Involving All Stakeholders in the Development of TV Applications for Elderly

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Abstract- **The development of new digital TV systems and the design practices adopted in the development of new TV based applications often isolate elderly and disabled users. By considering them as users with special needs and not taking their problems into account during the design phase of an application, developers are creating new accessibility problems or just keeping bad old habits. In this paper, we describe a novel adaptive accessibility approach on how to develop accessible TV applications, by making use of multimodal interaction techniques and without requiring too much effort from the developers. By putting user-centered design techniques in practice, and supporting the use of multimodal interfaces with several input and output devices, we confront users, developers and manufactures with new interaction and design paradigms. From their evaluation, new techniques are created capable of helping in the development of accessible TV applications, with special interest for a novel way of acquiring and providing knowledge from and to the users with an application called User Initialization Application.**

Keywords–multimodal; adaptation; developers; elderly; user initialization.

I. INTRODUCTION

Ageing is certainly an obstacle to adequate human-computer interaction, mostly because of physical and cognitive impairments. Traditional computational systems only provide keyboard and mouse interaction to users. This makes impossible, for example, for users with severe motor impairments to interact in any manner (at least effectively). Also, as recent developments are responsible for new television (TV) systems and applications, unimodal interaction is still being favored without accessibility concerns, excluding persons whom suffer from an impairment of the sensory channel needed to interact. This situation brings social exclusion and e-exclusion to the Human-Computer Interaction (HCI) world and new TV platforms, as it seriously restricts actions and information access to users with impairments (like the elderly), providing means of interaction exclusively for the so called "normal users". However, multimodality can resolve this issue by offering the possibility of presenting content in many ways (audio, visual, haptic), and in the most suitable way to each user's characteristics. Also, by offering users the possibility to use the inputs more adequate to them (or the context of interaction), in a single or combined manner, multimodal interaction can improve interaction efficiency and, more importantly, accessibility.

Multimodal interfaces aim to provide a more natural and transparent way of interaction with users. They have been able to enhance human-computer interaction (HCI) in many numbers of ways, including: User satisfaction: studies revealed that people favor multiple-action modalities for virtual object manipulation tasks [14]; Oviatt [17] has also shown that about 95% of users prefer multimodal interaction over unimodal interaction; Robustness and Accuracy: "using a number of modes can increase the vocabulary of symbols available to the user" leading to an increased accessibility [15]. Oviatt stated that multiple inputs have a great potential to improve information and systems accessibility, because by complementing each other, they can yield a "highly synergistic blend in which the strengths of each mode are capitalized upon and used to overcome weaknesses in the other" [18]; Efficiency and Reliability: Multimodal interfaces are more efficient than unimodal interfaces, because they can in fact speed up tasks completion by 10% and improve error handling and reliability [16]; Adaptivity: Multimodal interfaces also offer an increase in flexibility and adaptivity in interaction because of the ability to switch among different modes of input, to whichever is more convenient or accessible to a user [15]. However, Vitense [20] illustrates the need of additional research in multimodal interaction, especially involving elderly people. This paper tries to extend this knowledge.

Also, the majority of current approaches to the development of multimodal or adaptive systems, either addresses specific technical problems, or is dedicated to specific modalities. The technical problems dealt with include multimodal fusion [10], presentation planning [10], content selection [12], multimodal disambiguation [18], dialogue structures [3], or input management [9]. Platforms that combine specific modalities are in most cases dedicated to speech and gesture [19], speech and face recognition [11] or vision and haptics [13]. Even though the work done in tackling technical problems is of fundamental importance to the development of adaptive and multimodal interfaces, it is of a very particular nature, and not suited for a more general interface description. Also, frameworks supporting the development of interfaces for various devices exist; however, they do not consider the specificities of multimodal interaction in its design [5][6]; or they focus only on the use of the same modality in different devices [1]; or they ignore the possibility of adapting the components properties and features in run-time placing the burden on the designer [4]. In general, they do not consider in there architectures the introduction of modalities, and how they can be explored to achieve the goals of Universal Access.

In the following, we first explain how European funded project GUIDE [7], aims to adapt interaction and UI presentation to fit each user's characteristics and level of expertise. Also, resulting from specific user trials and discussions with developers, we also show how it makes use of a User Initialization Application to know and instruct its users, and how it supports adaptation by providing developers with solutions for UI modification, and tools for helping in the development of new user-centered and accessible applications. All this attending to user needs and differences, at the same time as it takes into consideration the developer's interests.

II. CHARACTERISTICS OF GUIDE PROJECT

A. *End-Users and Goals*

GUIDE [7] (figure 1) aims to achieve the necessary balance between developing multimodal adaptive applications for elderly and disabled users, and preserving TV and Set-Top Box(STB) developers/manufacturers design methodologies and efforts. Consequently, there are clearly two different end-users of this project: elderly and impaired users and developers of TV based applications. Creating a bridge between these two, we have also the STB manufacturers who dictate the rules about which type and which characteristics of applications can be used on a TV based environment. Firstly, for elderly and users with impairments, GUIDE has the goal of providing new ways of interacting with a TV, by applying multimodal interaction, supporting the use of different devices as well as different combinations of input and output techniques, and adaptation to each application's UI an each user's way of interaction. In other words, elderly or impaired users who are having difficulties interacting with modern TV systems because of their complexity, will be able to interact in a more intuitive way, using alternative modalities in a single or combined fashion, while each interface characteristics will also be adapted to fit user's characteristics automatically. For all this, GUIDE has as a clear defined target environment, a STB connected to a TV in user's home (and closed) environment. Secondly because developers tend to have no concerns about accessibility when designing TV applications, GUIDE has to be capable of reducing development effort in a radical manner. For that end, GUIDE wants to create a toolbox for accessible applications and UI design, shifting the design principle from a conventional user-centered design process to a GUIDE-assisted design and development process. Through all this, GUIDE also wants to ensure that developers (and also manufacturers) can maintain the control over the modifications made on their own applications UI. Meaning, the adaptation provided by the system for adapting interfaces to user characteristics must have boundaries that cannot be crossed. And these boundaries are defined by the developers.

B. *Multimodal Interfaces and Devices*

Input modalities to be supported in GUIDE are based in the more natural ways of communication for humans: speech and pointing (and gestures). Complementary to these modalities, and given the TV based environment, the framework should support the usage of remote controls and other devices capable of providing haptic input or feedback. As a result, GUIDE incorporates four main types of UI components (figure 1): visual sensing and gesture interpretation; audio; remote control; haptic interfaces and a

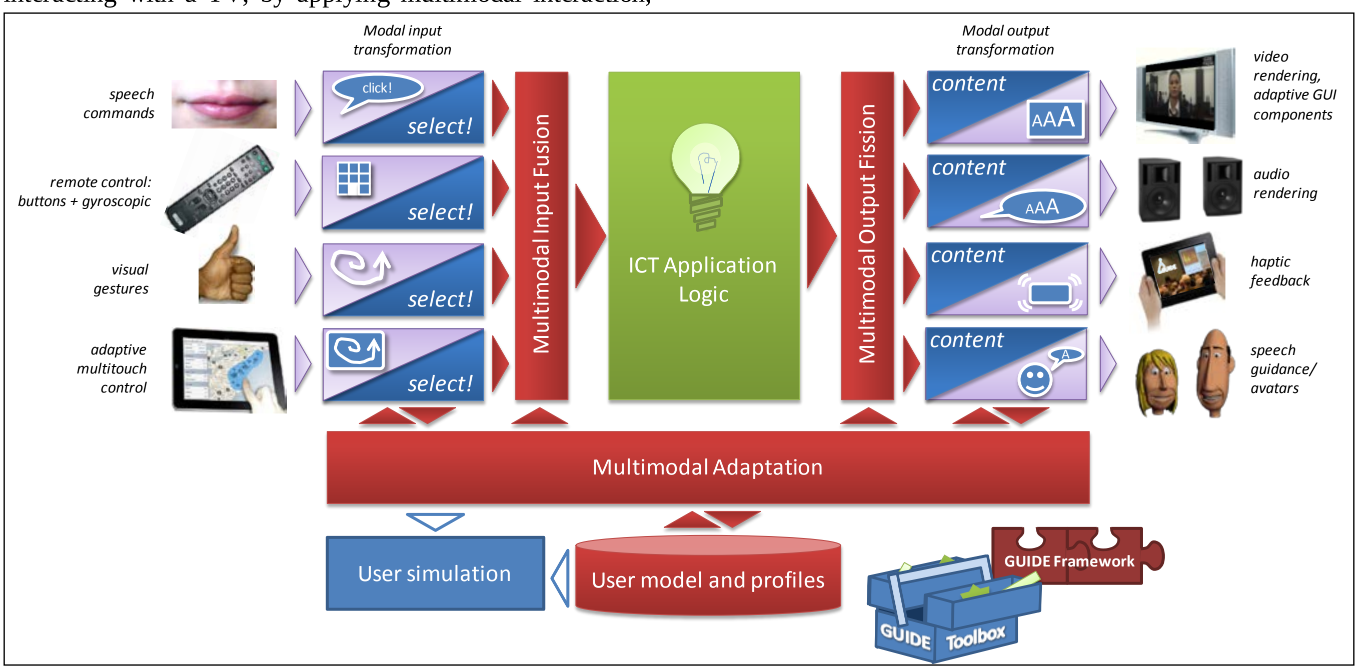

Fig 1. Features in GUIDE

multi-touch tablet. In what concerns the output modalities, the framework should consider and integrate the following output components: video rendering equipment (TV); audio rendering equipment (Speakers); tablet supporting a subset of video and audio rendering and remote control supporting a subset of audio rendering and vibration feedback. A tablet may also be used to clone the TV screen or complement information displayed on the TV screen but essentially is used as a secondary display. The main user interface should be able to generate various configurable visual elements such as text (e.g., subtitles or information data), buttons for navigation purpose, images and video (e.g., video conference or media content). Additionally also a 3D avatar is generated and expected to play a major role for elderly acceptance and adoption of the GUIDE system, being able to perform non-verbal expressions like facial expressions and gestures and giving the system a more human like communication ability.

In order for the UI to be adapted to the user's needs, these elements are necessarily highly configurable and scalable (vector-based). Size, font, location, and color are some attributes needed to maintain adaptability. These graphical elements enable the system communication with the users by illustrating, answering, suggesting, advising, helping or supporting them through their navigation. Also, both input and output modalities can be used in a combined manner to enrich interaction and reach every type of user.

C. *Discussion: What GUIDE needs to know*

For reaching its goals, GUIDE has to define a framework structure and collect information by asking and testing its end-users. So, the following questions have to be answered: What components the GUIDE framework has to have? What are the main preferences and typical behavior of elderly users when interacting with the system, and how to collect these preferences? How to perform automatic UI adaptation? How to help developers and manufactures in design process?

III. Learning From End Users

To get answers to the questions above, we firstly derive end user requirements from results obtained through a quantitative and qualitative analysis of data recorded in comprehensive user trials [8]. Secondly, we organized focus group sessions with developers and used an online survey as qualitative research tools in gathering additional requirements from developers and STB platform providers

A. *Initial User Trials*

The GUIDE project pursues a User Centered Design (UCD) process, taking into account that one of the main principles that characterize UCD is iterative design. According to this principle the system is designed, modified and repeatedly tested. This iterative cycle allows the designers to think in the product design and include the changes needed depending on the users' feedback. Following this approach, an initial study to elicit user requirements has been carried out.

1) *Main Objectives*

Additionally to the identification of viable usage methods (gestures, command languages) of novel traditional UI paradigms for the different impairments in the target groups via user studies in realistic user scenarios, this user trials also have the goal to generate quantitative and qualitative user data in order to establish and construct a generic user model. This user model will provide data representations for each user and will constitute the first step for adaptation in GUIDE, and will "virtualize" user impairments to try to capture the amount of knowledge needed for application design.

Fig 2. Test Application used in the technical user trials.

2) *Organization and Setting*

The initial user studies carried out can be divided in two different categories; one survey session and one technical trials session. While the aim of the survey was to collect qualitative information about application acceptance, user habits and modalities of interaction, the objective of the technical trials was to gather both quantitative and qualitative data and observe the interaction between the elderly and the system, performing simple tasks in the context of TV interaction. In this Test Application (figure 2), the users had the opportunity to experiment the different modalities and devices of interaction (table 1), and the tests were divided in several scripts concerning different types of interaction, or different UI elements and GUIDE aspects (table 2).

Device/Modality of Interaction	Input and Output on the User Test Application
Remote Control	Button selection (input)
Wii Remote + Wii Sensor Bar	Pointing, gesture and button selection (input)
Kinnect + Kinnect Sensor (originally a Led Camera Sensor)	Pointing, gesture and button selection (input)
Avatar Engine	Audio and visual output
Speech Synthesis	Audio output
Simulated Speech Recognition (Wizard of Oz)	Audio input
Tablet (Apple's IPad)	Touch screen input and visual and haptic output.

Table 1. User interface components used.

Type of tests	Task to perform	Devices (modalities) used
Modalities and devices experimentati on	Answering to questions related with preferences of interaction, experimentation of each device and modality. Menu items selection and navigation.	Input: Remote control, Wii remote, Kinnect. Output: Visual menus and Avatar
Visual capabilities and preferences	Answering to questions related with interface visual configuration (font size and colour, background colour and button size and location tests). Menu items selection and navigation.	Input: One or more devices chosen by the user. Output: Visual menus
Audio capabilities and preferences	Answering to questions related with audio preferences (audio volume)	Input: Speech Output: Audio
Cognitive capabilities	Localization of different items on the screen (cognitive scientific tests), Measuring time of response	Input: Speech, Wii Remote, Kinnect Output: Visual menus and pictures
Motor capabilities and preferences	Performing gestures. Menu items selection and navigation. Interacting with the Tablet. Answering to questions related with motor preferences and pointing mechanisms.	Input: Wii Remote, Kinnect, Tablet Output: Visual menus
Avatar preferences	Interacting with the Avatar. Answering to questions related with Avatar preferences.	Input: One or more devices chosen by the user Output: Visual menus, Avatar
Multimodal preferences	Menu items selection and navigation. Simulation of application contexts of use. Answering to questions related with multimodal interaction and preferences.	Input: One or more devices chosen by the user. Output: Visual and Audio menus, Avatar

Table 2. Modalities, tasks and devices.

In [8] you can find a more extensive description of the tests performed.

B. Developer Focus Groups and Survey

The GUIDE system is not exclusively focused on elderly users, but also centered in developers of TV based applications and manufacturers of STBs. For this reason, major discussions regarding subjects like adaptation, elderly user's interaction, type of applications, and developers requirements for making possible the GUIDE ideas, has taken place in this evaluation, by performing both focus group with these end-users and by launching an online survey with the same user target.

1) Main Objectives

The general goal is to explore and understand the common practice among developers working on STBs. Thus the first objective is to gain data about current tools and APIs used in Set top box/connected TV platforms and to investigate how accessibility is currently perceived and applied in the industry. Secondly, exploring developer knowledge to identify which tools would developers need to efficiently integrate GUIDE-enabled accessibility features into their applications. Additionally, stimulate new ideas through discussions and to identify new relationships between objects embodying GUIDE concepts and objects embodying common practice. And finally, inform STB application development community about GUIDE.

2) Organization and setting

Developer Focus Groups: Two focus group sessions were carried out with connected TV platform providers and developers of applications and user interfaces deployed on STBs in a natural and interactive focus group setting. The sessions were conducted by two moderators (for ensuring progress and topic coverage) and each focus group session had between six and eight participants and lasted between 120 and 150 minutes. Sessions were initiated with presentations of scripts containing development and use cases that cover different aspects of the GUIDE project and its concepts. Presentations of each development case script lasted 10 minutes and were followed by 30 minutes of interactive brainstorming, and discussions.

Developer Online Survey: A questionnaire was designed to investigate how accessibility is currently perceived and applied in the industry. In addition, the survey was used as a medium to let respondents vote on the most important features of the envisaged GUIDE framework and toolbox.

Both survey and focus group were composed by the following participant types: STB test developers, STB experts in Innovative part, Flash application developers, HTML developers, middleware STB developers, architects in STB platforms, GUI developers for STB, project managers for STB projects, managers in Innovative projects for STB, product and marketing managers, research community, and standardization bodies and related organizations. In total, 81 participants from 16 countries, and 30 companies all over the world, participated.

C. Results and Conclusions

From the realization of both initial user-trials and developers focus group (and online survey), we now summarize qualitative results which will work as starting points for the next section of this paper:

1) User Survey Results

The large numbers of variables contained in the data set were submitted to a two-stage process of analysis where correlations were made and a k-mean cluster analysis [2] was performed, reducing the results to only significant data (why we used the variables listed below are described in [9]). Resulting from this, 3 user profiles capable of discriminating differences between users were created – low, medium and high. These profiles were formed by combining and grouping all modalities simultaneously such that a specific grouping may represent capability on users perceptual, cognitive and motor capability ranges. The main differences noticed were the following measures: capability to read perfectly from close and distant vision; capability of seeing at night, and color perception; capability to hear sounds of different frequencies and to distinguish conversations in a noisy background; cognitive impairments; and mobility diagnosis like muscular weakness and tremors. Table 3 shows all the identified variables in the three profiles.

Vision	LOW	MED	HI
Close vision: level able to read perfectly	20/20	20/60	20/80
Distant Vision: level able to read perfectly (metres)	5	5	20
general eyesight	good	excellent	normal
seeing at distance	good	poor	poor
seeing at night	normal	poor	poor
colour perception	good	bad	bad
Hearing	LOW	MED	HI
Able to hear a sound of 500Hz?	Yes	Yes	No
Able to hear a sound of 2Khz?	Yes	Yes	Yes
conversation from a noisy background	excellent	normal	normal
Cognition	LOW	MED	HI
TMT (seconds) Cognitive executive function	30 (no impairment)	49 (low impairment)	136 (high impairment)
Motor	LOW	MED	HI
mobility diagnosis	none	hernia / slipped disc	none
muscular weakness	never	A few occasions	Frequently
write	No difficulty	No difficulty	Mild difficulty
Tingling of limb difficulty	No	Mild	Mild
Rigidity difficulty	No	Mild	Moderate

Table 3. Cluster centers

2) Technical User Trials Results

Big, centered and well-spaced buttons were preferred by users because they are easier to see and select (and elderly users typically have some kind of visual and motor impairments). Additionally, users prefer medium sized fonts and medium volumes for audio, but users with impairments tend to prefer bigger fonts and higher volumes. However, more than based on user abilities or preferences, both visual and audio elements configuration, depends on the interaction context and must be at all times modifiable and repeatable by the user. All the preferences described regarding visual components, reflect the low efficiency (lot of time needed for each selection) and accuracy (wrong target when selecting) registered when interacting with any type of pointing in these tests.

Users clearly preferred gestures easier to make (swipe and pinch), and have no problem whatsoever interacting by gestures. It was also evident that alternative ways of interacting with the TV (speech and finger pointing) are preferred to the traditional way. Also, training makes any type of modality more efficient as the user learns what is required to perform each interaction. However, any type of interaction should not be imposed on the users, but be available as an intuitive option for interacting with the TV. Additionally, when not used by the user intuition, modalities of interaction should be explained to the user before he or she starts using the system.

Every user is able to interact multimodally with the system and combine speech and pointing, even when they prefer only one modality. Users exhibited different multimodal interaction patterns during the trials and there is no specific interaction pattern for each user (a user can speak first and point afterwards, and in the next interaction do the opposite). Users can also change the way they interact depending on the type of feedback given while interacting. Regarding user preferences in input and output modalities, there are clear differences between what users say they prefer, and what users really ask for when interacting. In fact, 100% of the users want multimodal output every time information is presented to them, because every user who said to prefer only one type of feedback admitted differently when in specific interaction contexts. The same happened concerning input modalities, with almost half of the users admitting, when confronted with practical tasks, that they were wrong when they said to prefer only one modality.

The results obtained in these trials enforce the need of a multimodal system and also the need for adaptation, as we can see in a more detailed fashion in [8].

3) Developer Focus Groups and Survey Results

Developers agree that if users are involved in every development phase of the applications (or in the maximum phases possible), the resulting UI will be more usable. It was concluded that for elderly people UIs should be maintained clear and simple, however without giving the impression that it has been designed for someone with impairments (not leaving the feeling of a "system for seniors"). Additionally, costs are the current major reason for reduced application of user-centered design in the industry (followed by time and lack of awareness). As the current most important device on interaction with STBs, the remote control must continue to have a central role in the interaction, and should only be relegated to a secondary role if that is a result of each user interaction preferences. Gesture control and speech input are recognized as secondary technologies. In general, participants agree that automatic adaptation of user interfaces can help elderly users to access ICT services. However GUIDE adaptation mechanism should never change interface aspects unless it is mandatory for specific user interaction. Also, radical changes in the UI must be avoid so that the user feels he/she is in control and not get lost in the interface. If a radical change is indispensable the UI must inform the user of the proposed changes. Identified as the main obstacle to UI adaptation is the fact that elderly users present too many differences between each other. Therefore, for adaptation to fit each user, GUIDE has to first find a way to know his or her impairments, preferences or characteristics. This "discovery" will have to occur the first time the user interacts with the system, and will have to be short, not too much intrusive and entertaining to the user. The most important conclusion debated in this subject is the one saying GUIDE should support UI mark-up as interface between application and GUIDE adaptation. This way, developers will be allowed to keep tools and development environments and without too much additional effort, take a first step to accessible design. Web developers mostly use HTML editors as the most important tools in Web & TV development. However, having to learn new development processes will drive developers away from the GUIDE framework. So, developers should not be required to develop taken into consideration specificities of the multimodal operations but have a clear specification of how such devices interact with the framework. As it was already described in UI adaptation results, identification of UI components should be made using only mark-up language, however applications coded using dynamic HTML (through JavaScript) must continue to be able to change, remove or insert elements in the currently rendering page. Meaning, all changes in application presentation will need to be identified at run-time. For most participants connected TV platforms and STBs will be most relevant platforms in the future. Also, Web-based application environments will become more important for Web & TV. Manufactures stated increasing STBs capabilities cannot raise its price to much, or development will be more difficult and costly. Developers also pointed out GUIDE system must consider situations where multiple users are using the TV and services.

IV. Multimodal Application Development

From the results and implications reported in the previous section of this paper, we now derive GUIDE project solutions for giving answers to the same questions raised in the beginning of this paper.

A. *Multimodal and Adaptive Framework*

We now give an overview of the GUIDE framework [8] (figure 3) following an interaction cycle, starting from the

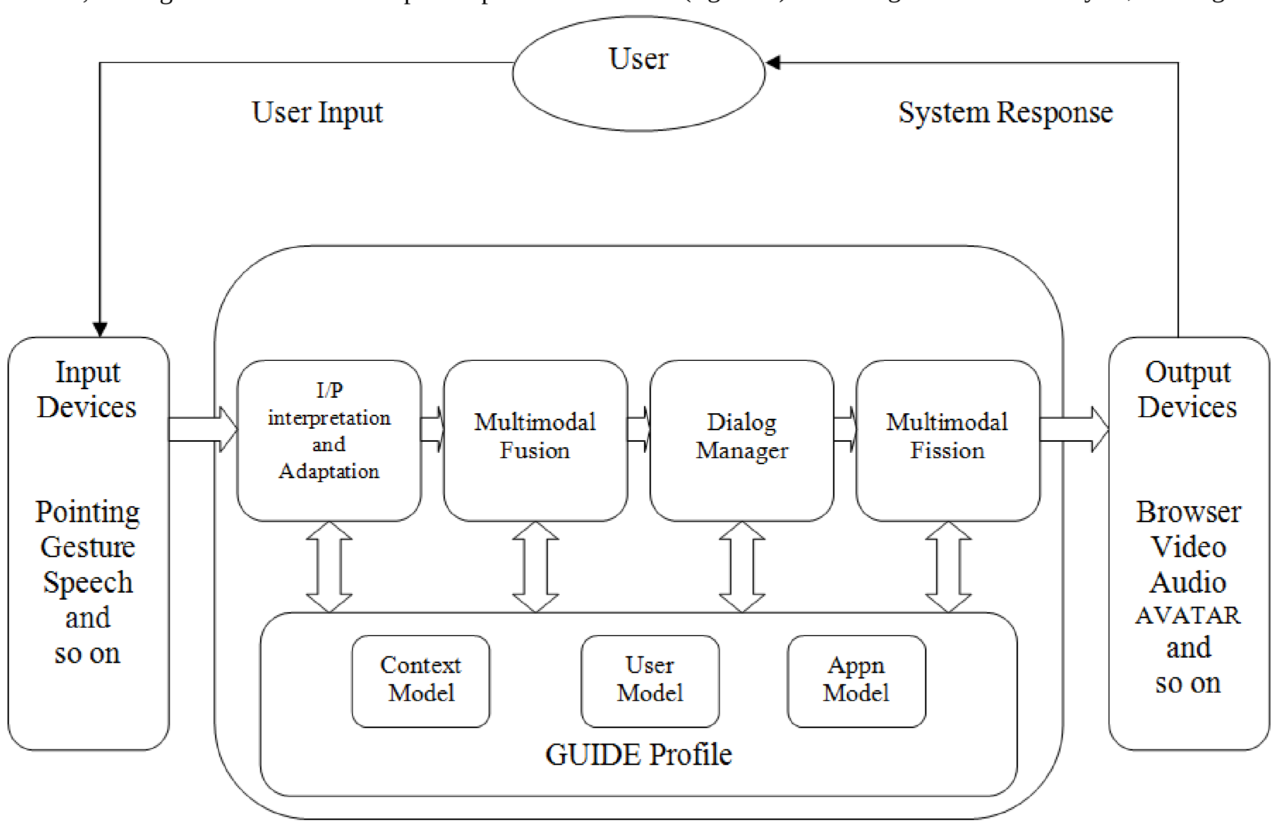

Fig 3. Multimodal and Adaptive Framework architecture in GUIDE

user input and going through the construction of the system's output to be presented to the user.

A user provides input through multiple devices and modalities which can be used simultaneously. The signals from recognition based modalities are processed by interpreter modules (e.g., a series of points from the motion sensor go through a gesture recognition engine in order to detect gestures). The signals from pointing modalities go through input adaptation modules (e.g., in order to smooth tremors from the user's hand). Both interpreter and adaptation modules base their decisions on knowledge stored in the user profile, thus improving the efficiency of noise reduction in the input signals. Then, the multimodal fusion module receives, analyses and combines these multiple streams (outputs of input interpreters and input adaptation modules, or raw data that did not go through any of these) into a single interpretation of the user command based on the user, context and application models (abstract representation of the application). This interpretation is sent to the dialogue manager who decides which will be the application's response, basing its decision on knowledge about the current application state and the possible actions that can be performed on the application in that state. The dialogue manager decision is fed to the multimodal fission module, which is responsible for rendering a presentation in accordance to which output to present (derived from the application itself and the application model), the user abilities (accessed through the user model) and the interaction context (made available through the context model). The fission module takes all this information and prepares the content to render, selects the appropriate output channels and handles the synchronization, both in time and space, between channels when rendering. This rendering is then perceived by the user, which reacts to it, and starts a new cycle by providing some new input.

B. *User Initialization Application*

In both technical user-trials and focus groups, it is the necessity of knowing every user characteristics, preferences and impairments from the first time he or she interacts with the system. This is mandatory because of the user's differences and the necessity of adapting both UI components and interaction to fit each user, as well as the necessity of instructing the user about every possibility of interaction in order to reach the maximum efficiency when using the system. GUIDE adaptation begins through a User Initialization Application (UIA) (figure 4) that allows for the acquisition of primary assumptions about the user. So, knowing that each user model contain assumptions about interesting characteristics of user subgroups, after "going trough" the UIA, a user is assigned to a user model as certain preconditions are met. From that moment on, and for any GUIDE application the user interacts with, the system is "initially" adapted to him/her. It's relevant to say that the UIA is presented to the user as a simple step-by-step configuration of a "general" interface. In each step, different types of contents and different contexts of interaction are presented, so the user can test different components and parameters, and the system learns the user characteristics, from his impairments to his preferences. Addressing the results from the developer focus groups, every UIA run as to be short in time, intuitive and transparent to the user and also

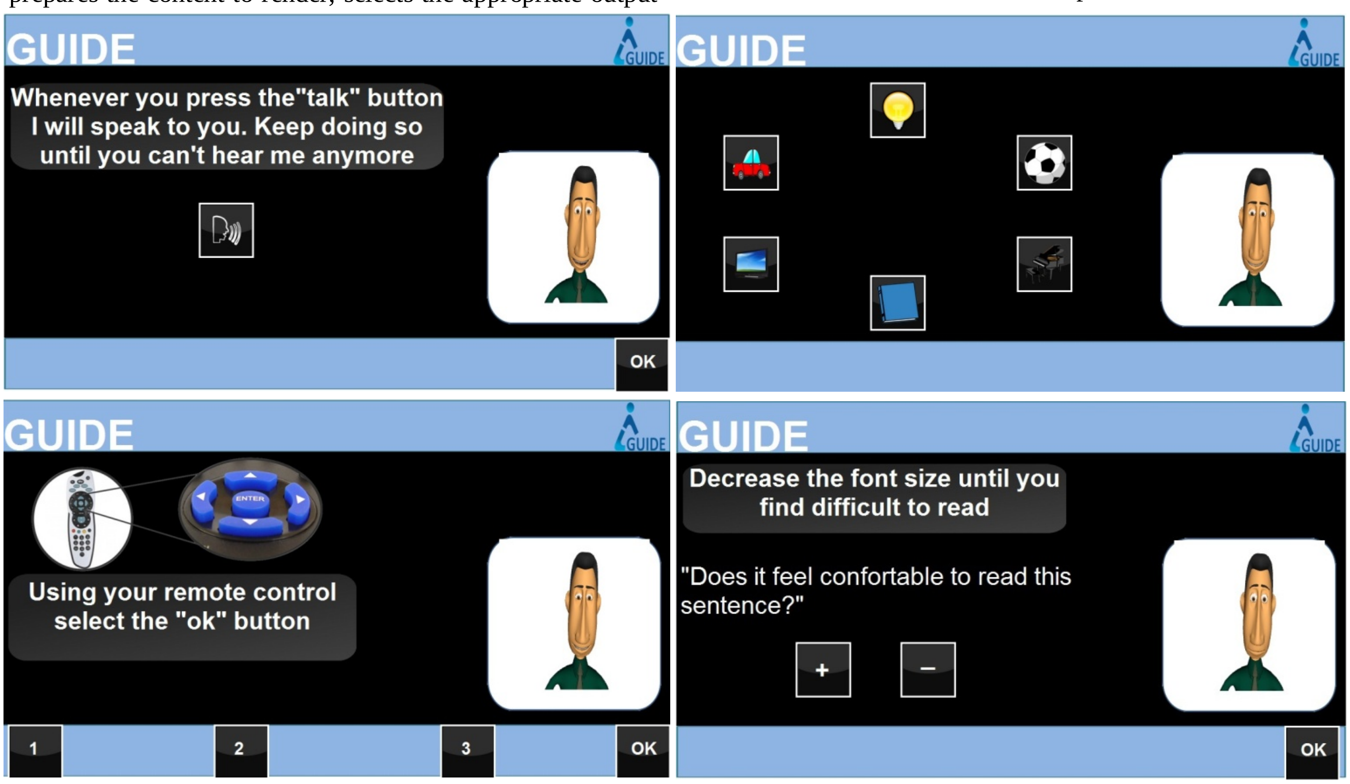

Fig 4. Screenshots of the first version of the User Initialization Application

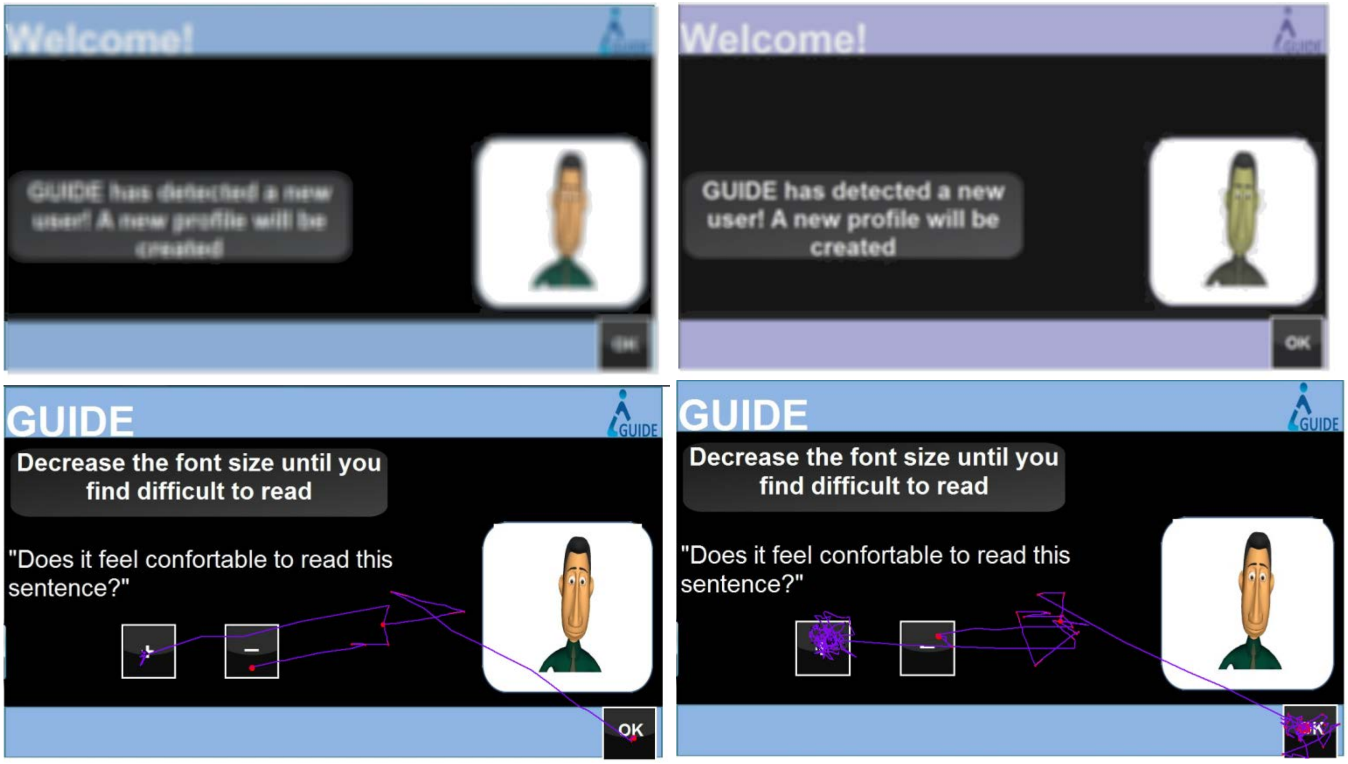

Fig 5. Applying simulation of User Initialization Application (top images show visual impairments - Macular Degeneration and Visual Acuity Loss -, bottom images show motor impairments - moderate motor impairment and Parkinson's Disease)

serve as a "tutorial" for learning every modality of interaction available in the system. Additionally, the user must be recognized (facial or voice patterns) by the system so that the information provided can be stored in a profile and loaded every time the user interacts with the system.

C. *Simulation of User Impairments*

As developers need tools for helping saving time and cost in the development of inclusive TV base applications, GUIDE offers a simulator [2] which will allow the developer to perform accessibility tests based on virtual users, saving much time in comparison to tests with real users. So, evaluation as a typically expensive step in user centered design is supported in GUIDE by a simulation functionality allowing to illustrate to developers how users with typical impairment profiles will perceive or may interact with an application. The simulator can show how certain visual and strength impairments influence the way a user perceives and visualizes a certain UI (e.g., how an elderly color blind user sees a specific UI), and also what are the effects of those impairments in the user interaction (e.g., predicting cursor paths on the screen or task completion times). This simulator can be characterized as a tool for helping developers to take adaptation into consideration at design time. Figure 5, shows the simulation results on top of the User Initialization Application for both visual and motor impairments.

D. *Filtering*

As verified by the inefficient and erroneous use of pointing interaction when performing selections in the user trials, elderly users potentially have a wide range of impairments that hinder their ability to communicate their intentions to an application. In some cases these impairments can be severe, and significantly affect the speed and accuracy. This leads to an inefficient or even undesirable interaction with an application. The use of cursor smoothing techniques in GUIDE consists in processing the raw user input to obtain a filtered input (Input Adaptation Module described in the framework). This requires the usage of efficient statistical signal processing schemes to estimate the user's intended operations in real time. Basically it consists in the application of corrective forces and forcing relatively smooth paths in a cursor interaction as well as assigning attraction fields to UI elements. Therefore, the following graphical UI filters can help improving pointing interaction within the GUIDE project:

- Exponential averaging: this modification calculates the cursor position pi as $pi = \alpha xi + (1-\alpha)pi-1$, where xi is the user input, pi-1 is the previous cursor position and $\alpha \in [0,1]$ is a parameter determining how strong the user input influences the cursor position. This method produces smooth cursor traces but has the drawback that it can produce a delay between user's intended position and the actual position;

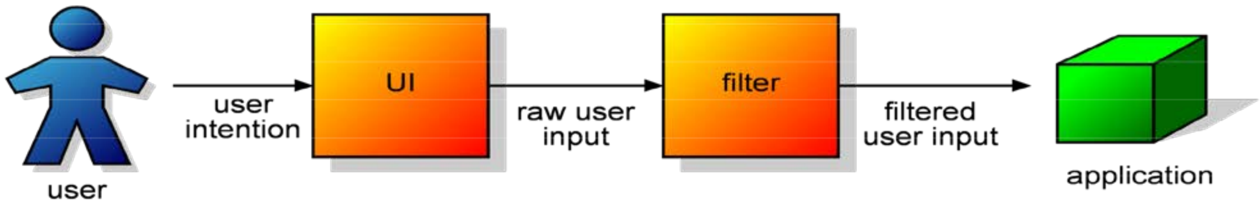

Fig 6. Process of detection of user intentionality by applying filtering

Fig 7. An example of missed clicking (left) and clicking with the gravity well filter (right)

- Damping: This method introduces a quadratic force that opposes the velocity of the cursor preventing sudden changes in directory or speed when interacting;
- Gravity well: This method warps the cursor space, generating attractive basins to ease the selection of visual targets. This simplifies pointing interaction selection forcing the selection of buttons or UI elements that are more close to the location where the user is pointing (figure 7).

Considering the different user characteristics and impairments, and the different UI element configuration, the existence of these filters make possible that motor impaired users can more easily interact with pointing and also makes possible the use of small and less spaced buttons in applications UIs avoiding errors in selection caused by the proximity of the buttons. All because pointing interaction accuracy is raised, and user intentionality when pointing is taken into consideration (figure 6).

E. Semantic Programming and Run-Time Adaptation:

The specification of TV based applications in GUIDE will be based on Web-based languages like HTML, CSS and JavaScript because of their wide acceptance among developers and compliance with STB specifications. However, in GUIDE exists the additional side-condition of specifying multimodal applications that needs to be merged with these web-based specification languages. This is made by specifying additional information about how an application is supposed to adapt in different modalities. For this semantic annotations are added to the HTML code, based on the WAI-ARIA draft specification of the W3C.Only by providing this type of supplementary information it is possible for the system to create an abstract representation of the application. Then, using an automatic application transformation module the system converts the annotated application description into a modality-independent application representation, the Application Model described in the framework. Subsequently, and depending on the user interacting and on the level of control defined by the application developer, adaptation of UI components is performed.

Developers can create their applications and UIs in an established manner, and GUIDE automatically adapts the UI to the user. This avoids having to design many user interface templates for various heterogeneous user groups. Therefore, GUIDE provides the application developers with two possible levels of adaptive control:

Augmentation: presentation and interaction options taken by the developer are not subject of change. Instead, if the user model suggests that the presentation is insufficient for the user abilities, the presentation is augmented in different modalities (for example supplementing a visual interface with sound feedback). The multimodal fission mechanism renders the application output directly, augmenting or not the rendered presentation depending on the user model. Figure 8 shows an augmentation example;

Adjustment: application rendering is adjusted to the abilities of the user (for example adjusting components of a visual interface to fit user characteristics, like raising font size or button size). The rendering changes can be achieved through CSS manipulation. Adjustment can be combined with augmentation. Figure 9 shows an adaptation example.

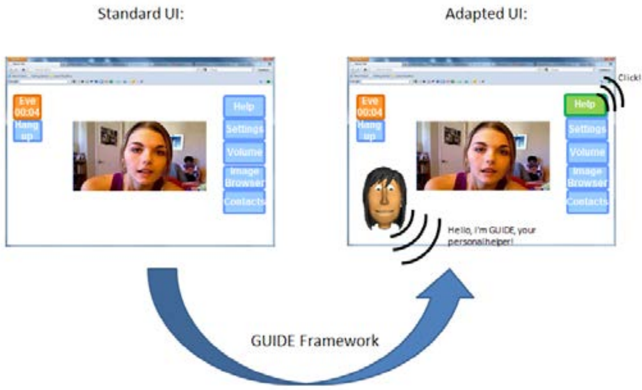

Fig 8. Example of Augmented adaptation

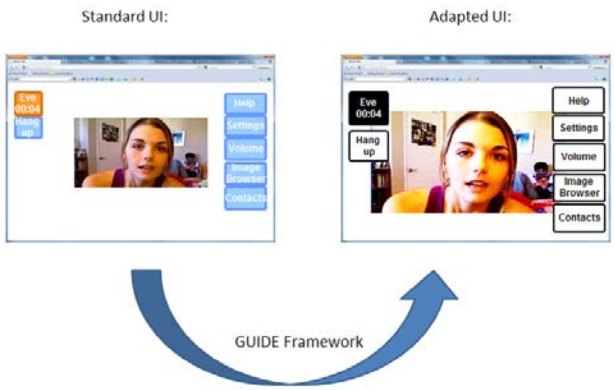

Fig 9. Example of Adjusted adaptation

V. Developing and Evaluating the User Initialization Application

A. *Development*

1) *Selection of tasks and metrics*

The tasks and metrics chosen for the UIA are the ones for which the resulting data is the most capable to assign the more appropriate profile to the user profile. They were selected from an analysis of the extensive survey data, taking into account the feasibility of gathering the data. For those instances where it was not feasible to gather the data in a living room environment, alternative sources were selected and combined to estimate the required data. A description of these variables is listed below: **Color Blindness**: Plates 16 and 17 of Ishihara Test [6] as it may classify among Protanopia, Deuteranopia and any other type of color blindness; **Dexterity**: We estimated Grip Strength and Active Range of Motion of wrist from age, sex and height of users following earlier Ergonomics research [2]; **Tremor**: We conducted earlier a test involving a Tablet device in horizontal position, and estimated tremor from the average number of times users need to touch the screen to select small buttons. Details of the study can be found in a separate paper [4]. Additionally, other tasks were chosen with the purpose of allowing users to personalize the system, while being a hands-on tutorial regarding new modality interaction and feedback configuration. The most relevant ones are the following: **Modality Introduction**: Self-explanatory videos of how to interact with each modality, followed by "do-it-yourself" tasks; **Button and Menu Configuration**: Button size, and font and background color configuration; **Cursor Configuration**: Cursor size, shape and color configuration; **Audio Perception**: Hearing capabilities and preferences.

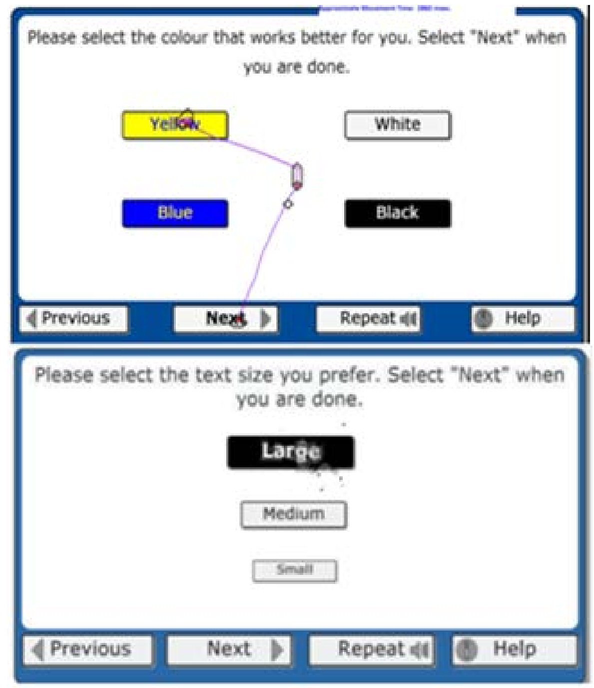

Fig 10. Applying Simulation on the UIA

2) *Accessible Interface*

The UIA has a simple user interface, with a different screen for every task and metric identified above. Few buttons are presented per screen (preventing user confusion). Every screen preserves the same navigation model - an area with "next", "previous" and "repeat" buttons, and another visually distinct area for presenting information and requests. For every metric to be measured, tests are presented as simple questions about preferences. Also, for every modality available in the system, a video introducing its use is presented, followed by the possibility for the user to try it out. A virtual character (Figure 11. first screen) accompanies the user through this process, offering explanations and assisting the user in the personalization. As the user goes through each task and preference setting, the UIA adapts itself to the preferences already manifested. For example, if user manifests preference for big, blue buttons with yellow text, all buttons will be presented with those settings from that moment onwards. It is worth pointing out that the results of our previous study are reflected in the UIA's design: high contrast colors, big, centered and well-spaced buttons, etc. Also, the GUIDE simulator was also used in the design of the UIA, to ensure that users with visual and motion impairments could use it with high efficiency (figure 10).

B. Evaluation

1) Study description

With the goal of evaluating the efficiency and acceptance of the User Initialization Application by elderly a study was conducted. First we want to measure the efficacy of this application in discovering the relevant characteristics of users and assigning user profiles; and secondly, we want to evaluate how understandable the UIA is in terms of its goals and the instructions it provides; and finally, how easy it is for elderly to interact with this application, or if they would do it if it was part of their daily lives.

2) Participants (Pre-Survey)

We recruited 40 elderly people (24 female and 16 male) with different age-related disabilities. Users were recruited in two countries, with 21 participants (14 female and 7 male) being recruited in Spain and 19 participants (10 female and 9 male) in the UK. The average age was 70.9 years old and the different user profiles were assigned to the participants in the following manner: 14 users with profile A, 22 users with profile B, and 4 users with profile C. All users participated voluntarily and all activities involved in this study were safeguarded from the ethical point of view.

3) Apparatus

The study was conducted in two locations (Spain and UK). Efforts were directed to create similar environment and technical conditions in both labs. Trials were conducted by usability experts. Users were given freedom to interact (the trial conductor would only intervene when really needed, or user asked for help). In what concerns the technical setup and specification, different modalities of interaction were configured: pointing resorted to the use of a Microsoft Kinect; for speech recognition we used the Loquendo SR engine; a simplified remote control, with less buttons than traditional ones and capable of controlling pointer coordinates using a gyroscopic sensor was made available; an iPad was used for tablet interaction; and a full 1080p HDMI TV with integrated speakers and a 32'' screen was used for visual and audio output. User interactions and answers were video recorded.

4) Design and Analysis

We used a within-subjects design where all users ran the UIA. Qualitative analysis was retrieved from pre, intermediate and post-questionnaires. Quantitative data was retrieved from the UIA (user profile and interface preferences). Herein, we discarded quantitative measures like trial errors and time as the trials followed a semi-supervised methodology: the participants were motivated to perform the tasks on their own but they were free to ask questions when they felt lost. For binomial measures, Mcnemar's test was performed, and Cohen's Kappa was used to assess the inter-reliability of the profile ratings.

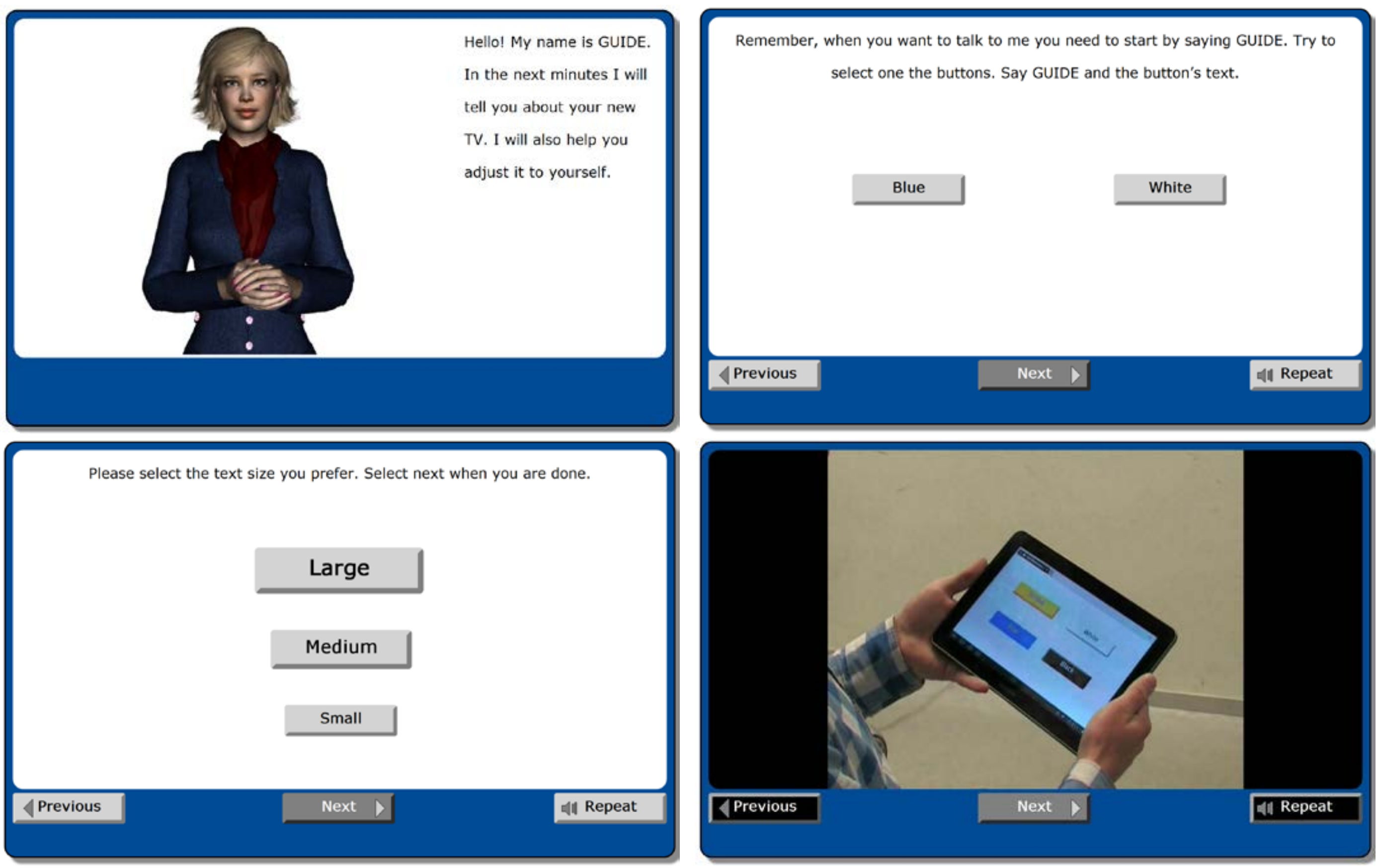

Fig 11. Implemented Version of the User Initialization Application

C. Results

1) Discovering Elderly Profiles with UIA

Our take for adaptation relies on a User Model fed by the UIA. All participants in our study performed both the pre-survey and the UIA. Twenty-nine out of forty profile assessments were performed similarly by the two methods (74%). The interrater reliability between the profiles assigned with the pre-survey and the UIA was found to be Kappa = 0.58 ($p < 0.001$), revealing a moderate agreement [21]. It is relevant to notice that the UIA enables the user to input preference values, something that goes beyond ability profile. This is likely to explain part of the mismatch (e.g., a user with no visual impairments is likely to prefer a higher contrast button when he is confronted with such an hypothesis). Another source of uncertainty may be the under-statements by part of the users in the pre-survey. Indeed, in a questionnaire it is likely that part of the users fail to acknowledge some limitations while they clearly state them when confronted with an interface with options to surpass it. A deeper understanding of the mismatches that are not created by these observed flaws can only be retrieved in a more extensive evaluation by analyzing how both methodologies enable the users to improve performance.

2) UIA evaluation by the Elderly

Users are not used to use something like UIA, so it is important to assess how the users see this component and if they are willing to use such a thing to improve their performance.

Question about the UIA	Median	IQR
Have you understood why we do the UIA? [1 - Yes ; 2 - No]	1	0
If you have had the system at home, would you go through it or skip it? [1 - Would do it ; 2 - Would skip it]	1	1
Do you think the UIA is too long? [1- Yes;2 - Neutral;3 - No]	3	0
Were the instructions easy enough to understand? [1 - Yes; 2 - No]	1	0
Did you notice any changes in the application while you were using it? [1 - Yes ; 2 - No]	1	1

Table 4: Subjective ratings to the UIA

The participants took between 12 and 37 minutes to complete the UIA (M=22.8, SD=5.9). Once again, although they were discouraged to engage in long dialogues the participants were free to express their opinions and doubts during the UIA which increased the time to finalize the process. The UIA classified 16 people as profile A, 20 as profile B, and 4 as profile C. Table 4 presents the subjective ratings given by all the participants to the questions posed. Regarding the understanding of the purpose of the UIA (Question 1), 9 out of 40 (22%) did not understand the purpose of the UIA. This indicates that such a process should be better motivated or else it will be likely ignored by the users. In line with this, 11 out of 40 (28%) stated they would skip the process if they had the system at home (Q2). Five participants stated to find the process too long while four other were neutral about it (Q3) All the remaining thought it was neither too long nor tiring. Most users (35) thought the UIA was easy to follow and understand (Q4). Regarding the adaptations felt during the UIA (Q5), 26 participants stated to have noticed them. This is easily explained as 16 participants were classified as profile A which means they had little or no adaptations done during the UIA. In sum, the users seem positive towards the UIA (Table 2) although it is clear that it should be well motivated and accompanied.

D. Discussion

Upon analyzing the UIA process and its impact on adaptation along with the usage of the GUIDE system and its underlying concepts, we answer our research topics as follows:

1) Deriving a suitable user adaptation profile through the UIA.

The UIA aims at creating a user profile by performing a simple set of questions and interactive tests. Results showed that the UIA is able to match profiles obtained with an extensive survey in 74% of the cases. Further, the UIA showed to be more realistic than its paper-based counterpart as data is likely to be more accurate when the users are faced with their limitations rather than just being questioned about them. Moreover, the UIA gives space for preference and subjectiveness. In sum, we consider that adapted TV applications based on simple initialization profiling are feasible and likely to improve over traditional methodologies.

2) Acceptance of the UIA.

The UIA took over 12 minutes, averaging around 23 minutes. This amount of time can be discouraging for an elderly user if the benefits are not clear. Taking in consideration that it is supposed to be ran only once, the participants showed to be very positive about it. This is supported by the almost general understanding of the purpose of the UIA: they understood the benefits of such an application and perceived the adaptations during the process. Most participants (35) considered the application easy to follow which indicates that although the concepts underlying the creation of the user model are complex, the interface to generate it is not.

VI. CONCLUSIONS

New interaction paradigms, supported by new modalities and applications, are transforming a classical appliance that is the TV. If not handled properly, this transformation can increase the access barriers to TV content for elderly users.

In this paper, we assessed several of the proposals that the GUIDE project puts forward in order to increase the accessibility of TV applications. GUIDE aims to provide application developers with a multimodal adaptive framework and a set of functionalities that will increase their products' accessibility, without demanding major changes in their development process. The assessment was based on a user trial, with 40 participants from two different countries.

The results obtained in this technical user-trials about the existence of disparity between what modalities users say they need, and what modalities they ask for when using the system, favors multimodality almost every time. This only helps to prove that the use of several input and output modalities is indispensable in the development of multimodal TV based applications for all. Also indispensable, are the components identified in the GUIDE framework, and the combined use of semantic programming and run-time adaptation mechanisms to fit UI components to each user characteristics. Additionally, the use of a simulator of user impairments can help developers understand at design-time how certain UI templates and components are perceived by different users with different impairments, preventing user exclusion and making accessible applications easier to design.

Being an adaptive framework, it relies on knowledge and information about users. Essential for both providing and collecting knowledge, is the UIA, a process that streamlines user profile identification, based on short number of tasks and questions. We present an assessment of the efficacy of this process, concluding that it is possible to reliably identify user profiles, while also recognizing ways in which to further improve the process. From the user's point of view, the process motivation was understood, and it was considered easy enough, although also here we were able to find ways to improve it.

These results show a positive acceptance of the GUIDE concepts and their expected impact in the quality of life of its users, validate the approach followed so far and pave the road for the project's future developments, which will be verified in a longitudinal trial for better assessing the effects of adaptation and multimodality.

A. Future work.

Regarding the use of modalities, speech interaction was singled out as the most attractive modality. In this study, a Wizard-of-Oz approach was used to replace the speech recognition engine, and as we question ourselves on how that might have contributed to the results, a follow-up study, where a real speech recognition engine is used, is necessary. It seems safe to say that speech plays an important role in promoting the adoption of these systems, and efforts to ensure its adequate operation are justified by the satisfaction it provides users with. Tablets, although not fully integrated with the system in this study, collected a positive response from participants, with 92% of them considering interacting with a TV using the Tablet. This tendency is also to be confirmed in the future with a study where users may be asked to execute tv-related tasks on a tablet. Finally, regarding the clustering process, by increasing the number of users available it will be possible to update the profiling process, resulting in a more accurate representation of the users' characteristics and a more precise identification of the relative importance of each variable.

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