Accessible and Assistive ICT

VERITAS

Virtual and Augmented **E**nvironments and **R**ealistic User **I**nteractions **T**o achieve Embedded **A**ccessibility Design**S**

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White Paper on VERITAS vision: Towards embedded accessibility designs

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Executive summary

The white paper on VERITAS vision aims to provide to the reader useful information on the current accessibility gaps and how they are dealt with, within VERITAS. Moreover, its goal is to emphasize on the unsolved accessibility issues before and after VERITAS, so as to provide in indication on a potential research roadmap that will follow and build upon the results of VERITAS. Initially the current problems related to product accessibility are analyzed that are followed by the VERITAS vision towards embedded accessibility designs. Then, the technologies developed within VERITAS are described, while subsequently emphasizing on the potential technologies that could be developed beyond VERITAS that could serve as first step towards a roadmap on simulated accessibility designs.

1 Introduction

It is important to realise that people with disabilities are not just a tiny minority of the population of the European Union. The lowest estimate, based on the currently defined disablement categories, estimates their total number at around 74 Million persons [1]. However, other estimates that take into account a) people with cognitive difficulties, and b) those people in the so-called hinterland between fully able bodied and the classically termed people with disabilities [2], should considerably raise those numbers [3].

Despite the rapid evolution of ICT over the last years and the increasing acknowledgment of the importance of accessibility, the developers of mainstream ICT-based products still act and struggle under total absence of structured guidance and support for adjusting their envisaged products and services with their user's real-time accessibility needs. As a result, a critical mass market, including that of older people and people with disabilities-friendly ICT-based products and services targeting older people and people with disabilities, remains highly locked.

A similar situation is observed in the development of non-ICT products and services, where developers toil to test and evolve their prototypes in terms of their functionality, without however being able to systematically test their developments in terms of their accessibility. Moreover, guidelines, for example in the domain of building design, are not the ultimate solution; they are often inadequate, sometimes wrong, not completely understood by designers, and there is no ex post verification that by following them the result of the design will be accessible. Thus, it is a technological challenge to provide to disabled and senior citizens with systems that could support their individual characteristics and increase their quality of life. These systems should improve the level of independence, promote the social relationships and encourage the psychological and physical state of the person.

AmI spaces could potentially bridge the accessibility gap

While the interest in Ambient Intelligence (AmI) has increased exponentially due to the widespread use of portable IT devices and networked sensors, AmI spaces could provide the necessary means to achieve accessible products. Technological advances are making the AmI vision a reality, but there still remains a question for designers and developers on how to effectively develop and deploy smart applications, devices and services to serve different categories of end users (beneficiaries) demonstrating flexibility, adaptability and situation adaptability (context awareness). As a result, the support of accessible solutions and services that can seamlessly operate in various and changing settings (e.g. home, workplace, etc.) sets new challenges that must be addressed by both the hardware manufacturers, software developers and designers.

ISTAG (the IST Advisory Group) has proposed Ambient Intelligence Space as a layer connecting different AmI environments (e.g. home, car, public spaces) in a seamless and unobtrusive way. Obviously, interoperability and standards are crucial in this respect. Context awareness is another issue that needs to be looked into more closely, especially when trying to integrate forms of context that are more sophisticated and user-oriented than current definitions of context.

AmI tomorrow

The convergence of pervasive computing, ambient networks and intelligent-user interfaces has enabled the development of ambient intelligence and associated services. Human beings and machines will be surrounded by intelligent interfaces supported by computing and networking technology in everyday objects. This will lead to situations in which the environment is “aware” of a human or agent presence, and in which the agents and devices are aware of their environment, their location and also the abilities and disabilities of their human operator. Taking into account the personal preferences, the current activities of the user and the behaviour of machines, services will be capable of tracking users and responding intelligently to all kinds of requests. Thus, the intelligent user interaction with systems and services is an essential aspect for emerging applications and has specific requirements to cope with people’s abilities.

The technology trends foreseen for the next 20 years as defined in the 2020 roadmap for the future[1] are outlined in the following Figure 1, which expects an evolution of the current technological advancements in Ambient Intelligence and Smart Environments that will make key technologies available for the adoption of accessible designs and services.

It is widely expected that increased interoperability and smart appliances will become mainstream in the retail industry around 2015. As this scenario will evolve, a vast amount of objects will be addressable, and could be connected to IP-based networks, to constitute the very first wave of the “Internet of Things”. Another very important aspect that needs to be addressed at this early stage is the one related to interaction standards, accessibility and personalised objects.

Extrapolation of technology trends and ongoing research

	Before 2010	2010-2015	2015-2020	Beyond 2020
Vision society	• Socially acceptable RFID	• Pervasive RFID	• Interacting objects	• Personalised objects
People	• Realising benefits (food safety, anti counterfeiting, health care) • Consumer concerns (privacy) • Changing ways to work	• Changing business (processes, models, ways to work) • Smart appliances • Ubiquitous readers • Access rights • New retail and Logistics	• Integrated appliances • Smart transportation • Energy & Resource conservation	• Mastered ambient intelligence • Interaction of physical and virtual worlds • Search the physical world (google of things) • Virtual Worlds
Politics & Governance	• De-facto governance • Privacy legislation • Address cultural barriers • Future Internet governance	• EU governance • Frequency spectrum Governance • Sustainable Energy Consumption guidelines	• Authentication, trust and verification • Security, social well-being	• Authentication, trust and verification • Security, social well-being
Standards	• RFID security and Privacy • Radio frequency use	• Sector specific standards	• Interaction Standards	• Behavioural Standards

	Before 2010	2010-2015	2015-2020	Beyond 2020
Vision technology	• Connecting objects	• Networked objects	• Executable objects /semi-intelligent objects	• Intelligent objects
Use	• RFID adoption in logistics, retail and pharmaceutics.	• Increased interoperability	• Decentralised code execution • Global applications	• Unified network that connects people, things and services • Integrated industries
Devices	• Smaller and cheaper tags, sensors and active systems	• Increasing memory and sensing capacities	• Ultra high speed	• Cheaper materials • New physical effects
Energy	• Low power chipsets • Reduced energy consumption	• Improved energy management • Better batteries	• Renewable energy • Multiple sources	• Elements of energy harvesting

Figure 1 Extrapolation of technology trends

[1] Internet of Things in 2020 ROADMAP FOR THE FUTURE

Accessibility issues

One of the main prerequisites of designers and developers, either designing for AmI environments/applications or not, is that interactions of end users must be multimodal and adaptive according to user preferences, disabilities and changing daily environments. In principle, different modalities can be used concurrently so as to increase the accessibility of available information or, alternatively, to present the same information in different contexts, or, redundantly, to address different interaction channels.

Nevertheless, nowadays many designers and developers suffer from lack of knowledge about accessibility and interoperability concepts and, as a result, are unaware of the accessibility barriers that are frequently generated when introducing a new product, and/or application to the market - or potential futre AmI market - and especially when they are trying to accommodate the seamless use of their components in different and changing environments. Also, due to time restrictions to delivering the product/service, the developer has no time to understand and integrate all the new information he/she gets about accessibility and interoperability.

Existing accessibility assessment tools and packaged solutions (e.g., several CAD tools or simulation environments like the ones developed within the VERITAS, VICON and VAALID projects) give developers and designers the possibility of seeing how the parameters and characteristics of different virtual users with disabilities (adopted static virtual user models and personas) can affect the simulation process and its results. This design paradigm, based on the notion of the Virtual User, could be described as “What You See Is What Other People Get –WYSIWOPG-, that is to say, developers may have a clear view of the interaction perceived the end user with or even without disabilities when interacting with a product in the development stage. The importance and significant potential of these approaches via the use of the virtual user models is obvious, since they can guarantee that the developments will be accessible for a vast percentage of the disabled population, while also improve the usability of the designs for all including able-bodied people.

Moreover, interface or design optimization for each individual is also possible. The adoption of dynamic virtual user models of end users (people with disabilities and elderly) could be instrumental in deciding how to use multimodality and interface adaptation for different users in different contexts and for setting the final design goals. Moreover it is paramount crucial also for physical interaction with «non-ICT» objects.

2 The Vision

The ultimate vision of VERITAS is to provide all necessary technologies so as to assess the accessibility of ICT but also non-ICT design in all phases of production. In the following the mid-term vision of VERITAS on “Embedded accessibility designs” and the long-term vision on “Accessible AmI Infrastructures” are briefly described.

Embedded accessibility designs

VERITAS aims to develop, validate and assess tools for built-in accessibility support at all stages of ICT and non-ICT product development, including specification, design, development and testing. The goal is to introduce simulation-based and virtual reality testing at all stages of assistive technologies product design and development into the automotive, smart living spaces, (buildings & construction, domotics), workplace and infotainment applications areas. VERITAS aims to ensure that future products and services are being systematically designed for all people including those with disabilities and functional limitations as well as older people. Delivering to product/software developers ‘generic’ instructions - embedded in an empowering virtual reality platform, for exploring new concepts, designing new interfaces and testing interactive prototypes that will inherit universal accessibility features, including compatibility with established assistive technologies is VERITAS’ ultimate goal.

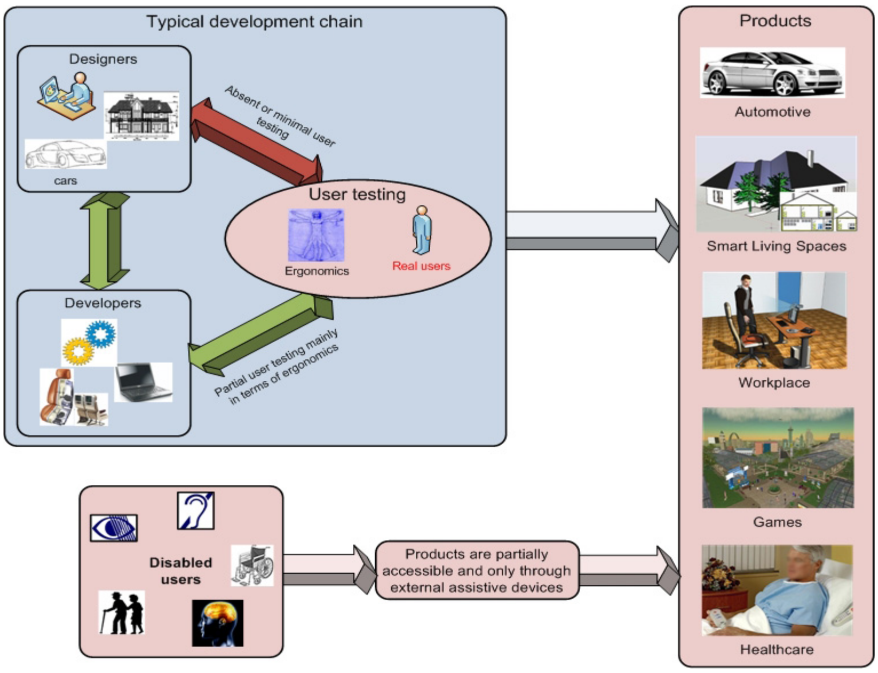

Figure 2 Typical development chain before VERITAS.

The typical development chain without and with VERITAS can be seen in Figure 2 and Figure 3 respectively. Without VERITAS it is very difficult if not impossible to perform accessibility evaluation of a product unless a prototype and real disabled users are available. On contrary with VERITAS it is possible to perform simulated accessibility evaluation in all steps of product development – even in the design phase – with virtual disabled users. The main VERITAS innovation lies in the fact that, even if there have been some limited and isolated attempts to support accessibility testing of novel products and applications, there is a clear lack of a holistic framework that supports comprehensively virtual user modeling, simulation and testing at all development stages and realistic/immersive experience of the simulation.

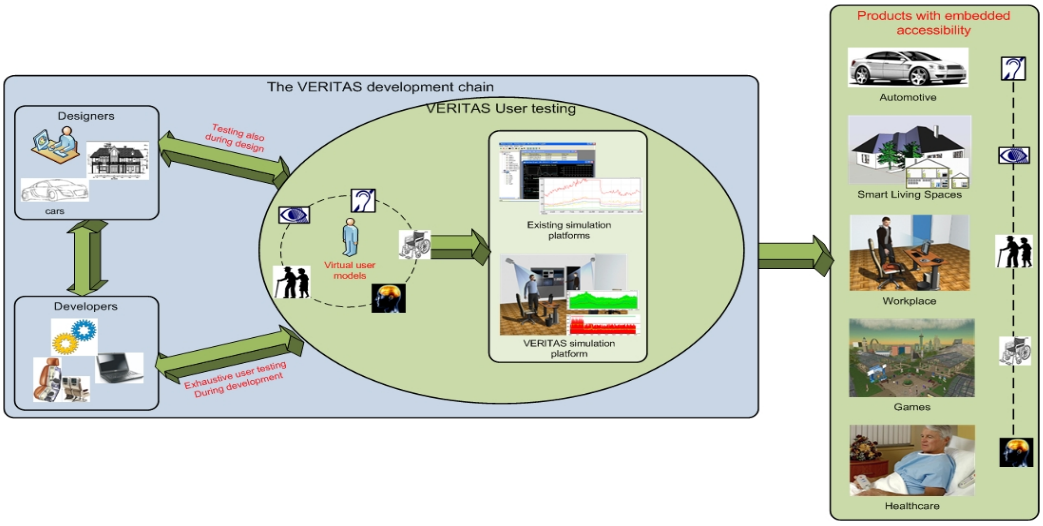

Figure 3 Typical development chain after VERITAS.

While VERITAS aims to revolutionize accessible product development by providing novel means to perform accessibility evaluation and testing in the design phase, its ultimate vision can be summarized in the following:

- To investigate and develop an open library of various categories of virtual user models, including VR models, covering a wide range of population groups and especially focusing on groups in risk of exclusion, e.g. older people, people with disability (vision, hearing, speech, motor), people with co-existent condition, etc.
- To provide novel virtual reality tools for testing the accessibility of the environment providing also support for ICT and non-ICT products.
- To capture the personal preferences and interaction-related parameters of the people with disabilities, the older people as well as people with changing functional abilities during the day and map them to dynamic virtual user models.
- To research and develop methodologies for introducing simulation and testing framework, including the virtual user and the simulation models, to a wide variety of ICT and non-ICT applications.
- To include automatic simulation and testing of the interfaces on the portable devices by taking into account the dynamic and personalized virtual user models and constraints imposed by the specific application being accessed by the device.

<u>Accessible AmI Infrastructures</u>

In ubiquitous and changing daily environments, AmI applications must support context-awareness since end users (beneficiaries) need to seamlessly access services and networked sensors, without adequate knowledge of the procedure to be followed to achieve this. However, implementing context-awareness directly in an application is a very difficult and, in most cases, time consuming task. An application designer and/or developer does not like to be concerned with such complexity and for that reason it is desirable to embed context-awareness in an overall ubiquitous framework that can effectively communicate with the developed application. Thus, the ability of products and applications to be dynamically adapted to specific user behavior patterns (profiling) and situations (context awareness) requires a real time and dynamic updating mechanism that can be adapted on the fly and based on the context according to the end user real-time accessibility needs.

In a typical AmI environment, there are many non-intrusive and invisible devices and networked sensors interacting with end users (beneficiaries), which are integrated into the environment. These devices generate information about the environment, user's preferences and changes in both of them. However, existing AmI environments cannot be dynamically adapted to end user's real time capabilities and/or to different interaction modalities. In order to seamlessly support the integration and adaptation of solutions and services for persons with disabilities, in various and changing settings, VERITAS foresees, as a long-term goal, a holistic simulating environment which is capable of recognizing, responding and adapting to individuals (by taking into consideration their personal dynamic virtual user models) in a seamless and unobtrusive way. As a result, a continuously evolving gap can be identified between the constantly and rapidly evolving AmI environment, sensing capabilities, interoperability and their potential use so as to provide accessibility of the environment through seamless, customized and personalized services to the elderly and disabled (E&D) population.

VERITAS envisions tools for accessibility assessment and prototypes for accessing in a seamless and personalised way: a) the environment, b) the ICT and non-ICT products integrated in the environment and c) the information originating from sensors integrated in the environment. The combination of virtual user modelling and virtual reality simulation and testing with prototype development and adaptive interface provision – through on the fly accessibility simulation - for operating devices and products integrated in AmI environments is considered critical for the emerging AmI infrastructures. The concept of the virtual user models should be highly interoperable for providing online and real-time personalised services to people with disabilities and older people in various changing environments and conditions.

The following debrief the long-term vision of VERITAS:

- Novel virtual reality tools for testing the accessibility of the environment providing also support for ICT and non-ICT products, with limited ICT functionalities, and sensors integrated on it.
- Capture the personal preferences and interaction-related parameters of the people with disabilities, the older people as well as people with changing functional abilities during the day and map them to dynamic virtual user models.

- To develop ICT and non-ICT prototypes that can be seamlessly operated by the beneficiaries in various environments and changing settings.
- To include automatic simulation and testing of the interfaces by taking into account the dynamic virtual user models, information provided by the AmI and constraints imposed by the specific application being accessed.

3 Making the vision reality

VERITAS aims to rapidly gallop towards its vision through a layered structured architecture that is outlined in the following of this chapter. Moreover, the basic building blocks of the VERITAS architecture are analyzed in more detail.

3.1 A Holistic Architecture

The VERITAS modular architecture is depicted in Figure 4. More specifically, VERITAS aims at creating new tools and methods that facilitate and streamline the process of creation, design, construction and seamless deployment of accessible technological solutions and services for persons with disabilities in various daily life environments.

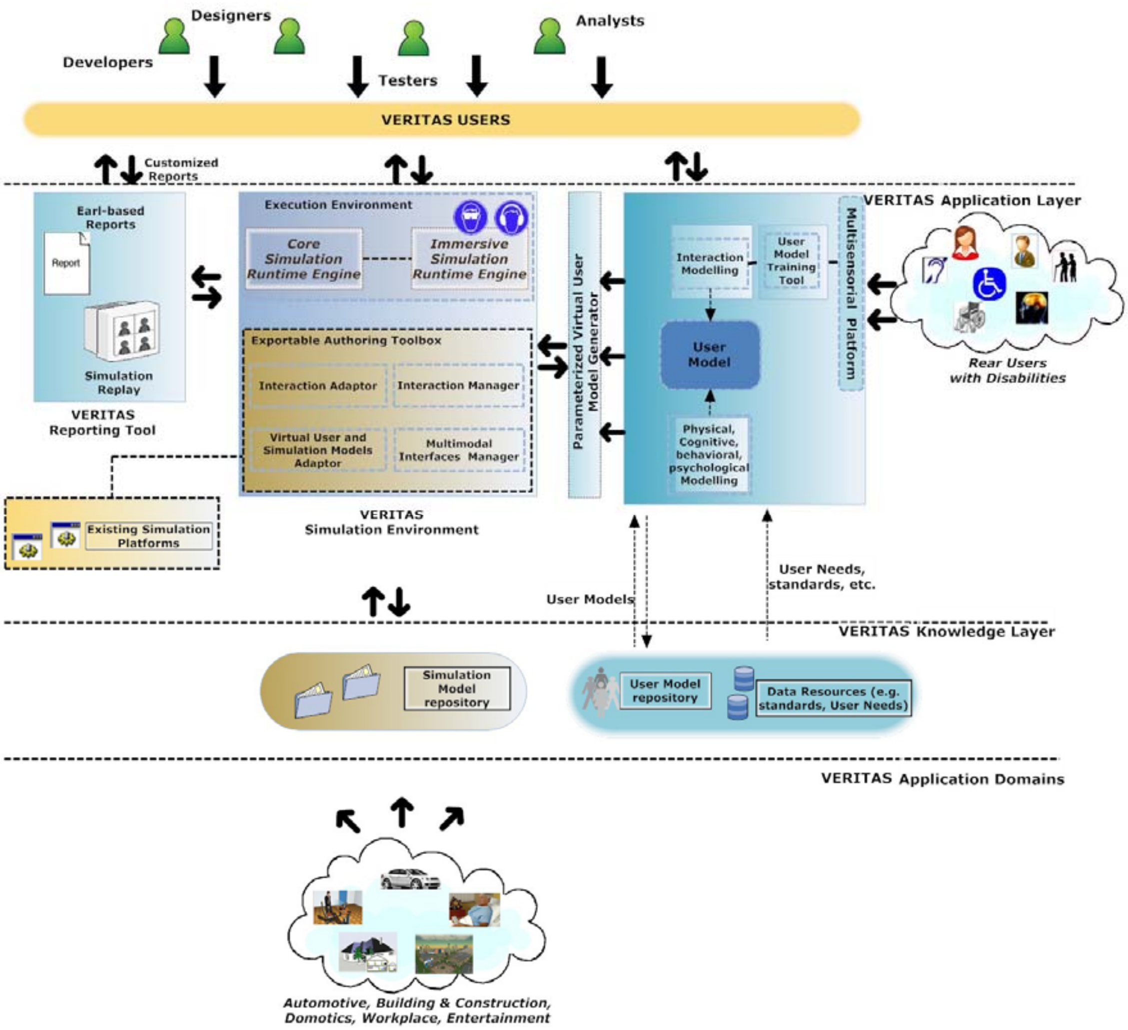

Figure 4 VERITAS architecture

The user models are generated based on the analysis of user needs, existing models (physical, cognitive, behavioural and psychological), guidelines, standards, methodologies and existing practices but also based on a multisensorial platform designed and implemented within VERITAS that will "sense" the needs of real users with disabilities by measuring their behaviour in simulated environments referring to the applications areas targeted by the project as described in Sections 3.2 and 3.3 respectively.

The open simulation platform includes the core simulation runtime engine and the immersive simulation engine that are analyzed in Sections 3.4 and 3.5 respectively. Additionally, an exportable toolbox will be developed supporting access to the virtual user and simulation models of VERITAS as well as supporting interfacing with the virtual environments of external to VERITAS applications. Finally, the simulation scenarios (simulation models) for the VERITAS application areas will be designed and integrated in a common framework with the VERITAS simulation platform and with external design and/or simulation platforms.

The development and testing of the VERITAS application test-bed will be comprised by ICT and non-ICT scenarios in the automotive, smart living spaces, workplace, infotainment and personal healthcare sectors. Iterative testing of specific designs with virtual users will be performed for all application scenarios, while results are provided through EARL based reporting.

3.2 Virtual user modeling

The VERITAS user modelling methodology is being built based on four major building blocks that are the following:

- Task Models
- Abstract User Models
- Generic Virtual User Models
- Virtual User Models (implemented in VERITAS as personas)

Abstract User Models

The Abstract User Models refer to a high level description of potential users. They are developed with respect to several specific disabilities and are broken down according to the disability category, i.e. cognitive user models, physical user models, behavioural & psychological user models. An abstract user model, that will be stored in ontologies, will include several disability related parameters like disability description, disability metrics, ICF functional abilities, etc.

Generic Virtual User Models

A Generic Virtual User Model describes a set of users having a specific set of disabilities. In a Generic Virtual User Model the description is also augmented with actions (primitive tasks) that are affected by the specific set of disabilities. For instance, for users with hemiplegia actions that are affected by the disability could include gait, grasping, etc.

Virtual User Models

A Virtual User Model describes an instance of a virtual user (e.g. Persona) that will be synthesized in the VERITAS “Virtual User Model Generator”. All the disabilities of the user are included in the Virtual User Model as well as the affected actions (primitive tasks). They also include several disability-related parameters describing the severity of the disorder. For instance, the value of the gait cycle for a specific virtual user who suffers from spinal cord injuries, is 2.1 sec, etc.

Task Models

The actions that are being systematically performed in the context of the five VERITAS application areas are described within the task model. Moreover, these tasks are developed using a hierarchical approach. Thus, high level tasks are related to more complex abstract actions, e.g. driving, and are broken down into simpler tasks, e.g. steering, and primitive tasks, e.g. grasping.

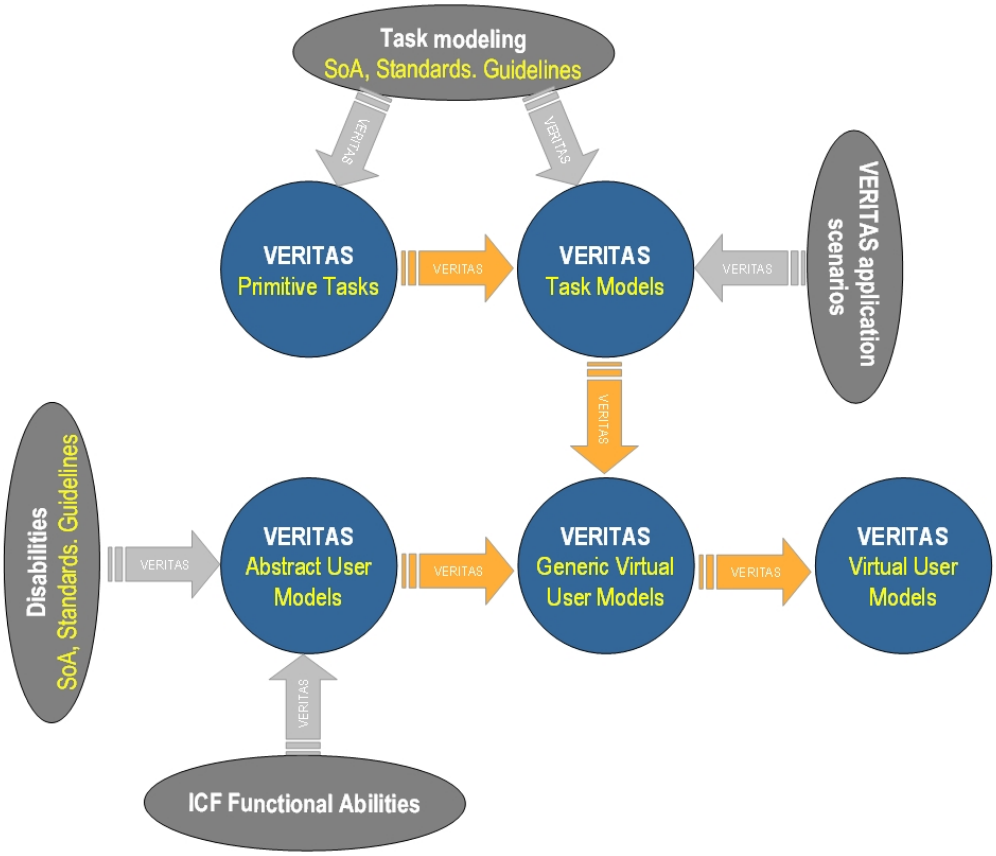

Figure 5 VERITAS User/Task Modeling Methodology

Figure 5 illustrates an outline of the VERITAS user modeling methodology. The development of the user models can be performed in four distinct but interrelated steps:

1. The VERITAS Abstract User Models are initially formed by examining the current state-of-the-art, existing standards and guidelines related to several disabilities.

Moreover, this information is augmented utilizing the WHO ICF functional abilities framework.

2. The VERITAS Task Models are developed for the five VERITAS application scenarios and are reflecting the actions that are systematically performed by the users in the context of these scenarios. They follow a hierarchical structure from high level tasks to low-level primitive tasks. It is very important to have a limited but sufficient number of primitive tasks, since they will be related to disabilities.

3. The Generic Virtual User Models refer to a specific category of virtual users and can be comprised from one or more Abstract User Models, e.g. a Generic Virtual User Model can include the propanopia and hemiplegia disabilities. They also include description on how the specific disabilities affect the execution of specific tasks (primitive or not) that are described in the task models.

4. Finally, the Virtual User Models are instances (virtual users, Personas) of the Generic Virtual User Models and describe a specific virtual user with specific disability related parameters. They will be synthesized in the VERITAS “Virtual User Model Generator” and will follow the needs and requirements of specific accessibility evaluation application scenarios.

As it can be assumed by the above description and methodology, VERITAS follows a top-down approach, where initially at the top-level the Abstract User Models refer to descriptions of specific disabilities, described via ontologies that can be potentially used-extended by the broader community. In the mid-level of the hierarchy the Generic Virtual User Models refer to description of specific classes of disabled user exhibiting the same kind of disability. Here the User Models are also related to the Task Models that refer to actions performed in the five VERITAS application scenarios. The results of this level could also be potentially used by the broader community for applications that are however relevant to the five VERITAS applications scenarios. On the bottom-level of the hierarchy, the Virtual User Models refer to instances generated for a specific application scenario and for specific accessibility evaluation needs and requirements.

3.3 The multisensorial platform

There is often a difference between how people interact with a product or application interface and how the designers intended people to interact with it. Sometimes this leads to errors that have to be corrected, on other occasions it will not lead to errors but to suboptimal functioning of the application. What should we model then, the actual usage or the intended usage? While some say we should better model exactly what the real user does, others think this is impossible because in most development and design processes we don’t have the participation of real users and developers, or designers they often don't know what a real person should do or how end users with disabilities should react with the produced products. This is why most existing modelling tools only model error-free, "designer or developer and expert" behaviour instead of modelling real user’s behavior.

One of VERITAS' innovations with respect to virtual user modelling is the introduction and use of a multisensorial platform for the training of parameterised user models based on real user measurements in real testing conditions. In order to optimise the virtual user modelling process, VERITAS provides an integrated and innovative mechanism of task-based analysis to validate, update and train the parameterised user models developed in VERITAS, based on real user measurements in real testing conditions (with the participation of users with disabilities from the VERITAS consortium). The multisensorial platform is fully parameterized and adapted to the VERITAS application areas and will be used to capture user feedback while executing a number of tasks that will be mapped in the VERITAS virtual user models. Special sensors will be used for data capturing ranging from face monitoring cameras for driver monitoring to wearable sensors for body motion analysis, to motion trackers and gait analysis sensors for analysing user kinematic patterns while executing specific activities and tasks and also to environmental sensors for monitoring the interaction of users with the real environment. Thus, within VERITAS, the virtual user models will be iteratively trained and verified by people with disabilities in real testing conditions and with real end users, utilising the VERITAS multisensorial platform.

The common framework in this capturing of user interaction characteristics will be to provide parameterized modeling of the users so as to allow the automated and (if needed for testing) quasi-random generation of a large pool of virtual users that will comprise the test-bed subjects for the simulated accessibility evaluation of the ICT or non-ICT products. Such user-centric approach, where technology builds as an ambient network around the user (body area, then personal area, and then surrounding/public area), is at the core of VERITAS.

3.4 Simulated accessibility evaluation

The end users of the platform (designers and developers) will access the simulation platform through the external applications they typically use to develop their prototypes. They will be provided with two options of simulated accessibility assessment; either through the VERITAS core simulation platform; or via the immersive simulation platform, where the designer will be placed in the position of the beneficiary (E&D). Moreover, developments should go one step further by allowing smart and accessible product design and evaluation, where the designer will be able to use the available designer/developer aids, assistive technologies and/or adaptive interfaces so as to directly design accessible and interoperable solutions that will be assessed in the simulation platform concerning their accessibility.

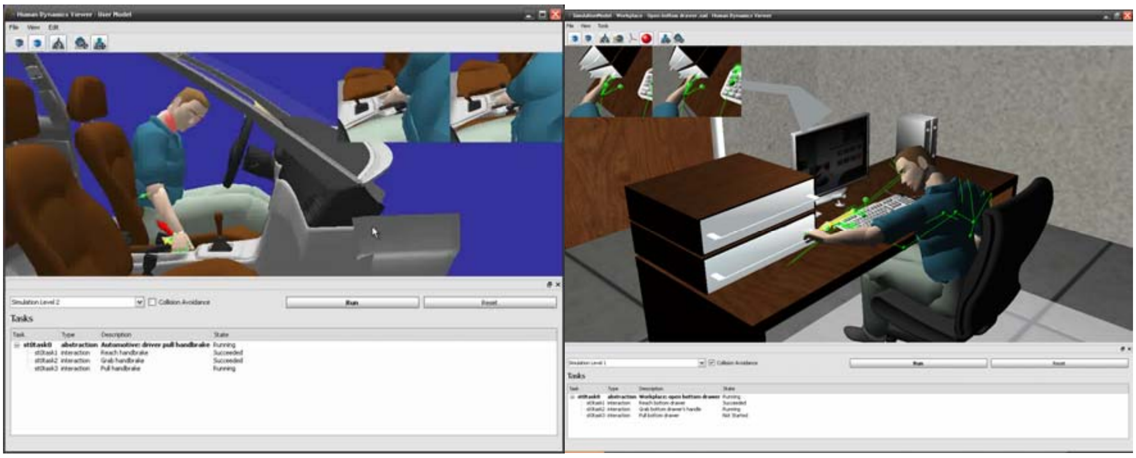

Figure 6 Simulated accessibility evaluation

In general, the simulation platform is foreseen as the major accessibility assessment utility. The role of the simulation platform is outlined in the following:

- **To develop an Open Simulation Platform (OSP)** for virtual reality simulation and testing of new products at all stages of iterative product planning and development, i.e. specification, design, development, validation and testing.
- **To provide simulated accessibility evaluation in virtual reality and immersive virtual reality environments.** Used by designers and developers to assess the accessibility and main interoperability issues of their designs and virtual prototypes. It should be emphasized that physics based simulation is performed for the motor tasks using inverse dynamics, while cognitive and behavioural aspects should be covered through probabilistic models
- **To define measures and metrics for evaluating accessibility** for every application scenario during design and development through VR simulation (graphs, statistics, distance metrics in general).

3.5 Virtual reality simulation

The VR simulation platform is the fundamental module of VERITAS for providing simulated accessibility evaluation of designs, prototypes but also of the environment. The simulation platform will further develop existing technologies, while it will also provide to the designers, interaction tools for simulating the behaviour of the E&D in an immersive environment.

VERITAS will adapt the VR simulation platform to the specific simulation and interaction needs raised by the project objectives, thus generating an ultimate accessibility simulation and assessment environment. The VR simulation platform will provide to the user simulation capabilities using immersive VR and providing to the user-developer a simulation scenario where he/she would interact with the virtual environment as if being a user with disability with a specific profile, thus directly testing the accessibility of the environment.

The Immersive Simulation Platform of VERITAS will be used for virtual user simulation and will offer the designer/developer the possibility to experience the simulation from the position of the user. This design paradigm, based on the notion of the Virtual User, could be described as “What You See Is What Other People Get –WYSIWOPG-, that is to say, developers may have a clear view of the interaction perceived the end user with disabilities when interacting with a product in the development stage. Immersive simulation will offer realistic and iterative testing facilities to the designer as well as multimodal (visual, aural, etc.) feedback in order to support virtual user testing (putting the designer in the position of the user). Using the immersive platform the designer will be able to experience in a realistic way the interaction of a user with disability with the designed environment and assess accessibility both as an observer and as a participant to the simulation.

Figure 7 Accessibility evaluation at the immersive platform of VERITAS partner FhG/IAO

4 Beyond VERITAS

VERITAS demonstrates undoubtedly the first attempt towards simulated accessibility evaluation via the use of virtual reality and realistic modeling of virtual humans with disabilities. However, due to the fact that this particular research domain is highly interdisciplinary, ranging from medical analysis, to user modelling, ICT, realistic simulation and virtual reality, there are several areas identified, where innovative research could provide groundbreaking results and lead to embedded and context aware accessible designs for ALL. Below the most prominent technologies are briefly discussed.

Dynamic virtual user models

One of the major research challenges is to move from a static approach with respect to user modelling to a dynamic one, where the virtual user models will be continuously updated taking into account user interactions, preferences and real-time accessibility needs.

The dynamic VUM repository will provide the information about specific virtual user models to the application designers, while it will also receive information on the interaction history, user profile update and customization that will be contextualized using the information received by the environment related to physical measurements and interaction context. This iterative procedure can be seen as a “measurement loop”. Moreover, the dynamic VUM platform will continuously perform an off-line optimization procedure that will use the interaction and environmental measurements, of the mobile platform and AmI infrastructure, respectively, and map them to the virtual user model specific parameters. Then it will iteratively perform training of the virtual user models according to specific interaction contexts. This procedure, “VUM optimization loop”, will result to dynamic up-to-date virtual user models that will be subsequently used whenever required.

Iterative “on the move” optimization

One of the major grand challenges identified by the VERITAS partners is the introduction of a mobile simulation platform, which could be potentially a sub-set of the core simulation platform that will automatically and without user intervention perform automatic *interface* accessibility assessment tests, interface optimization and iterative adaptation, based on the dynamic virtual user models, the environmental measurements and contextual information.

Initially, a multivariate accessibility metric should be defined that will provide quantitative accessibility evaluation scores taking into account specific interface characteristics and the parametric virtual user model. The metric will be multivariate in terms of providing local metrics for different variables, like interface object type, interaction modality, environmental variables, etc., while all local metrics will be integrated into one global metric. The local and global metrics will be estimated for a specific interface, a specific virtual user and the relevant environmental set-up, by the “context-aware personalized assessment” module. Then, “template-based adaptation recommendation" will be performed by estimating the accessibility metric in the local neighbourhood of the parameter metric space that will result in the estimation of the gradient (i.e. tendency) of the multivariate accessibility metric with respect to small variations of several parameters. In other words, the mobile simulation platform could potentially evaluate the accessibility (through the accessibility metric) for interfaces that are similar but not identical to the interface proposed by the "interface adaptation module" and will then provide an indication to the latter on the possible modifications that could improve the accessibility of the interface. Finally, after this iterative procedure has been finalized, in close-to-real-time, the optimal, personalized and context-aware interface will be provided.

Smart adaptive interfaces

Smart adaptive user interfaces should support high-level accessibility of ICT products and services in daily life. On the basis of a specific user profile from the virtual user model (VUM), the Adaptive Interfaces Platform should put together proven user interface components to an individualised user interface which will fit the specific user requirements and constraints.

The approach to adaptive user interfaces should support users also in a smart AmI environment where an extremely large number of options can lead to quite complex interactions. An interface that directly offers all the possibilities to the user may result cumbersome and complex. Smart adaptive User Interfaces (UI) that will be provided in different portable devices will be able to adapt themselves to the changing habits, preferences and requirements of the user in terms of the presentation and interaction modes, and based on the past choices made by the user within changing daily environments.

Figure 8 Dynamic, on-the-fly, smart interface adaptation

The user interfaces should adapt to the gradual development of an individual user profile that reflects long-term changes in the physical, perceptual and mental state of the end user and the increasing completeness and reliability of the user profile which is refined during the time of use. Moreover, it should also react to short-term variations in the current context of use including the presence of other users or objects of personal interest. Multimodal as well as implicit interaction modes should be also covered in order to account for individual user needs and changing environmental context conditions (ambient intelligence / ambient interaction/adaptation)

Besides automatic user interface adaptation, the foreseen smart adaptive user interfaces should provide the possibility for manual individualization. This helps users and their relatives, carers or alike to keep control over the user interface appearance. For this purpose, the user profiles/models as well as the user interface profiles can be viewed, modified and completed manually. Thus, the user can change for example the background colour, font size, structure of some user interface elements, font colour, etc. from the UI template as provided by the Adaptive Interface Platform. Figure 8 indicatively illustrates interface adaptation examples for four different application scenarios.

Seamlessly operating products

Of significant importance for the emerging accessible designs and technologies is to provide seamless roaming of the individuals between different domains of daily life, by retaining dynamic time-varying needs, temporal habits and accessibility constraints. Such prototypes should be interoperable and should be transparently connected to the AmI, while they should also provide sufficient mechanisms to allow for adaptive device control and information presentation/rendering. During run-time, the prototypes, the AmI should communicate so as to dynamically provide optimal interaction and interfacing solutions to the users.

Holistic cognitive-behavioural-motor modelling

A key research technology that should be mentioned is the making of user models a step beyond VERITAS, in the sense that they fully integrate cognition and physics. In other words further research and efforts should be addressed to produce some kind of «copy» of human beings that reproduces cognition, decision, motion planning, motor control and physical movement. Such kind of model would be able, for example, to produce itself the task tree to achieve a goal, to plan primitive movements, to execute and adjust them, and to ultimately interact in a realistic humanlike way with objects and interfaces.

Such kind of virtual user (call it a digital human) will produce motion primitives and solution strategies that are influenced by it own capabilities. Therefore user behaviour and tasks will emerge from user capabilities and goals (just like for real human beings). As an example, consider the goal of grasping an object. A holistic cognitive-motor virtual user that has some limitation in the mobility and control of hands resulting from, say, from Hereditary Motor Sensor Neuropathy (Charcot Marie Tooth disease) will produce workaround strategies for grasping and grasping patterns that (if the model is accurate enough) resembles the ones people with that disability use [1]. Another example is the emergence of gait patterns: a holistic cognitive-motor virtual user will walk according to its own capabilities, for example include spasticity.

Attempts to replicate human behaviour in such way have been carried out with some success with Cognitive System in limited domains. For example, the project DIPLECS [6] developed an Artificial Cognitive System that “learns by watching humans, how they act and react while driving, building models of their behaviour and predicting what a driver would do when presented with a specific driving scenario”. This learning process can be seen as the process of making a «copy» of the human driver (in this case limited to driving task). The technology used in the above project is a *subsumptive* [7] Perception-Action architecture [8],[9].

For making humanlike holistic virtual users, other methodologies could also be used and integrated as well, raging from cognitive architectures [10], to multibody system dynamics (*e.g.*, [11] available for free), to optimal motion planning etc. Concerning optimal control, motion primitives in writing have been derived by Viviani [12] based on optimal control and minimum jerk principle. Further evidence that sensory-motor strategies customized for goal at hand, emerge from objectives, constraints by application of optimal control principles [13].

Lastly, it is necessary to improve the understanding of low-level cerebellum motor primitives, and of the control of muscles, including spasticity and tremors. As an example a model of muscle control and tremor in Parkinsons’s disease is give in [14].

In conclusion, further research is needed beyond VERITAS to advance the methodologies that allow to model human behaviour in a holistic way. What is needed is to model the complete cognition-motor chain. So far, fine models exist for the kinematic and dynamics of human body. However such models present a large number of degrees of freedom and the problem of how to move them in a human-like fashion exists. Knowledge is fragmentary about motor primitives in the human cerebellum, how these motor primitives are triggered by upper level goals, how human being plans movement, how strategies emerge from goals, how cognition and psychological states can be integrated etc. A lesson that can be learnt from driver models is to organize digital human models into several layers, from high-level psychological level down to low-level kinematics. When a technology to make such digital human copies will be available, context awareness and adaptive interfaces would also benefit, because there will be models to be used for adaptation process.

5 VERITAS as a spark for embedded accessibility designs

VERITAS demonstrates the first attempt towards simulated accessibility evaluation of designs using virtual user models for a large variety of disability categories. Even if this objective per se requires heavy research efforts in multidisciplinary domains, VERITAS envisions that this effort will be just a spark for a large outbreak of research and development targeting embedded accessibility designs.

In this context, taking into account the ongoing research performed within VERITAS the following research activities are expected to result in high-payoff research:

- Virtual user modeling taking into account measurements with real users so as to provide realistic virtual user databases to be used in tests in all phases of product design and development
- Simulated accessibility evaluation for the exhaustive accessibility assessment of ICT and non-ICT designs using virtual users.
- VR simulation for putting the designer in the position of the end-user

Moreover, future activities in simulated accessibility designs should mainly focus in the following areas:

- Dynamic virtual user modeling
- Real-time on-the-move simulation and interaction optimization
- Smart adaptive interfaces
- Seamlessly operating products
- Holistic cognitive-behavioural-motor modelling

Taking also into account that the AmI infrastructures ranging from “AmI at home”, “at work” or even “on the move” are being currently a hot topic in the European market, the next generation of research on accessibility is expected to provide seamless roaming of individuals, either able-bodied or disabled in different environments, while the provided products and services will be aware of their real-time dynamic accessibility needs, diminishing this way the gap of current technologies from the theoretical targets of the “Design for All” concept. Towards this grand challenge, VERITAS takes the first step by introducing virtual user modeling for the simulated accessibility evaluation of ICT and non-ICT products in virtual environments and is thus expected to boost research and development in the field of embedded accessibility designs.

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