==

A User Agent Capabilities Model is a formal machine-readable representation of the capabilities of the user agent related to user interaction.

==Application Model==

An Application Model is a formal machine-readable representation of the states, transitions and functions of an application that is subject to interface adaptation (also in the sense of adaptive behaviour) or simulation.

==User Interaction Model==

A User Interaction Model is a machine readable representation of the interaction behaviour of an application. The interaction model is maintained UI-agnostic, which means it is independent of the concrete format of user interface output- and input data. Interaction model is often also referred to as abstract user interface model, like for example UIML, UI Socket, XForms, etc. It should be noted that the Interaction model can be used for adaptation of Human Machine Interfaces (HMI) and for simulating the use of an application /product with a virtual user.

==Context Model==

A Context Model is a machine-readable representation of information that can be used to characterize the situation of an entity. An entity is a person, a place, a device, or a product that is considered relevant to the interaction between a user and an application, including the user and applications themselves. All the different models that are employed within the VUMS cluster to capture information about users, devices, the environment, and the application are contributing to the overall context and can be considered as (part of) a context model.

==Simulation==

Simulation is the process that enables the interaction of the virtual user with the application model within an artificial environment. The simulation can be real-time or off-line. Real-time simulation can be performed autonomously or manually, where the operator can interact with the environment from a 1st or 3rd person perspective. Accessibility assessment and evaluation can be performed automatically or subjectively by the operator.

==User Model/Profile Validation==

User Models are always simplified descriptions of the user. Validation is the process to determine whether the model is an appropriate representation of the user for a specific application. For a mathematical model it needs a statistical validation process. If the model is non-mathematical then it should be validated through qualitative processes.

==Adaptive User Interface==

Adaptive User Interfaces are user interfaces that adapt their appearance and/or interaction behaviour to an individual user according to a user profile. In contrast to adaptable user interfaces, which are modified by a deliberate and conscious choice of a user, adaptive user interfaces automatically initiate and perform changes according to an updated user profile.

== User Interface Design Pattern ==

A User Interface Design Pattern is an approved user interface solution to a recurring design problem. User Interface Design Patterns have a formalized description. For the use in adaptive user interfaces, design patterns have a representation in form of reusable software components which can be put together to complete user interfaces during run-time.

5. Use Cases for Interoperability (WP)

5.1 Exchange of user models for simulation

In this section, the exchange of user models for simulation between VICON and VERITAS is presented. VICON Virtual User Models are expressed in RDF format (more details can be found in 10.2) while VERITAS Virtual User Models are expressed in UsiXML (more details can be found in 10.1). There are some variables of VICON Virtual User Models that are non-applicable for VERITAS. Similarly, there are many user characteristics described in a VERITAS Virtual User Model that are non-applicable for VICON (due to their large number they are not presented in this section; the whole attributes that are supported by the VERITAS Virtual User Model are depicted in Figure 2 and Figure 3).
Table 1 below presents the use case of using transforming a VICON Virtual User Model into the VERITAS Simulation Platform.

Table 1 Use case: Using a VICON Virtual User Model in the VERITAS Simulation Platform

Use case title	Evaluation of the interaction between a virtual user with arthritis and a virtual prototype of a mobile phone using a VICON Virtual User Model in the VERITAS Simulation Platform
Input	• A VICON Virtual User Model describing a user with arthritis. • A virtual prototype of a mobile phone
Output	Evaluation results of the VERITAS simulation platform regarding the interaction of the virtual user with the virtual prototype.
Scenario	This use case presents how a VICON Virtual User Model can be used in the VERITAS Simulation Platform.
Processing steps	• A VICON Virtual User Model describing a user with arthritis is developed. • The VICON Virtual User Model is transformed into a VERITAS Virtual User Model. • The .owl file representing a VICON Virtual User Model is being parsed. • A VERITAS Virtual User Model having the default value (the default value corresponds to a user with no disabilities) for each user variable is created. • Regarding the common user variables: The value of each variable of the VICON Virtual User Model is being copied into the corresponding variable of the VERITAS Virtual User Model. • Regarding the similar user variables: The value of each variable of the VICON Virtual User Model is being transformed into the value space of the corresponding variable of the VERITAS Virtual User Model. • Regarding the VICON variables that are not supported by VERITAS: They are ignored.

	• Optional step: More details regarding the range of motion (e.g. wrist flexion etc.) can be specified in the Virtual User Model, as the VERITAS Virtual User Model supports a large number of physical parameters. • The VERITAS Virtual User Model is being saved in a .usi file (UsiXML format). • The generated VERITAS Virtual User Model and the virtual prototype of the mobile phone are given as input to the VERITAS Simulation Platform. • After the completion of the simulation process, the VERITAS Simulation Platform returns the evaluation results.

Table 2 presents the properties/variables supported by the VICON Virtual User Model and the corresponding ones of the VERITAS Virtual User Model.

Table 2 Correspondence between VICON and VERITAS Virtual User Models

VICON Virtual User Model – RDF Property	Type	Comments	VERITAS Virtual User Model – XML Element	Comments
UserModelName	any	The name to identify a person, this is the only one primary predicate, that means it is mandatory to define it in an instance	`<name>`	The name of the virtual user
UserModelNickname	any	Optional nickname for the person	Not supported	
UserModelGender	any	Gender: "Male" or "Female"	`<gender>`	gender: "Male" or "Female"
UserModelAge	int	The age of a User Model in years	`<ageGroup>` Note: The value of VICON "UserModelAge" has to be transformed into the VERITAS "ageGroup" value space.	Age groups: 18-70, 18-29, 30-49 and 50-70
UserModelDescription	any	Optional Information, to help the Designer to decide for a UserModel	`<comment>`	Optional information regarding the virtual user model
UserModelVirtualmodel	any	A uri where to find a virtual model e.g. in form of a wavefront .obj file format	Not supported	
UserModelArthritis	any	Did the user report Arthritis? (yes or no)	`<disability type="Motor" name="Arthritis" >`	`<disability>` is a generic container for any disability
UserModelGrip	int	Difficulty in gripping small items, for example a pen or the handle of a cup (Integer 1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	`<affectedTask id="grip_ID" type="motor" name="grip" taskObject="" details=" Difficulty in gripping small items, for example a pen or the handle of a cup" failureLevel="" />`	`<affectedTask>` is a generic container for any affected (by the disabilities) task
UserModelButtons	int	Difficulty when using buttons or keys, for example when using the number keys on a phone (Integer: 1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	`<affectedTask id="useButtons_ID" type="motor" name="use buttons" taskObject="" details="Difficulty when using`	`<affectedTask>` is a generic container for any affected (by the disabilities) task

VICON Virtual User Model – RDF Property	Type	Comments	VERITAS Virtual User Model – XML Element	Comments
			buttons or keys, for example when using the number keys on a phone" failureLevel="" />	
UserModelControls	int	Difficulty when using controls such as knobs or sliders (Integer: 1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	<affectedTask id="useControls_ID" type="motor" name="use controls" taskObject="" details="Difficulty when using controls such as knobs or sliders" failureLevel="" />	<affectedTask> is a generic container for any affected (by the disabilities) task
UserModelDiscomfort	int	Discomfort in hands when gripping small objects or operating controls (Integer: 1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	Not supported	
UserModelColour	int	Cannot distinguish colours (Integer: 1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	Not exactly the same but correlated with <spectralSensitivity longValue="1.0" middleValue="1.0" shortValue="1.0"/> Note: The value of VICON “UserModelColour” has to be transformed into the VERITAS “spectralSensitivity” value space.	e.g. <spectralSensitivity longValue="0.0" middleValue="1.0" shortValue="1.0"/> corresponds to Protanopia
UserModelGlasses	any	Are glasses used? (yes or no)	Not supported	
UserModelGlassesWithProduct	any	Would the user wear glasses with the product (yes or no)	Not supported	
UserModelChangeFocus	int	It is difficult to change focus when looking at something near and then far away (Integer: 1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	Not supported	
UserModelLightLevels	int	Hard to adjust to changes in light	Not exactly similar but correlated with	Expressed as a percentage.

VICON Virtual User Model – RDF Property	Type	Comments	VERITAS Virtual User Model – XML Element	Comments
		levels (Integer: 1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	<contrastSensitivity> Note: The value of VICON “UserModelLightLevels” has to be transformed into the VERITAS “contrastSensitivity” value space.	Contrast sensitivity is a measure of the ability to discern between luminances of different levels in a static image.
UserModelGlare	any	More sensitive to light and glare than used to be (Integer: 1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	<glareSensitivity> Note: The value of VICON “UserModelGlare” has to be transformed into the VERITAS “glareSensitivity” value space.	Expressed as a percentage. Glare sensitivity is defined as lowered contrasts in a patient’s field of vision due to outside sources of light. This may be caused by an oncoming headlight, floodlights, or the sun.
UserModelBlurry	int	Without glasses, things appear to be indistinct/blurry (Integer: 1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	Not supported	
UserModelFieldOfVision	int	Reduced field of vision (finds it hard to see things to the side, top, bottom of what they are looking at) (Integer: 1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	Not supported	
UserModelDistance	int	Hard to judge distance (Integer: 1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	Not supported	
UserModelHearingAid	any	Does the user have a hearing aid (String Y or N)	Not supported	
UserModelHearingAidWithProduct	any	Would the user use a hearing aid with the product (yes or no)	Not supported	
UserModelBackgroundNoise	int	Threshold of speech intelligibility with background noise. Percentage of background noise volume compared to speech volume. (Integer 0 - 200)	Not supported	

VICON Virtual User Model – RDF Property	Type	Comments	VERITAS Virtual User Model – XML Element	Comments
UserModelHearing500Hz	int	Threshold hearing level in dB at 500Hz (without aid)	`<hearingThreshold2 measureUnits="dB" value="" frequency="500" frequencyMeasureUnits="Hz"/>`	Hearing threshold in dB at 500Hz
UserModelHearing1kHz	int	Threshold hearing level in dB at 1kHz (without aid)	`<hearingThreshold3 measureUnits="dB" value="" frequency="1000" frequencyMeasureUnits="Hz"/>`	Hearing threshold in dB at 1000Hz
UserModelHearing2kHz	int	Threshold hearing level in dB at 2kHz (without aid)	`<hearingThreshold4 measureUnits="dB" value="" frequency="2000" frequencyMeasureUnits="Hz"/>`	Hearing threshold in dB at 2000Hz
UserModelHearing4kHz	int	Threshold hearing level in dB at 4kHz (without aid) (Integer -10 - 120)	`<hearingThreshold5 measureUnits="dB" value="" frequency="4000" frequencyMeasureUnits="Hz"/>`	Hearing threshold in dB at 4000Hz

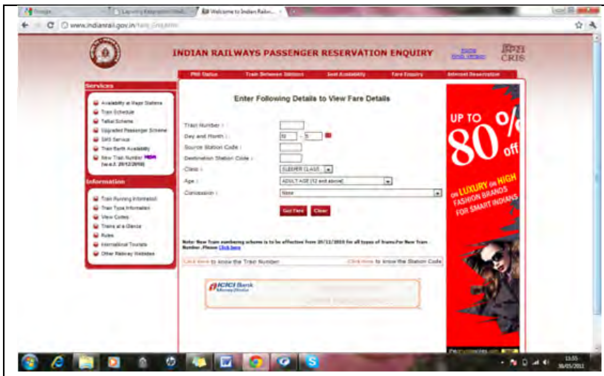
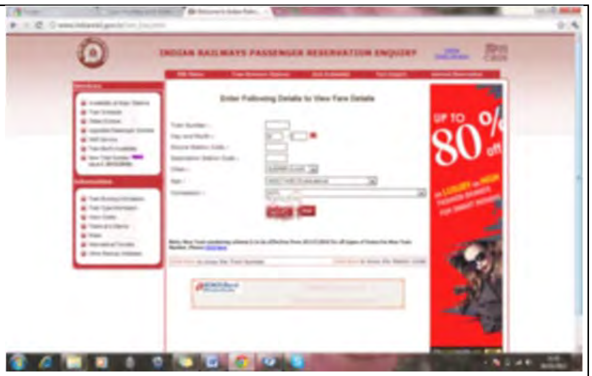
In a similar way, a VERITAS Virtual Model could be used in the VICON Simulation Platform.

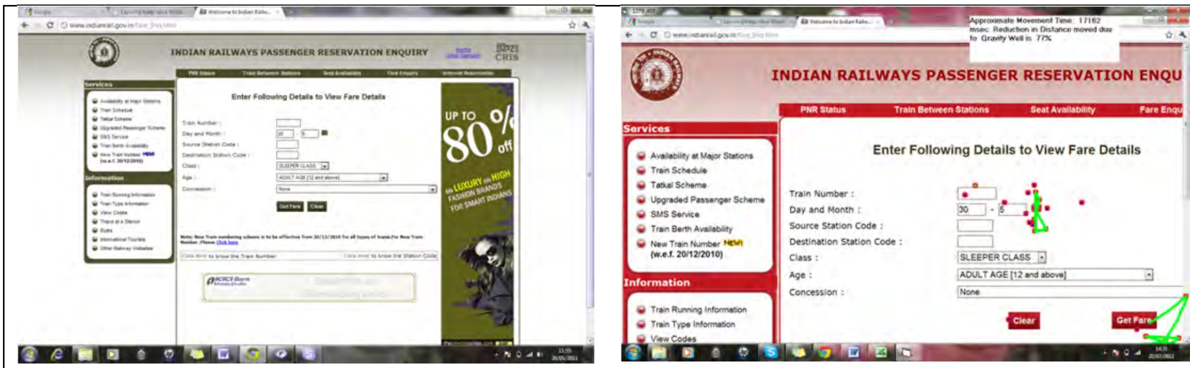
5.2 Exchange of user models for UI adaptation

In the following paragraphs we have described a situation where user model developed by the GUIDE project can be used by another project in the VUMS cluster. The GUIDE project stores user details using a set of variables from the pool of variables defined in VUMS and described later in section 8.´ The GUIDE simulator and run time system use it to provide offline and online adaptation, which is discussed in further detail in section 11. If any project can store detail about users in this format, they can use the guide simulator for design optimization and run time adaptation. The following case study demonstrates this idea further

The GUIDE project works for digital TV interface. However the user profile and the simulator can be used for other platforms as well. Let us assume a scenario of a web based application developed for a kiosk or computer. If this system follows the common user profile standard then it can use the simulator for design optimization and run time adaptation system during online use. We start with a simple web interface as shown in Figure 3. The simulator can initially be used to diagnose problems with any interface by visualizing the effect of age and impairment like Maccular Degeneration, Colour Blindness and motor impairment like tremor in finger respectively. The last screen shot also predicts an approximate movement time using a touchscreen system (as used in Railway Kiosks) and the effect of an adaptation algorithm viz Gravity Well. It attracts a pointer when it is near a target and thus helps to reduce random movement during homing and clicking during a pointing task. The gravity well algorithm helps in pointing and in the present case requires the users' finger to move 77% less distance in the screen to point and click on a button.

The system designer can optimize the interface based on the shared user profile for different level of impairment. If the shared profile is also used during run time, the gravity well algorithm or similar adaptation algorithm can be used to further enhance interaction experience. This run time adaptation system can be used for different modalities of interaction. We have already demonstrated the use of the adaptation system for an eye tracking and scanning based system and also gesture based interaction, detail can be seen at the following video http://www.youtube.com/watch?v=TOqSEQaWhB0

 Example of an interface	 Perception of a person with mild wet macular degeneration



Perception of a person with colour blindness (Protanopia)

Finger movement on screen of a person having tremor and effect of adaptation

Figure 3 Example of an interface and different views in the simulator

5.3 Exchange of user models between simulation and adaptation

As described in the above sections, user models for adaptation require a much deeper level of detail than user models for UI adaptation. In order to simulate an interaction between a specific user (group) with a specific object and task in a specific environment, all relevant characteristics f these entities need to be defined clearly (cf. e.g. the VERITAS user model described in section 10.1). On the other hand, for UI adaptation it can be sufficient to know which elements of a user interface need to be adapted in which direction in order to suit a specific user in a given situation (cf. e.g. the MyUI user model described in section 10.4). Therefore, the exchange of user models between approaches for simulation and adaptation is more difficult compared to the cases above.

If a user profile from a simulation-oriented user modelling approach shall be transformed into a UI adaptation user modelling format, several (simulation) user model variables need to be interpreted and integrated to one (adaptation) user model variable. This process can be regarded as a reduction of dimensions which is associated with a loss of information (see Figure 4). From a technical point of view this transformation is possible, but will require suitable discrimination rules for the “translation” of detailed user information into coarser UI concepts and requirements. However, as the mapping between both models is not bijective, a reverse transformation from the compressed to the extensive user model is not possible.

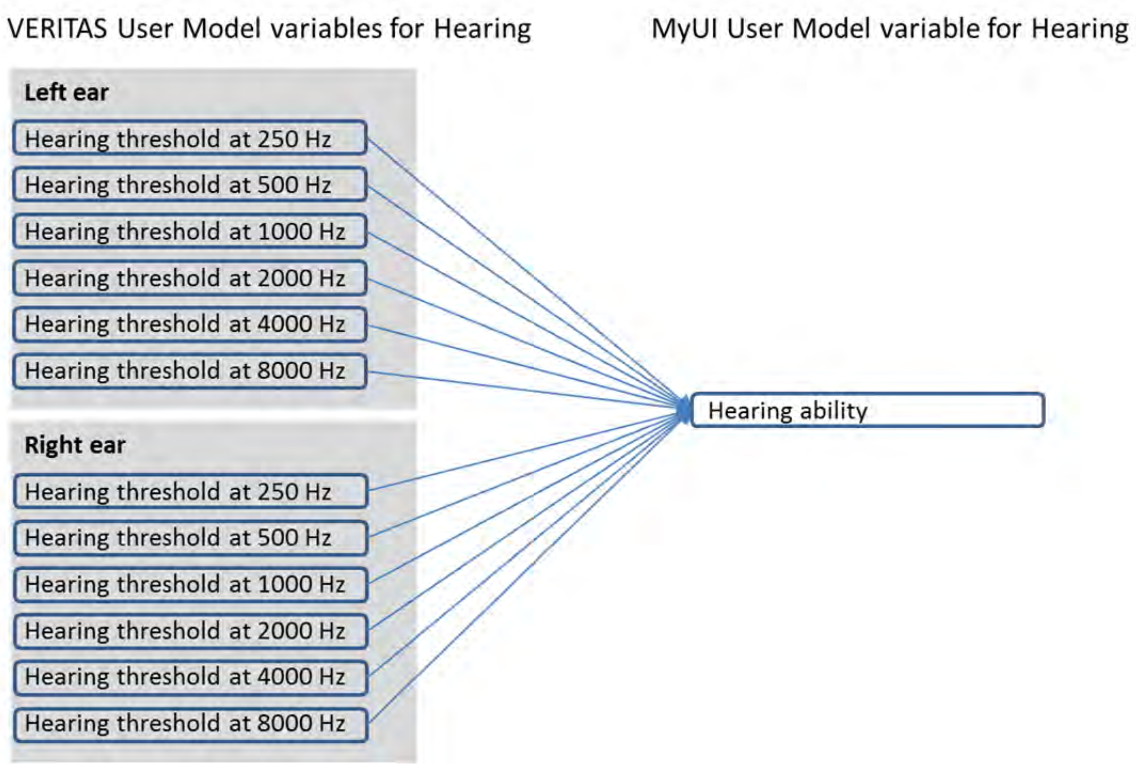


Figure 4 Exchange user models from simulation-oriented to UI adaptation-oriented approaches

Another essential difference between user models for simulation and user models for UI adaptation is the purpose and therefore the object of modelling. Most simulation cases aim at exploring how well users with different disabilities can work with a specific product. Therefore, the used user profile represents a certain user group and can be seen as a representation of a *stereotypical* user (*hypothetical*, not real). In UI adaptation, we are working with a user profile which represents the relevant characteristics of an *individual real* user.

Interesting use case for the exchange of user models between simulation- and adaptation-oriented approaches include the following:

Validate the effectiveness of UI adaptation mechanisms in simulations

- Select hypothetical user profiles (e.g. from VERITAS) as test cases
- Simulate the interaction between hypothetical users and standard UI (e.g. in the VERITAS simulation framework), analyse accessibility problems
- Transform hypothetical user profiles into individual user profiles (e.g. MyUI format)
- Generate adapted user interface in adaptation framework (e.g. MyUI)
- Simulate the interaction between hypothetical user and adapted UI (e.g. in the VERITAS simulation framework), analyse accessibility problems
- Evaluate if simulation yields significantly better accessibility results for the adapted UI than the standard UI

Use frequent user profiles (from simulation) as stereotypes for UI adaptation

- Create/select user profiles which cover a majority of actual disabled users (e.g. VERITAS)
- Transform hypothetical user profiles into individual user profiles (e.g. MyUI format)
- Generate adapted user interface in adaptation framework (e.g. MyUI)
- Optimize resulting adapted UIs
- User profiles and adapted UIs can be used as stereotypes in order to simplify and improve run-time user profiling and UI adaptation

6. State of the Art (WP)

This section contains a revision of the main trends on User Modelling related to accessibility and usability with the aim of providing some insight into the development of user models. It is commonly accepted that usable and accessible interfaces of software applications, AAL services (ambient Assisted Living) and consumer products depend upon the adaptation and customization of content and presentation of these interfaces to user needs expressed usually in user models and implemented through user profiles.

As mentioned above user models are used to describe the relevant characteristics of the user or group of users that will interact with the user interface. These include physical and sensory attributes, cognitive, habits, preferences and accessibility capabilities (VAALID deliverable D2.2. 2010). With such a model the designer can define as many user interaction profiles as needed to address the whole range of requirements from a target population (adaptation perspective). The existing standards related to User Modelling provide beside the above mentioned adaptation as well guidance to ICT and non-ICT product and service designers on issues and design practices related to Human Factors. They aim to help designers and developers to maximize the level of accessibility and usability of products and services by providing a comprehensive set of Human Factors design guidelines and meta-models in machine-readable formats (VERITAS deliverable D1.6.4), which could be used in virtual spaces to visualize accessibility and usability issues (Simulation perspective).

There was a plethora of systems developed during the last three decades that are claimed to be user models. Many of them modelled users for certain applications - most notably for online recommendation and e-learning systems. These models in general have two parts – a user profile and an inference machine. The user profile section stores detail about users relevant for a particular application and inference machine use this information to personalize the system. A plethora of examples of such models can be found at the User Modelling and User-Adapted Interaction journal and proceedings of User Modelling, Adaptation and Personalization conference. On a different dimension, ergonomics and computer animation follow a different view of user model (Duffy, 2008). Instead of modelling human behaviour in detail, they aim to simulate human anatomy or face which can be used to predict posture, facial expression and so on. Finally, there is a bunch of models which merges psychology and artificial intelligence to model human behaviour in detail. In theory they are capable of modelling any behaviour of users while interacting with environment or a system. This type of models is termed as cognitive architecture (e.g. SOAR (Newell, 1990), ACT-R/PM (Anderson & Lebiere, 1998), EPIC (Kieras, & Meyer, 1990) and so on) and has also been used to simulate human machine interaction to both explain and predict interaction behaviour. A simplified view of these cognitive architectures is known as the GOMS model (John & Kieras, 1996) and still now is most widely used in human computer interaction. Considering all these approaches together, it becomes challenging to define what a user model actually is. This lack of definition also makes the interoperability of user models difficult. On the other hand, there was a plethora of standards about human factors, user interface design, interface description language, workplace ergonomics and so on, that can be used to develop user models. The VUMS project cluster aims to standardize user modelling efforts to increase interoperability among user models developed for a wide variety of applications like designing automobile, washing machine, digital television interface and so on.

User Modelling and computers have in fact already a long tradition. In the last decades various generic User Modelling systems have been developed to allow adaptation in different software applications (Kobsa et al., 2001), and especially for hypermedia (Brusilovsky, 1996). The majority of these developments was academic and had very little impact in mainstream software (mainly with very limited customization options in mainstream operating systems).

Later there were efforts on user modelling coming from the Smart Cards and accessibility domain, such as the “European Standard EN 1332-4 Identification Card Systems – Man-machine Interface:

Coding of User Requirements for People with Special Needs," a standard, written at a time when the main relevant application areas were financial transactions, fixed line telecommunications and public transport. On top of these issues, there is still a gap in developing user models that can cope with multi-modality. In this category there are many other standard, which are listed here:

- ETSI TS 102 747; Human Factors (HF); Personalization and User Profile Management; Architectural Framework
- ETSI ES 202 746; Human Factors (HF); Personalization and User Profile Management; User Profile Preferences and Information
- ETSI EG 202 116; Human Factors (HF); Guidelines for ICT products and services; "Design for All"
- ETSI TR 102 068; Human Factors (HF); Requirements for assistive technology devices in ICT
- EG 202 325 - Human Factors (HF); User Profile Management
- ISO 11228-2:2007 (Ergonomics -- Manual handling -- Part 2: Pushing and pulling)
- ISO/DIS 24502 (Ergonomics -- Accessible design -- Specification of age-related relative luminance in visual signs and displays)

The emergence of mobile devices showed the need for a description of device characteristics so content providers could customize their offers to the capabilities of the devices. The World Wide Web Consortium developed the Composite Capabilities/ Preference Profiles framework (CC/PP; Klyne et al., 2003). CC/PP offers the possibility to define user and device profiles for an adequate adaptation of content and presentation for Internet services. CC/PP is based upon RDF (Resource Description Framework; Lassila and Swick, 1999) a general-purpose metadata description language. RDF provides the framework with the basic tools for both vocabulary extensibility, via XML namespaces, and interoperability. RDF can be used to represent entities, concepts and relationships in the Web. So far, the only practical implementation of CC/PP is the User Agent Profile (UAProf)[1], developed by the Open Mobility Alliance (formerly the WAP-Forum) and targeted to mobile devices. This approach was extended by further developments by W3C groups in the W3C Delivery Context Ontology, it provides a formal model of the characteristics of the environment in which devices interact with the Web or other services. The Delivery Context includes the characteristics of the Device, the software used to access the service and the Network providing the connection among others. The Universal Remote Console - URC Standard (ISO/IEC 24752) the goal of URC technology is to allow any device or service to be accessed and manipulated by any controller. Users can then select a user interface that fits their needs and preferences, using input and output modalities, and interaction mechanisms that they are familiar with and work well with them.

With the explosion of the Web, and e-commerce in particular, several commercial user modelling tools appeared in the market with the objective of adapting content to user tastes and preferences. Standards and recommendations in this area had to cope with the spread of service-oriented architectures in ubiquitous environments and to cover workflow and user interface aspects e.g. UsiXML[2], EMMA[3] (Extensible MultiModal Annotation markup language) and MARIA XML[4] in all these frameworks contains a user model component but does not cover all user modelling aspects.

The WHO has developed a standard to describe the abilities of a human being according to health indicators "International Classification of Functioning, Disability and Health (ICF)" (World Health Organization 2001/2002). This standard offers a balance between a purely medical and a purely

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[1] http://www.openmobilealliance.org/tech/affiliates/wap/wap-248-uaprof-20011020-a.pdf
[2] http://www.usixml.org
[3] http://www.w3.org/TR/emma/
[4] http://giove.isti.cnr.it/tools/Maria/

social approach of describing the limitations of people. This mixed approach allows grouping of limitations that are not only due to impairments but produce an equivalent result in the interaction with the proposed system.

Another major source for the development of user models was the E-Learning sector, here we mention IMS AccLIP (Access For All Personal Needs and Preferences Description for Digital Delivery Information Model) and AccMD, which have been internationalised in the ISO/IEC JTC1 Individualised Adaptability and Accessibility for Learning, Education and specification for the User Modelling software Training (ISO/IEC 24751-1:2008).

Table 3 summarizes the main characteristics of each of the mentioned standards; it indicates if a standard supports the descriptions of user needs, the device characteristics, and user characteristics. It contains an indication if a standard provides guidelines for developing user interfaces (UI), guidelines that have to be followed by designers and implementation details as meta-models, UML diagrams, ontology schemas, XML schemas, and machine-readable formats in general.

Table 3 Standards related to User Modelling

Standard	Description of user needs/ preferences	Description of device characteristics	Description of user characteristics (physical, cognitive, etc.)	UI definition support	Guidelines	Impleme ntation details
ETSI TS 102 747					✓	
ETSI ES 202 746	✓					✓
ISO/IEC 24751-1:2008						✓
ISO/IEC 24751-2:2008	✓					✓
W3C Delivery Context Ontology		✓				✓
W3C CC/PP	✓	✓				✓
URC Standard (ISO/IEC 24752)	✓	✓		✓		✓
IMS Access For All Personal Needs and Preferences Description for Digital Delivery Information Model	✓					✓
ETSI EG 202 116		✓	✓	✓ (Multimodal)	✓	
ETSI TR 102 068		✓	✓		✓	
ETSI EG 202 325					✓	
BS EN 1332-4:2007	✓					✓
ISO 11228-2:2007			✓		✓	
ISO/DIS 24502			✓		✓	
WHO ICF			✓			

There is additional need in user models for awareness of context, location and emotional state, as well as seamless roaming and portability (Mohamad et al., 2003), the key issue here is as well the need to cope with demands of different granularity requirements as in applications at design time (simulation), where detailed information are required and runtime adaptations, where less detailed information are sufficient.

All these developments show the need for developing standard user models that can respond not only to everyday scenarios nowadays, but also can be flexible enough to cope with future scenarios coming from ubiquitous, wearable computing and Ambient Assisted Living.

7. Concept of a generic user model (WP)

The discussions within the VUMS cluster revealed that a wide variety of user models are in use and will be in use in future. They all depend heavily on their specific use cases. There are a number of reasons for this:

- A full model of the user, meaning a model that includes facets according to the state of the art would be rather complex and inefficient in use for both simulation purposes and even more for implementation in a product's user interface.
- Existing devices might not be able to handle big user models
- Not all facets are needed for the specific use case. E.g. modelling some severe visual impairment is not relevant when designing a car.
- Specific requirements might require modifications in existing user models.
- The ways of measuring variables might differ between use cases.
- New findings may result in changes and updates of models.

Therefore it appears reasonable not to standardise specific user models but rather to focus on a more generic level. Thus, standardisation of user profiles in the sense they are defined in the glossary above is not expected to be of real benefit. However, standardisation at the level of user models or generic user model seems to be reasonable.

7.1 Providing an interface for interoperability (WP)

One main objective of standardisation is interoperability in the sense to enable systems or subsystems to work together. This means in particular the definition of appropriate interfaces. It shall be possible to transfer user models

- from one process step to another,
- from one system or a subsystem to another,
- from one user to another,
- from one project to another.

A standard on user models shall fulfil all these needs if possible.

7.2 The declarative approach (WP)

A user model can be seen from a functional/procedural point of view or from a more declarative point of view. In the first case the focus is laid on processes and actions. In the second case the focus is set on definitions and descriptions. The first view is dynamic the latter is static. A procedural approach would start from asking about user tasks and activities. This again is highly depending on the use case. A declarative approach would start from the question, what a user is. Thus for communication about interoperability a more declarative approach seems to be more suited.

Therefore, it is proposed to focus in standardisation of user models on a declarative approach and to separate the user model strictly from the task model.

In the VUMS cluster, we have taken a declarative approach. It means we have categorized a set of criteria to describe users and kept the procedural section of modelling psychological processes open to individual projects. It does not undermine the procedural aspect as we aim to standardize the model calibration and validation process so that some procedural aspects can also be made interoperable.

7.3 A set of variables describing the user (WP)

When defining users and user profiles all VUMS cluster projects started from certain characteristics of the user. What characteristics describe the user in the certain use context? In order to work with these characteristics by measuring them or calculating with them, a formal description as mathematical variables is a natural and rather compelling approach.

This means that the generic user model can be described as a set of variables describing the user adequately for a certain use case or application.

In order to work appropriately with variables a precise definition is needed, a way to express them in numbers and the unit of measure to relate them to physical reality. Those items are needed for each of the variables in the set.

A standard for user models should include this definition and approach.

7.4 A machine and human readable presentation (WP)

To cover all areas of interoperability as mentioned in 8.1 human models need to be read as well by humans as by machines. Interoperability between systems and subsystems results in the requirement of machine-readable user models. The exchange of user models between projects or between process steps can also mean that humans have two read and understand the user models. Therefore a standard should require that user models are both machine and human readable.

This has some implications on the syntax and the format of the formulation of user models. Instead of using different formats and syntaxes for humans and machines it seems the simplest to have one common formats and syntax for both. The use of extended markup languages (XML) is one of the potential appropriate ways to achieve this.

As user modelling has an ontological trait the use of an ontology description languages is an option, too. The OWL Web Ontology Language seems a reasonable candidate.

It is however important to avoid big overheads in the formal description so that human readability is not impaired.

7.5 A flexible structure that adapts to user needs and applications (WP)

Because the one and only user model does not exist and their application depends strongly on the specific application, the possibility to apply flexibility in formulating user models is required to achieve good acceptance of a standard on user models.

A standard should give the required degrees of freedom to its user. Rigid regulations will reduce acceptance. The standard should not be closed but open for amendments.

As stated above, the standard shall not try to define models of specific users. It shall deal more with structural aspects of the user model. Defining the structure of user models in the standards will be helpful. This structure shall be able to convey both syntax and semantics.

7.6 A living standard in the Internet (WP)

While the structural aspects of the user model are general enough to persist for some years, the number and type of variables considered, their definitions, the ways to measure them and the related units of measure evolve rapidly. This holds true for the work in the VUMS cluster projects but is expected to be the case during the next years and decades.

Therefore it seems advisable to separate the more persistent parts of a standard from the rapidly changing ones. Persistent ones can be printed. Rapidly fluctuating ones require quicker ways of distribution. A reasonable approach is to keep the fluctuating parts accessible from the Internet.

The idea is to have a repository of definitions of variables and or user models (set of variables) on the internet, which can be updated and changed by the community - a living standards in the Internet.

8. Structure of the VUMS user model (WP)

8.1 A taxonomy of variables (WP)

The categories of the user variables' taxonomy are the following:

- **Anthropometrics**: Physical dimensions, proportions, and composition of the human body (e.g. weight, stature, etc.)
- **Motor parameters**: Parameters concerning the motor function of the human body
    - **Gait parameters**: Parameters concerning human gait (e.g. step length, step width, etc.)
    - **Upper body parameters**: Parameters concerning human upper limbs (e.g. wrist flexion, etc.)
    - **Lower body parameters**: Parameters concerning human lower limbs (e.g. hip extension, etc.)
    - **Head and neck parameters**: Parameters concerning human head and neck (e.g. lateral bending, etc.)
    - **Spinal column parameters**: Parameters concerning the spinal column (e.g. spinal column flexion, etc.)
- **Strength parameters**: Parameters concerning human strength (e.g. maximum gripping force of one hand, etc.)
- **Dexterity/control parameters**: Parameters concerning motor skills of hands and fingers
- **Affective parameters**: Parameters concerning human emotions (e.g. anger, disgust, etc.)
- **Interaction related states**: Parameters concerning human body response to situations of physical or emotional pressure (e.g. stress, fatigue, etc.)
- **Hearing parameters**: Parameters concerning hearing (e.g. hearing thresholds in specific frequencies, etc.)
- **Visual parameters**: Parameters concerning vision (e.g. visual acuity, colour perception, etc.)
- **Cognitive parameters**: Parameters related to information-processing abilities of humans, including perception, learning, remembering, judging and problem-solving (e.g. working memory capacity, etc.)
- **Equilibrium**: Parameters concerning the sense of balance.
- **Others**: Parameters that cannot be included in the before mentioned categories.

8.2 Descriptors for variables (WP)

In order to describe a virtual human in detail, for each user model variable the following properties are defined:

- **Name**: The name of the variable
- **ID/tag**: The tag to be used for defining the specific variable in a user profile
- **Description/definition**: A description/definition of the variable
- **Unit**: The measurement unit of the variable
- **Value Space**: The value space of the variable (nominal, ordinal, interval, ratio, absolute)
- **Taxonomy/super categories**: Refers to the categories described in section 9.1
- **Data type**: The data type of the variable (character/string, enumeration, list/vector, integer, float, set)
- **How to measure/detect**: Refers to techniques/devices used to measure the value of the variable (e.g. goniometer, tape measure method, etc.)
- **Reference/source**: Literature references where information regarding the variable can be found
- **Relations**: Statistical correlation to other variables, function of others, dependency of others
- **Source Project**: The name of the project of VUMS cluster that introduced the variable
- **Supported/used by Project:** The name(s) of the project(s) of VUMS cluster that use the variable in their user profiles.
- **Comment**: Comments concerning the variable (status, cross-references and others)

Table 4 below presents an example of a variable definition of the VUMS User Model.

Table 4 VUMS User Model variable definition example

Name of variable	ID/tag (This is the tag to be used in defing user profile)	Description/ definition	Unit	Value Space (nominal, ordinal, interval, ratio, absolute)	Taxonomy/ supercategories	Data type (computer science) (character/string, enumeration, list/vector, integer, float, set) Note: use XSD-Terminology	How to measure/ detect	Reference/ source	Relations (statistical correlation to others, function of others, dependency of others)	Source Project	Supported/ used by Project	Comment (status, cross-references and others)
Anthropometric data												
Shoulder-elbow length	shoulderElbow Length	The distance from the top of the acromion process to the bottom of the elbow. The subject sits erect with his upper arms vertical and forearms and hands extended forward horizontally.	cm	Men : 30.0 - 39.9	Physical	Float	Tape measure, anthropometer	Anthropometric Source Book, Volume I: Anthropometry for Designers, NASA, 1978		VERITAS	VERITAS	

9. Syntax for user models

As outlined in section 8.4 User Models shall be both machine-readable and human-readable. This requires syntaxes and formats which are accessible to both a variety of humans and variety of machines. This can be either achieved by a single common format and syntax that has to be learnt by all users or by a number of formats and/or syntaxes that are accessible by the various users.

However, in the latter case translations between the different languages are required. In case of n user model description languages $n \cdot (n-1)/2$ bidirectional translators are needed to provide full interoperability. This is quite expensive. A way to avoid this is to agree on a common language for data exchange, an interfacing language. Then only n-1 bidirectional translators to this language are required to achieve interoperability.

This desirable common interface language has not yet been defined. However there are some requirements which can be formulated:

- Preferably simple text file format (ASCII)
- Mark-up language (familiar and readable)
- Comprehensible names and tags
- Avoid overhead (restrict the exchange format to the very needs of user models)
- Usable as an extension for other mark-up languages
- Suitable for ontology-based approaches

The following paragraphs show the syntactical approaches of the individual VUMS cluster projects.

9.1 VERITAS Virtual User Model

In order to create user models that could be automatically used by the VERITAS Simulation Framework, the use of a machine-readable format is essential. VERITAS needs a formal way to describe users, including elderly and people with disabilities. Thus, the VERITAS Virtual User Model, which is based on UsiXML, supports the detailed description of user’s disabilities as well as the affected/problematic (due to the disabilities) tasks.

UsiXML has been chosen to be the basis of the VERITAS user modelling technique, as it can sufficiently describe user tasks, has some primal support for user description and it is easily extensible, due to its XML nature. VERITAS introduced two new models, which have been added to UsiXML’s *uiModel* (Figure 5):

a) the *disabilityModel* (Figure 6) and
b) the *capabilityModel* (Figure 7Figure 7).

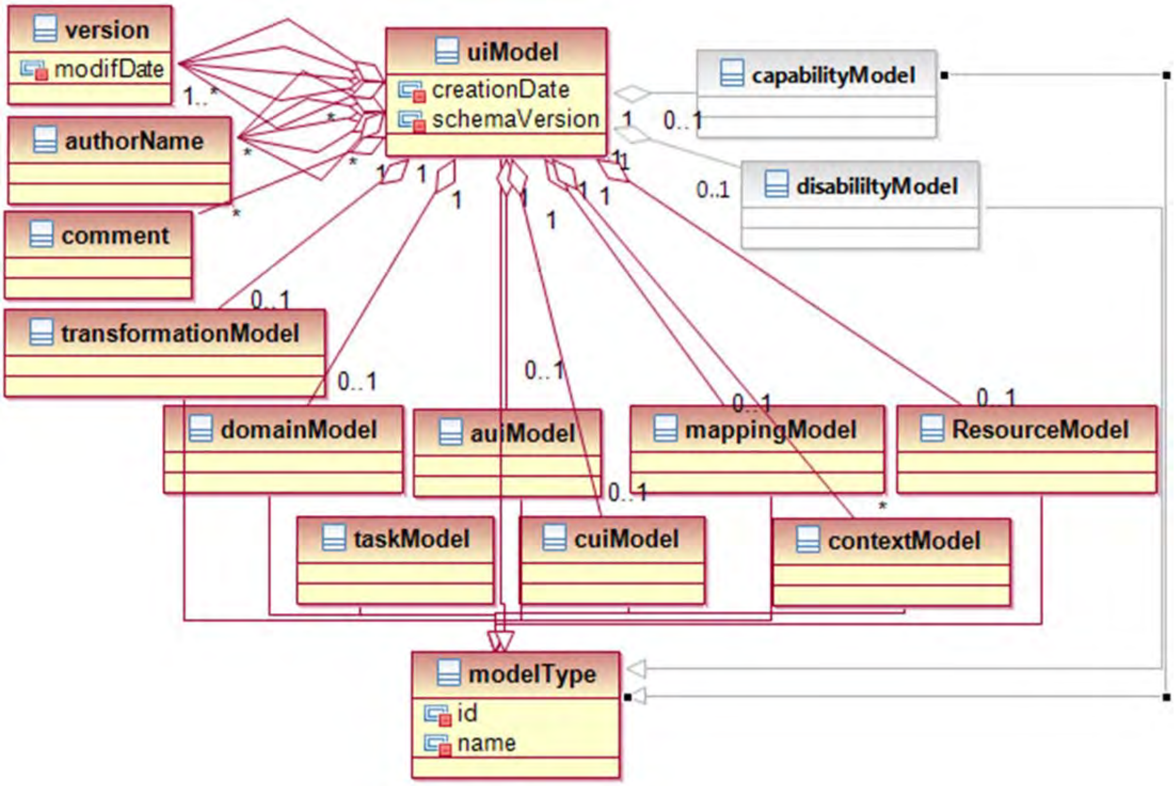


Figure 5 uiModel – UML class diagram

The *disabilityModel* describes all the possible disabilities of the user as well as the affected by the disabilities tasks. Each disability element has a name and a type (e.g. motor, visual, etc.). Each *affectedTask* element has the following attributes:

- *id*: task's unique identity
- *type*: the type of the task (e.g. motor, visual, etc.)
- *name*: task's name
- *taskObject* (optional): the name of the task object (e.g. "door handle" may be the task object for task "open door")
- *details* (optional): some details/comments concerning the execution of the task
- *failureLevel*: an indicator showing the failure level of the task due to the disabilities [accepted values: 1 to 5] – failureLevel=5 means that the user is unable to perform the specific task

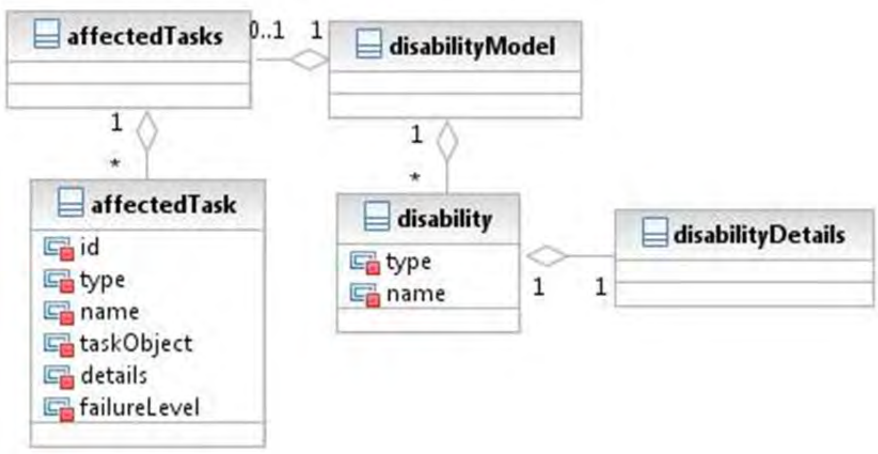


Figure 6 DisabilityModel – UML class diagram

On the other hand, the *capabilityModel* describes in detail the physical, cognitive and the behavioral/psychological user characteristics. The majority of the parameters of the proposed user model concerns the physical characteristics, as most of them are measurable and independent from the environment, in contrast with the cognitive and behavioral/psychological ones.

More specifically, the *capabilityModel* contains the following basic elements:
a) *general*: container for some general characteristics (e.g. gender, ageGroup)
b) *generalPreferences*: container for user's needs/preferences (e.g. preferred input/output modality, preferred sound volume, etc)
c) *anthropometric*: container for the anthropometric data (e.g.: weight, stature, head length, sitting height bideltoid breadth, etc.),
d) *motor*: container for the motor parameters (e.g.: wrist/elbow/shoulder flexion, hip abduction, etc.),
e) *vision*: container for the visual parameters (e.g.: visual acuity, glare sensitivity, spectral sensitivity, etc.),
f) *hearing*: container for the hearing parameters (e.g.: resonance frequency, hearing thresholds, etc.),
g) *speech*: container for the speech parameters (e.g.: voice pitch, fundamental frequency, syllable duration)
h) *cognition*: container for the cognitive parameters (e.g.: memory, etc.) and
i) *behaviour*: container for the behavioral parameters (e.g.: valence, emotional intelligence, etc.).

Appendix A presents an example of a VERITAS Virtual User Model.

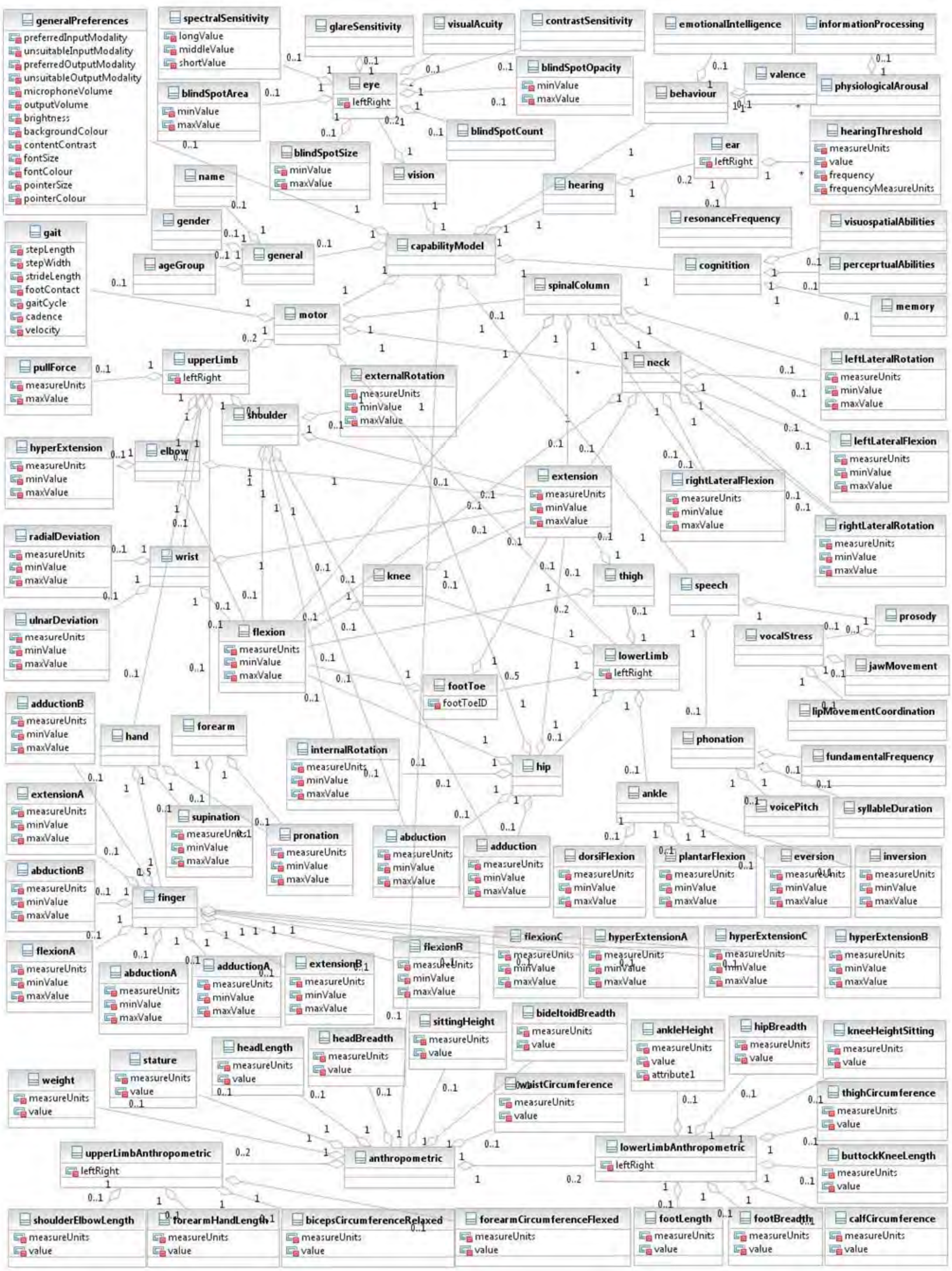


Figure 7 capabilityModel – UML class diagram

9.2 VICON User Model

VICON User Model, where all information about a user such as physical impairments or diseases are stored. The predicates for this model were acquired through user studies. User Models are divided into eight WHO ICF based Subgroups, where for every criterion the profiles are divided into different levels of impairments. Additionally there are mixed profiles describing the group of elderly people suffering upon a mixture of hearing, sight and dexterity impairments. The user model is stored as OWL ontology in a repository.

Figure 8: Iterative Creation of a Virtual User Model based on Inference

As described in Table 5 the syntax of the VICON user model consist basically of variables of a specific data type and a description.

Table 5 Excerpt of the VICON user model

USER MODEL PARAMETER		
Variable	**Datatype**	**Description**
Name	String	The name to identify a person, this is the only one primary predicate, that means it is mandatory to define it in an instance
Nickname	String	Optional nickname for the person
VirtualModel	String	A uri where to find a virtual model e.g. in form of a wavefront .obj file format
Age	Integer (65-116)	Age in years
Gender	String (male or female)	Gender
Hearing500Hz	Integer (-10 - 120)	Threshold hearing level in dB at 500Hz (without aid)
Hearing1kHz	Integer (-10 - 120)	Threshold hearing level in dB at 1kHz (without aid)
Hearing2kHz	Integer (-10 - 120)	Threshold hearing level in dB at 2kHz (without aid)
Hearing4kHz	Integer (-10 - 120)	Threshold hearing level in dB at 4kHz (without aid)
BackgroundNoise	Integer (0 - 200%)	Threshold of speech intelligibility with background noise. Percentage of background noise volume compared to speech volume.
HearingAid	String (yes or no)	Does the user have a hearing aid
HearingAidWithProduct	Integer (no, yes or yes with T setting)	Would the user use a hearing aid with the product
Blurry	Integer (1 = No, 2 = Slightly, 3 =	Without glasses, things appear to be indistinct/blurry

	Moderately, 4 = Strongly)	
ChangeFocus	Integer (1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	It is difficult to change focus when looking at something near and then far away
FieldOfVision	Integer (1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	Reduced field of vision (finds it hard to see things to the side, top, bottom of what they are looking at)
Colour	Integer (1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	Cannot distinguish colours
Distance	Integer (1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	Hard to judge distance
LightLevels	Integer (1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	Hard to adjust to changes in light levels
Glare	Integer (1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	More sensitive to light and glare than used to be
Glasses	String (yes or no)	Are glasses used?
GlassesWithProduct	String (yes or no)	Would the user wear glasses with the product
Arthritis	String (yes or no)	Did the user report Arthritis?
Grip	Integer (1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	Difficulty gripping small items, for example a pen or the handle of a cup
Controls	Integer (1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	Difficulty when using controls such as knobs or sliders
Buttons	Integer (1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	Difficulty when using buttons or keys, for example when using the number keys on a phone
Discomfort	Integer (1 = No, 2 = Slightly, 3 = Moderately, 4 = Strongly)	Discomfort in hands when gripping small objects or operating controls

As VICON focuses on the evaluation of the interaction between the user and the consumer products we have selected the disabilities having direct impact on successful usage of such products (washing machines and mobile phones):

- Sensory abilities: Vision (Visual Field, Visual Acuity and Quality of Vision) and hearing (Sound and Speech discrimination).
- Physical abilities: Manipulation (Lifting, Carrying or Putting down objects) and Dexterity (Pulling, Catching, Pushing etc).

9.3 GUIDE User Model

The GUIDE user model simulates basic perceptual, cognitive and motor capabilities of users. The user model is a set of mathematical models which takes parameters on users' and devices' properties and capabilities. The models are calibrated, validated and used through a simulator, which is explained in the next section.

Figure 9 below shows the architecture of the **simulator**. It consists of the following modules:

- **The Environment model** contains a representation of the application and context of use. It consists of:
  - **The Application model** containing a representation of interface layout and application states.
  - **The Task model** representing the current task undertaken by a user that will be simulated by breaking it up into a set of simple atomic tasks following the KLM model (John & Kieras, 1996).
  - **The Context model** representing the context of use like background noise, illumination and so on.
- **The Device model** decides the type of input and output devices to be used by a particular user and sets parameters for an interface.
- **The User model** simulates the interaction patterns of users for undertaking a task analysed by the task model under the configuration set by the interface model.
  - The perception model (Biswas & Robinson, 2009) simulates the visual perception of interface objects. It is based on the theories of visual attention.
  - The cognitive model (Biswas & Robinson, 2008) determines an action to accomplish the current task. It is more detailed than the GOMS model (John & Kieras, 1996) but not as complex as other cognitive architectures.
  - The motor behaviour model (Biswas & Robinson, 2009) predicts the completion time and possible interaction patterns for performing that action. It is based on statistical analysis of screen navigation paths of disabled users.

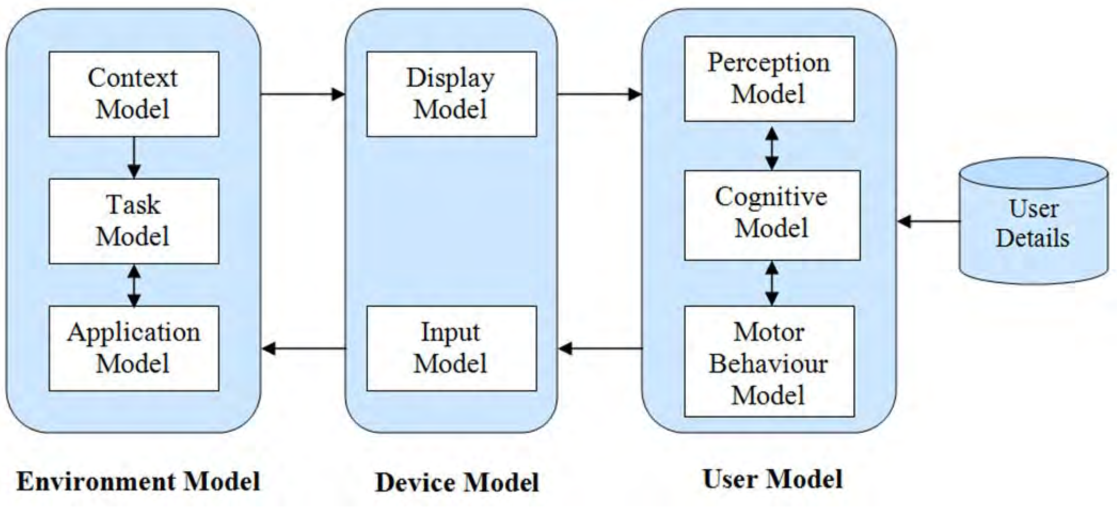


Figure 9 Architecture of the Simulator

The details about users are stored in xml format in the user profile following the ontology shown in Figure 10 below. The ontology stores demographic detail of users like age and sex and divide the functional abilities in perception, cognition and motor action. The perception, cognitive and motor behaviour models take input from the respective functional abilities of users.

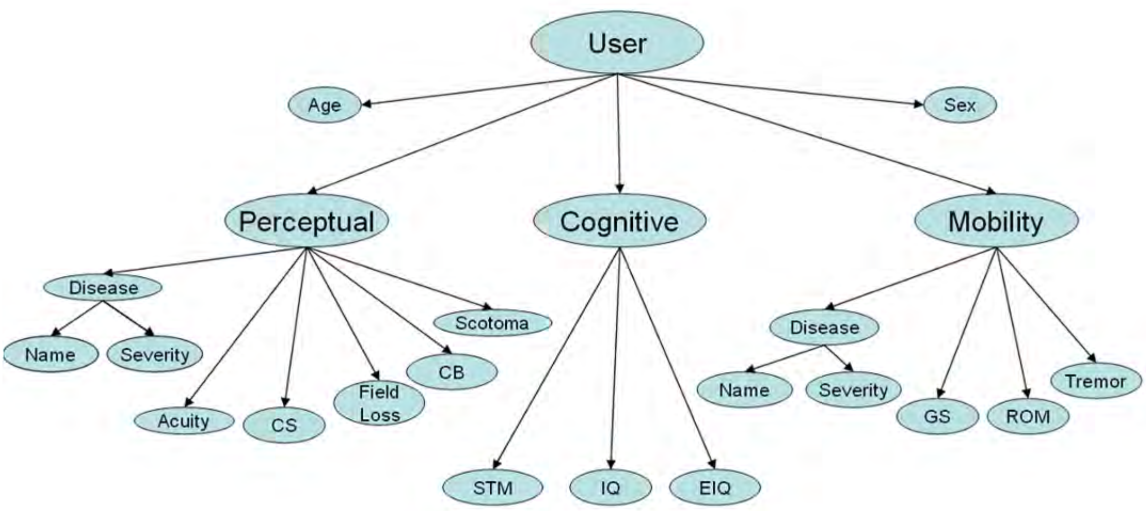


Figure 10 User Ontology in GUIDE
(STM: Short Term Memory, IQ: Intelligent Quotient, EIQ: Emotional Intelligent Quotient)

Each of the perception, cognitive and motor behaviour models were calibrated and validated separately involving people with and without visual and mobility impairments.

- The visual perception model (Biswas & Robinson, 2009) was validated through an eye gaze tracking study for a visual search task. We compared the correlation between actual and predicted visual search time, eye gaze and also investigated the error in prediction. The actual and predicted visual search time correleated statistically significantly with less than 40% error rate for more than half of the trials.
- The cognitive model (Biswas & Robinson, 2008) was used to simulate interaction for first time users and to simulate the effect of learning as well.
- The motor behaviour model (Biswas & Robinson, 2009) was validated through ISO 9241 pointing task. The actual and predicted movement time correlated statistically significantly with less than 40% error rate for more than half of the trials.
- The whole simulator (Biswas, Langdon & Robinson, 2011) has been validated for an icon searching task involving people with and without visual and mobility impairments.

The following is a tentative sample user profile from GUIDE.

```
- <xml>
  - <User>
    - <Demography>
        <Age>71</Age>
        <Sex>F</Sex>
        <Height>147</Height>
      </Demography>
    - <Perception>
      - <VisPercpDisease>
          <Name>Visual Acuity Loss</Name>
          <Severity>2</Severity>
        </VisPercpDisease>
      - <VisPercpAcuity>
          <Value>-3.5</Value>
          <Acuity1>6</Acuity1>
          <Acuity2>8</Acuity2>
        </VisPercpAcuity>
        <VisPercpContrSens>80</VisPercpContrSens>
        <VisPercpFieldLossP>0</VisPercpFieldLossP>
        <VisPercpFieldLossC>0</VisPercpFieldLossC>
        <VisPercpCB>0</VisPercpCB>
        <VisPercpScotoma>0</VisPercpScotoma>
      </Perception>
    - <Cognitive>
        <CogDisease>Dyslexia</CogDisease>
        <CogSTM>12</CogSTM>
      </Cognitive>
    - <Mobility>
      - <MobDisease>
          <Name>Parkinson's Disease</Name>
          <Severity>2</Severity>
        </MobDisease>
        <MobGripStr>9</MobGripStr>
        <MobROMW>63</MobROMW>
        <MobTremor>625</MobTremor>
      </Mobility>
    </User>
  </xml>
```


Figure 11 Sample User Profile from GUIDE

9.4 MyUI User Model

In general, a MyUI user profile is collection of information about an end-user of the MyUI system. This includes personal information like email address, first name, last name, etc. as well as information about user capabilities and characteristics as far as they are relevant to determine the human computer interaction (HCI) abilities of a user. The general idea is to collect and continuously adapt HCI-relevant user information, so that human computer interfaces (also called user interfaces) can be dynamically adapted to the current capabilities, needs and limitations of a user.

In more technical terms and based on the RDF data model. RDF describes relationships in terms of resources. Resources can be differentiated into subjects, predicates, objects and statements. A statement is a triple consisting of subject, predicate and object. An RDF-statement roughly translates to a data representation of a simple natural language sentence that captures statements about the subjects. In RDF resources are referenced by Uniform Resource Identifiers URIs. In relation to MyUI a statement always addresses a user capability, characteristic or short property of a user. The user is the subject. The property is the predicate. The value that is stated for this property is the object of the statement.

Based on this a MyUI user profile is a collection of statements referring to the same user URI, i.e., one user profile is always connected to one and only one user. The allowed properties and possible values are defined in the MyUI User Profile Ontology, which describes the constraints under which a user profile is considered valid. Only valid user profiles can be processed by the MyUI system. Two constraints have already been defined in the previous section, namely:

- C1: A MyUI user profile must be a collection of statements.
- C2: A MyUI user profile must consist of statements referring to a specific user URI. One user URI must always uniquely refer to one specific user.

When it comes to adaptation (WP2), we are using the term "user profile variable". This corresponds to a statement where the subject is the specific user this variable belongs to. The property, which can be seen as the predicate in a RDF-statement, is also called "user profile variable name", and the object is called "user profile variable value".

- C3: Every property in a MyUI user profile must correspond to a specific characteristic of the user, which is called "user profile variable name".

In short, one could say that the property must be the name of a user profile variable. A detailed overview of the currently defined user profile variables and a description of the method used to define these variables is provided in chapter 2.2.2. This list is not fixed yet which means the user profile variables (and therefore the properties) are not fixed yet and might change in the future of the project.

Although MyUI's modelling does not rely on OWL conceptual it is closely linked to the GUMO modelling principles described in (Heckermann et al., 2005) as

$$\texttt{subject} \left\{ \mathit{UserModelDimension} \right\} \texttt{object}$$

In contrast to GUMO, MyUI is aiming for a much more task-oriented user profile, where information capturing disabilities and impairments in relation to human computer interaction are captured. This makes it impossible to simply reuse the high-level user model dimensions proposed by GUMO. Therefore, MyUI is extending the GUMO model with the user variable concept.

The range of a property defines which values can be used as an object in a statement (i.e. it defines the type of the corresponding user profile variable). We can distinguish the following three cases:

- *Numerical Literal*: We use numerical literals to represent user profile variables which are ratio-scale. In this case one value is selected from a predefined, continuous interval for a user profile variable of this type. In the current ontology this interval is considered to be the same for all ratio-scaled user profile variables (in contrast to nominal-scaled user profile variables where a different set of possible values is defined for each user profile variable). The interval is specified to be [0,4] (i.e. all possible values between 0 and 4 including 0 and 4 can be assigned). Although, we want to avoid an exact medical definition, 0 can roughly be mapped to "not limited or normal", 2 can roughly be mapped to "mildly limited" and 4 can roughly be mapped to "severely limited". This kind of type is typically assigned to user profile variables that represent limitations and capabilities of the user like hand precision, visual acuity. Assigning a value of 0 to hand-precision, therefore, maps to the statement that this user's hand-precision is not limited or normal. The default value is 0. However the above mapping exists, this doesn't have to be applicable for all user profile variables. The user profile variable "ambient light" for example uses another mapping (0 translates to no ambient light meaning absolute darkness, 4 translates to very high ambient light). Concluding it can be said that the meaning of the values of a numerical literal depends on the concrete user profile variable. The mapping for each defined user profile variable can be found in Table 1. Using a continuous, ratio-scaled interval has the advantage that there exists a strong order between the distinct values for a user profile variable. Furthermore using continuous values is helpful by providing the possibility to have a fine-grained differentiation.

- *String Literal*: This corresponds to a free-text user profile variable. This means any value can be assigned to this kind of user profile variable as long as it is a string. This user profile variable type is used for user characteristics like first name, last name and email address. Although, in principle any value is accepted (as opposed to a set or interval of values), the format of the string might be constrained in a clearly defined way. For example, the email address must be a syntactically correct email-address; or the first name must not exceed a certain number of letters. The default value for a user profile variable of this kind is an empty string.
- *Enumeration*: This means a subset from a set of predefined values (represented as concept instances) can be assigned to a user profile variable which is nominal-scaled. This user profile variable type is used to specify the languages that are accepted by a person. In a collection of statements, an “assigned subset” maps to a set of statements with the corresponding property for that user profile variable. The collection must not be empty if it is explicitly assigned. Enumerations also support default values, which are used when there is no corresponding statement. The default value is one specifically marked value of the set of possible values (since only subsets can be assigned, technically it would be a set containing only this single element).

All this can be condensed into the following constraints.

C4: A property with a string literal range must appear at most once. Its value can be any string that complies with the format restriction of the corresponding user profile variable. The default value is an empty string.

C5: A property that corresponds to a nominal-scaled variable can appear multiple times. Its value must be selected from the instances of an assigned range concept. If there is no property instance, the specified default value is used.

C6: A property that corresponds to a ratio-scaled user profile variable must appear at most once. Its value must be selected from an (currently common) interval. The default value is 0.

The resulting defined ontology formalism can be seen as RDF plus a subset of RDFS (concept and property hierarchies) which is interpreted as constraints, i.e. range definitions constrain the allowed values for certain properties.

In MyUI, a function-based user modelling approach is used. Hence, user profile variables are connected to specific user interaction abilities and constraints subdivided into perceptual, cognitive and motor attributes. Variables relevant for MyUI have been initially selected from the WHO ICF guidelines. Further sources, e.g. the ISO 22411 standard and major requirements determined in D2.1 (Requirements for User Interface Adaptation), are also considered.

The following key questions have been underlain the selection process:

1. Does a certain attribute affect the interaction with ICT products?
2. Can user interface adaptation overcome or weaken the interaction constraints?

If both questions can be answered with “yes” the attribute has been included as additional user profile variable to the MyUI user model.

The initial list of user profile variables used in the current version of the MyUI system is presented below. Each variable is shortly explained, appropriate valid value ranges and references to existing standards are given. Possible methods of resolution are not detailed here, but will be part of D2.2 (Adaptation concept and Multimodal User Interface Patterns Repository).

Table 6 MyUI user profile variables.

Area	User Profile Variable	Interpretation	Range	Reference
Perceptual Vision	visual acuity and sensitivity	ability to perceive what is displayed on the screen	[0, 4] 0 - normal; 4 - severely impaired	WHO ICF b2100 visual acuity functions, b21022 contrast sensitivity, b21020 light sensitivity ISO 22411 URS07, URS09 FRS01-02
	colour perception	ability to distinguish colours (without any limitation such as e.g. red-green, blue-yellow blindness)	0 - colours can be distinguished without restrictions 1 – not all colours can be distinguished	WHO ICF b21021 colour vision ISO 22411 URS15 FRS02
	field of vision	ability to perceive without limited vision in certain areas	[0, 4] 0 - normal; 4 - severely impaired	WHO ICF b2101 visual field functions ISO 22411 URS10 FRS02
	ambient light	ambient light conditions	[0, 4]; 0 - no ambient light, absolute darkness; 4 - very high ambient light level, e.g. dazzling sun light on the screen	WHO ICF b21020 light sensitivity ISO 22411 ER01-03 FRS03 FRE01
Hearing	hearing	ability to hear	[0, 4] 0 - normal; 4 - severely impaired	WHO ICF b2300 sound detection ISO 22411 URS11
	ambient noise	ambient noise conditions	[0, 4]; 0 - normal; 4 - high noise level	WHO ICF b2300 sound detection ISO 22411 FRE02
Cognitive Language	language reception	ability to comprehend written or spoken language	[0, 4] 0 - normal; 4 - severely impaired	WHO ICF b1670 reception of language ISO 22411

	language production	ability to produce written or spoken language	[0, 4] 0 - normal; 4 - severely impaired	WHO ICF b1671 expression of language ISO 22411 URC07 (limited literacy)
	understanding abstract signs	ability to understand abstract symbols or icons	[0, 4] 0 - normal; 4 - severely impaired	URC20
	attention	Covering selective, focused and divided attention abilities[5]	[0, 4] 0 - normal; 4 - severely impaired	WHO ICF b140 attention functions ISO 22411 URC05
Information processing	processing speed	ability to process information in an appropriate time	[0, 4] 0 - normal; 4 - severely impaired	WHO ICF b1470 psychomotor control ISO 22411 URC04 FRC01
Memory	working memory	ability to remember exact sequencing of multi-step procedures and to orientate oneself in long sequences of steps	[0, 4] 0 - normal; 4 - severely impaired	WHO ICF b1440 Short-term memory ISO 22411 URC03 FRC02
	long term memory	ability of learning, storing and retrieving new information	[0, 4] 0 - normal; 4 - severely impaired	WHO ICF b1441 long-term memory ISO 22411 URC02 FRC02
ICT skills	ICT literacy	skills and experiences in using current ICT user interfaces	[0, 4] 0 - normal; 4 - severely limited	URC01
	need for security / ICT anxiousness	importance to which security is needed including risk-avoiding	[0, 4] 0 - normal; 4 – particularly pronounced	URG03 FRG10/11
Coordination	hand-eye coordination	ability to move hands according to visual feedback	[0, 4] 0 - normal; 4 - severely impaired	WHO ICF b1471 Quality of psychomotor functions ISO 22411 URC 19

[5] selective attention: ability to attend to one thing without losing control of another one
focused attention: ability to concentrate on only one thing at a time and get not distracted by irrelevant information
divided attention: ability to split attention to more than one thing at a time

Motor Speech	Speech articulation	ability to articulate speech	[0, 4] 0 - normal; 4 - severely impaired	WHO ICF b310 voice functions, b320 articulation functions ISO 22411 URP07 FRP04
Dexterity	finger precision	ability to move the fingers	[0, 4] 0 - normal; 4 - severely impaired	WHO ICF d440 fine hand use ISO 22411 URP02 FRP01, FRP03
	hand precision	ability to move the hands	[0, 4] 0 - normal; 4 - severely impaired	WHO ICF b730 muscle power functions WHO ICF d4453 Turning or twisting the hands or arms WHO ICF d4402 Manipulating ISO 22411 URP10 FRP01-02
	arm precision	ability to move the arms	[0, 4] 0 - normal; 4 - severely impaired	WHO ICF d4453 Turning or twisting the hands or arms
Muscle strength	contact grip	ability to apply a unidirectional force by a finger, the thumb or the hand [according to ISO 22411], e.g. by touching or operating via touching	[0, 4] 0 - normal; 4 - severely impaired	WHO ICF b265 Touch function ISO 22411 URP06 FRP03
	pinch grip	ability to hold the control by the fingers and/or thumb without clenching the fist hand [according to ISO 22411], e.g. when holding sth between the fingers.	[0, 4] 0 - normal; 4 - severely impaired	WHO ICF d440 fine hand use, d4400 Picking up ISO 22411 URP06 FRP03
	clench grip	ability to use all fingers wrapped around a control [according to ISO 22411].	[0, 4] 0 - normal; 4 - severely impaired	WHO ICF d4402 Manipulating ISO 22411 URP06 FRP03
General data	first name	first name	any string	
	last name	last name	any string	
	email address	email address	any well-formed email address	

	preferred language	preferred languages	**English**, German, Spanish	URG02 FRC04

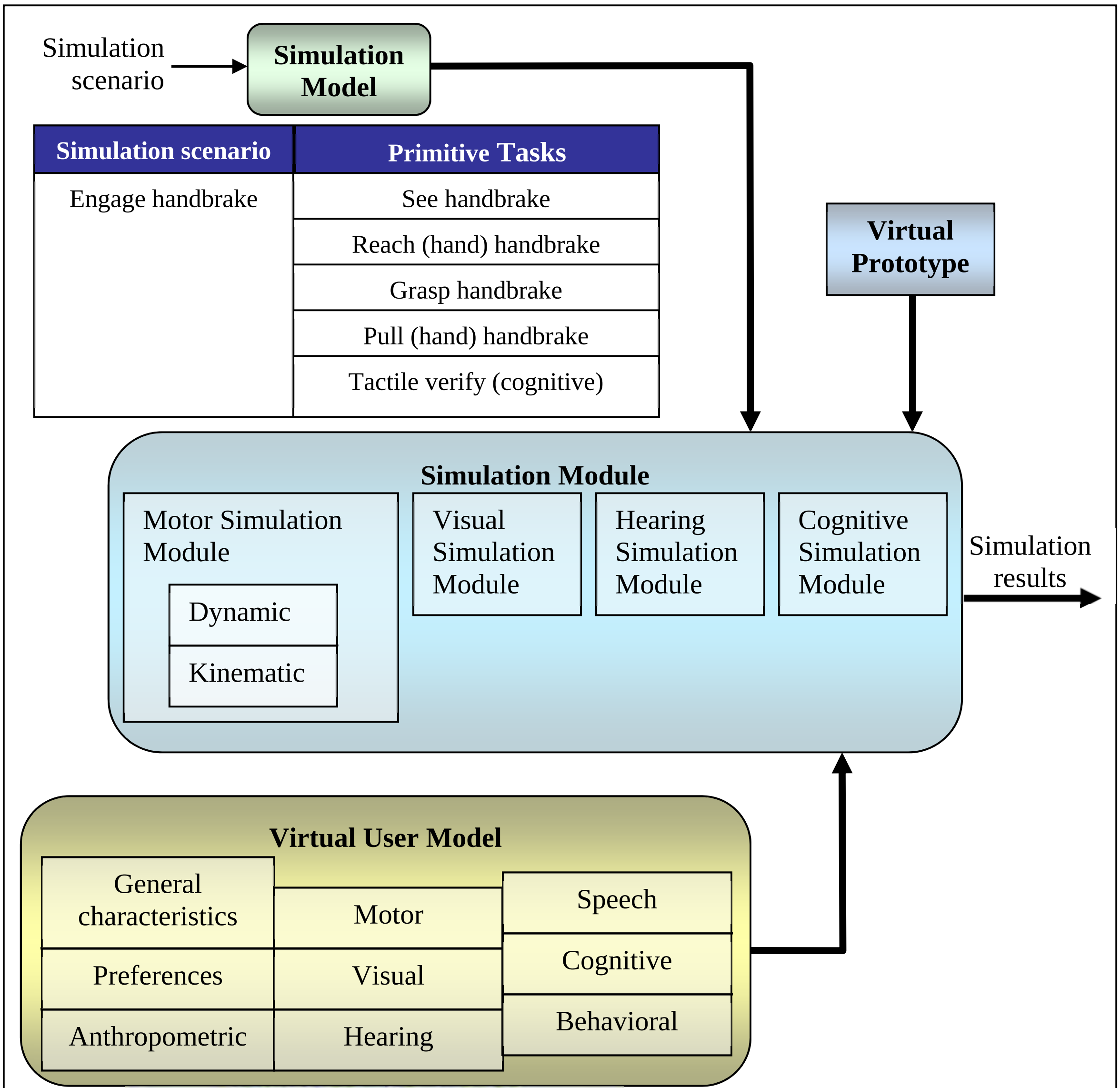
10.How to use the model

The following use cases illustrate the use of the user model in the VUMS Cluster projects.

The **VERITAS** Virtual User Model is used by the Simulation Module, which is the core component of the VERITAS Simulation Framework. As depicted in Figure 4, the Simulation Module includes four sub-modules:

- The **Motor Simulation Module**, which is responsible for the simulation of motor tasks, performing both kinematic and dynamic analysis.
- The **Visual Simulation Module**, which is responsible for the simulation of visual tasks.
- The **Hearing Simulation Module**, which is responsible for the simulation of hearing tasks.
- The **Cognitive Simulation Module**, which is responsible for the simulation of cognitive tasks.

The Simulation Module simulates the interaction of the virtual user (as it is defined in the Simulation Model) with the virtual environment. The disabled virtual user is the main “actor” of the simulation that aims to assess if the virtual user is able to accomplish all necessary actions described in the Simulation Model, taking into account the constraints posed by the disabilities (as defined in the Virtual User Model). Simulation planning is performed using inverse kinematics, while dynamic properties of the human limbs (e.g. torques and forces) related to the corresponding actions (e.g. grasping) are obtained using inverse dynamics.



Virtual Model - Elderly (60-84)	
Hand maximum pull force (N)	76.8
Wrist radial deviation (°)	0 – 19
Wrist ulnar deviation (°)	0 – 26
Forearm supination (°)	0 - 74
Forearm pronation (°)	0 - 71
Elbow hyper-extension (°)	0 - 4
Shoulder abduction (°)	0 - 67
Shoulder internal rotation (°)	0 - 63
Spinal column flexion (°)	0 – 23.6
Spinal column extension (°)	0 - 17
Spinal column left lateral flexion (°)	0 - 19
Spinal column right lateral flexion (°)	0 - 20

Figure 12 VERITAS Virtual User Model in practice

In Figure 12 a simple simulation scenario is presented, where the handbrake use is simulated for an elderly virtual user (there are some restrictions in the range of motion and in the force of the upper limbs) in a virtual car interior (Figure 13Figure 13).

Figure 13 Virtual prototype example representing a common car interior

The simulation results for two different designs are presented in Table 7. In the first design, the handbrake (mass 200gr) had a resistance (torque) of 17Nm, which loosely speaking it can be translated into lifting a weight of about 4.8kgr, while in the second the resistance was 6Nm (~1.7kgr).

Table 7 Simulation results

Task	Virtual User	Virtual prototype parameters	Simulation result	
Pull handbrake	Elderly (60-84)	Handbrake resistance (torque) : 17Nm		Failure – Reduced hand pull force
		Handbrake resistance (torque) : 6Nm		Success

The elderly virtual user failed in handbrake use when resistance was 17Nm, which means that the specific environment is inaccessible for this user.

In VICON we have identified three phases of product development, where VICON will support the designer, the Sketch Phase, the Design Phase and the Evaluation Phase. In the design phase the designer works especially with a CAD system to implement the sketch design of products. Our intention is to provide the designer with functionalities for the integration of product design in a usual work environment, and then conduct the evaluation of the product design in a virtual environment with a virtual user based on a user profile. The evaluation results will be visualized to the designer and provided in alternative forms e.g. as textual report. The CAD design phase will be supported as well by the Recommender System (RS) as a plug-in, which produces context sensitive recommendations for the designer.

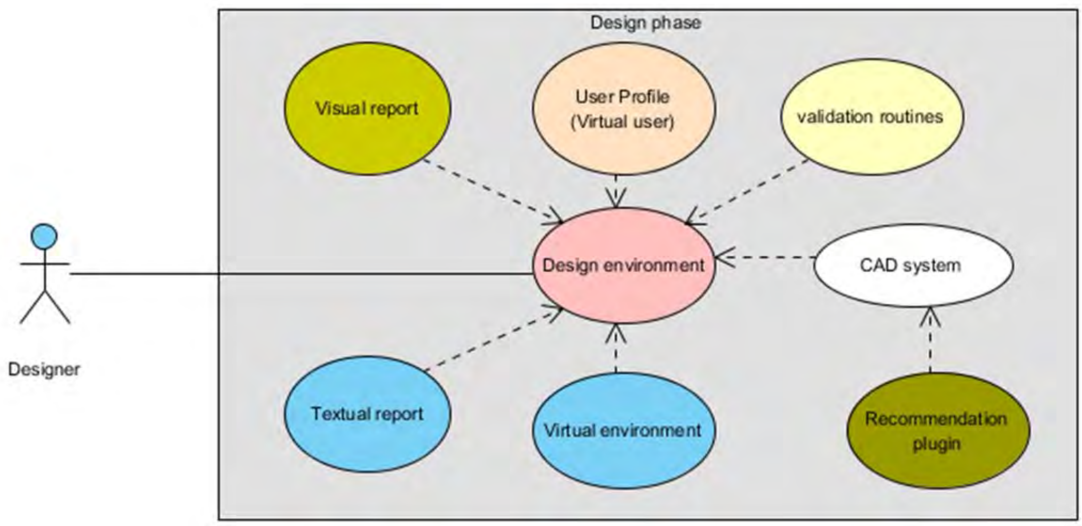


Figure 14 Overview of VICON Design Phase

- Sketch Phase:
  In the sketch phase the designer will work with the Virtual User Model to get Recommendations and Guidelines regarding the design of a specified product. The designed product (washing machines or mobile phones in particular) will be created by the designer as a Virtual Object in the Design Phase and is not available in this phase.
- Design Phase:
  The design phase refers to the creation of a Virtual Object of the product. In this phase the user creates the functionality and the design of the product that will be evaluated in the Evaluation Phase of VICON.
- Evaluation Phase:
  The evaluation phase refers to the conduction of the evaluation of products in an virtual environment. The output will be a report about the quality of the design in regard to fulfilling the needs of the beneficiaries of the VICON project. The reporting will be provided in two versions, the first one will be a visual report displayed in the virtual environment itself and the other will be a textual report about the shortcomings of the design.

The VICON workflow consists of many steps (see Figure 15), where the recommendation system is available as a standalone application and provides as well an API to be integrated into other applications.

Figure 15: Overview VICON workflow

In the following an example will describe the **VICON recommendation system** on inclusive design for mobile phones and washing machines to assist designers from the beginning utilising existing guidelines, standards and materials:

The designer is planning to design a new mobile phone and wants to incorporate accessibility features into the future mobile phone. The designer invokes the standalone VICON recommendation system and selects from the device list “mobile phone” and configures from the “target user group” list the target user group. Based on the entered information the system lookups into its repositories and displays for him a list of existing use cases and additionally links to existing guidelines like the **MobileOK guidelines** from W3C. In the further course the designer starts the Photoshop application and makes a sketch layout of the future mobile phone, saves it and imports it to the VICON recommendation system. The system then displays more accurate recommendations dedicated to the sketch layout and the selected target user group. In the design phase the designer creates a CAD model of the target device, where he a well can get recommendations on how to improve the design to accommodate the target user group needs. In the evaluation phase the designer imports the CAD design into the VICON virtual environment, where he can analyse different scenarios with a target user group (See Figure 16).

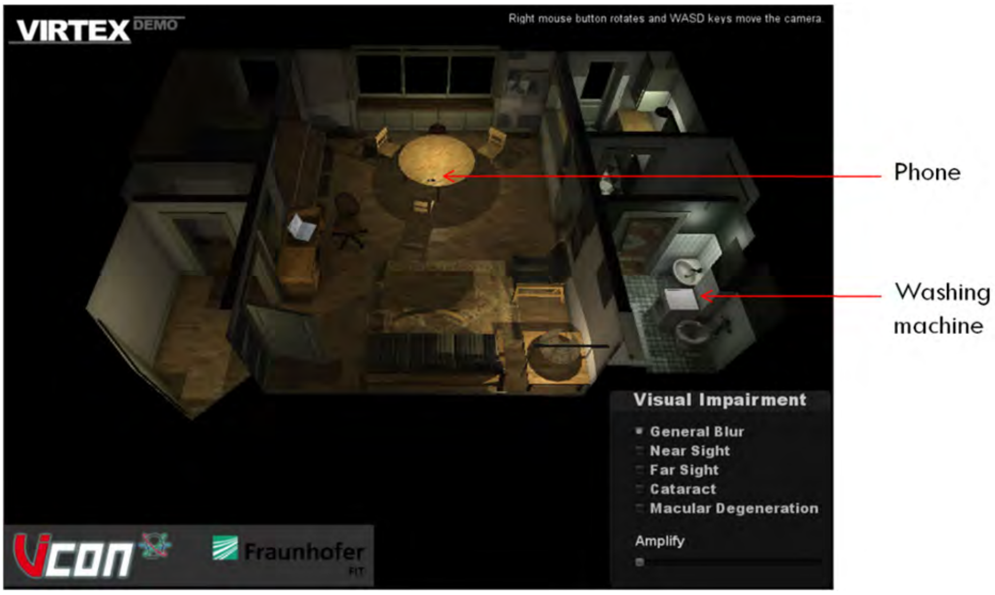


Figure 16: Screenshot from VIRTEX showing an overview of an exemplary apartment

In **GUIDE** the user model and corresponding simulator will be used to

- Select appropriate modality of interaction
- Optimize interface layout
- Develop and provide adaptation algorithm

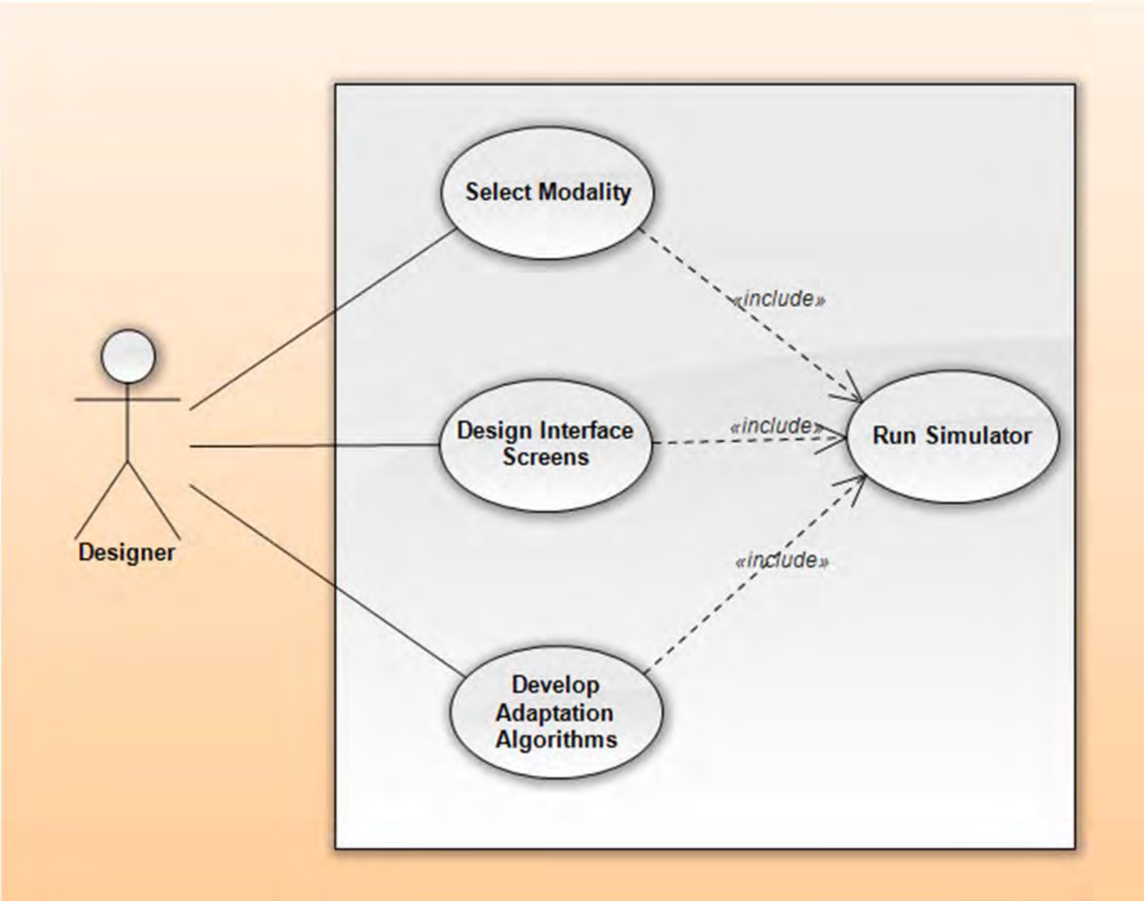


Figure 17 Use case diagram on simulation

Design optimization

The following example demonstrates a case study of using the simulator to select input and output modalities of interaction and personalizing interfaces from user profile. Initially we have selected a set of user characteristics and modalities of interaction. Then we present conditions for selecting different modalities for different types of users. For example we can develop a rule based system based on the results obtained from our simulator (Biswas & Robinson, 2009) as follows:

- People having less than -5.5 Dioptre Visual Acuity will not prefer to use screen and thus pointing devices.
- People having less than 20 kg Grip Strength will prefer to use pointing device with haptic feedback than the ordinary one like mouse or gesture based pointing device like Wiimote.
- People having Colour Blindness (especially red-green colour blindness) will prefer white text in blue background.

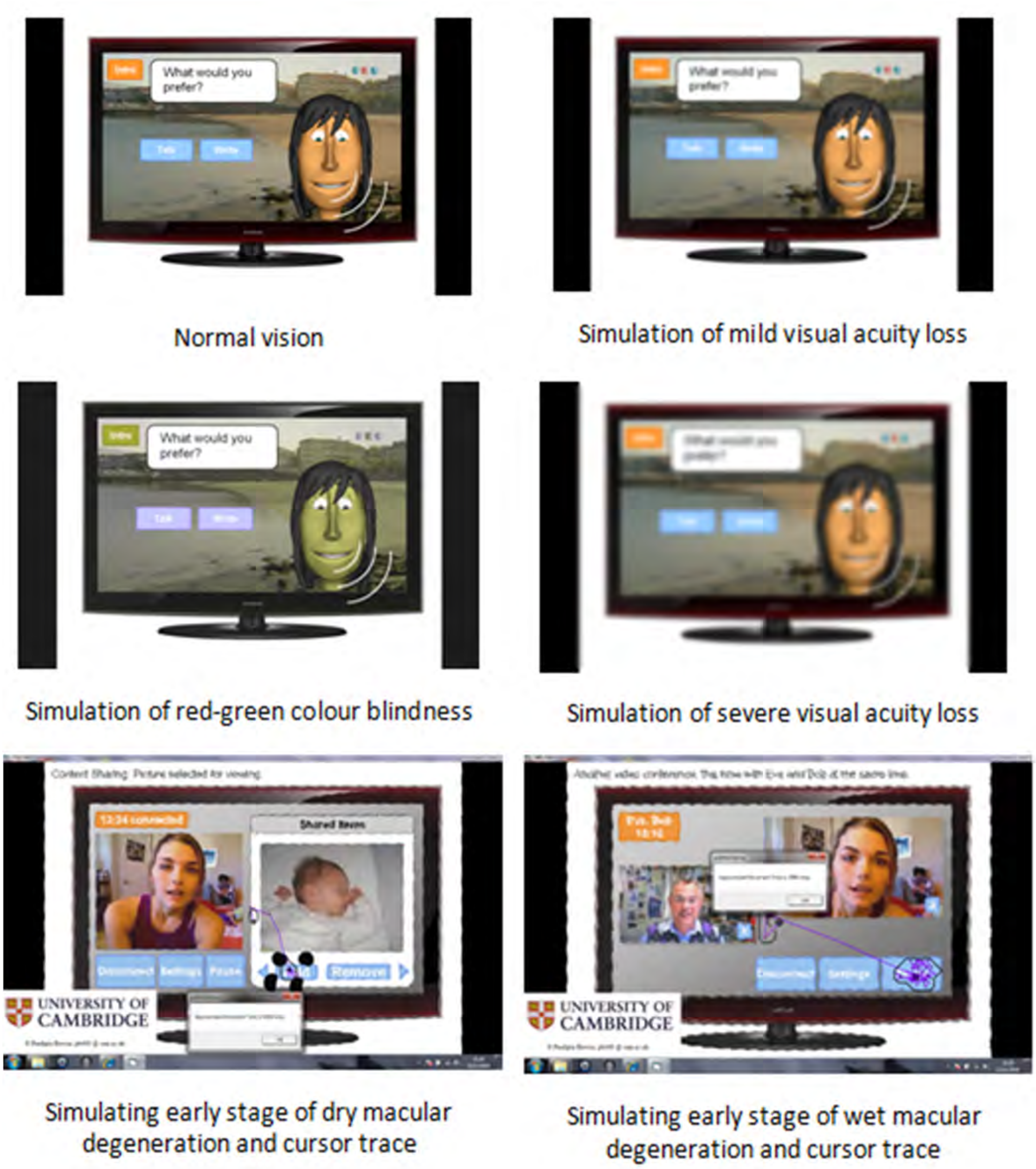


Figure 18 Screen design using simulation

Apart from appropriate modality selection, we have also used these rules on deciding the font size and colour contrast of the screen (Figure 18). The fonts are sufficiently large to accommodate slight visual acuity loss for aging or disease like Myopia or distorted vision due to disease like macular degeneration. The colour combination is selected as white in blue background so that it can remain legible for dichromatic colour blindness. The buttons are sufficiently large to accommodate random cursor movement during homing on a target using a pointing device.

Run time adaptation

We have used the simulator to develop the GUIDE profile that helps to adapt interfaces based on the user, context and particular application in use. It works in the following way (Figure 3). The user can provide input through multiple devices like motion sensors (like Wiimote) and speech recognizers, meaning he can use multiple modalities like pointing, gesture and speech simultaneously. The signals from recognition based modalities are processed by interpreter modules like a series of points from the motion sensor go through a gesture recognition engine in order to detect gestures. Signals corresponding to pointing modalities go through input adaptation modules (e.g. in order to smooth tremors from the user's hand or to guess the intention of the user). Both interpreter and adaptation modules base their decisions on knowledge stored in the GUIDE profiles achieving noise reduction in the input signals. The multimodal fusion module analyzes the raw input signals and the outputs of input interpreters and input adaptation and combines these multiple streams into a single interpretation based on the user, context and application models. The interpretation resulting from the input signals are sent to the dialog manager who decides which will be the application's response. This response is fed to the multimodal fission module, which again takes help from the user, context and application models and prepares the output appropriately (like embedding a HTML page in a video with subtitle and voice output) to be rendered in the output devices. The user perceives this output and provides further input.

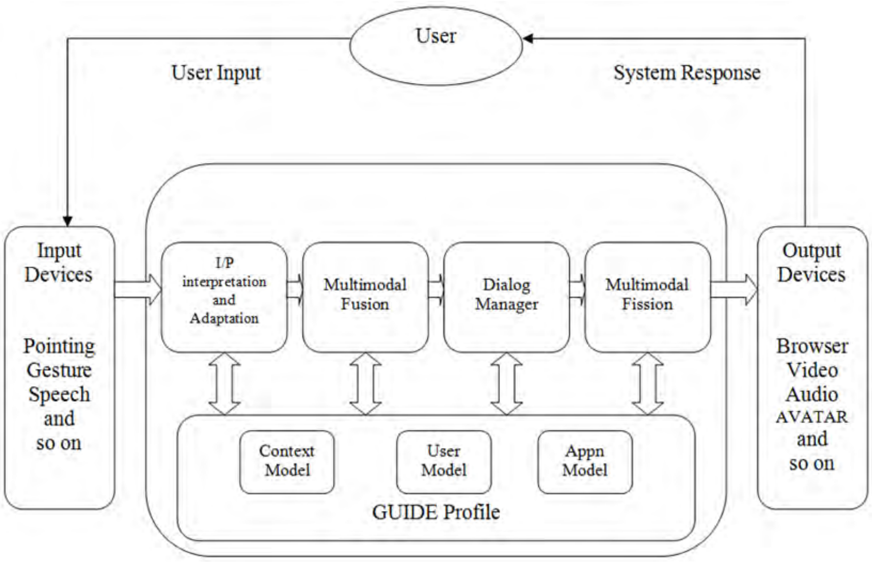
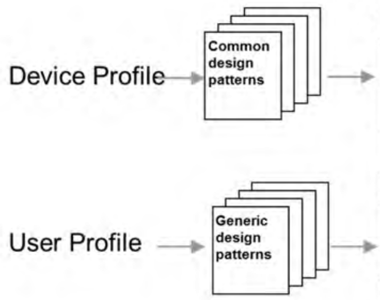


Figure 19 Run time adaptation

In **MyUI**, the user profile serves as the main basis for the user interface adaptations which aim at improving the accessibility and usability for an individual user.
The conceptual back bone of the MyUI adaptation is the *design patterns repository* which includes proven design solutions for optimal accessibility and usability. Each pattern is described in a defined structure as proposed by Borchers (2001) and is associated with software components that can be composed and modified in order to achieve accessible user interfaces. The MyUI design patterns repository includes four categories of design patterns:

1. *Common patterns*,
2. *Generic patterns*,
3. *Interaction patterns* and
4. *Transition patterns*.

Each pattern type fulfils distinct functions in the MyUI adaptation framework and therefore, requires a specific description format. Common patterns define all the stable features of a user interface for a specific device which are not subject to adaptations, e.g. the resolution of the screen, a basic layout grid, etc. The generic design patterns link the current user profile to the UI generation and adaptation process. They are the core piece of the automatic user interface individualization. They are closely related to specific user characteristics as stored in the user profile. They process the current user profile and "translate" user characteristics into user interface features, i.e. global settings. Together with the common design patterns, they create and update a User Interface Profile which includes all global settings of the user interface for a specific user at a certain time (see Figure 18).



User Interface Profile

Global UI variable	Range	Description
Title Font Size	{**36 pt**; 55 pt; 83 pt; 110 pt}	Font size of title elements
Body Text Font Size	{**24 pt**; 34 pt; 51 pt; 68 pt}	Font size of all body text elements
Complementary Text Font Size	{**18 pt**; 21 pt; 32 pt; 42 pt}	Font size of all complementary text elements, e.g. additional descriptions or comments of minor importance for the user
Contrast	Tbd.	Level of contrast
Max. Elements Per Screen	{**infinite**; 7; …}	Restricts the number of interactive elements displayed in the content and functions area of the screen
Eye Candy	{**on**; off}	Defines if decorative elements are hidden or displayed
Cursor Navigation	{**on**; off}	Defines if navigation with cursor keys is enabled or disabled
Numeric Navigation	{on; **off**}	Defines if navigation with numeric keys is enabled or disabled
Display Mode	{text only; **mainly text**; text and graphics; mainly graphics; graphics only}	Defines the proportion of text and graphics displays, refers to the two different codes of visual information presentation: verbal vs. spatial
Tonal Audio Output	{**on**; off}	Defines if tonal (non-speech) audio output is enabled or disabled
Speech Audio Output	{on; **off**}	Defines if speech audio output is enabled or disabled
Audio Output Volume		Defines the volume level of audio output
Audio Output Speed		Defines the speedof audio output
Voice Input	{**off**; on}	Defines if voice input is enabled or disabled

Figure 20 User interface parameterization on the basis of the user profile in MyUI

Further steps in the MyUI adaptation process include the user interface generation and adaption managed by the *interaction design patterns* which provide the interactive elements needed in the current interaction situation as drawn from an abstract application model and stored in the session profile. In order to support the usability and acceptability of run-time adaptations, *transition patterns* define the transition from one instance of the user interface to another so that the user can notice, understand and control UI adaptations. Figure 21 illustrates the role of the user model and user profile in the two-stage process of UI generation and adaptation in MyUI (see Peissner, Schuller & Spath, 2011 for a more detailed description of the MyUI adaptation framework).

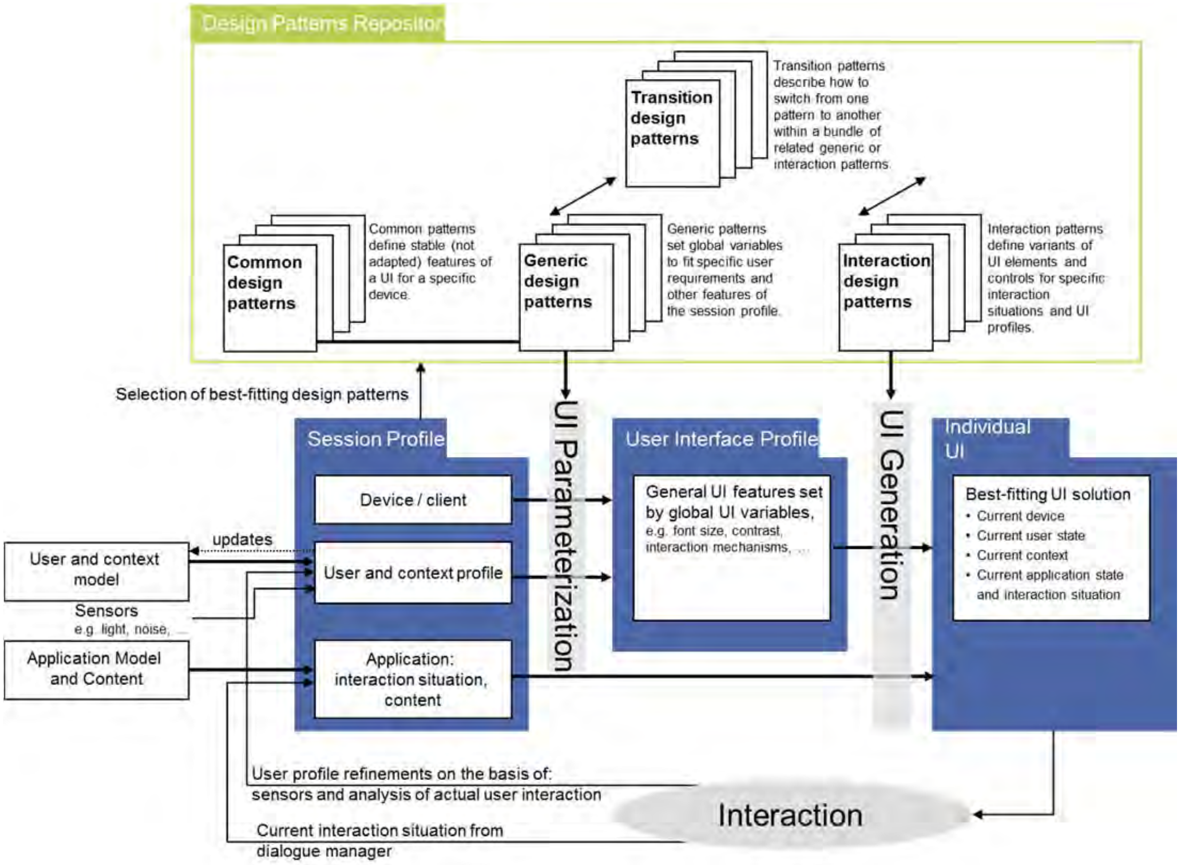


Figure 21 Two-stage process of user interface generation and adaptation in MyUI

11.VUMS Model as Open Standard

During the initial consultations of the VUMS cluster projects in the first year it became clear that an interoperable user model standard is best maintained in an "open standard" approach, as it is based on the fusion of developments in 5 research projects, and will have receive further input from other initiatives in the future. As the cluster is currently in discussions with ISO, which of course has its own standardisation processes and policies, it has to be defined in detail which parts of the standardisation could be maintained publicly. This could mean for example that cluster deliverables, white papers, exemplary draft user model tables, use case descriptions and general documentation will be provided on a public repository, e.g. a web server with WiKi-style services, whereas direct contributions to the ISO working groups would be of course maintained compliant with ISO rules and policy. Further decisions on this will be made during negotiations with the finally chosen standardisation body at the VUMS workshop in autumn 2012.

The general concept "open standard" can refer to different definitions, but usually it means that a standard is publicly available and that there are comprehensive rights on its use associated with it. Further it can mean that also the process of standardisation specification is maintained in an open way, such that everyone has free access to the standard specification.

A definition from ITU-T defines open standards in the following way: "Open Standards" are standards made available to the general public and are developed (or approved) and maintained via a collaborative and consensus driven process. "Open Standards" facilitate interoperability and data exchange among different products or services and are intended for widespread adoption[6].

[6] http://www.itu.int/en/ITU-T/ipr/Pages/open.aspx

ITU-T also names other elements that "Open Standards" may include, but are not limited to:

- Collaborative process – voluntary and market driven development (or approval) following a transparent consensus driven process that is reasonably open to all interested parties.
- Reasonably balanced – ensures that the process is not dominated by any one interest group.
- Due process - includes consideration of and response to comments by interested parties.
- Intellectual property rights (IPRs) – IPRs essential to implement the standard to be licensed to all applicants on a worldwide, non-discriminatory basis, either (1) for free and under other reasonable terms and conditions or (2) on reasonable terms and conditions (which may include monetary compensation). Negotiations are left to the parties concerned and are performed outside the SDO (Standard-developing organization).
- Quality and level of detail – sufficient to permit the development of a variety of competing implementations of interoperable products or services. Standardized interfaces are not hidden, or controlled other than by the SDO promulgating the standard.
- Publicly available – easily available for implementation and use, at a reasonable price. Publication of the text of a standard by others is permitted only with the prior approval of the SDO.
- On-going support – maintained and supported over a long period of time.

The VUMS cluster will mostly follow the principles of “Collaborative process” and “Publicly available” during the further specification of standard documents.

The W3C has also released a definition of open standards, which defines the following set of requirements that a provider of technical specification must follow to qualify for the adjective Open Standard:

- **transparency** (due process is public, and all technical discussions, meeting minutes, are archived and referencable in decision making)
- **relevance** (new standardization is started upon due analysis of the market needs, including requirements phase, e.g. accessibility, multi-linguism)
- **openness** (anybody can participate, and everybody does: industry, individual, public, government bodies, academia, on a worldwide scale)
- **impartiality** and consensus (guaranteed fairness by the process and the neutral hosting of the W3C organization, with equal weight for each participant)
- **availability** (free access to the standard text, both during development and at final stage, translations, and clear IPR rules for implementation, allowing open source development in the case of Internet/Web technologies)
- **maintenance** (ongoing process for testing, errata, revision, permanent access)

Refering to this definition, VUMS will focus on the aspects of “transparency”, “relevance”, “openness”, “”impartiality and consensus” and “availability”.

A possible process model for open and collaborative authoring of the VUMS user model standard could be the W3C process, which has been established and refined through the last years in many standardisation areas where W3C is active. This of course has to be further investigated in advance and discussed with the involved standardisation body.

12.Roadmap for VUMS Cluster Standardization

The current main focus of VUMS cluster standardization activities is the active contribution to the planned revision of ISO 24751. This standard is currently targeting "individualized adaptability and accessibility in e-learning, education and training" but is intended to broaden its scope to interactive applications in general. Timing, technical focus and existing relationships of VUMS members to the related bodies were strong arguments for addressing this standard. However, further opportunities for international standardization will be kept considered – at least until the upcoming discussion with external experts and standardization bodies before end of 2011. One essential aspect of decision is the question how the idea of an open standard (cf. section 12) can be made compatible with ISO standardization. The following Figure 22 provides an overview of the roadmap for VUMS Cluster Standardization.

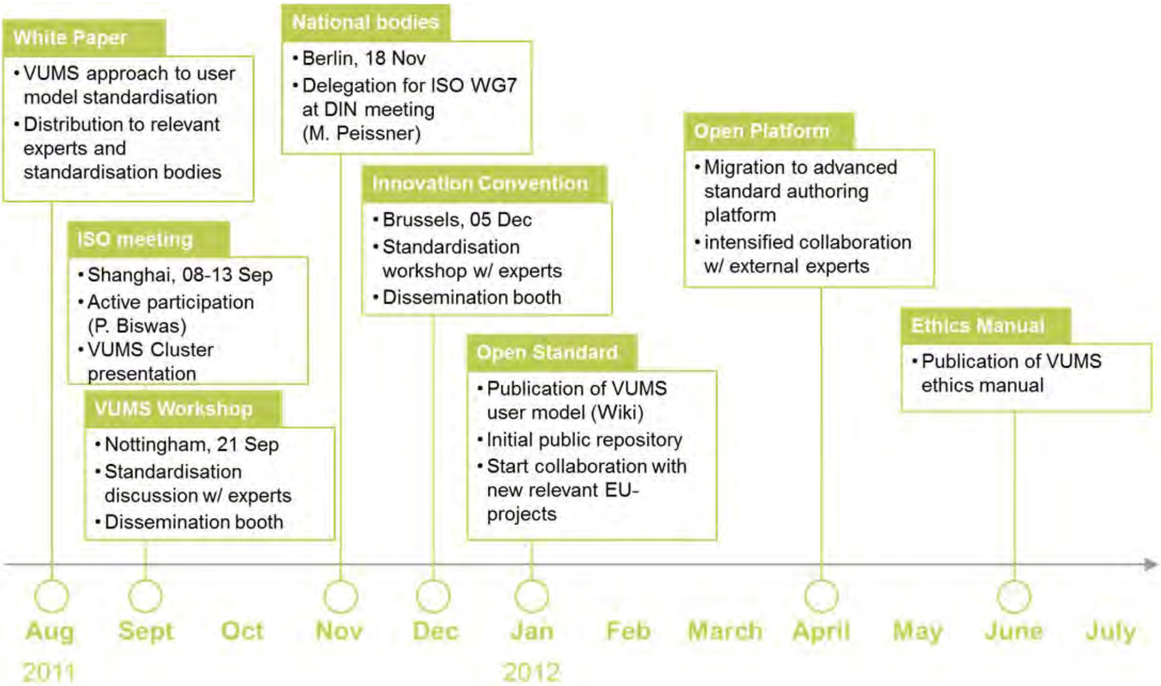


Figure 22: Roadmap for VUMS Cluster Standardization

The most important next step is a technical in-depth discussion with relevant experts and standardisation bodies. This discussion will be prepared by extracting a public White Paper from this joint VUMS deliverable which will be used for contacting national and international standardization groups and which will be spread together with invitations to the upcoming expert workshops in September and December. The white paper of course is not considered yet a standard draft, but it already comprises a glossary of terms, variables taxonomy, scope, syntax and structure of the intended user model specification. The white paper will be made available to the standardisation community and will generate expert feedback until the workshop in Nottingham, where the collaboration with the standardisation body will be decided. Afterwards a first version of a standard document will be published on the VUMS Wiki (→ public repository approach), allowing invited experts to comment and edit. Later, once cooperation with standardisation bodies is more concrete, the document might be migrated to another more suitable authoring and management platform / Wiki.

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http://infostore.saiglobal.com/store/Details.aspx?ProductID=1124808
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Appendix A: VERITAS Virtual User Model example


```xml
<?xml version="1.0" encoding="UTF-8"?>

<uiModel xmlns="http://www.usixml.org" xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance" xsi:schemaLocation="http://www.usixml.org/spec/UsiXML-ui_model.xsd"
id="User_Model" name="Exported Virtual User Model" creationDate="2011/02/03 14:53:46"
schemaVersion="1.8.0">
  <head>
    <version modifDate="2011/02/03 14:53:46">1.0</version>
    <authorName>Automatically generated by the VERITAS User Model Editor</authorName>
    <comment>This model has been generated using the VERITAS User Model Editor</comment>
  </head>
  <disabilityModel>
    <disability type="Motor" name="Spinal Cord Injury">
      <disabilityDetails>Spinal cord injury (SCI) refers to an injury to the spinal cord.
It can cause myelopathy or damage to nerve roots or myelinated fiber tracts that carry
signals to and from the brain. Depending on its classification and severity, this type of
traumatic injury could also damage the grey matter in the central part of the cord, causing
segmental losses of interneurons and motor neurons.</disabilityDetails>
    </disability>
    <affectedTasks>
      <affectedTask id="walking_ID" type="motor" name="walking" taskObject=""
         details="inability to effectively transfer weight between legs, abnormal step
         rhythm, excessive plantar flexion during swing phase, falling during activities"
         failureLevel="" />
    </affectedTasks>
  </disabilityModel>
  <capabililtyModel>
    <general>
      <name>Virtual User No.1</name>
      <gender>male</gender>
      <ageGroup>30-49</ageGroup>
    </general>
    <generalPreferences>
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      <sittingHeight measureUnits="cm" value="92.0"/>
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        <forearmHandLength measureUnits="cm" value="48.0"/>
        <bicepsCircumferenceRelaxed measureUnits="cm" value="34.0"/>
        <forearmCircumferenceFlexed measureUnits="cm" value="27.0"/>
      </upperLimbAnthropometric>
      <upperLimbAnthropometric leftRight="right">
        <shoulderElbowLength measureUnits="cm" value="35.5"/>
        <forearmHandLength measureUnits="cm" value="48.0"/>
        <bicepsCircumferenceRelaxed measureUnits="cm" value="34.0"/>
        <forearmCircumferenceFlexed measureUnits="cm" value="27.0"/>
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        <hipBreadth measureUnits="cm" value="38.0"/>
        <kneeHeightSitting measureUnits="cm" value="54.0"/>
        <buttockKneeLength measureUnits="cm" value="63.0"/>
```

```
      <footLength measureUnits="cm" value="26.0"/>
      <footBreadth measureUnits="cm" value="10.2"/>
      <thighCircumference measureUnits="cm" value="63.0"/>
      <calfCircumference measureUnits="cm" value="39.0"/>
    </lowerLimbAnthropometric>
    <lowerLimbAnthropometric leftRight="right">
      <ankleHeight measureUnits="cm" value="13.0"/>
      <hipBreadth measureUnits="cm" value="38.0"/>
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      <buttockKneeLength measureUnits="cm" value="63.0"/>
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      <footBreadth measureUnits="cm" value="10.2"/>
      <thighCircumference measureUnits="cm" value="63.0"/>
      <calfCircumference measureUnits="cm" value="39.0"/>
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  </anthropometric>
  <motor>
    <upperLimb leftRight="left">
      <pullForce measureUnits="N" maxValue="335.0"/>
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```

```
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```

```
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          <internalRotation measureUnits="degrees" minValue="0.0" maxValue="80.0"/>
          <externalRotation measureUnits="degrees" minValue="0.0" maxValue="12.0"/>
        </shoulder>
      </upperLimb>
      <lowerLimb leftRight="left">
        <hip>
          <abduction measureUnits="degrees" minValue="0.0" maxValue="37.5"/>
          <adduction measureUnits="degrees" minValue="0.0" maxValue="25.0"/>
          <flexion measureUnits="degrees" minValue="0.0" maxValue="135.0"/>
          <extension measureUnits="degrees" minValue="0.0" maxValue="10.0"/>
          <internalRotation measureUnits="degrees" minValue="0.0" maxValue="40.0"/>
          <externalRotation measureUnits="degrees" minValue="0.0" maxValue="40.0"/>
        </hip>
        <thigh>
          <flexion measureUnits="degrees" minValue="-1.0" maxValue="-1.0"/>
          <extension measureUnits="degrees" minValue="-1.0" maxValue="-1.0"/>
        </thigh>
        <knee>
          <flexion measureUnits="degrees" minValue="0.0" maxValue="135.0"/>
          <hyperExtension measureUnits="degrees" minValue="0.0" maxValue="7.5"/>
        </knee>
        <ankle>
          <dorsiFlexion measureUnits="degrees" minValue="0.0" maxValue="25.0"/>
          <plantarFlexion measureUnits="degrees" minValue="0.0" maxValue="45.0"/>
          <eversion measureUnits="degrees" minValue="0.0" maxValue="32.5"/>
          <inversion measureUnits="degrees" minValue="0.0" maxValue="30.0"/>
        </ankle>
        <footToe footToeID="1">
          <flexion measureUnits="degrees" minValue="0.0" maxValue="35.0"/>
          <extension measureUnits="degrees" minValue="0.0" maxValue="35.0"/>
        </footToe>
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          <extension measureUnits="degrees" minValue="0.0" maxValue="35.0"/>
        </footToe>
        <footToe footToeID="3">
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          <extension measureUnits="degrees" minValue="0.0" maxValue="35.0"/>
        </footToe>
        <footToe footToeID="4">
          <flexion measureUnits="degrees" minValue="0.0" maxValue="35.0"/>
          <extension measureUnits="degrees" minValue="0.0" maxValue="35.0"/>
        </footToe>
        <footToe footToeID="5">
          <flexion measureUnits="degrees" minValue="0.0" maxValue="35.0"/>
          <extension measureUnits="degrees" minValue="0.0" maxValue="35.0"/>
        </footToe>
      </lowerLimb>
      <lowerLimb leftRight="right">
        <hip>
          <abduction measureUnits="degrees" minValue="0.0" maxValue="37.5"/>
          <adduction measureUnits="degrees" minValue="0.0" maxValue="25.0"/>
          <flexion measureUnits="degrees" minValue="0.0" maxValue="135.0"/>
          <extension measureUnits="degrees" minValue="0.0" maxValue="10.0"/>
          <internalRotation measureUnits="degrees" minValue="0.0" maxValue="40.0"/>
          <externalRotation measureUnits="degrees" minValue="0.0" maxValue="40.0"/>
        </hip>
        <thigh>
          <flexion measureUnits="degrees" minValue="-1.0" maxValue="-1.0"/>
          <extension measureUnits="degrees" minValue="-1.0" maxValue="-1.0"/>
        </thigh>
        <knee>
          <flexion measureUnits="degrees" minValue="0.0" maxValue="135.0"/>
          <hyperExtension measureUnits="degrees" minValue="0.0" maxValue="7.5"/>
        </knee>
        <ankle>
          <dorsiFlexion measureUnits="degrees" minValue="0.0" maxValue="25.0"/>
          <plantarFlexion measureUnits="degrees" minValue="0.0" maxValue="45.0"/>
          <eversion measureUnits="degrees" minValue="0.0" maxValue="32.5"/>
          <inversion measureUnits="degrees" minValue="0.0" maxValue="30.0"/>
        </ankle>
        <footToe footToeID="1">
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          <flexion measureUnits="degrees" minValue="0.0" maxValue="35.0"/>
          <extension measureUnits="degrees" minValue="0.0" maxValue="35.0"/>
        </footToe>
        <footToe footToeID="2">
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          <extension measureUnits="degrees" minValue="0.0" maxValue="35.0"/>
        </footToe>
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        </footToe>
        <footToe footToeID="4">
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          <extension measureUnits="degrees" minValue="0.0" maxValue="35.0"/>
        </footToe>
        <footToe footToeID="5">
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          <extension measureUnits="degrees" minValue="0.0" maxValue="35.0"/>
        </footToe>
      </lowerLimb>
      <neck>
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        <extension measureUnits="degrees" minValue="0.0" maxValue="40.0"/>
        <leftLateralFlexion measureUnits="degrees" minValue="0.0" maxValue="45.0"/>
        <rightLateralFlexion measureUnits="degrees" minValue="0.0" maxValue="45.0"/>
        <leftLateralRotation measureUnits="degrees" minValue="0.0" maxValue="70.0"/>
        <rightLateralRotation measureUnits="degrees" minValue="0.0" maxValue="70.0"/>
      </neck>
      <spinalColumn>
        <flexion measureUnits="degrees" minValue="0.0" maxValue="90.0"/>
        <extension measureUnits="degrees" minValue="0.0" maxValue="30.0"/>
        <leftLateralFlexion measureUnits="degrees" minValue="0.0" maxValue="25.0"/>
        <rightLateralFlexion measureUnits="degrees" minValue="0.0" maxValue="25.0"/>
        <leftLateralRotation measureUnits="degrees" minValue="0.0" maxValue="30.0"/>
        <rightLateralRotation measureUnits="degrees" minValue="0.0" maxValue="30.0"/>
      </spinalColumn>
      <gait>
        <stepLength>0.75</stepLength>
        <stepWidth>-1.0</stepWidth>
        <strideLength>1.58</strideLength>
        <footContact>-1.0</footContact>
        <gaitCycle>-1.0</gaitCycle>
        <cadence>112.0</cadence>
        <velocity>82.0</velocity>
      </gait>
    </motor>
    <vision>
      <eye leftRight="left">
        <visualAcuity>1.0</visualAcuity>
        <contrastSensitivity>1.0</contrastSensitivity>
        <glareSensitivity>1.0</glareSensitivity>
        <spectralSensitivity longValue="1.0" middleValue="1.0" shortValue="1.0"/>
        <blindSpotArea minValue="0.0" maxValue="0.0"/>
        <blindSpotSize minValue="0.0" maxValue="0.0"/>
        <blindSpotOpacity minValue="0.0" maxValue="0.0"/>
        <blindSpotCount>0</blindSpotCount>
      </eye>
      <eye leftRight="right">
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        <contrastSensitivity>1.0</contrastSensitivity>
        <glareSensitivity>1.0</glareSensitivity>
        <spectralSensitivity longValue="1.0" middleValue="1.0" shortValue="1.0"/>
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        <blindSpotSize minValue="0.0" maxValue="0.0"/>
        <blindSpotOpacity minValue="0.0" maxValue="0.0"/>
        <blindSpotCount>0</blindSpotCount>
      </eye>
    </vision>
    <hearing>
      <ear leftRight="left">
        <resonanceFrequency>10.0</resonanceFrequency>
        <hearingThreshold1 measureUnits="dB" value="-1.0" frequency="250"
frequencyMeasureUnits="Hz"/>
        <hearingThreshold2 measureUnits="dB" value="-1.0" frequency="500"
frequencyMeasureUnits="Hz"/>
        <hearingThreshold3 measureUnits="dB" value="-1.0" frequency="1000"
frequencyMeasureUnits="Hz"/>
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```
        <hearingThreshold4 measureUnits="dB" value="-1.0" frequency="2000"
frequencyMeasureUnits="Hz"/>
        <hearingThreshold5 measureUnits="dB" value="-1.0" frequency="4000"
frequencyMeasureUnits="Hz"/>
        <hearingThreshold6 measureUnits="dB" value="-1.0" frequency="8000"
frequencyMeasureUnits="Hz"/>
      </ear>
      <ear leftRight="right">
        <resonanceFrequency>10.0</resonanceFrequency>
        <hearingThreshold1 measureUnits="dB" value="-1.0" frequency="250"
frequencyMeasureUnits="Hz"/>
        <hearingThreshold2 measureUnits="dB" value="-1.0" frequency="500"
frequencyMeasureUnits="Hz"/>
        <hearingThreshold3 measureUnits="dB" value="-1.0" frequency="1000"
frequencyMeasureUnits="Hz"/>
        <hearingThreshold4 measureUnits="dB" value="-1.0" frequency="2000"
frequencyMeasureUnits="Hz"/>
        <hearingThreshold5 measureUnits="dB" value="-1.0" frequency="4000"
frequencyMeasureUnits="Hz"/>
        <hearingThreshold6 measureUnits="dB" value="-1.0" frequency="8000"
frequencyMeasureUnits="Hz"/>
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    </hearing>
    <speech>
      <phonation>
        <voicePitch>120.0</voicePitch>
        <fundamentalFrequency>135.0</fundamentalFrequency>
        <syllableDuration>-1.0</syllableDuration>
      </phonation>
      <prosody>
        <vocalStress>
          <lipMovementCoordination/>
          <jawMovement/>
        </vocalStress>
      </prosody>
    </speech>
    <cognition>
      <memory>-1</memory>
      <perceptualAbilities>Undefined</perceptualAbilities>
      <visuospatialAbilities>Undefined</visuospatialAbilities>
    </cognition>
    <behaviour>
      <physiologicalArousal>
        <informationProcessing>Undefined</informationProcessing>
      </physiologicalArousal>
      <valence>Undefined</valence>
      <emotionalIntelligence>Undefined</emotionalIntelligence>
    </behaviour>
  </capabililtyModel>
</uiModel>
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