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LONG PAPER

Universal Remote Console-based next-generation accessible television

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Abstract This paper presents a new approach to make current and future television universally accessible. The proposed approach provides a means of universal accessibility both for remotely operating the TV set and for interacting with online services delivered through the TV. This proposal is based on the ISO/IEC 24752 "Universal Remote Console" (URC) standard. This standard defines an abstract user interface layer called the "user interface socket" and allows the development of pluggable (plug-in) user interfaces for any type of user and any control device. The proposed approach lays the foundation for the development of advanced user interfaces that can be interacted within various modalities. Different prototypes have been developed based on this approach and tested with end users. The user tests have shown this approach to be a viable option for the proposed scenarios. Based on the experience gathered with the prototypes, recommendations and implementation options are suggested for commercial adoption.

Keywords Accessible TV · ISO/IEC 24752 · Universal Remote Console—URC · Universal Control Hub—UCH · Multimodal interaction · Pluggable user interfaces

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1 Introduction

The TV set is one of the most common communications device, present in most homes worldwide. Furthermore, watching TV is one of the activities that take up most of people's leisure time [36].

Together with the widespread use of the TV, the TV sets' evolution from the analogue world to the digital world has opened up a new range of possibilities. These possibilities include the option to add new functionality that can be integrated with the TV and at the same time the option of providing universal access to previously existing basic functionality, as well as to future functionality.

With regard to the inclusion of new functionality in the TV, interactive services are cited as the most important of recent advances. Interactive services have been integrated into TVs in many research projects. These types of services can be categorised according to their level of interactivity [26]:

- Broadcast-only services: EPG (Electronic Programme Guide), Local Games, VOD (Video On-Demand), PVR (Personal Video Recorder), etc.
- One-way interactive services: Advertisement direct response, opinion polling, voting, etc.

- Two-way interactive services: TV banking, interactive TV content, email, social networking, etc.

Aside from research developments, reacting to user interest in interactive services, manufacturers started including iTV applications in commercial products. This inclusion has occurred gradually, from set-top boxes and PC-based media centre solutions, to the TV's themselves. The level of interactivity of the services implemented has followed a likely path, from simpler to more complex services, from integrating simple VOD applications to integrating latest social networking applications.

A good example of these developments is the commercial availability of TVs supporting interactive services widgets technology from Yahoo Connected TV [35] or Sony Applicast.

This growing interest in providing interactive services through the TV can also be found in proposals such as HbbTV [17], in which regular broadcasts are complemented by interactive services available on-line, with the aim of providing those services seamlessly on a TV set.

Regarding the TV set's universal access, there have been advances in different areas. In the content accessibility area, the main success has been the transition of accessibility standards from analogue television to digital television. Existing subtitle description standards have been adapted from teletext to the Digital Video Broadcasting (DVB) environment.

Moving on to TV set remote controls, TV remote controls have changed their appearance and advances in usability have been achieved, but the interaction paradigm based on infrared remote control technology has remained unchanged for more than a decade. Effort has been made to make remote controls as user-friendly as possible, but a significant impact on accessibility has yet to be achieved. For many users, remote controls are too complex to use. Some may not see buttons very well, others may not have the dexterity to handle the device or manipulate its buttons without difficulty.

Other users, for example, those with cognitive difficulties, require training on how to use the remote control. Even so, many times they are unable to remember the location of the buttons on the remote control or how to use the TV's On Screen Display (OSD) menus.

Going beyond the remote control, other remote interaction technologies have been researched, such as speech interaction, or the use of different interaction objects such as pillows to make the TV set's remote control accessible to all.

Finally, the provision of universally accessible interactive services on the TV has not been a deeply researched area. Most efforts have been targeted on making EPG use accessible through speech output.

For many people, the integration of online services into a TV set means being able to access online banking, e-health services, having web presence or socialising via social networks, which otherwise would be inaccessible due to a lack of computer skills or other accessibility barriers.

Governmental interest [13] in promoting initiatives to build the Future Internet based on such services, together with the commercial integration of these services into the TV, should not exclude disadvantaged users along the way. Rather than following a "one size fits all" approach, the Future Internet should support different users with heterogeneous needs and preferences through personalised user interfaces and services. Therefore, the future TV should be based on a design approach that allows an easy extension to the TV implementation with the resources required to adapt to each person's specific usage context.

Even if there have been advances in the TV accessibility research area, these have produced specific solutions that solve particular issues, but an approach that would make the TV universally accessible from design is still missing.

Section 2 surveys the current body of work related to the problem presented in the introduction. Next, Sect. 3 introduces the proposed approach to solve this problem. Afterwards, Sect. 4 describes the implementations done to test the proposed approach, together with a summary of the results obtained from the user tests. Section 5 analyses the implementation options of this approach in real-life contexts, and Sect. 6 summarises the paper and draws conclusions.

2 State of the art

2.1 TV accessibility

The Assessment of the Status of eAccessibility in Europe report [12], analysing both the accessibility of broadcast programmes and end-user TV equipment, showed that TV accessibility is still far away from being implemented to its full extent. This report also points out the accessibility opportunities and challenges that the introduction of Digital TV brings. The opportunities include the lower cost and the easier incorporation of accessibility features into a digital system. But at the same time, there is a consideration of a key challenge, related to universal access to new interactive services (e.g., electronic programme guides), provided from the start rather than as an afterthought which has been the case until today.

This survey also highlights the initiatives that different European Member States are carrying out. Even though only a few of them address these challenges in a policy

context, many Member States are promoting the development and implementation of automatic media translation (e.g., text-to-speech and vice versa) as well as imposing higher targets and/or quality standards for accessibility services in the digital environment.

The challenge of inclusiveness in a developing technology such as interactive television has already been highlighted by the iTV research community in [15]. This paper suggests that possible solutions should include inclusive (multimodal) design, personalisation and standardisation.

A study with a broader perspective but centred on digital TVs usability and accessibility is presented in [23]. This study analyses the usability and accessibility of the basic remote control of TV and interactive services, together with accessibility in a prior phase, where a product is selected, purchased and installed in the home. This study reports the results and findings from user tests, classified by each class of exclusion.

There are some commercial implementations [25] and firmware developments for Linux-based set-top boxes [19] that go further than subtitles options, through implementing text-to-speech technology and allowing contrast adjustment, but these are specific developments for specific platforms, whose extension would imply being tied to a particular platform.

There have been areas of iTV research more closely related to support activities that have gone further than analysing usability and promote including accessibility consideration from the start of their development process approaches.

In this context, a research paper [7] proposed an affective UI evaluation methodology that takes into consideration the accessibility concerns and TV-specific characteristics (TV medium, TV audience and context of use), ensuring that the developed iTV applications are not only accessible and usable, but they also cope with the established TV experience. A related study [10] presents different qualitative research methods applied to the field of interactive television (iTV) application design and evaluation, suggesting that applying these methods to specific user groups can help in understanding accessibility problems while developing universally accessible iTV applications.

Regarding technological support for the universal access in the TV set, from the authors' point of view three working areas directly related to accessible TV interaction must be tackled: content accessibility, accessible remote controls and the accessibility of interactive services. The state of art in these working areas is presented in the following subsections.

The approach proposed in this paper is based on the Universal Remote Console (URC) framework, which makes a clear separation between the services to be accessed and the UI to be used for accessing and controlling such services.

To aid the reader in understanding our proposed approach, the URC framework is introduced at the end of this section.

2.1.1 *Content accessibility*

This work area covers the efforts of providing means of following regular audiovisual content for people with different disabilities, through alternative synchronised media provided with the original content.

The accessibility services defined as to be included in accessible broadcast content are audio description for the visually impaired, close captioning for the hearing impaired and sign language also for the hearing impaired. Ensuring the availability of these services involves complying with the relevant production, distribution and viewing legislation and standards.

The main efforts in this area have become regulation through standards agencies. AENOR has provided a normative reference on how to create audio-descriptions [2] and subtitles for teletext [1]. With the transition from analogue to digital TV, ETSI has published a standard [11] on how subtitles should be managed in DVB.

DVB offers the possibility to include different content streams for audio, video and data, which allows broadcasting of audio-descriptions, sign language signing or subtitles as additional channels. Thus, the user is able to select the combination of channels to be displayed on their viewing device.

As introduced in the previous section, the amount of accessible TV content produced is still well below 100% in traditional TV broadcasting. Furthermore, there is a substantial challenge to assure content accessibility on a TV content consumption paradigm change, where the user's role is changing from a simple consumer to that of content producers, where the production, distribution and viewing will no longer be in the hands of few parties and fixed set of technologies, which has been the case until now.

2.1.2 *Accessible remote control*

This work area covers the efforts in providing a means of remotely controlling basic TV functionality, such as channel up/down, volume up/down or turning the TV on/off, to all user groups.

Usability advances for different user groups have led to changes in the appearance of the TV remote controls. Some good examples of these remotes are the Weemote [34] and the Falck Vital [14], as shown in Fig. 1.

The research community has driven efforts to extend the capabilities of the remote control. These efforts are

Fig. 1 Example of usable remote controls

classified and numbered in [6]. Some of these approaches that could help making the TV remote control more accessible rely on the use of everyday objects such as pillows [28], gesture recognisers [22], speech interaction and dialogue systems [4], and the use of devices such as mobile phones and PDAs. These efforts target-specific scenarios and the developments cannot be directly applied in future implementations.

2.1.3 Accessible interactive services

This work area covers the effort in providing iTV applications that can be used by everybody.

Most of the work in this area has been related to EPG applications. Some have extended the implementations of text-to-speech capabilities available for the TV set's remote control to EPG applications, while there is an interesting initiative that integrates a paper-based remote concept [3] for navigating through EPG information. As in the TV remote control case, these efforts give specific solutions to particular iTV applications, for a limited number of TV platforms.

After reviewing the state of the art in the TV accessibility topic, the need emerges to elaborate an approach that provides universal accessibility both for remotely operating the TV set and for interacting with online services delivered through the TV.

2.2 The URC framework

The Universal Remote Console (URC) framework [20] was published in 2008 as a 5-part international standard (ISO/IEC 24752). It defines a "user interface socket" (or "socket" for short) as the machine-operable access and control point for a target device or service. It can be seen as a user interface "model" that exposes the functions and current state of a target device or service, without specifying how it should be presented to a user. Sometimes this is also referred to as an "abstract user interface" (without specific rendition) as opposed to the "concrete user interface" (that provides a specific rendition of the abstract user interface).

In essence, a user interface socket consists of the following elements:

- *User interface variables* that reflect the current state of the target device or service and that may be modified by the user/controller. For example, in a sample user interface socket for a TV (see Fig. 2), the variable "volume" specifies the current volume setting as a number between 0 and 50. Variables can be of any XML-valid type, such as string, number, boolean, etc. For complex devices or services, variables may hold XML structures (e.g., the content of an EPG table).

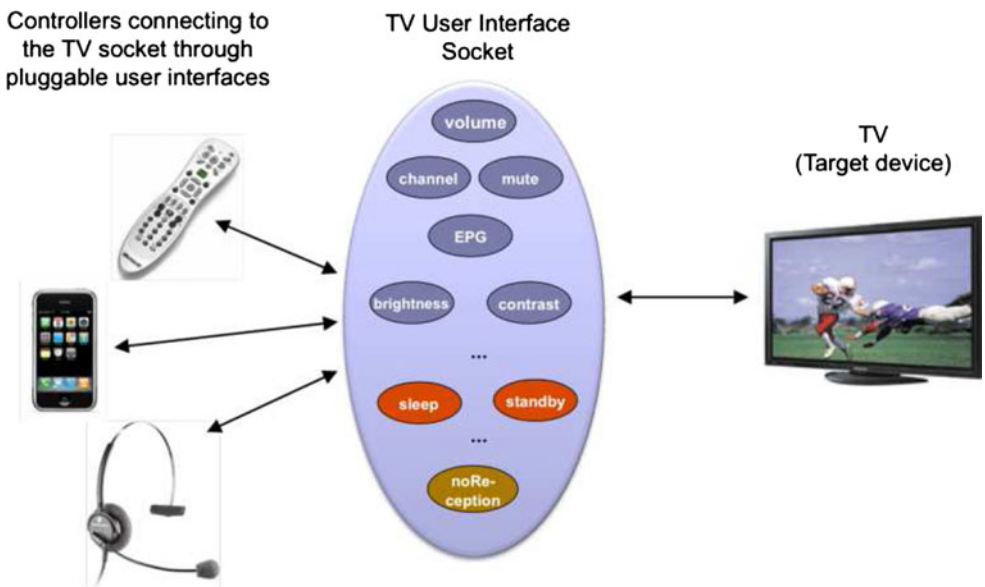

Fig. 2 Sample user interface socket for a TV

- *User interface commands* that can be triggered by a user/controller to invoke a specific function that the target device or service provides. For example, in the TV socket, the command "sleep" programs the TV to switch off automatically after a pre-defined period of time, let us say after 60 minutes. A command may have one or more parameters that are to be specified by the user/controller when triggering the command. The "sleep" command could have the switch-off duration as a parameter in order to allow the user to specify their individual "switch-off duration" every time they invoke the command.
- *User interface notifications* that can be raised by a target device/service to notify the user about an event or state. For example, in the TV socket, the notification "noReception" could inform the user that no signal can be currently received. Each notification has a category, which denotes its nature and urgency. Possible categories are information, alert and error.

It is important to note that the user interface socket contains "live" values and triggers only, and no canned labels or icons for the labelling of socket elements (variables, commands, and notifications). Labels and other user interface resources are provided by external "resource sheets." One resource sheet could contain English labels, another one Spanish labels, etc. Also, there could be yet another resource sheet containing icons or audio clips for each of the socket elements. Some users may only want to see a textual label; others may want to have a text label plus icon, yet another group may prefer icons only. Thus, a user interface can be easily localised or personalised just by exchanging the resource sheet, or by adding icons or audio clips from another resource sheet.

As the name suggests, a user interface socket is just one (the abstract) part of a user interface. A concrete user interface implementation is needed, which "plugs" into the socket to "render" the socket, i.e., presents it to the user and allows the user to send input to the socket. The concrete user interface part is called "pluggable user interface." There may be multiple pluggable user interfaces (i.e., multiple renditions) for a user interface socket, varying in many aspects, including their fitness for different controllers. For example, one pluggable user interface for the TV socket may be presented on the TV screen itself, another one on the user's iPhone and a third one may allow voice control of the TV (see Fig. 2).

Pluggable user interfaces allow a high degree of individualisation and personalisation. For example, one pluggable user interface could only expose the most used functions of the TV (so that grandma can easily use it) or include all bells and whistles of the TV (for users who want to see all functions of their TV at once).

The URC technology is an open user interface platform, allowing third parties to create pluggable user interfaces and use them with any target device/service that exposes its functionality through a socket. The framework includes "resource servers" as global market and distribution places for resource sheets and pluggable user interfaces to be shared among the user community.

Today's devices and services do not come with a user interface socket. However, many of them come with some kind of remote controllability, through infrared, wired or wireless communication technologies. It is possible to build a bridge (gateway) between the communication technology implemented by a target device/service and the URC technology. The Universal Control Hub (UCH) is a gateway-oriented architecture for implementing the Universal Remote Console (URC) framework in the digital home [37]. Thus, the UCH is the gateway between any target device/service and any controller, exposing user interface sockets of all connected targets and facilitating pluggable user interfaces that plug into the sockets.

The main features of the UCH are as follows:

- It acts as a bridge between targets and controllers, each with its own communication and control protocol, that otherwise would be unable to talk to one another.
- Standard-based user interface sockets. The UCH is based on the URC framework previously described.
- A variety of user interface protocols. The UCH allows different user interface protocols (DHTML over HTTP, Flash, etc.) to be implemented and used by controllers.
- Globally available resource servers. The UCH can get distributed resources, such as resource sheet, pluggable user interfaces and other run-time components of the UCH from resource servers.

Figure 3 shows the UCH architecture for the URC standard.

In the UCH architecture, a pluggable user interface is represented by a User Interface Protocol Module (UIPM). A UIPM is responsible for presenting one or multiple sockets to the user through a user interface that is rendered on a controller.

The URC-HTTP protocol, as defined by [29], facilitates remote access by a controller to the sockets running in a UCH. This protocol defines the HTTP-based messaging and functions for a controller accessing the sockets on a UCH. The implementation of this protocol is optional for a UCH, but once implemented it offers a standardised and powerful method for advanced clients to access the UCH.

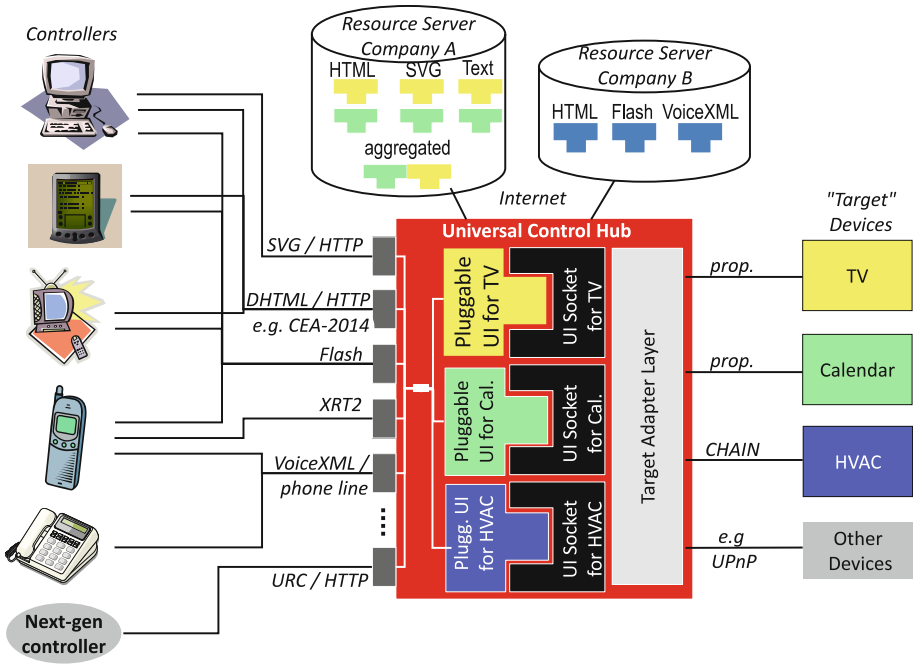

Fig. 3 UCH architecture

3 Proposed approach

This section presents a solution that provides universal accessibility both for remotely operating the TV set and for interacting with online services delivered through the TV.

The novelty of this paper is the exposition of how, by using the UCH architecture, it is possible to achieve both goals at the same time. The next subsection will explain how the TV set's integration is understood from the UCH architecture perspective.

Once the architectural view is explained, the following two subsections present how this technology should be implemented to provide a solution for each of the targeted goals.

3.1 Proposed architecture

In the proposed solution, for each targeted functionality (TV Remote Control and Access to Interactive Services through the TV), the TV set plays a different role. In the case of a TV remote control, the TV is acting as a target to be controlled (TV as target use case), and in the case of the access to interactive services through the TV, the TV acts as a controller which lets the user access the targeted services (TV as controller use case).

Today, TV sets are very heterogeneous (standalone TVs, set-top boxes, media centres, etc.), and these devices can implement a target use case, a controller use case or contain both use cases in the UCH architecture.

Figure 4 shows a TV set that works only as a Target in the UCH architecture. In this case, the TV set is acting as a remotely controllable TV, which can be controlled by a controller to change volume, channel, etc.

Figure 5 outlines a TV set that works only as a Controller in the UCH architecture. In this case, the TV set is acting as a controller, which is able to interact with interactive services through the UCH architecture.

In the case of Fig. 6, the TV set works both as a Controller and as a Target in the UCH architecture. Following an implementation of a mixed (controller + target) use case, it is possible to remotely control the same TV set from the TV set configuration, or alternatively, from a second controller. It is also possible to interact with interactive services that have been integrated into the UCH.

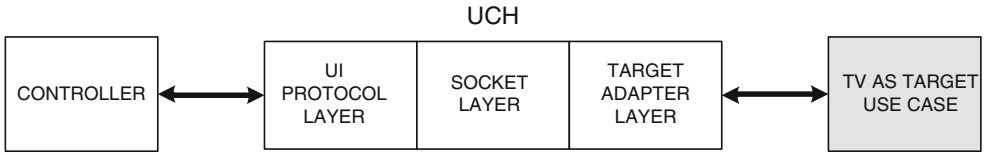

Fig. 4 TV as target use case

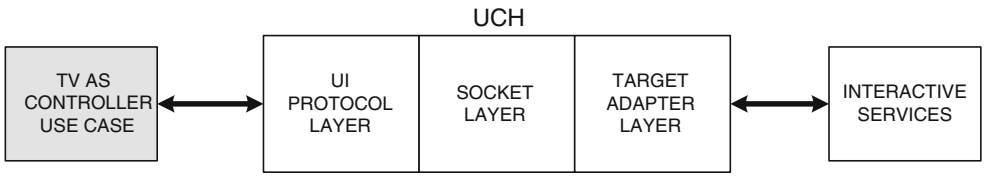

Fig. 5 TV as controller use case

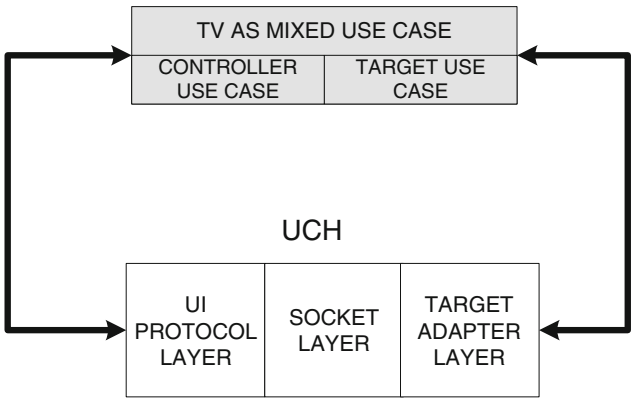

Fig. 6 TV as mixed use case

3.2 TV as target use case: accessible remote control of the TV

The objective of specifying this use case solution is to provide people with the remote control device plus a user interface that best suits them. As said in the introduction, not everyone feels comfortable with the regular IR remote controller, which tend to have smaller buttons and to be more complex. This solution would allow them to use alternative devices like PDAs, tablets, microphones or a combination of such devices.

The main requirement to implement this solution, and to integrate the TV as a UCH's target device, is the remote controllability of the TV set. The requirements to integrate a target to the UCH are described below.

The target device must have an interface for clients to remotely control the complete functionality of the target.

In more detail, there are three categories of requirement on the networking platform of a target:

- Discoverability: A target must be discoverable and identifiable on the home network. This can be implemented as the target advertising a service or the target responding to search messages from the client, or both.
- Controllability: A target must be controllable, i.e., a client must be able to invoke its commands remotely.
- Eventing: A target must send out events to inform a client about its state changes.

These requirements would address the full integration of a TV set, but having remote control via IR is a possible starting point. Later on, a discussion will be presented of the available TV technologies and their possible integration.

The TV set's remote control functionality integration into the UCH architecture is achieved by means of defining the required XML files (UI Socket, Target Description and Target Resource Sheets) and implementing the corresponding code for the target adapter layer requirements (Target Discovery Module and Target Adapter). For more information see [30].

Once a TV set is integrated as a target in the UCH, it is possible both to develop a UCH's User Interface Protocol (UIPM) or to use an existing one. Through the available UIPMs, the different pluggable UIs can remotely control the TV set, using the controller most comfortable for the user.

Also, the UCH can be connected to different resource servers on the Internet that offer UIs and UCH integration modules that may be downloaded and used directly.

Figure 7 outlines a proposal for the TV set's accessible remote control. This figure shows different pluggable user interfaces that can interact with a TV set that has been integrated with the UCH as a target. A resource server object reflects the option of using the pluggable user interfaces and integration modules downloaded directly from the Internet.

More information on the solution proposed for the TV set's accessible remote control can be found in [9].

3.3 TV as controller use case: accessible interactive services on TV

The aim of developing a solution for this use case is that of providing people with interactive services on their preferred device that they use the most during their leisure time. For many people, the integration of online services into a TV set means being able to access online banking, e-health services, having web presence or socialising via social networks, which otherwise would be inaccessible due to a lack of computer skills or other accessibility barriers.

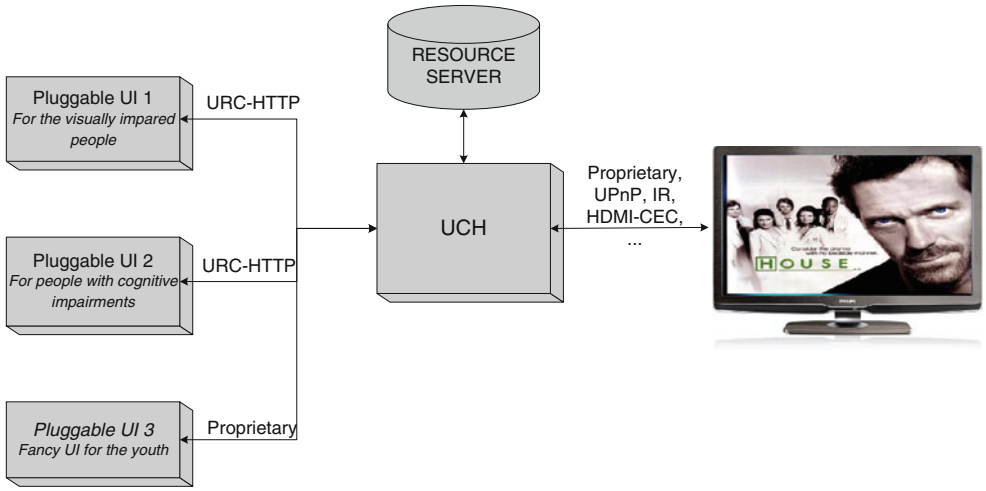

Fig. 7 Proposed solution for the TV set's accessible remote control

The requirements for implementing this solution are that the targeted services are capable of integration with the UCH, which means that they should have an access API or they should be based on web service technology, depending on the openness of the service providers.

In this case, the TV set is playing the role of a controller in the UCH, from an architectural point of view. The requirements for integrating a TV set as a controller in the UCH architecture, and to use it as a pluggable user interface, are that the TV set must implement a bidirectional communication technology and a programmable user interface system.

The services integration into the UCH architecture is achieved by means of defining the required XML files (UI Socket, Target Description, Target Resource Sheets) and implementing the corresponding code for the target adapter layer requirements (Target Discovery Module and Target Adapter) for each interactive service. The interactive services can be running locally or on the Internet. For more information refer to [31].

Through the implementation of a UCH's User Interface Protocol (UIPM), it becomes possible to implement any TV set's compatible communication protocol. Using the UIPM's, the different pluggable UIs can be plugged-in to different TV sets.

After achieving the integration of the services with the UCH and the required UIPM, UIs can be created for any service. This approach also allows the creation of aggregated UIs composed of different services.

At the same time, the UCH can be connected to different resource servers on the Internet that offer UIs and UCH integration modules that may be downloaded and used directly.

Figure 8 outlines the proposed approach to make interactive services accessible to all. This figure shows different target services integrated using their own protocols and accessed from a TV set. The resource server object reflects the option of using the UIs and integration modules downloaded directly from the Internet.

4 Implementation and validation

This section covers the implementations made to validate the proposed approach. As stated previously, a TV set can implement one of the two use cases of the approach, or both. Therefore, the developed implementations are presented and classified in the same sections as the proposed approach.

An interesting outcome of the implementations has been the developer's experience showing the easiness to access the technology, integrate new interactive services, integrate TV set configurations as targets and develop TV set UIs for different UI technologies.

The approach has been implemented in projects such as i2home [18] and Vital [32], following the User Centred Design (UCD) methodology [8], and it has proven to be a good approach to use together with the UCD cycles. The developed UIs have been validated with the targeted users, obtaining encouraging results.

4.1 Tv as target use case: accessible remote control of the TV implementations

4.1.1 Integration of TV sets with the UCH as targets

For the validation of the solution, two different TV sets have been integrated as UCH architecture targets. One of the integrated systems was a PC running Windows Vista Media Center (WMC), and the other one was a Dreambox 7020 set-top box.

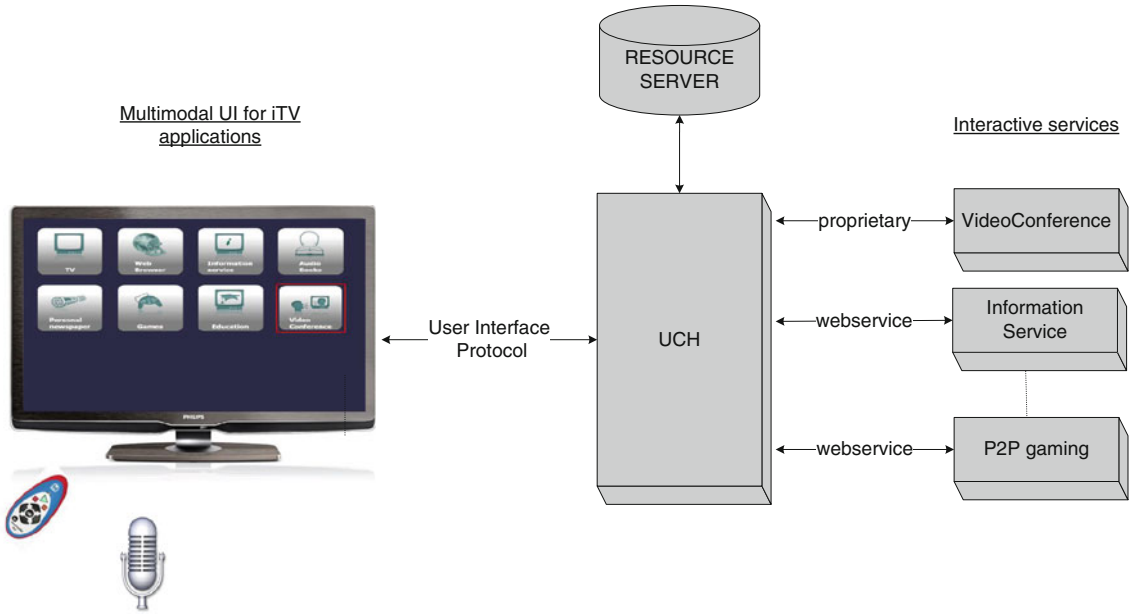

Fig. 8 Proposed solution for the universally accessing interactive services in our personalised TV set

The main reason for selecting these devices has been that they either offer a well-documented API (WMC) or are based on open source code (Dreambox), thus making them easier to integrate. Also, both solutions have IP connectivity, and they fulfil the remote controllability requirements for a target device to be integrated with the UCH architecture (see Sect. 3.2)

A single UI socket has been defined for both TVs, which is the interaction point between a pluggable user interface and a target device, exposing the functionality required to control volume and live TV (Channel selection, Pause-Resume TV). Then, the integration of the targets has been implemented, in the case of WMC including the time shifting functionality.

4.1.2 *Pluggable user interfaces for the TV sets' accessible remote control*

4.1.2.1 Multimodal UI on smartphone The first UI consists of a multimodal (gestures and speech) UI running on a Smartphone. This UI has been developed with young persons with mild cognitive impairments in mind. The typical difficulties faced by this user group are concentration problems and memory deficits.

The main ideas behind this UI have been a large touch screen, a modern mainstream controller (HTC 7500 Advantage PDA) to prevent this user group becoming stigmatised and, finally, a free choice of modalities, or possibly a combination thereof.

The UI is implemented as a client server-architecture based on the ODP platform. This is a platform for implementing multimodal user interfaces based on combinations of any modality. Examples of these modalities are speech, gesturing and mimicking. For more detail, see [27].

Figure 9 shows a depiction of the TV GUI. The bottom row contains artifacts visible in all views of the GUI. There is a back button to the left, a home button to the right and in the middle, current time and the battery status. The middle field activates the speech recogniser. The TV UI has been simplified, and most of the features of a normal TV remote

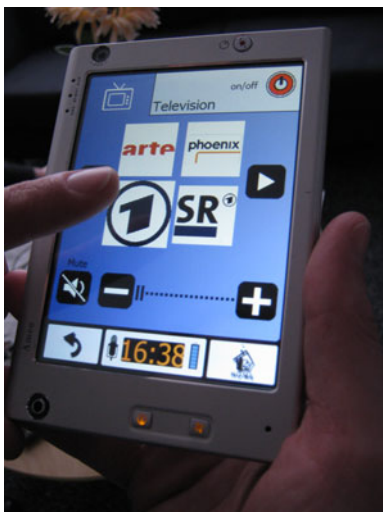

Fig. 9 Multimodal UI based on gesture and speech interaction running on a PDA controller: HTC 7500 Advantage. The GUI implements the requirements posed by a young person with cognitive impairments

have been removed. The only functionalities left are on/off (top left), volume (bottom), mute (bottom left) and a scrollable 2 × 2 matrix for TV channel overview and selection (central position). All functionalities are accessible via gestures, speech or a combination. Thus, it is possible to switch off the TV by pointing at the on/off button or saying "Switch off (the TV)". Similarly, the volume can be adjusted by gestures or the command "increase (the volume (of the TV))." Great care has been taken to make graphical elements large enough and the interaction simple and intuitive.

Evaluation has been carried out with 10 persons with mild cognitive impairments living in Sweden. The age of 9 test participants was between 22 and 40, and one participant was 50. Each participant was instructed to operate the TV. The tasks consisted of switching on/off the device, changing the volume and switching between different channels. The test result was valuated as good, since all participants successfully completed the test. The result of the evaluations shows a preference for gesture-based interaction since these users find it strange and unnatural to talk to a machine. Additionally, the suggested animation was too fast for the users. For more information, see [24].

4.1.2.2 Accessible DHTML for the visually impaired

The second pluggable user interface was developed for people with visual impairments and blind people to remotely control the UCH integrated TV sets. It is based on a DHTML page, which is displayed on a vertically handled Tablet PC. The controller connects to the UCH using the URC-HTTP protocol over a wireless connection. The URC-HTTP protocol is implemented as a JavaScript library [30], and this library is used in the HTML to interact with the TV via the UCH.

The DHTML page is rendered in a web browser. Both Microsoft Internet Explorer and Mozilla Firefox are supported. The developed DHTML page has been correctly tagged. Therefore, it is compatible with screen readers such as Jaws [21].

Figure 10 illustrates the developed accessible DHTML page. This DHTML page was created in compliance with the WCAG 2.0 guidelines [33]. The web page is designed using large buttons and fonts, and the colours can be changed to match the user preferences. Colours and font sizes can be adapted easily to the users' needs by the use of style sheets. This DHTML page even allows for different colour schemes depending on the time of the day, which would be helpful for some of the visually impaired.

The tested tasks consisted of switching on/off the device, changing the volume and switching between different channels.

The tests were performed during two accessibility workshops in Horn Bad Meinberg, Germany. Forty-two

Fig. 10 Tablet PC rendering an accessible DHTML for the visually impaired

elderly persons with their personal care taker (mostly relatives of the disabled person) took part in the workshops.

Each test was carried out on a one-to-one basis by at least two accessibility experts who assisted the participants at any time. Feedback was monitored in individual and round-table discussions.

The majority of the participants were visually impaired. Only some of them were completely blind.

The workshops provided interesting discussions between the parties concerned. The tests led to meaningful and sustainable information that will have an important influence on the accessibility design of the user interfaces.

4.2 Tv as controller use case: accessible interactive services on TV implementations

4.2.1 URC-MCML-based applications on window media center

The first prototype was carried out to validate the TV as controller use case was based on the Windows Media Center (WMC). WMC uses a XML-based markup language called MCML for defining the appearance of the applications together with .NET code for the application logic. A .NET library implementation of URC-HTTP protocol has been used to develop URC-MCML applications. This development was not tested with real users.

Figure 11 shows a screenshot of the URC-MCML UI implementation for remotely controlling a Heating, Ventilating and Air Conditioning (HVAC) device that was already integrated as a target in the UCH architecture, and Fig. 12 shows a URC-MCML UI for receiving reminder notifications. The reminder system is also integrated as a target service to the UCH architecture and has Google calendar synchronisation capabilities.

Fig. 11 URC-MCML UI for remotely controlling a HVAC device

Fig. 12 URC-MCML UI for receiving reminder notifications

4.2.2 Avatar for people with cognitive impairments

A second validation of the TV as controller use case has been done by developing a TV UI system for people with cognitive impairments such as Alzheimer's disease.

Persons suffering from Alzheimer's disease, with a mild stage of progression, typically present cognitive and functional impairments affecting memory, concentration and learning. Furthermore, Alzheimer's usually affects those over 65.

The developed TV UI system is composed of an avatar together with the logic to provide interaction.

This prototype is deployed as a mixed use case TV set since the avatar's TV UI system is deployed together with the WMC target integration introduced previously.

The avatar TV UI system has been validated to provide the notifications of target device or services integrated to the UCH architecture (i.e., home appliances and a reminder system) with very good results. The user of this controller is usually watching the TV set functionality provided by the WMC target, and whenever a notification is generated, the avatar pop ups and establishes a dialogue with the person using the system.

The validation tests were performed at the Matia Foundation IZA Day Care Center, San Sebastian, Spain. An initial neuropsychological screening was carried out first on each candidate user, from which 21 members were selected for the tests. All suffered from Alzheimer's disease with a Global Deterioration Scale (GDS) measure ranging from 3 to 5 (from mild to moderate). The user validations were done on a one-to-one basis.

For the tests, two simple predefined dialogues were executed. These dialogues were triggered by the integrated reminder system. In dialogue 1, the avatar first informed the user that a Basque Handball match was about to start on another channel, asking whether the user wished to watch it or not. At this point, the user pressed a button labelled "Yes" or "No" on the remote control. In dialogue 2, the avatar asked the user to write their name on a piece of paper that was placed beside the chair where they were seated. After a while, the avatar requested confirmation from the user with a "Yes" or "No" type challenge. On each occasion, the test was personalised by introducing the name of the test subject into the system, so that the avatar initially greeted the user using their own name.

From a qualitative point of view, a remarkable result of the tests was how well the group engaged with the avatar. At no point did they exhibit fear, misunderstanding or inconvenience to seeing the avatar on the television, that it had interrupted the TV broadcast or, most importantly, that the avatar spoke to them directly.

From a quantitative perspective, during both dialogues, 100% of the users followed the instructions given by the avatar without difficulty. In dialogue 1, all users were able to respond with their choices. During dialogue 2, when asked by the avatar to write their names, all users fulfilled the task successfully. Finally, when the avatar said goodbye, a majority of the users responded by speaking directly to the avatar.

Figure 13 shows a person interacting with the avatar TV UI system.

More detail on these prototype developments and validations are described in [5].

4.2.3 Interactive services for improving the quality of life of the elderly

Last but not least, a validation of the TV as controller use case focused on elderly users was carried out. More specifically, the focus was on healthy elderly users, with no special impairment. A multimodal TV UI system that was

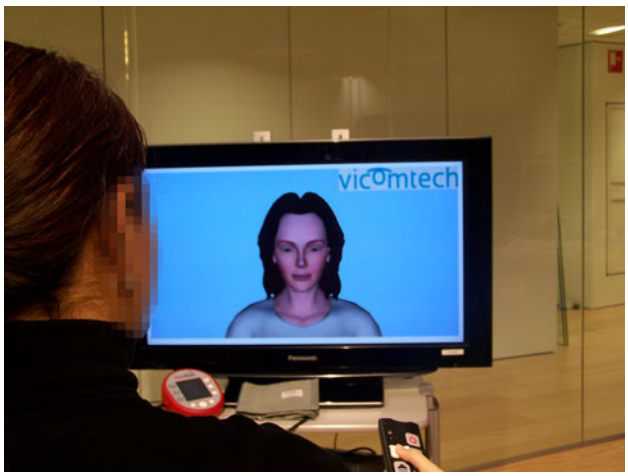

Fig. 13 User interacting with an avatar displayed on a TV set

interacted with a simplified remote control (weemote) or via speech was developed. Only the simplified remote control-based interaction has been validated with the real users.

The aim of this development was to significantly increase the quality of life of the average elderly user. In this sense, the interactive services integrated with UCH and provided through the multimodal TV UI system were videoconference as a social inclusion application, information service as a personalised information provider application, and audio book, P2P gaming (quizzes and chess) and education to enhance their leisure time and their cultural enjoyment.

The validation tests were carried out in parallel in San Sebastian, Spain and in the Durham County Councils, United Kingdom. The sample size was of 30 persons on each site.

To tests the developed TV UI system and the applications, two methods of assessment were used. First, two questionnaires were administered to (1) obtain sociodemographical data, experience with technology and (2) obtain information about TV usage. Second, a semi-structured interview with general questions about the developed system was conducted in order to manage correctly the focus groups. The objectives of the focus groups were to evaluate the usability and accessibility of developed system and to analyse whether the application is interesting for the participants.

The sample was quite heterogeneous concerning education profile and experience with technology.

The result of the tests showed that the users found the system easy to use through the simplified remote and the provided user interface. All the proposed applications were found interesting. Most of the issues found were related to bringing a prototype to a product.

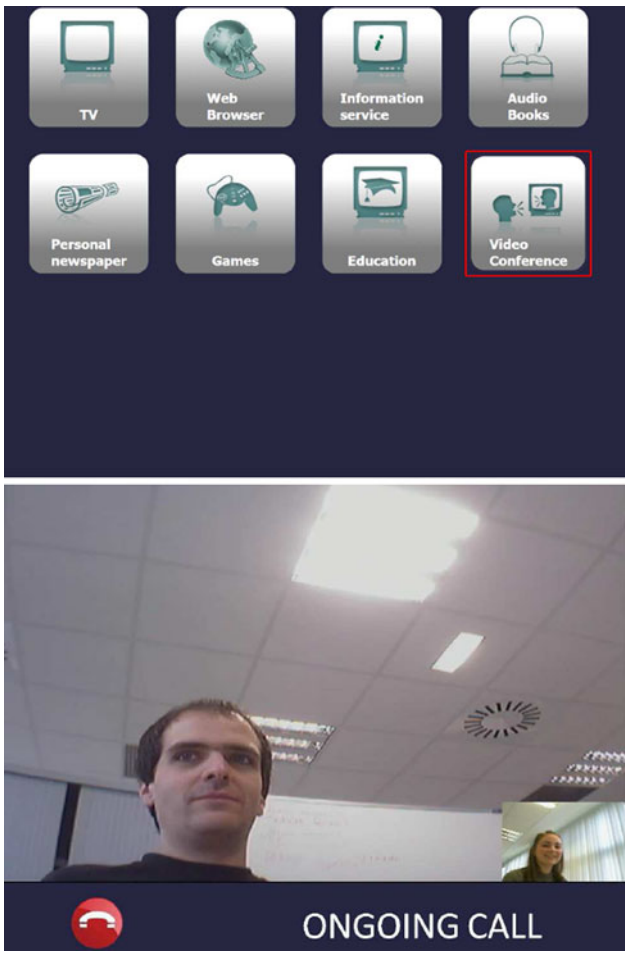

Fig. 14 TV UI system targeted to the elderly

Regarding the products adoption, they would consider it, depending on the cost and easiness to integrate with the devices they already have at home.

Figure 14 shows the main menu of the developed TV UI system, together with an example interface for the videoconference application.

5 Implementation recommendations for mass-market devices

Based on the experience gained in the previous implementations realised to validate the proposed approach, this section discusses how current mass-market devices can be adapted to follow this approach and related recommendations are provided. For new products, the recommendation is to follow the proposed approach from the beginning of their design.

As it has been shown through the implementation and validation developments, the TV set can range from a TV to a set-top box or a PC-based media centre solution.

Next, different options for implementing the UCH in the digital home are analysed, and the available technological options to implement each use case of the approach are analysed.

5.1 UCH implementation

In the digital home, the UCH architecture can be implemented for the accessible TV set scenarios presented in this paper, but it can also provide access to the different devices available in the household, as well as to interactive services (running locally or on the Internet), through the controller that best fits each person's needs.

Therefore, the following three possible hardware options are proposed for hosting the UCH in the digital home:

- Home server for AV purposes.
- Broadband Router.
- UCH in a TV set: If the aim of the implementation is only the accessible TV set scenario this is a feasible option, otherwise the TV must remain switched on. Technically this has already been done for the WMC-based developments and seems to be feasible for the TV, meaning not a PC or a set box implementation, since nowadays many TVs are built on the UCLinux operating system that could allow deployment of a UCH in a TV set.

5.2 TV as target use case

As specified in the proposed approach section a candidate TV set needs to be a remotely controllable target.

Today's TVs can be controlled using one of the following technologies: Infrared, Serial, HDMI-CEC, Firewire, DLNA Renderer profile and IP connectivity using proprietary protocols.

The most widespread communication technology is infrared, but this technology's implementation typically only allows a one-way communication, which allows to operate the TV, but restricts receiving feedback on TV status. With this known disadvantage, it is possible to integrate a TV with the UCH using IR signal, either using an IR transmitter in the machine the UCH runs on, or by using a master controller [16] that has different IR outputs that can be accessed over IP networks. There are IR signal databases of different devices available, so this limited implementation should be possible for most current TVs.

The remainder of the proposed communication technologies offer bidirectional flows, which would help in meeting the requirements for a UCH integrated target. At present, the problem is that none of these communication technologies are extensively implemented in commercial products, and some of them have their own private protocol implementations. This means that an implementation for each communication technology would need to be provided.

Therefore, the recommendation for currently available marketed devices is to either follow a limited IR technology approach, which once done for one TV would be easily extended to other models leveraging IR code databases, or to develop UCH target integrations for mainstream device technologies, as was the case in the performed WMC implementation, thus bringing the technology to a wider range of users.

5.3 TV as controller use case

In the case of the TV set's controller use case, a TV set requires a bidirectional communication technology and a programmable UI system.

As presented in the introduction, reacting to user interest in interactive services, manufacturers have started to include iTV applications in commercial products. This has taken place gradually from set-top boxes and PC-based media centre solutions, to the TVs themselves.

A good example of these developments is the commercial availability of TVs connected to the Internet and supporting widgets technology from Yahoo Connected TV [35] or Sony Applicast.

In the implementation and validation section, solutions have been presented that run on a PC (WMC MCML, Avatar TV UI system, TV UI system for the elderly), which gives a greater opportunity to include accessible technologies. Different modalities have been integrated, like speech and haptics together with virtual characters, to make the interface more natural and accessible to the targeted users.

In these implementations, bidirectional communication is achieved through inter-process communication, if it is implemented in the same machine where the UCH is running, or an IP-based connection, which is the preferred option.

The recommendation for implementing the TV set's controller use case, in order to have everything in one device, is to use a TV that implements the Yahoo Connected TV technology. It supports IP communication and a widget-based UI technology and can be connected to the UCH through the available URC-HTTP JavaScript library. The problem of all-in-one TV device solutions is that they are not usually open platforms, which allow the installation of third party UI system and hinder the integration of assistive products.

Therefore, in order to be able to provide universal access to its fullest extent, the TV set based on a PC or an open source-based set-top box would be the preferred recommendation. In this way it would be possible to use custom

TV UI systems, or use existing fully documented API in cooperation with assistive technologies and create more natural and accessible UIs with speech, gestures or virtual character multimodal interaction.

6 Conclusions

This paper has presented an innovative approach to provide universal access to TV sets. The proposed approach solves two accessibility issues at the same time, which are the accessibility to the TV set's remote control and the access to interactive services on the TV. The proposed implementation options can solve both accessibility issues at the same time or any one of them independently for the same TV set. Furthermore, once the chosen solution is implemented, it is seamless to the user.

The approach is based on the ISO/IEC 24752 Universal Remote Console (URC) standard and its implementation in the UCH architecture. Each accessibility issue's solution is detailed in the paper, identifying the requirements and the development necessary to integrate the solution with the UCH architecture.

The implementations developed to validate the approach have been presented and explained. These developments include the integration of two different TV sets as UCH target devices, together with two accessible pluggable user interfaces to validate the accessible remote control scenario. For the validation of the accessible interactive services on the TV scenario, local and remote interactive services have been integrated with the UCH, and different TV UI systems have been developed for the different target groups.

There is also a third use case for accessible television that should be mentioned. This is the provision of synchronised media in multiple modalities, i.e., captions for hearing impaired users, audio description for vision-impaired users and possibly simple language provision for users with cognitive impairment. Although not part of the current implementation, the URC technology does support this use case by inclusion of streaming variables in the user interface socket, as defined in ISO / IEC 24752. Based on this concept, the user can pick any combination of synchronised streams (video, audio and text) that is most suitable for them.

Additionally, based on the experience gained in the validations, it is believed that the UCH technology is sufficiently mature to be implemented in current mass-market devices and to be considered for integration from the earliest phases of new product development processes. In this sense, various recommendations have been put forward on where the UCH should be implemented and which TV sets to target for integration first.

Finally, the authors' opinion is that this approach will help in providing universal access to TV sets, by means of allowing TV set configurations that include advanced UIs, natural language UIs, assistive technologies and multimodal streaming. This architecture allows the deployment of these alternative user interfaces in a plug-and-play fashion. In this sense, customisable pluggable UIs can be developed by third parties to address the needs of different user groups. This situation opens the door to a new market for UIs. Business models for this new market are still a topic of research, but resource server-based marketplaces may be the best approach. Furthermore, these resource servers cannot only store UIs or their resources, but can also contain UCH integration modules, which help the automation of the installation and the updating of current mass-market devices to support the approach proposed for universal access.

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