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VICON

Virtual User Concept for Inclusive Design of Consumer Products and User Interfaces

Deliverable Report

D2.2: Virtual user model (final release)

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Deliverable abstract	This deliverable describes the concept and structure of the final version of the VICON Virtual User Model. It has the status of an accompanying document the Virtual User Model ontology. This deliverable is a resubmission taking into account the requests of the 2nd year review in Brussels March 23rd, 2012. All changes are highlighted in yellow.

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Executive summary

This document provides a description of the final release of the Virtual User Model (VUM) developed within the VICON project. It defines the complete ontology architecture pre- and post- reasoning. This description is divided into two sections.

The first section introduces the virtual user concept and a general approach for a design workflow supported by VUM. The second section describes the realization of the VUM in greater detail.

The outcome of this deliverable, the Virtual User Model, will be used in further framework parts for the support of designers during product development (see [1], [2], [3], [4] and [5]).

According to the proposed virtual user concept the knowledge base for storing the VUM data is composed of five partial models:

- User
- Environment
- Task
- Component
- Recommendations

Each of these models provides a piece of context knowledge combined into the VUM which encapsulates the entire usage context. The VUM is used as a context representation during the entire development workflow to provide designers with a meaningful support for creating accessible consumer products.

The usual design workflow has been studied in the course of conceptualization of the VUM. It has been identified as an iterative process composed of the three design phases per iteration:

(1) Sketch,
(2) CAD design,
(3) Evaluation.

The roles and responsibilities of the VUM vary depending on the design phase it aims to support. At the sketch stage the VUM identifies a set of design recommendations for a specified usage context. In the CAD design phase the VUM provides data for presentation of design templates and calculation of interactive suggestions. During the evaluation it is used for configuring a 3d scene according to a given usage context and conducting task analysis.

The VUM has been realized in the form of an ontology. The OWL ontology language and JENA ontology framework have been used for the implementation. The five sub-models of the VUM are represented by five OWL classes respectively. For the interpretation of inquiries – e.g. selection of certain model instances, like user profiles or environments, in order to get a set of the recommendations – a generic rule reasoner is used. The reasoning process comprises five inferences transforming the VUM from an initial model to a final one. In addition to the initially existing knowledge encapsulated by the five ontology classes, this final model contains new class instances for target user groups, environments etc. and their semantic relationships represented by assignment of recommendations.

The description of the realized virtual user concept is supported by a case study given in the section 3 of the document. It provides further insights into the VUM, and outlines the boundaries of the VUM as well as topics for further research.

Introduction

The concept of user modelling has been explored in many different fields like ergonomics, psychology, pedagogy and computer science. However, it still lacks a holistic approach. Psychological models often need a lot of parameter tuning reducing their use by non-experts [6] while ergonomic models often miss to model cognition [7]. Carmagnola and colleagues [8] presented an excellent literature survey on web based user models but completely missed out user models in human computer interaction [9]. The focus in VICON is on developing user models for older people who have age-related (mild to moderate) physical impairments (age-related hearing loss, macular degeneration, etc) rather than those with profound impairments. This group of people does not require 'special' assistive devices but mainstream consumer products. However they fully benefit from consumer products, when their UIs incorporate accessible multimodal interaction capabilities providing good usability. A full survey of existing user models and how the VICON model is related to them has been reported in the VUMS cluster report VERITAS D1.6.4 [10].

The main intentional limitation of the VICON's virtual user model is that it doesn't cover cognitive usage aspects, but focuses entirely on physical interactions.

Alongside the state-of-the-art human modelling mentioned above the development of the VUM is based upon the results of the Task 1.3 described in D1.1 [5] and Task1.1 described in D1.3 [11].

After these results have been evaluated and post processed, user and environment description templates have been generated. Moreover the tasks for the VICON's preliminary target product groups (mobile phone, remote control and washing machine) have been identified. See APPENDIX A for detailed information on the parameterization of the VUM. In addition, APPENDIX B provides explanatory details for each single parameter of the user model and for the predefined user profiles. The provided user profiles are based on a number of user personae. These personae are presented in APPENDIX C.

In order to represent the gained knowledge in a proper data structure with ability to add new knowledge and to provide functionality for semantic analysis the VICON consortium has decided to employ an ontology system. Section 2 describes how the VUM is realized by means of ontology, how the ontology data structure is designed and how the reasoning is established.

Before however a detailed realization description is given, the general concept of the VUM and its application on the product development process is presented in the next section.

1 Virtual user concept

Since a virtual user model (VUM) as an abstract representation of an envisaged user group includes a description of the underlying context, it is legitimate to consider the VUM as a context model.

Context represents on a universal scale, the relevant aspects of usage situations with respect to user groups. Hence, a context model should describe the characteristics of personas and behaviour of a specific user group as well as other relevant user features. Complementarily it includes the aspects related to the product's user interface and interactions a user can perform with it. The interactions are encapsulated in the so-called tasks. In addition, model-based description of environment, where she or he interacts with consumer products, provide important environmental usage context.

Accordingly, the VUM, as proposed by the VICON consortium, addresses an extensive set of usage facets and possesses a great potential in supporting the product development process. We suggest calling the approach "virtual user concept" because it is a design concept based upon the development and implementation of a virtual user model.

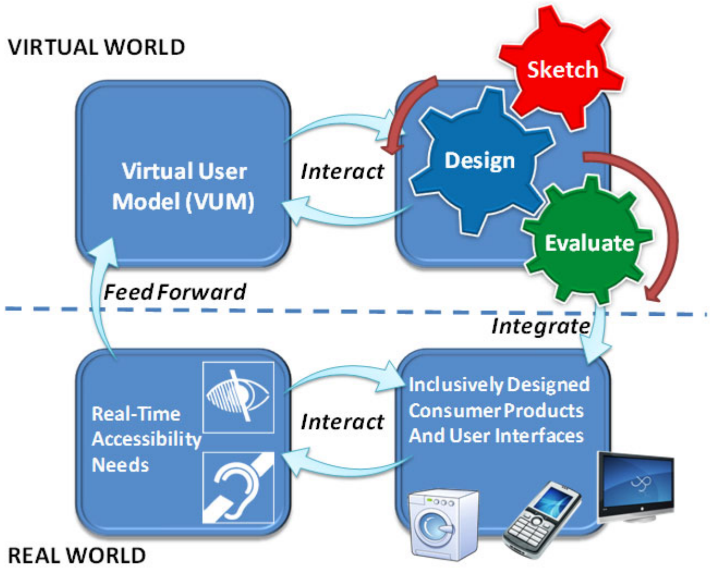

Figure 1 – Overview of the Virtual User Concept

Figure 1 provides an overview of the underlying concept emphasizing the interplay between the virtual and real world. The virtual user model is based upon real-time accessibility needs of the envisaged end user groups. In the virtual world the VUM interacts with the sketch, design and evaluation phase of product design process.

It is foreseen that the support by the VUM works in the following way:

In the initial sketch phase, a support appears in form of text-based recommendations with respect to potential user interface elements. Up to this point, the recommending character of the Virtual User Model can be compared to an expert system as defined in [12]. However, expert systems are usually highly domain specific, thus are not easily adaptable to other domains.

Next to the feature that the VUM should be easily adaptable to other contexts by the designer, the Virtual User Concept goes beyond the provision of recommendations. In the design phase the VUM will guide the designer with templates and interactive suggestions for interface components of consumer products.

For the evaluation phase, a 3d virtual character in a virtual environment will be established in order to evaluate a conducted product design against predefined usage context. After several iterative development cycles, the results are then used for realization of a physical prototype and final product in the real world.

In summary, the Virtual User Concept should go beyond existing approaches by:

- Accompanying the design process from the scratch until the final CAD design cycle, by providing different standalone recommendation systems for the idea finding stage, the sketch phase and components for integration with CAD systems,
- Incorporating different accessibility features in the user profiles,
- Adding new reporting mechanisms e.g. web based reports and visual responses in the virtual user itself.

To make this description of our approach more comprehensive, an example is presented focussing upon the sketch and design phase:

A designer is planning to design a new product such as a mobile phone and would like to incorporate accessibility features into the new product. The designer invokes the recommendation system, selects from the device list “mobile phone” and configures from the “target user group” the required target user group or groups. Based on the entered information, the system presents the designer with a list of existing recommendations and additionally links to existing guidelines. The designer then sketches the design supported by the recommendations he got from the system.

After a certain sketch has been selected for virtual prototyping the designer creates the preliminary model of the new mobile phone in CAD software (Siemens NX), subsequently resulting in more accurate recommendations relevant to the layout of the interface components of the CAD model and the selected target user group. For instance, a recommendation could state that in order to better meet the needs of users with a certain kind of manual dexterity disability of a certain degree, the distance between the keys of a mobile phone should not be smaller as a recommended minimal distance. Based upon these kinds of recommendation, the design of the user interface component can be completed.

In the final phase the designer’s objective would be to assign a scenario to the virtual user – this means a task and an environment should now be specified in order to be manifested in a virtual environment – and let him or her virtually evaluate the product design. For example, this could be “making a phone call in a relatively dark indoor environment”. For this reason the designer runs a virtual user 3d system, which could be a part of the CAD application, or a separate application which allows the import of CAD designs while providing appropriate analysis tools. After the required environment has been created and the tasks have been assigned to the virtual user, an execution procedure reports the results visually to the designer. Based upon the results, the designer can return to a preceding phase and make adaptations to the design, until the final user interface design is accomplished.

2 Realization of Virtual User Model

In this section the realization of the Virtual User Model is presented. First the general realization approach in form of ontology is advocated. Then the ontology structure as well as the roles and responsibilities of the ontology at the three different design stages are described. Finally the reasoning of the ontology and its different inference states are explained.

2.1 Rationale for realization approach

The Virtual User Model, as a context model, contains knowledge about the contextual aspects of product usage. As mentioned in the previous section (see 1 Virtual user concept) these aspects can be divided into four categories: Aspects related to (1) abilities of users, (2) usage environment, (3) product’s properties and condition as well as (4) type and complexity of the interactions (or tasks) the product’s interface offers its users. In order to provide designers with a meaningful support at each stage of the development process, the VUM data should be interpreted respectively to the needs and aims of the current design stage and available contents.

To address these requirements as well as the requirements identified for the design process and described in D1.4 [13] the VICON consortium agreed on the realization of the context knowledge base in form of ontology.

The three main requirements categories identified for VICON framework, as a highly adaptable system, are as follows (for further details and a detailed description of requirements see [13]).

1. ***Comprehensible and human readable***
   To maintain a modification ability, the whole data structure must be human readable (e.g. XML)
2. ***Dynamically modifiable***
   It must be able, to change and modify different objects and structures of the data storage
3. ***Model-based encapsulation***
   Model based architecture is recommended, with respect to different models of the realization (e.g. user model, task model, environment model)

With respect to the state of the art of context-aware systems, Strang and Linnhoff-Popien [14] presented a survey based upon demands on context modelling approaches. The conclusion of the evaluation of the survey indicates that ontology based models fulfil most of the requirements for context aware systems.

1. ***Distributed composition (dc)***
   This requirement is irrelevant to the VICON framework, with respect to existing server-client architecture for maintenance purposes (see requirement dossier [13])

2. ***Partial validation (pv)***
   In the VICON project, various models and relationships must be described, e.g. user profiles or recommendations based upon different values. This issue is mainly important for a realization of reasoning.

3. ***Richness and quality of information (qua)***
   With respect to sensorical data, this requirement describes support for quality and richness of incoming data. This issue is not relevant for the VICON framework.

4. ***Incompleteness and ambiguity (inc)***
   This issue represent the importance of the feature to manipulate and use data, even if it is incomplete. For VICON it is not important, due to the non existence of sensorical data.

5. ***Level of formality (for)***
   The level of formality describes how precise contextual facts and interrelationships between instances and models can be represented. Regarding the requirements of the VICON project, formality is a very important issue to indicate different values (abstract, nominal, etc.) in one and the same model.

6. ***Applicability to existing environments (app)***
   An applicability with respect to VICON represent the possibility to use the ontology in different other applications. This feature is relevant for future possibilities and VUMS cluster interoperability purposes.

With respect to VICON related requirements, *pv*, *for* and *app* requirements are primary important. The evaluation, described in [14] and Table 1, advocate that ontology based models are the most suitable for the implementation of the VICON Virtual User Model.

Approach	dc	pv	qua	inc	for	app
Key-Value Models	-	-	-	-	-	+
Mark-up Scheme Models	+	++	-	-	+	++
Graphical Models	-	-	+	-	+	+
Object Oriented Models	++	+	+	+	+	+
Logic Based Models	++	-	-	-	++	-
Ontology Based Models	++	++	+	+	++	+

Table 1 – Appropriateness indication, see [14]. The columns marked gray emphasize the requirements primary important for VICON.

Furthermore the ontology solution is characterized by the following advantages:

- ***Object oriented data structure***
  Ontology formally represents knowledge data including instances and relations. Each instance, e.g. a user model, can be related to different other classes and inherit various attributes like the age of a target user or if she or he needs glasses.

- ***Highly adaptable vocabulary***
  In addition (or as a consequence) of the object oriented data structure, ontologies have the advantage to be highly adaptable to a problem by extending the ontology vocabulary.

- ***Availability of reasoning***
  Aside of the main purpose of the application of ontologies, reasoning is used to infer new states based upon initial models. These engines can be used to automate classification processes and decisions.

There are multiple ontology frameworks on the market. For the following reasons we decided to use JENA [15]:

- ***Adaptable interface***
  The JENA ontology framework offers a sophisticated ontology interface with the advantage to manipulate all resources, predicates and values directly from within JAVA. With respect to the requirement of a server - client architecture in VICON, the server - implemented in JAVA – is able to perform changes within all ontology instances.

- ***Inference support***
  JENA contains a reasoning engine which is able to operate with different sets of ontologies (RDFS, OWL/lite, OWL/full). Also a very generic reasoner is included, which can be manually extended by build-in rules (see [15], chapter "The general purpose rule engine").

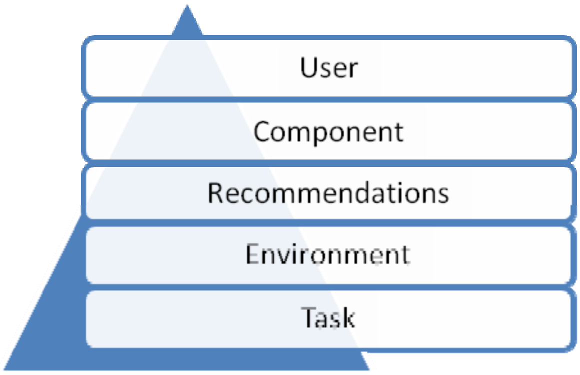

Figure 2 – Ontology classes of VICON. Each class contains data instances

2.2 Ontology description

The knowledge stored in the ontology is divided into five models: Four models are pure usage context models and the fifth model, called *Recommendations*, encapsulates design guidelines generated in the course of the context interpretation.

At each of the three stages of the design process – sketch, CAD design, evaluation – the virtual user model possesses slightly different roles and responsibilities with respect to the product design lifecycle itself. This section begins with a description of a general structure of the knowledge base. Afterwards the roles and responsibilities of the VUM respectively the sketch, CAD design and evaluation phases are explained.

The complete ontology used in the Virtual User Model is available on the VICON Project Website[1], divided into the main ontology model (Main OWL File) and device dependent partial models for washing machines, TV remotes and mobile phones.

2.2.1 General structure

The virtual user data model is based on data types and classes of the OWL ontology. OWL is an ontology language based on RDF Schema. It enriches the RDFS modelling primitives by adding support for further features like disjointness of classes. For details see [16]. The VICON ontology used the OWL DL sublanguage due to requirements of a representation of abstract values and a subclass hierarchy retaining computational completeness. The VUM consists of the following 5 classes (see Figure 2, for description of parameterization of each partial model see APPENDIX A):

- **User Model**, where all information about a virtual user such as physical disabilities or diseases are stored. The predicates for this model were achieved through user studies [5]. WHO ICF based subgroups, also called *user profiles* (see [5], [17] and APPENDIX B for detailed information), have been instantiated. For every criterion of diseases the profiles are divided into different levels (no impairment, mild and moderate) of impairment groups. Additionally there are mixed profiles describing the group of elderly people suffering upon a mixture of hearing, sight and dexterity impairments.

- **Environment Model** stores all representative data for physical environments. It refers to descriptions of workplace where a human interacts with a device like a washing machine or

[1] All OWL files available at: http://vicon-project.eu/?page_id=80

mobile phone by performing tasks. These descriptions include physical conditions, surrounding objects and other characteristics of a physical environment.

- **Task Model** describes how to perform activities to reach a pre-defined goal and what user, environment and component characteristics are related to a particular activity. This model is based upon hierarchical task analysis (HTA) [18].

- **Component Model** describes components of the product's user interface and adds specific functionality to different instances of the model. E.g. a button component can be in two states: Pressed and unpressed. Accordingly, the button component instance consists of the functional attribute of a 2 state switch. This model is used to connect recommendations with components especially in the second phase, where the user input is component related.

- Model for **Recommendations**, where guidelines and experience information are stored. The recommendations consist of the predicates "Name", "Text", "Summary", "Rules", "Phases" and an "Attachment", where e.g. links to Sketch Phase Template Layers can be stored. A "Component" attribute defines rule sets for the design phase, if a recommendation is related to a specific component or component functionality like "Audio Output".

2.2.2 Data-model for sketch phase

In the sketch phase the VUM is responsible for computation of the design recommendations for a usage context specified by the designer. The data model of the sketch phase supporting system is based on data types and classes of the OWL Ontology described in the previous paragraph 2.2.1 and showed on Figure 2. In the following the roles and responsibilities of these classes w.r.t. the sketch phase are described.

- The **User Model** class in the sketch phase provides access to the user related data for a target user group. This data is used for calculation of the recommendations. The target user group is encapsulated by a user model instance, which can be selected in the Sketch Application to view the related recommendations.

- **Environment Model** describes a typical usage environment for a product type. For example bathroom is a typical usage environment for washing machines. The bathroom environment is, in this case, an instance of the environment model. Values, like the background lighting, of such environment instances are used to present applicable recommendations to the designer.

- **Task Model** is used similar to the environment model. Task instances define issues for the user, if a product task is executed. After a designer has selected a task, recommendations are presented in relation to these issues.

- **Component Model** is not used in the sketch phase, according to a nonexistent virtual 3d prototype of a product. Thus the components are not related to the tasks in this phase.

- The **Recommendation** class in this phase is used for assignment and presentation of textual recommendations, which are displayed after specification of usage context, i.e. user, environment and task instances are known before related recommendations can be identified.

2.2.3 Data-model for CAD phase

The data model of the CAD design phase extends the recommendation system data model available at the sketch design stage.

- **User Model** is used to identify and present all recommendations, which were already presented in the sketch design phase. Thus the computation is based on the stored user profile selection made in the previous sketch phase.

- **Environment Model** is used to compute and present recommendations based on the environment selection made in the first phase.

- **Task Model** is analogously used as the environment and user models for the presentation of recommendations based upon first phase selections of the user.

- **Component Model** is used to generate recommendations based on the type and functionality of the components available in the CAD interface design of the product. The input of the user is an annotation of each component in CAD, which is necessary in order to identify recommendations with relation to a particular component.

- In the CAD phase two different types of **Recommendations** are available: Textual recommendations, which define textual suggestions to the designer and quantitative recommendations including e.g. minimum values for different parameters, which can also be applied to the current model.

2.2.4 Data-model for evaluation phase

At the evaluation stage of the design workflow the VUM is responsible for supporting the hierarchical task analysis by providing appropriate context knowledge. Corresponding roles and responsibilities of each of the five ontology classes are described in the following.

- **User Model** serves the product evaluation application with existing user profiles. A user profile is retrieved from the user model in order to carry out a single evaluation scenario. The user data is needed for initialization of the virtual 3d scene, which includes a virtual human model, and for the hierarchical task analysis. During the task analysis the user abilities, represented by the user profile, are compared with the minimum required abilities necessary for the definite success of the particular task.

- **Environment Model** allocates data of a certain environment profile requested by the evaluation application. According to the retrieved environment profile a virtual environment can be initialized as a part of a 3d scene. Furthermore the ontology's environment class is used for the retrieval of quantitative recommendations for the specific virtual environment. For instance, if the virtual environment represents a kitchen, the environment instance of a kitchen is used in order to extract relevant recommendations.

- The **Task Model** at this stage is used to obtain a selection of tasks which can be executed for a particular product type. The model offers a hierarchical task description, i.e. each task is represented as a sequence of subtasks. The tasks build the core of product assessment: They describe how the virtual user interacts with the product and, thus, how evaluation should be conducted. Furthermore the task model should interrelate the product's interface, which is composed of components, to the user and its environment.

- **Component Model** provides the component types available at the current development iteration and appropriate set of attributes for each of these types. Based on this information the properties of a component involved in the user interaction can be assessed within the task analysis. The assessment is based on the quantitative recommendations provided by VUM.

- Regarding the outcome of the evaluation process, only **Recommendations** which contain specific values for recommendations, such as minimum values for a space between buttons are used in this phase. Textual recommendations are irrelevant.

2.2.5 *Ontology DL Expressivity*

Description Logic Expressivity describes the complexity of operators used throughout the ontology. The VICON ontology used the following expressions (see [19] and [20] for more details):

AL	Attributive language. This is the base language which allows: • Atomic negation (negation of concept names that do not appear on the left hand side of axioms) • Concept intersection • Universal restrictions • Limited existential quantification
C	Complex concept negation.
H	Role hierarchy (sub properties - rdfs:subPropertyOf).
(D)	Use of data type properties, data values or data types.

Table 2 – DL Expressivity of the VICON ontology

The initial model, which describes the model before the reasoning step of VICON, has the dl expressivity **ALH(D)**, using role hierarchy expressions especially for a hierarchical structure of the recommendations and data type properties for attribute values of instances (e.g. UserModelAge with an integer value). The complexity of the final result, as described in the following section, is **ALCH(D)**, adding complexity between classes and hierarchies into the previous set by inference.

2.3 *Generic rule reasoner*

Figure 3 presents the complete reasoning process for the final ontology. Based upon the initial ontology, as shown in the previous section, the process contains five inferences until the final model. The first inference classifies user model instances using different rules according to WHO ICF user profiles [17]. With respect to the ontology model, this step adds new memberships for each user model to different, already created profile classes. These classes are separated into no impairments (e.g. HProfile0 for no hearing impairment group), mild (e.g. VProfile1 for mild visual impairment group) and moderate (e.g. MDProfile2 for moderate manual dexterity impairment group) levels for visual, manual dexterity and hearing impairments. The second inference deals with component recommendations, resulting in analogue new classes with member instances for each recommendation related to an annotated component. These recommendations will be presented in the CAD phase. The last three steps deal with the immediate textual recommendations presented in the sketch phase regarding the selection of the designer of a user model, typical environment and typical task (see 2.3.2 for detailed view).

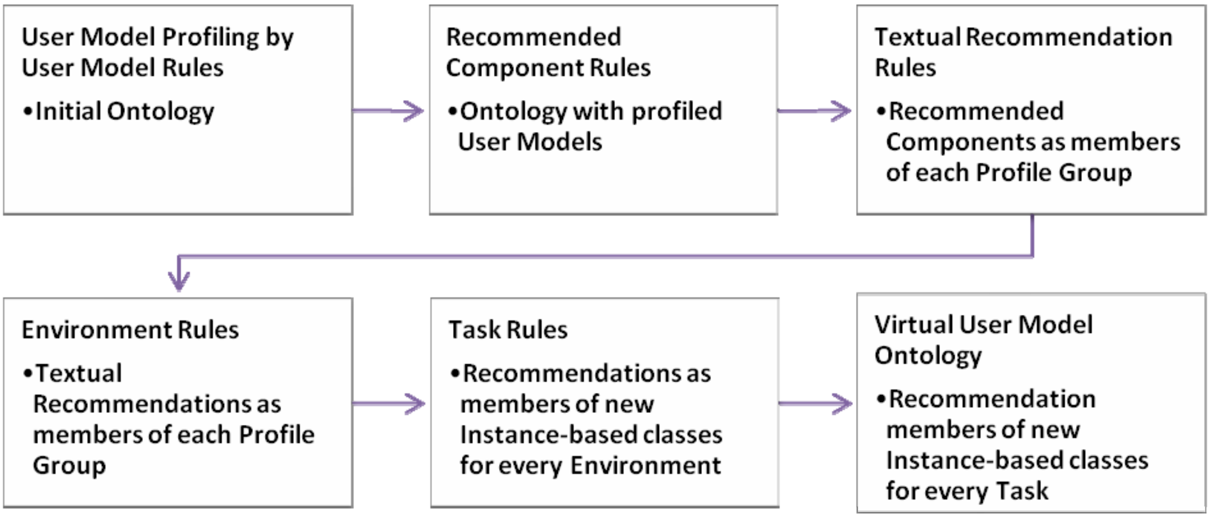

Figure 3 – Reasoning of ontology data resulting the final Virtual User Model

2.3.1 Rules

Rules are used to adjust instances of the ontology as members of different other groups. For instance all User Models are classified into impairment groups using predefined rules. As previously mentioned, the VICON reasoning consists of several stages in the creation of the final Virtual User Model. In the first stage, based upon a user study, carried out in D1.1 [5], User Model instances are added as members to impairment groups (see previous section).

To simplify the reasoning so the user can add / change rules directly, the syntax was reduced so predicate values of instances are already assigned and the user can use them without a definition. Each predicate value can be compared using the syntax presented in Table 3.

Rule	:= *bare-rule* . or [*bare-rule*] or [ruleName : *bare-rule*]
bare-rule	:= *term*, ... *term* -> *hterm*, ... *hterm* // forward rule or *bhterm* <- *term*, ... *term* // backward rule
hterm	:= *term* or [*bare-rule*]

term	:= (*node*, *node*, *node*) // triple pattern
	or (*node*, *node*, *functor*) // extended triple pattern
	or builtin(*node*, ... *node*)// invoke procedural primitive

bhterm	:= (*node*, *node*, *node*) // triple pattern
functor	:= functorName(*node*, ... *node*) // structured literal
node	:= *uri-ref* // e.g. http://foo.com/eg or prefix:localname // e.g. rdf:type

	or *<uri-ref>* // e.g. <myscheme:myuri> or *?varname* // variable or 'a literal' // a plain string literal or 'lex'^^typeURI // a typed literal, xsd:* type names supported or number // e.g. 42 or 25.5

Table 3 – Rule syntax of the generic rule reasoner

After this step, each user model instance is classified by parameter values. For instance the classification of mild manual dexterity impaired user groups is made using the following rule:

"equal(?arthritis,"N"), equal(?grip,2), equal(?controls,2), equal(?buttons,2), equal(?discomfort,2) -> (?x rdf:type Vicon:MDProfile1)."

By using build-in commands like "equal(x,y)", values are compared to each other. The right arrow defines the state, if all axioms are true (forward chaining). Usually all variables (starting with a "?") must be defined first before the first comparison. For instance, to get the value of the predicate, if the user model suffers from arthritis, the first axioms should be:

"(?x rdf:type Vicon:UserModel),(?x Vicon:UserModelArthritis ?arthritis) [...]"

In the first axiom, an instance of the user model class is selected ("?x"). The value of the arthritis predicate (analogue other predicates) can be set afterwards by using the direct predicate name, always beginning with "Vicon" and the class name.

Analogue this scheme all stages of reasoning are compiled, resulting new inference models until the final Virtual User Model.

2.3.2 Steps

The reasoning consists of 5 different steps (see Figure 3):

1. ***User Model Profiling***
   This step classifies all user model instances based upon a user study [5] by their attribute values as members of different impairment groups.

2. ***Component Recommendations***
   Creation of new classes for recommendations, which are related to components. After this step, each annotation instance name is also a class concatenated with "_Reco" (e.g. all recommendations for leds are members of the "leds_Reco" class).

3. ***User Model Recommendations***
   In this step, each recommendation is classified by the recommendation predicate "profile" value as members of each impairment group of the first step concatenating with "_Reco".

4. ***Environment Recommendations***
   To get environment recommendations, the recommendation predicate "EnvRule" is used. This predicate can also contain build-in rules as defined in Table 3.

5. ***Task Recommendations***
   All recommendations, which are related to typical tasks of a device, are joined using task rules.

2.4 Inferred ontology

The final ontology contains all already mentioned information and applied rules. All new classes for the selection of recommendations are created. Figure 4 presents the recommendation classes for the user profiles[2]. Each recommendation, which does have an impact on different impairments, is a member of the matched impairment group. Regarding the output of recommendations, for instance the result of the user model selection is a collection of all recommendations, which are members of each impairment group class, in which the UM instance is a member. So if the user model is a member of the mild visual and moderate hearing impairment groups, the result would be all recommendations of the "VProfile1_Reco" and "HProfile2_Reco" classes.

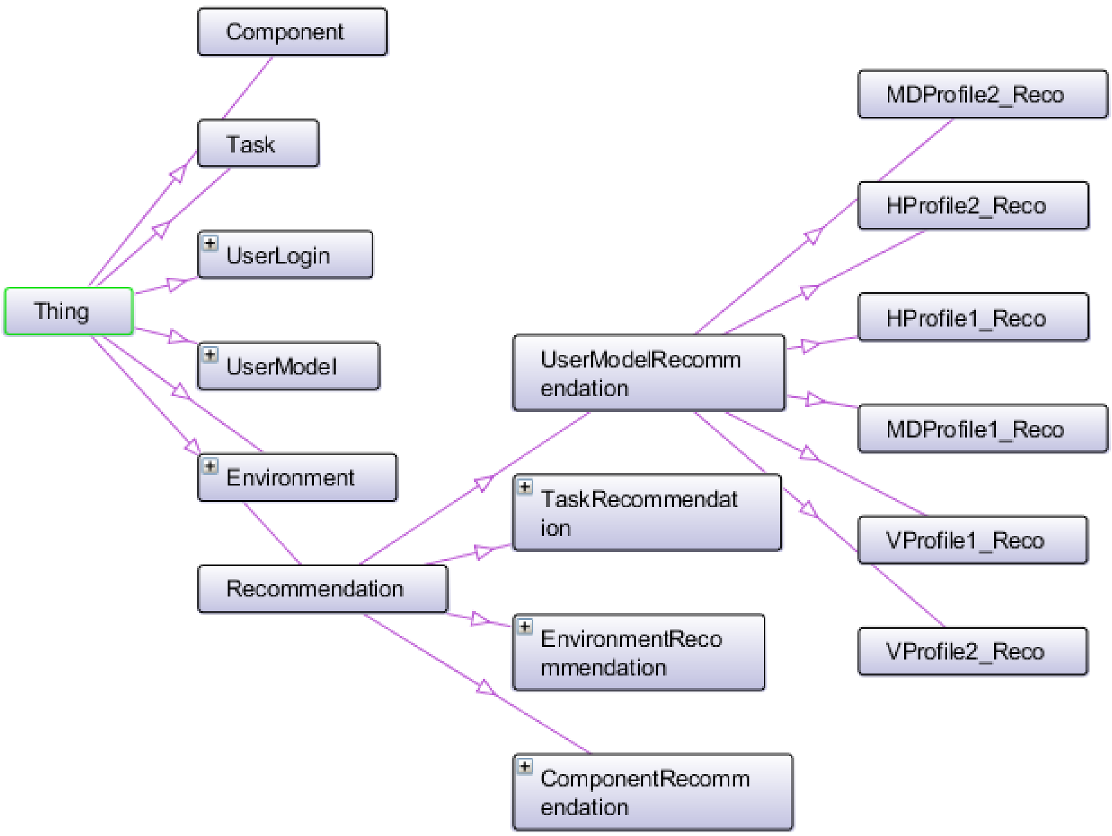

Figure 4 – User Model Recommendation classes in final Virtual User Model

[2] The *UserLogin* class, which is not mentioned before, contain login information regarding the administration view. It contains predicates for a user name and a password, which is encrypted stored within the ontology.

3 VUM application study

This section intends to illustrate the applicability of the Virtual User Model (VUM) realized within the VICON project on a simple case study. The study is presented in three subsections. First subsection gives a case overview and objectives. The next subsection deals with the case analysis, and the final subsection concludes with the results of the study.

3.1 Case overview

A consumer goods producer decides to enrich its mobile phone product line by a device addressing elderly customers. This decision is based on the fact that the company received a lot of negative feedback from a group of the elderly users. The users complained about difficulties while operating buttons of several phone models of the company's mobile phone brand. At the same time the users appreciated the contemporary appearance of the brand and didn't want to switch to other products manifesting their disabilities.

This case reflects a common situation of habituation of users with certain products with goes in line with the fact, that some of the features of the product are (or became) inaccessible for them, and a need for inclusive (re)design comes to the fore.

Actors involved in this case are the marketing department of the company and the designer team in charge of this project. To simplify the case no difference is made between the single designers of the team.

The designer's work can be structured in three subsequent phases: sketch, CAD design and evaluation as described in section 1. In our case the design process goes through these phases with an objective to overcome the difficulties by operating buttons reported for all previous mobile phone models of the product line.

The VICON's virtual user model is used to support the inclusive design process and to ensure that the end product is in fact accessible for the target user group.

3.2 Case analysis

The subject of the analysis is the case introduced above, where an inclusively designed mobile phone is developed using the VICON's VUM. Therefore the case study is structured according to the workflow of the VICON design process. It begins with discussion on the events and activities, which are preparatory to the actual creative design process. That followed by the description of the VUM support for designers during the sketch, CAD design and design evaluation phases of the product development process.

3.2.1 Initial product development activities

First, the marketing department of the company specifies a target user group. The VUM provides a number of predefined user profiles describing the most common disability cases: There are six profiles for the three pure types of disability (two levels for each type: visual, hearing and manual dexterity) and five user profiles for mixed disability types available. The 'mixed disability' profiles are based on the personae presented in APPENDIX C. In addition, the VUM offers an interface for creation of new user profiles, thus the marketing department could define its own target user profiles.

Based on the information gathered about the user group, which gave feedback regarding the existing mobile phones, and an additional market analysis the marketing team decides to focus the development with respect to the user group reflected in the existing profile 'Gandalf' (see APPENDIX C). 'Gandalf' represents an elderly user group with moderate hearing, visual and manual dexterity disabilities. Table 4 shows the data stored in this user profile.

Predicate	Value
General characteristics	
Name	Gandalf
IDName	P5
Description	Gandalf is an active older gentleman who refuses to let his age stop him from doing things. He has a moderate/severe hearing loss and wears digital hearing aids all day long. He can follow conversations in quiet places without them but the aids make his life much easier. Due to his moderate visual impairment he wears his new varifocal glasses all of the time. Moderate arthritis in both hands does not stop him doing things but can cause him discomfort, especially in cold weather. So he often wears gloves in all seasons except the height of summer. Gandalf still drives a car and enjoys walking his Labrador dog. He lives alone he tries to go to as many daytime social events as he can, for company and entertainment.
Nickname	
VirtualModel	Gandalf
Age	80
Gender	M
Hearing	
Hearing500Hz	30
Hearing1kHz	45
Hearing2kHz	65
Hearing4kHz	75
SpeechWithBackgroundNoise	0
HearingAid	1
HearingAidWithProduct	1
Vision	
VisualAcuity	2
FieldOfVision	3
Colour	1
NearFocus	2
DepthPerception	2
ContrastSensitivity	2
Glare	1
Glasses	1
GlassesWithProduct	1
Manual dexterity	
Arthritis	1
Grip	3

Buttons	2
Discomfort	2
TouchSensitivity	2

Table 4 – User profile 'Gandalf' representing an elderly user group with moderate hearing, visual and manual dexterity disabilities

Second, environmental aspects of the usage context should be defined. That means, either the existing environment profiles should be selected or certain new profiles should be created, and then selected. As defining the target user group it would be a job coordinated by the marketing department. The VICON's ontology already offers a number of environment profiles. For the upcoming mobile phone design the 'Kitchen' profile has been chosen by the marketing team, because kitchen is a popular room among the target users and it possesses rather challenging characteristics. Table 5 presents the 'Kitchen' profile available in the VUM knowledge base.

Predicate	Value
General characteristics	
Name	Kitchen
IDName	Kitchen
Description	Standard kitchen with wall tiles and glossy furniture surfaces
RoomType	3
RoomWidth	4
RoomLength	5
Door	2
Window	1
Hearing	
Acoustics	2
BackgroundNoiseLevel	1
BackgroundNoiseType	7
Vision	
LightingLevel	1
LightingType	1
DirectLights	1
Manual dexterity	
Temperature	1
WMClearSpaceFront	2,4
WMClearSpaceRight	1,3
WMClearSpaceLeft	0,8

Table 5 – Environment profile 'Kitchen' available in the VUM ontology

The previous activities can be seen as a part of initial work defining the starting point of the VICON design process, i.e. these activities are going on before the design concepts for a product have been found, before sketching the product. After the target user group and environment have been identified, and the appropriate data is available in the VUM knowledge base the actual design process addressing these requirements can be initiated.

During the initial stages of the design process the features of the product are elaborated along with other concepts. The product features allow the users to conduct certain tasks, e.g. turn the phone on and off or dial a phone number. All the tasks a user can perform with a product can be already specified in the forefront of the sketch design phase. In case of opening up new markets it is however possible, that certain useful tasks – like call emergency – get invented during sketching the product. Both cases are supported by VUM. A number of tasks can be defined – according to the task model of the VUM – for each product type. There are tasks for mobile phones, remote controls and washing machines predefined in the knowledge base.

Since such tasks as 'Turn on/off the phone' or 'Dial a phone number', which are strongly related to operating buttons, are already available in the VUM, our exemplary consumer goods producer decides to use the mobile phone tasks predefined in the VUM ontology. Table 6 shows the 'Dial a phone number' task profile available in the VUM knowledge base.

Predicate	**Value**
Name	Dial a phone number
IDName	T-0
Nr.	1
Description	To accomplish this task a user has to locate the control (Vision) and then to operate it (Manual dexterity).
Hearing	0
Vision	1
ManualDexterity	1
Component	Button
Complexity	2
InputRequired	1
Input	01234567891
InputDescription	A phone number of medium complexity consisting only of digits
NumberOfSubtasks	44
Subtasks	1.1 Identify button with label '0', *// identify a button, read, is it button '0'? If not, identify next..* 1.2 Reach the button 0, 1.3 Press button 0, 1.4 Identify success of the task 1.5 Identify button with label '1', 1.6 Reach the button 1, 1.7 Press button 1, 1.8 Identify success of the task 1.9 Identify button with label '2', 1.10 Reach the button 2, 1.11 Press button 2, 1.12 Identify success of the task 1.13 Identify button with label '3',

	1.14 Reach the button 3, 1.15 Press button 3, 1.16 Identify success of the task 1.17 Identify button with label '4', 1.18 Reach the button 4, 1.19 Press button 4, 1.20 Identify success of the task 1.21 Identify button with label '5', 1.22 Reach the button 5, 1.23 Press button 5, 1.24 Identify success of the task 1.25 Identify button with label '6', 1.26 Reach the button 6, 1.27 Press button 6, 1.28 Identify success of the task 1.29 Identify button with label '7', 1.30 Reach the button 7, 1.31 Press button 7, 1.32 Identify success of the task 1.33 Identify button with label '8', 1.34 Reach the button 8, 1.35 Press button 8, 1.36 Identify success of the task 1.37 Identify button with label '9', 1.38 Reach the button 9, 1.39 Press button 9, 1.40 Identify success of the task 1.41 Identify button with label '1', 1.42 Reach the button 1, 1.43 Press button 1, 1.44 Identify success of the task

Table 6 – Task profile 'Dial a phone number' available in the VUM ontology

3.2.2 Sketch design procedure

The usage of the VUM in the course of the sketch design provides the designer with textual recommendations w.r.t. the user, environment and task. The recommendation model is presented in A.5 of APPENDIX A. For selected user profile 'Gandalf' (environment and task unspecified) the designer receives the following list of recommendations:

R-1	Improve the tactile detection of key tops
R-2	Large keys for better differentiation
R-5	For better tactility keys should be raised above the body of the phone
R-6	Key activation pressure
R-7	Auditory and tactual feedback of successful key activation
R-11	The basic functions of a phone should be easy to use and accessible

R-12	Allow the user to use the product at his own pace
R-21	Maximise the grip of the material
R-22	The phone should be able to lie on a table and be operated one-handed
R-23	Audio and visual indication when the phone is switched on or off
R-24	Messages and instructions should be clearly understandable for non-technical users
R-25	All labels and instructions should be in short and simple phrases or sentences
R-27	The user should be able to set the volume of the ring tone
R-28	The ringing/alerting tone should include low as well as high frequencies
R-29	Provide prompts and alerts in as many formats as possible
R-30	The battery should be easy to install or replace
R-31	Provide both audio and visual indication of battery status
R-32	The phone should give a tactile response when the charger is connected
R-33	It should not be possible to connect the charger incorrectly
R-34	The charger should not be difficult to handle
R-35	Reduce interference to external hearing technologies to the lowest possible level
R-36	Provide a means for effective wireless coupling to hearing aids
R-38	Minimum strength is needed to open and close the door
R-39	Controls should be easy to grip and turn
R-51	Allow the user to adjust audio output volume
R-52	Provide the facility to repeat a message or alert
R-53	Keep audible instructions as clear and concise as possible
R-54	The volume control amplification up to at least 65 dB
R-55	Allow user to easily reset the volume to the default level when desired
R-59	Tactile cues should be complemented with visual and audible cues
R-60	Surfaces which may be touched inadvertently during normal operation should not get excessively hot or cold
R-61	Warnings of where temperatures may be excessively high or low should be clearly presented
R-66	Avoid complex instructions and operations
R-73	Choose good accessibility for easy operation of controls
R-74	Avoid presenting complex information to include users with hearing impairments.
R-75	Affordance to ease recognition
R-77	Shape to facilitate grasping
R-78	Button Force
R-80	Button Size
R-82	Button Depth
R-83	Neighbour Buttons Interspace in Millimetres
R-84	Neighbour Buttons Interspace in Button Size Percentage
R-87	Screen Interface Component Size

Hereby each recommendation can be viewed in greater detail. For example a detailed view of the recommendation 'R-1, Improve the tactile detection of key tops' is composed of the following information:

R-1

Name:
Improve the tactile detection of key tops

Priority:
Nice to have

Profile:
VI1,VI2,MD1,MD2

Source:
NCBI, http://www.cardiac-eu.org/guidelines/keys.htm, http://www.cardiac-eu.org/guidelines/telecoms/mobile.htm

Summary:
Key tops should be convex or flat with a raised edge.

Text:
People with low vision tend to rely on touch to operate mobile phone keys. Keys that are small and close together can be difficult to differentiate by touch. To improve tactile detection, key tops should be convex or flat with a raised edge.

Recommendation 1 – (R-1) Improve the tactile detection of key tops

If the designer selects environment 'Kitchen' along with selected user 'Gandalf', the VUM provides him/her with recommendations related to 'Kitchen' in addition to recommendations for 'Gandalf'. So by selecting user, environment and task simultaneously the designer would receive all recommendations related to these usage aspects.

The designer reads attentively all the recommendations he/she received for his/her context selection and takes a note of some recommended aspects, which appear the most valuable or interesting to him/her. At the same time he/she starts to sketch a phone in a sketch-book. In doing so the designer tries to create a design that conforms to the recommendations. Hereby the designer pays special attention to recommendations with regard to interactions with buttons.

An interesting question for further research is whether a possibility of receiving recommendations for certain component types (like buttons) is valuable at this stage or not. Currently it is not provided by the VUM in the sketch phase.

3.2.3 CAD design procedure

After a final sketch has been created and accepted for 3D prototyping a designer conveys the sketched design to a 3D CAD model. At this stage the designer can access the same recommendations as previously, and in addition – as soon as annotations of the product components have been made – the recommendations related to the annotated components.

As the objective of the design project requires, the recommendations related to the usage of keys should earn the highest attention of the designer. So via a specialized UI he/she lets the VUM know which parts of the 3D model are 'Button' components, and provides additional information about them such as colour of the button or the font of the button label, i.e. he/she 'annotates' the model parts. Afterwards for each annotated component the designer requests recommendations. For buttons these are the following:

- R-1, Improve the tactile detection of key tops
- R-2, Large keys for better differentiation
- R-5, For better tactility keys should be raised above the body of the phone
- R-6, Key activation pressure R-21, Maximise the grip of the material
- R-59, Tactile cues should be complemented with visual and audible cues
- R-78, Button Force
- R-80, Button Size
- R-82, Button Depth
- R-83, Neighbour Buttons Interspace in Millimetres
- R-84, Neighbour Buttons Interspace in Button Size Percentage

The designer can even 'apply' some of these recommendations to the 3D product prototype. It is however only possible to apply such recommendations, which contain a distinct condition for measurable entities of a usage aspect. E.g. the recommendation 'R-2, Large keys for better differentiation' (see below) contains a condition for the distance between the keys. This condition can be applied to the button geometry, in case it wasn't already fulfilled by the design.

R-2

Name:
Large keys for better differentiation

Priority:
Must have

Profile:
VI1,VI2,MD1,MD2

Source:
NCBI, http://www.cardiac-eu.org/guidelines/telecoms/mobile.htm

Summary:
Keys should be as large as possible without reducing the distance between the keys to less than half the key width.

Text:
The spacing between the keys is as important as the size of the keys, as spacing enables keys to be more easily distinguished both visually and by touch. Keys should be as large as possible without reducing the distance between the keys to less than half the key width.

Recommendation 2 – (R-2) Large keys for better differentiation

3.2.4 Evaluation procedure

As soon as the 3D product modelling reaches its final stage, where an annotated product model is available, the 3D design can be evaluated with help of the knowledge stored in the VUM ontology.

In our case the designer wants to evaluate his/her product design for the user 'Gandalf', which is using the mobile phone in the 'Kitchen' environment. In combination with the virtual experience simulation environment, which serves with realistic product and environment appearance as well as advanced visualization of the visual disabilities, the VUM provides background inclusive design assessment knowledge.

In order to ensure, that the proposed 3D design is accessible in this usage context with respect to the interactions with buttons, the designer instructs the system to simulate 'Dial a phone number' task (see Table 6) available in the VUM.

During the simulation the designer can observe how a virtual 'Gandalf' dials the phone number specified in the task profile. Each task is composed of a sequence of subtasks described in the 'Subtasks' field of a task profile. The simulation is conducted according to this subtasks structure: in our case the 44 subtasks, defined in the task profile 'Dial a phone number' and presented in the Table 6, are sequentially executed. The front end virtual environment provides a run-time visualization of the back end evaluation and enriches it with additional simulation features available in the virtual reality medium. The back end evaluation is based on functional relationships between the user, environment, task and component entities stored in the VUM and partially on the relationships stated in the analysis subsystem of the evaluation application.

As soon as 'Gandalf' has virtually conducted the 44 subtasks of the 'Dial a phone number' task in the 'Kitchen' the designer receives analysis results both visually and summarized in a textual form. In addition to a summary the textual results provide a detailed overview of the success estimation for all subtasks.

3.3 Results

The VICON's virtual user model provides designers with a knowledge framework, which is able to support the designer's work during the entire design process, i.e. during the sketch, CAD design and evaluation of a product. The knowledge available in VUM is related only to physical aspects of product usage. Three product types – mobile phones, remote controls and washing machines – are already instantiated in the VUM ontology. There are a number of standardized user profiles and standard usage environments available in the VUM ontology as well. Thus the VUM provides a sufficient framework to proof the industrial practicability of the virtual user concept, as stated in 1, and for further research in the virtual human modelling area as well as on problems of usability and model precision of the developed VUM.

As identified during the case analysis, a designer relies on the recommendations provided by VUM in order to create a design accessible for a target user group. Some recommendations of the current VUM are rather concrete and quantifiable, e.g. R-2 (see Recommendation 2), the most of them however are of an abstract nature describing conditions for a comfortable product usage in a qualitative manner, e.g. R-21 (see Recommendation 3). Qualitative aspects (usually described with such words like 'easy', 'comfortable', 'weak', 'simple', 'clearly understandable' etc.), that are not related to an underlying standard scale, hold no absolute, objective measure. Thus in order to provide an objective evaluation, which is based on comparison, a need for a certain formalisation of qualitative differences of each aspect arises.

Note, that even though the 'official' VICON evaluation is scheduled after the CAD design phase, the product design stands under the evaluation actually from the beginning of its creation process: At the sketch design phase the designer compares his/her sketches with the recommendations –

he/she already ‘evaluates’ his/her designs. So the evaluation activities go in fact though the entire design process.

Since the designer uses a number of qualitatively formulated recommendations for certain usage aspects, his/her own evaluation (during the sketch and CAD design phase) regarding these aspects remains subjective. Here the VUM aims to serve an objective design evaluation in the evaluation phase. For this purpose a number of qualitatively described aspects have been related to a quantitative scale or to functions of measurable arguments, in the course of the development of the VUM.

There are two major points to be mentioned regarding this approach. First, the quantification made should be proved and the model should be refined accordingly, which can be done in further focused studies in the future. Second, a reasonable balance between the following three factors needs to be found: the complexity of design assessment, the effort required from a designer in order to conduct such an assessment and the exactness of the evaluation results needed for a meaningful design support. This might be also a focus for future research. The last statement is based on the consideration, that the exacter assessment results should be, the more complicated the VUM gets, the more different kinds of information, in particular about the product design, are required for input into the model.

To give an example, in order to provide an objective highly exact estimation for success of a task related to grip of product surface a complex material assessment with respect to capabilities of user’s hand is needed. In this case an exact description of the material (according to a certain material model) a designer selected for the product should be provided by the designer. Such exact virtual material representations are currently unusual in the product design – a physically available material library is used instead. Thus requiring additional exact material descriptions from designers is probably not very welcome, a virtual material library could be a feasible approach instead. Such a virtual library however would also need appropriate maintenance. To answer questions of this kind further targeted studies are required.

R-21

Name:
Maximise the grip of the material

Priority:
Must have

Profile:
MD1,MD2

Source:
http://www.cardiac-eu.org/guidelines/telecoms/mobile.htm

Summary:
The phone should be easy to hold by someone with a weak grip.

Text:
People who have problems with manual dexterity or people who have low strength might have difficulty holding a phone that is very small and/or is made of slippery material. External features can be designed into the phone, for example physical design features such as contours or non-slip materials, to maximise grip. The phone should be designed in such a way that it is easy to hold by someone with a weak grip.

Recommendation 3 – (R-21) Maximise the grip of the material

4 Ethical issues

It is vital that user relevant information is carried out to the highest levels of ethical consideration for all participants. To this end in this and subsequent work, especially when building user models and profiles, we have ensured and will ensure that ethical issues are observed, making special emphasis in preserving the anonymity and privacy of users.

5 Conclusions & outlook

The VUM, which encapsulates the knowledge relevant for representation and simulation of the product usage, has been realized in the form of an ontology system.

This approach allows for logic-based knowledge representation and classification as well as for semantic reasoning of stored information. The reasoning procedure modifies the existing knowledge base and answers queries over its classes and instances according to specific rules.

The classification as well as the interpretation has been realized according to the findings of the beneficiary studies and their further evaluation.

Even though the current VUM approach is encouraging, there is potential for improvement and further research. In particular the accuracy of the real world approximation by VUM can be improved. As presented in this document the current VUM provides quite abstract qualitative description of the real world, which in particular doesn't allow for more or less precise quantitative analysis. To be able to model certain usage aspects more precisely, there is a need for further comprehensive and focused studies, which could be done in the future.

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APPENDIX A Ontology class predicates for VUM

This appendix aims to present the parameterization of the virtual user model. Each section reveals a list of predicates used to represent one particular usage aspect – user, environment, task – in the appropriate partial model. This data is based on investigations described in D1.1 [5]. For further explanations see also APPENDIX B.

A.1 User model

USER PARAMETER		
Predicate	**Datatype**	**Description**
	General characteristics	
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
IDName	String	The ID name, which is unique for each object of the ontology class. E.g. each user profile has a unique IDName assigned.
Description	String	Description of the user profile or persona represented by the profile
Nickname	String	Optional nickname for the person
VirtualModel	String	An 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
	Hearing	
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)
SpeechWithBackgroundNoise	Integer (0 - 200%)	Threshold of speech intelligibility with background noise. Percentage of background noise volume compared to speech volume.
HearingAid	Integer (0 = No, 1 = Yes)	Indication if the user has a hearing aid
HearingAidWithProduct	Integer (0 = No, 1 = Yes)	Will the user wear a hearing aid when using this kind of product?

	Vision	
VisualAcuity	Integer (0 = Normal, 1 = Mild, 2 = Moderate)	Visual acuity describes the "sharpness of vision"; value of normal = 20/12.5-20/25, mild = 20/32-20/63, moderate = 20/80-20/160
FieldOfVision	Integer (0 = No, 1 = Slightly, 2 = Moderately, 3 = Strongly)	Reduced field of vision (finds it hard to see things to the side, top, bottom of what they are looking at)
Colour	Integer (0 = No, 1 = Yes)	Colour indicates if the user is colour blind
NearFocus	Integer (0 = No, 1 = Slightly, 2 = Moderately, 3 = Strongly)	Ability to clearly focus on objects at near distance (can be measured as Amplitude of Accommodation in centimetres)
DepthPerception	Integer (0 = Normal, 1 = Mild, 2 = Moderate)	Ability to judge distance
ContrastSensitivity	Integer (0 = Normal, 1 = Mild, 2 = Moderate)	Pelli-Robson Score as a measure of contrast sensitivity; value of normal = 1.6-2, mild = 1.1-1.5, moderate = 1.1-1.5
Glare	Integer (0 = No, 1 = Yes)	Glare indicates if the user is sensitive to light and glare
Glasses	Integer (0 = No, 1 = Yes)	Indication if the user has glasses or contact lenses
GlassesWithProduct	Integer (0 = No, 1 = Yes)	Will the user wear glasses, or contact lenses, when using a product?
	Manual dexterity	
Arthritis	Integer (0 = No, 1 = Yes)	Answer to the question "Did the user report Arthritis?"
Grip	Integer (0 = No, 1 = Slightly, 2 = Moderately, 3 = Strongly)	Grip describes difficulty by holding small items, for example a pen or the handle of a cup, or items made of slippery material

Buttons	Integer (0 = No, 1 = Slightly, 2 = Moderately, 3 = Strongly)	Buttons estimates difficulty when using buttons or keys, for example when using the number keys on a phone
Discomfort	Integer (0 = No, 1 = Slightly, 2 = Moderately, 3 = Strongly)	Discomfort in hands when gripping small objects or operating controls
TouchSensitivity	Integer (0 = Normal, 1 = Mild, 2 = Moderate)	Sensitivity by touching different surfaces

Table 7 – Ontology class parameters for User model

A.2 Environment model

ENVIRONMENT PARAMETER		
Name	**Datatype**	**Description**
General characteristics		
Name	String	The name to identify an environment, this is the only one primary predicate, that means it is mandatory to define it in an instance
IDName	String	The ID name, which is unique for each object of the ontology class. E.g. each environment profile has a unique IDName assigned.
Description	String	Textual description of the environment
RoomType	Integer (1 = Living room, 2 = Dining room, 3 = Kitchen, 4 = Living/dining room, 5 = Kitchen/dining room, 6 = Utility / storage room, 7 = Kitchen/dining/living room, 8 = Bathroom, 9 = Cellar, 10 = Other)	Room in which user trial took place

RoomWidth	Integer (1-99)	Estimate of room width (in meters) in which user trial took place
RoomLength	Integer (1-99)	Estimate of room length (in meters) in which user trial took place
Door	Integer (1-999)	Number of doors in room where field trial took place
Window	Integer (1-999)	Number of windows in room where field trial took place
	Hearing	
Acoustics	Integer (1 = Good, 2 = Bad)	Acoustics in the room in which user trial took place
BackgroundNoiseLevel	Integer (0 = No background noise, 1 = Low, 2 = Loud)	Level of background noise in room in which user trial took place
BackgroundNoiseType	Integer (1 = TV/radio, 2 = People talking, 3 = Dog barking, 4 = Road works, 5 = Alarm, 6 = Traffic, 7 = Cooking appliance, 8 = Other household appliance, 9 = None)	Type of background noise in room in which user trial took place
	Vision	
LightingLevel	Integer (0 = Poor, 1 = Medium, 2= Bright)	Estimate of lighting level in room in which user trial took place
LightingType	Integer (1 = Natural lighting, 2 = Artificial lighting)	Estimate of type of lighting in room in which user trial took place
DirectLights	Integer (0 = No, 1 = Yes)	Existence of direct lights in the environment (direct lights and glossy surfaces are related to glare)
	Manual dexterity	
Temperature	Integer (0 = Cool, 1 = Comfortable, 3 = Warm)	Estimate of temperature level in room in which user trial took place
WMClearSpaceFront	Integer (1-999)	Amount of clear space (in cm) in front of the

		washing machine
WMClearSpaceLeft	Integer (1-999)	Amount of clear space (in cm) at the left of the washing machine
WMClearSpaceRight	Integer (1-999)	Amount of clear space (in cm) at the right of the washing machine

Table 8 – Ontology class parameters for Environment model

A.3 Task model

TASK PARAMETER		
Name	**Datatype**	**Description**
Name	String	Name of the task, which is presented to the user in the UI
IDName	String	The ID name, which is unique for each object of the ontology class. E.g. each environment profile has a unique IDName assigned.
Nr.	Integer (1 - 999)	The task number identification code, unique for every task
Description	String	Textual description of the task
Hearing	String	“True”, if a hearing impairment has an impact on a specific task, else “False”
Vision	String	“True”, if a hearing impairment has an impact on a specific task, else “False”
Dexterity	String	“True”, if a hearing impairment has an impact on a specific task, else “False”
Component	String	Specific component name, which is involved in a task, see component model
Complexity	Integer (0 = Not complex, 1 = Mildly complex, 2 = Severe)	The complexity estimate of a task
InputRequired	Integer (0 = No, 1 = Yes)	Identifies if an input to the task object is required
Input	String	Input character chain, if required (can be extended to regular expression describing the input)
InputDescription	String	Textual description of the input, if required
NumberOfSubtasks	Integer (1 - 99)	Number of subtasks the task is composed of
Subtasks	String	Hierarchically numbered list of subtasks. The

		numbering scheme is as follows <Nr.>.<SubtaskNr>, e.g. 2.4 for the fourth subtask of the task number two. The subtasks in the list are separated by comma.

Table 9 – Ontology class parameters for Task model

A.4 Component model

COMPONENT PARAMETER		
Name	**Datatype**	**Description**
State	String	The available states of a component, 1-n
Name	String	The annotation name of a component, will be presented in CAD module
Function	String	The function of a component (e.g. acoustic input)

Table 10 – Ontology class parameters for Component model

A.5 Recommendation model

RECOMMENDATION PARAMETERS		
Name	**Datatype**	**Description**
Name	String	The name of a recommendation
Priority	Integer (1 = Low, 2 = Middle, 3 = High)	The importance level of one recommendation. High priority means that the recommendation is a "MUST HAVE"
Summary	String	An optional summary of a recommendation
Text	String	The complete text of a guideline recommendation
Source	String	The source of a recommendation (e.g. ISO Guideline or experience)
Attachment	String	An URI, where an attachment can be found
Profile	String	The profile or profiles of a recommendation, which are used for the rules

EnvRule	String	The rule with JENA inference syntax, if a recommendation should be presented, related to environment selection of the user
TaskRule	String	The rule with JENA inference syntax, if a recommendation should be presented, related to task selection of the user
Component	String	A component name, if the recommendation is directly related to a specific component (e.g. “Button”)
ComponentRule	String	The rule with JENA inference syntax, if a recommendation should be presented, related to component functionalities and attributes
Phase	Integer (1 = Sketch, 2 = CAD Design, 3 = Evaluation)	VICON Application Phase definition, when a recommendation should be presented

Table 11 – Ontology class parameters for Recommendation model

APPENDIX B Supporting document for User model predicates

This appendix provides background information for the predicates specified for the User model. It explains the meaning of some of them in greater detail and refers to the relevant literature.

B.1 Supporting document to D2.2 User hearing profiles

Every person will have individual and differing levels of sensory abilities. The information on hearing loss presented in D2.2 User Profiles is intended to give typical, indicative figures and characteristics which will cover a significant number of people who have a hearing loss. The results are typical of people who have binaural, age-related, high-frequency hearing loss and no significant levels of tinnitus.

The predicates chosen by RNID to quantify, or describe, hearing loss followed a similar approach to that used in the 'inclusive design toolkit' [3] such that they will be relevant, and of benefit, to product designers. The predicates are relevant to how someone uses a product and are based upon data which is available from published sources.

Supporting information for each predicate:

1. ***Hearing @ xHz***

The standard hearing test (pure tone audiometry) measures Hearing Threshold Levels (HTL) at 6 or more differing frequencies (covering 5 octaves) in each ear. In a pure tone audiogram of someone with age-related, high frequency loss the HTL's will increase with frequency. The level and pattern of hearing loss is likely to be similar in each ear. So, someone with moderate hearing loss will have an average loss between 41dB and 70dB and the individual thresholds will follow a typical downward curve shape as in diagram 1[4]. Please note that each HTL is measured to the nearest 5dB.

The British Society of Audiology [5] has published audiometric descriptors based on severity-bands of average hearing loss across frequencies. But in terms of functional significance, research studies (Davis et al, 2007[6]) have identified an important distinction between people with average losses of at least 35 dB in the better ear – who will almost certainly benefit from hearing aids – and people with milder loss who may not.

[3] Inclusive design toolkit http://www.inclusivedesigntoolkit.com/

[4] http://www.hearing.com.au

[5] British Society of Audiology Recommended Procedure: Pure tone air-conduction and bone-conduction threshold audiometry, with and without masking. Draft revision, October 2010. http://thebsa.org.uk/docs/RecPro/outforcomment/RP_PTA_draftrevision_25Oct10_Consultation.pdf

[6] "Acceptability, benefit and costs of early screening for hearing disability: a study of potential screening tests and models" A Davis et al. Health Technology Assessment 2007; Vol. 11: No. 42.

a. **HI0**

For the user model HI0 (no hearing impairment) you would expect an HTL (dB) range of 0 -19. Hence for this user model we have constructed a typical audiogram, see Diagram 1, with a mean HTL of 10 dB.

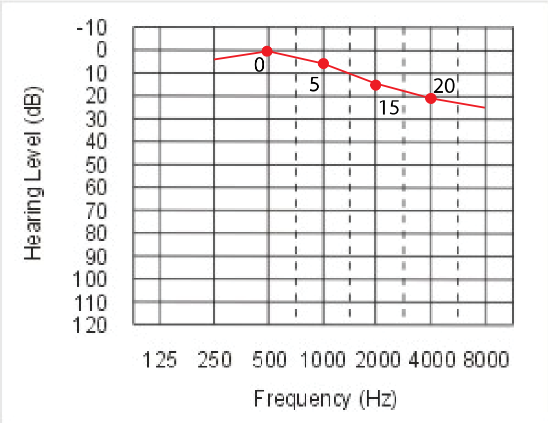


Diagram 1 – Audiogram of HI0

b. **HI1**

For the user model HI1 (mild hearing impairment and unlikely to benefit from hearing aids) based upon data from the British Society of Audiology we might expect to see an HTL (dB) range of 20 – 40. However, we are using an HTL (dB) range of 20 – 35 based upon the findings of Davis, et al, 2007. For this user model we have constructed a typical audiogram, see Diagram 2, with a mean HTL of 27.5 dB.

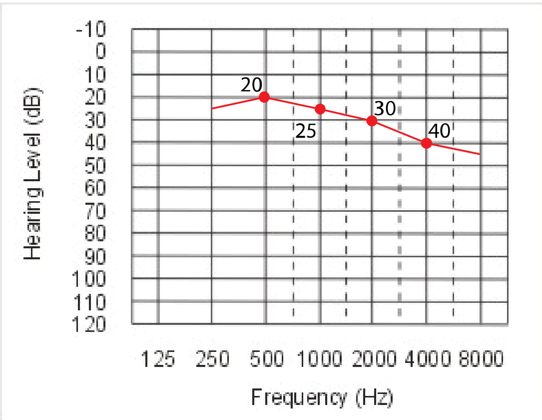


Diagram 2 – Audiogram of HI1

c. HI2

For the user model HI2 (moderate hearing impairment and likely to benefit from hearing aids) based upon data from the British Society of Audiology we might expect to see an HTL (dB) range of 41 – 70. However, we are using an HTL (dB) range of 36 - 70 based upon the findings of Davis, et al, 2007. For this user model we have constructed a typical audiogram, see Diagram 3, with a mean HTL of 53.0 dB.

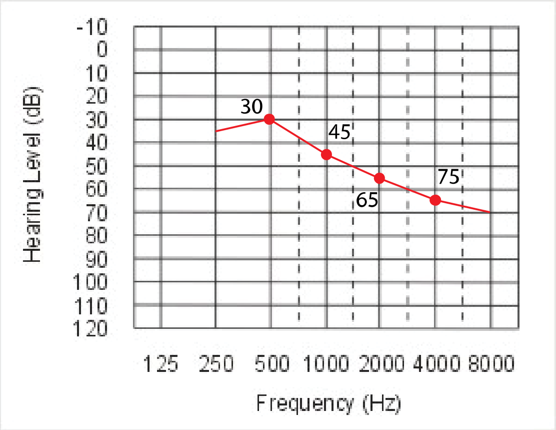


Diagram 3 – Audiogram of HI2

2. $SRTT_n$

$SRTT_n$ represents the signal-to-noise ratio, where a person recognises 50% of the speech material correctly. The disabling factor of not understanding speech in noise is the most frequent disability among hearing-impaired people[7].

All the SRTTn values are attributed from "Results From the Dutch Speech-in-Noise Screening Test by Telephone, Cas Smits and Tammo Houtgast

a. HI0

The SRTT value is -6.5dB which is the most common score for people without a hearing loss.

b. HI1

The SRTT value is -2.75dB which is the midpoint in the "insufficient" category (between -4.1 and -1.4dB) in the telephone test. The insufficient category is very similar to the HI1 profile.

c. HI2

The SRTT value is -1.4dB which is the borderline between the "insufficient" and "poor" categories in the telephone test.

[7] Kramer, Kapteyn & Feston, 1998

3. *Probability that the user has a hearing aid and the probability that the user will wear a hearing aid when using the product*

Studies show that a person with an average hearing loss of 35dB will benefit from using a hearing aid. However, due to other external issues, the majority of people who are first fitted a hearing aid have an average loss of 50dB.

These predicates are based on the probability that an individual which fits this profile will have hearing aids and the probability that they will be wearing them when operating a washing machine (typically in the home) or a mobile phone (either in the home environment or outside).

Average hearing loss in better ear (4 freq av.)	29 dBHL	54 dBHL
Probability of hearing aid use %	10	33
Prob. use h/a when use washing machine %	5	20
Prob. use h/a when use mobile phone %	5	20

Profile HI0 has no hearing impairment and so there is an estimated 0% probability that they will have a hearing aid.

Profile HI1 has a mild hearing impairment, below an average loss of 35dB, so might benefit from wearing a hearing aid but is unlikely to have one. There is then a reduced probability that they will be wearing them when using a washing machine as many people with a mild hearing loss only use their hearing aids when in social situations or are out of their home environment. When using a mobile phone a user might be wearing hearing aids if they are out of their house but some people experience interference between their mobile phone and their hearing aid so reducing the probability.

Profile HI2 has a moderate hearing impairment, just above 50dB, so will benefit from having nearing aids and is much more likely to have them. However, research suggests that still only 33% of people with this level of hearing loss have had hearing aids fitted. The reasons for the lower probabilities when using a washing machine or mobile phone are the same as discussed for profile HI1 above.

Probability estimates based on data from:

a. Davis A. *Hearing in adults*. London: Whurr; 1995.
b. “Acceptability, benefit and costs of early screening for hearing disability: a study of potential screening tests and models”, A Davis et al. Health Technology Assessment 2007; Vol. 11: No. 42.
c. MRC Survey of ENT symptoms 1999, A Davis et al.

B.2 Supporting document to D2.2 User vision profiles

CEN Guide 6 [12] defines seeing as “sensing the presence of light and sensing the form, size, shape and colour of visual stimuli”.

The incidence and severity of visual impairment increase with age. Changes in the physical structure of the eye affect several aspects of visual functions, including [12]:

- loss of visual acuity (the image appears indistinct),
- loss of near and/or distance vision (inability to accommodate changes of focus),
- reduced field of vision (inability to see things to the side, top or bottom of where looking),
- perception of colour, including age-related yellow vision (inability to distinguish colours),
- depth perception (inability to judge distances),
- speed of adaptation to changing light levels (temporary inability to see whilst eye adjusts to different lighting levels, for example on entering a building), and
- sensitivity to light; generally, older persons need more light to read than they did at 20 years of age.

Supporting information for each predicate:

1. Visual Acuity

The World Health Organisation [11] defines visual acuity functions as “Seeing functions of sensing form and contour, both binocular and monocular, for both distant and near vision.”

Clinical testing of visual acuity is typically based on letter recognition, for example the Snellen Eye Chart [1]. Letter recognition is complex, in that it requires the ability to see the image (vision), to recognize it (cognitive) and the ability to respond to questions about it (motor, cognitive). It should be noted that a lower than average score of a visual acuity assessment may be due to an individual’s inability to respond, rather than the result of optical factors. This therefore must be controlled for in any visual acuity testing scenario.

Based on the results of Snellen Tests, and other similar assessments, The World Health Organisation and the International Council of Ophthalmology [1; page 15, Table 6] has defined categories of visual acuity, which include visual acuity ranges for people classified as having normal vision, near-normal vision and moderate low vision. These three levels were selected for VICON as follows, respectively:

For VICON, Visual Acuity value with the range of:

- 20/12.5 - 20/25 = Normal
- 20/32 - 20/63 = Mild
- 20/80 - 20/160 = Moderate

The WHO ICF [11] code for Visual acuity functions is b2100.

2. *Field Radius*

The World Health Organisation [11] defines visual field functions as “Seeing functions related to the entire area that can be seen with fixation of gaze.”

A second visual function that can be tested when assessing degree of functional vision is field of vision or field radius. It should be noted that quantifying field of vision into a single figure is “a serious oversimplification of a complex reality”, as – for example – many different eye conditions affect different parts of the visual field in different ways and central vision loss (or other locations of the visual field) may not be accounted for.

Field of vision can be assessed using paper and pencil, an overlay grid or on an automated perimeter [1]. The test is described as follows [1]:

> “50 points are assigned to the central 10° radius (20° diameter), since this area corresponds to about 50% of the primary visual cortex; the other 50 points are assigned to the periphery. The points are arranged along ten meridians, three in each of the lower quadrants and two in each of the upper quadrants. This gives the lower field 50% extra weight. Measuring along meridians within the quadrants, rather than along the principal meridians, avoids special rules for hemianopias. Along each of the ten meridians 5 points are counted from 0° to 10° and 5 points from 10° to 60°. This maintains the traditional equivalence between a visual acuity loss to 20/200 (0.1) and a visual field loss to 10°, and assigns 100 points to a field of 60° average radius.’

Similar to Visual Acuity above, Visual Field assessment results can be loosely classified as corresponding to normal vision, near-normal vision and moderate low vision [1; page 35, Table 13] as follows, respectively:

For VICON, Visual Field Radius values of:

- 60 degrees = Normal
- 50 degrees or 40 degrees = Mild
- 30 degrees or 20 degrees = Moderate

The WHO ICF [11] code for Visual field functions is b2101.

3. *Colour Blindness*

The World Health Organisation [11] defines colour vision as “Seeing functions of differentiating and matching colours.”

The Ishihara tests for colour blindness [2] comprise 24 plates. The first 15 plates determine the “normality or defectiveness of colour vision”, and require the test subject to identify numbers and to call these out to the tester. The colour and design of the numerals and surrounds are such that someone with a colour vision deficiency will (for some or all plates) see no numeral or will see a different numeral to someone with no colour vision deficiency.

According to Ishihara [2]:

> "If 13 or more plates are read normally, the colour vision is regarded as normal. If only 9 or less than 9 plates are read normally, the colour vision is regarded as deficient."

For VICON, Ishihara Test result values of:

- 13 or more plates read correctly = Normal
- 10-12 plates read correctly = Mild
- 9 or less plates read correctly = Moderate

The WHO ICF [11] code for Colour vision is b21021.

4. Near Focus

The World Health Organisation defines Binocular acuity of near vision (i.e. near focus using both eyes) as "Seeing functions of sensing size, form and contour, using both eyes, for objects close to the eye".

Amplitude of accommodation (AA) is a measurement of the eye's ability to focus clearly on objects at near distances (i.e. accommodation).

The average amplitude of accommodation, in diopters, for a patient of a given age can be estimated by Hofstetter's formula: 18.5 minus one third of the patient's age in years [3] [4]. We therefore selected the ages of 20 years, 60 years and 90 years of age to estimate amplitude of accommodation for people with no, mild and moderate vision impairments, respectively.

Accordingly, for VICON, Near Focus (Amplitude of Accommodation) scores of:

- 8.5 diopters = Normal
- -1.5 diopters = Mild
- -11.5 diopters = Moderate

The WHO ICF code for Binocular acuity of near vision is b21002.

5. Depth Perception

Stereopsis is defined as "the ability to determine relative depth through the use of binocular disparity clues". It plays a vital role in many sensory-motor activities including reaching, manipulation of objects, and the ability to guide one's body or a vehicle in the environment[5].

Coren and Hakstian [5] developed a method for screening stereopsis without the use of technical equipment. Their Stereopsis Screening Inventory Scale (SSI) classifies percentage of stereopsis, with a score of 65% representing the "low fence for basic stereopsis screening between normal stereopsis and moderate stereopsis impairment" and a score of 25% representing the "high fence between moderate and severe stereopsis deficit".

Accordingly, for VICON, Stereopsis Screening Inventory scores of:

- 90% and over = Normal
- 65-90% = Mild
- 25-65% = Moderate

6. Contrast Sensitivity

The World Health Organisation [11] defines contrast sensitivity as "Seeing functions of separating figure from ground, involving the minimum amount of luminance required."

Ability to detect contrast has a considerable effect on quality of vision. The Pelli-Robson Score is an example of one accepted measure of contrast sensitivity [6].

The Pelli-Robson test measures contrast sensitivity using groups of letters (of same size), which are presented to the test subject in varying degrees of contrast from high to low. The letters are read, starting with the highest contrast, until the text subject is unable to read two or three letters in one group.

According to the University of Illinois [7], a Pelli-Robson score of 2.0 indicates normal contrast sensitivity of 100 percent. Scores less than 2.0 signify poorer contrast sensitivity. Pelli-Robson contrast sensitivity score of less than 1.5 is consistent with visual impairment and a score of less than 1.0 represents a visual disability.

For VICON, Contrast Sensitivity (Pelli-Robson) scores of:

- 2 = normal
- 1.6-1.9 = mild
- 1.0-1.5 = moderate

The WHO ICF [11] code for Contrast sensitivity is b21022.

7. Light Sensitivity

The World Health Organisation [11] defines light sensitivity as "Seeing functions of sensing a minimum amount of light (light minimum), and the minimum difference in intensity (light difference.)"

Light sensitivity can be estimated using the Disability Glare Index (DGI), which is calculated as Visual Acuity Rating (VAR) for normal lighting minus VAR for high glare.

Bailey and Bullimore [8] carried out a comparison of light sensitivity in older (50 – 80 years) and younger (15 – 41 years) patients. For VICON, VI0 and VI2 figures are based on results from this study of older and younger patients respectively. As no intermediate estimate could be found, the VI1 figure is the midpoint between the older and younger DGI scores.

For VICON, Light Sensitivity (DGI) scores of:

- 2 = normal
- 6 = mild
- 10 = moderate

The WHO ICF [11] code for Light sensitivity is b21020.

8. Glasses

It could be assumed that assigned values for VI0, VI1 and VI2 for the predicate 'Glasses' would be no, yes and yes respectively. This however would be based on the assumption that an individual with no vision impairment will not have glasses or contact lenses, and individuals with mild or moderate vision impairment will.

It should be noted however that the incidence of uncorrected refractive errors could be quite high, with estimates (in Australia) of 0.5% in those aged 40-49 years to 14.5% in those aged 90 years and older and (in UK) of 26% of those 75 years and older [9]. Using the results of the latter study (as this age group is closer to those on which VICON is focusing) it could be estimated that a person with a refractive error has a 75% probability of wearing glasses or contact lenses. For the purposes of this project we make the assumption that a person with a moderate vision impairment will have 100% probability of wearing glasses or contact lenses.

For VICON, an estimate of % probability of wearing glasses was therefore used for the 'Glasses' predicate, as follows:

- 0% probability = normal
- 75% probability = mild
- 100% probability = moderate

9. Glasses with Product

There are very few available data on behaviour of those who have glasses or contact lenses, for example, how much the glasses/contacts are worn and in what context. A survey carried out in Ireland in 1998 on lifestyle, attitudes and nutrition [10] found that 85.8% of respondents wear glasses or contact lenses all or some of the time. Based on this finding we estimate that a person with moderate vision impairment will have an 85% probability of wearing glasses or contact when using a product. It can be assumed that a person with no vision impairment will have a 0% probability. For people with a mild vision impairment, we chose a midpoint between the two estimates.

For VICON, an estimate of % probability of wearing glasses while using a product was therefore used for the 'Glasses with Product' predicate, as follows:

- 0% probability = normal
- 45% probability = mild
- 85% probability = moderate

References

[1] Colenbrander, A. (2001) Measuring Vision and Vision Loss. Duane's Clinical Ophthalmology, Volume 5, Chapter 51.

[2] Ishihara, s. (1972). Tests for Colour Blindness. Kanehara Shupran Co., Ltd., Tokyo, Japan.

[3] Scheiman, Mitchell and Wick, Bruce. Clinical Management of Binocular Vision. Lippincott, New York. 1994.

[4] Rutstein, R.P. and Daum, K.M. (1998). Anomalies of Binocular Vision: Diagnosis & Management, Mosby.

[5] Coren, S. and Hakstian, A.R. (1996). Screening for Stereopsis without the Use of Technical Equipment: Scale Development and Cross-Validation. International Journal of Epidemiology, 25(1): 146-152.

[6] National Research Council (2002) Visual Impairment: Determining Eligibility for Social Security Benefits. Committee on Disability Determination for Individuals with Visual Impairments. Peter Lennie and Susan B. Van Hemel, editors. Division of Behavioral and Social Sciences and Education. National Academy Press, Washington, DC.

[7] The Eye Digest (2009) The University of Illinois Eye and Ear Infirmary, Chicago. http://www.agingeye.net/cataract/cataracteyeexam.php

[8] Bailey, I.L. and Bullimore, M.A. (1991). A New Test for the Evaluation of Disability Glare. Optometry and Vision Science, 68(12): 911-917.

[9] Jackson, A.J. and O'Brien, C. (2008) Eyes on the Future Ireland, 2008.

[10] Sheily, F. and Kelleher, C. (2004). Older People in Ireland: A Profile of Health Status, Lifestyle and Socio-Economic Factors from SLAN. National Council on Ageing and Older People, Report No. 82.

[11] World Health Organisation (WHO) International Classification of Functioning, Disability and Health. WHO, 2001.

[12] CEN Guide 6. Guidelines for Standards Developers to Address the Need of Older Persons and Persons with Disabilities.

B.3 Supporting document to D2.2 User manual dexterity profiles

The Australian/Canadian (AUSCAN) Hand Osteoarthritis Index

The AUSCAN hand osteoarthritis index was recently developed to determine the degree of a person's manual dexterity and impairment. It was developed with the intention of evaluating patients with hand osteoarthritis, however the Index has been subsequently validated for use in patients with rheumatoid arthritis. Two population-based surveys have been carried out with the AUSCAN Index, targeting 60,000 members of the general public selected at random from the electoral role. The combined responses from both surveys were in the order of 13,000 subjects.

The AUSCAN Index is a proprietary health status questionnaire. It is the only hand Index, and certainly the only hand OA Index for which there exists proposals for MCII, PASS and age and gender- specific population-based normative values.

The AUSCAN index gives medical practitioners the ability to measure the extent of a patients hand osteoarthritis and benchmark their status against that of age and gender-matched peers in the general population.

AUSCAN index results differ between the sexes, hence different predicates for both male and female users.

References

[1] Bellamy, Wilson and Hendrikz (2009) : Population-based normative values for the Western Ontario and McMaster (WOMAC) osteoarthritis index and the Australian/Canadian (AUSCAN) hand osteoarthritis index functional subscales. Inflammopharmacology, December 2009.

Predicates based on the VAALID project

Another method of describing and assessing manual dexterity impairments was suggested by VAALID. This was a EU supported project titled' Accessibility and usability validation framework for AAL interaction design process' and was completed in 2010.

This project identified a number of key dexterity issues, based upon the ICF descriptions, the most relevant to the VICON project being twisting, reaching, turning, pushing and pulling. These are described as:

d4450 Pulling
Using fingers, hands and arms to bring an object towards oneself, or to move it from place to place, such as when pulling a door closed.

d4451 Pushing
Using fingers, hands and arms to move something from oneself, or to move it from place to place, such as when pushing an animal away.

d4452 Reaching
Using the hands and arms to extend outwards and touch and grasp something, such as when reaching across a table or desk for a book.

d4453 Turning or twisting the hands or arms Using fingers, hands and arms to rotate, turn or bend an object, such as is required to use tools or utensils.

(From http://apps.who.int/classifications/icfbrowser/)

Each of these dexterity predicates is explained in the VAALID report in accordance with the ICF extended description of abilities. The ICF description relies upon self-assessment of an ability where a respondent will assess their ability in the following categories:

1. No Problem
2. Mild Problem
3. Moderate Problem
4. Severe Problem
5. Complete Problem

MILD – at a level that you can tolerate, occurs rarely.
MODERATE – sometimes interferes with your day to day life, occurs occasionally
SEVERE – partly disrupts your day to day life, occurs frequently.
COMPLETE – totally disrupts your day to day life, affects you every day.

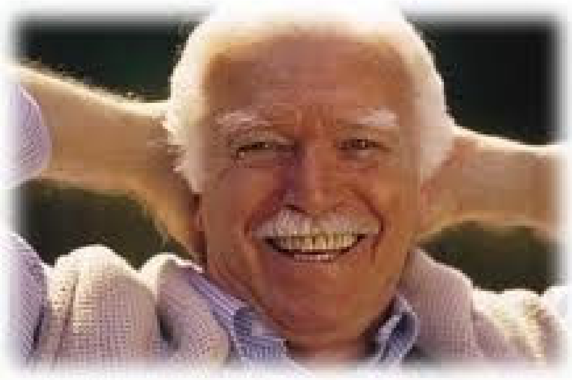
References

[1] National Disability Authority report ,Chapter 4:
http://www.nda.ie/Website/NDA/CntMgmtNew.nsf/0/F6D0B29EC738D268802570660054EC10?OpenDocument
[2] http://apps.who.int/classifications/icfbrowser/
[3] VAALID project report

APPENDIX C User personae

To better help explain the personae presented in the D2.2 user profiles, here we present more detailed descriptions of typical personae including a representative image.

Trevor (65)



A recently retired man with no hearing, visual nor manual dexterity impairments. He does not wear a hearing aid, glasses or contact lenses.

Trevor is generally fit and healthy and leads an active life. He does not see himself as being old and is starting to enjoy his retirement and having more time for his garden and family.

Eileen (69)

Eileen retired a few years ago, at the same time as her husband. She has mild/moderate hearing and manual dexterity impairments, but they don't affect her everyday life. She does not wear a hearing aid but is aware that she is listening to the TV much louder these days and would probably benefit from a hearing aid. She has no visual loss, so does not wear glasses or contact lenses.

Eileen is generally healthy and active. In the week she helps look after her young grandchildren and at weekends she enjoys travelling and gardening with her husband.

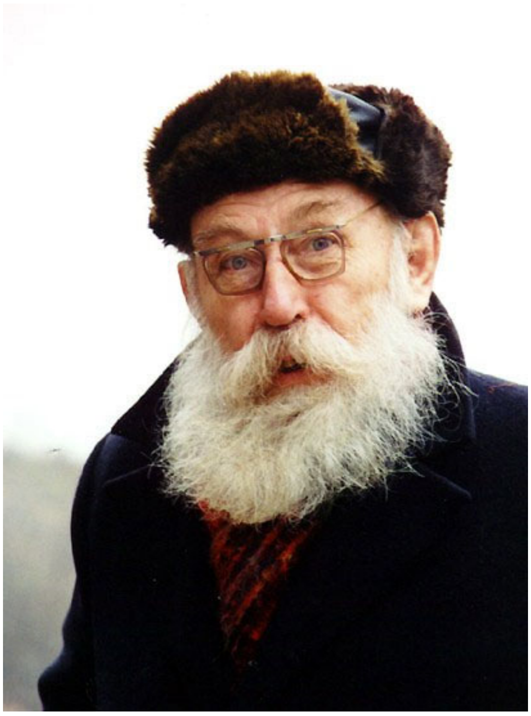
Mark (72)

An elderly man with mild/moderate hearing, visual and manual dexterity impairments. Mark has two, new digital hearing aids but normally only uses them when out of the house or on the phone. He wears glasses, but mainly for reading small writing such as with his mobile phone, the newspaper or packaging. He has some stiffness in his fingers, but this doesn't affect his main hobby which is fishing.

Mark enjoys his life and always keeps busy, he is involved with many local organisations and helps run his local angling and allotment associations.

Dorothy (76)

Dorothy has a moderate hearing loss and has had hearing aids for 12 years. She doesn't find them very comfortable to wear so usually only wears them if she has company, to use the phone or if she is leaving her home. She copes well with her hearing loss but now tends to avoid socialising in noisy places. She has worn glasses all her life but has recently developed mild macular degeneration making it harder for her to see things clearly. Dorothy has no problems with manual dexterity and still enjoys knitting and going to bingo with her daughters.



Gandalf (80)

Gandalf is an active older gentleman who refuses to let his age stop him from doing things. He has a moderate/severe hearing loss and wears digital hearing aids all day long. He can follow conversations in quiet places without them but the aids make his life much easier. Due to his moderate visual impairment he wears his new varifocal glasses all of the time. Moderate arthritis in both hands does not stop him doing things but can cause him discomfort, especially in cold weather. So he often wears gloves in all seasons except the height of summer.

Gandalf still drives a car and enjoys walking his Labrador dog. He lives alone he tries to go to as many daytime social events as he can, for company and entertainment.