GORKA EPELDE UNANUE

USER INTERFACE ABSTRACTION FOR ENABLING TV SET BASED INCLUSIVE ACCESS TO THE INFORMATION SOCIETY

The television (TV) set is present in most homes worldwide, and it is the most used Information and Communication Technology (ICT). Despite its large implantation in the market, the interactive services' consumption on TV sets is limited. This thesis focuses on overcoming the following limiting factors: (i) limited human computer interaction (HCI) and (ii) lack of consideration of users' real life context in the digital television(dTV) service integration strategy. Making interactive services accessible to TV set's large user base is understood as the path to integrate the mankind with the information society, especially the most vulnerable ones. This thesis explores the use of user interface abstraction technologies to reach the introduced goals. The main contributions of this thesis are: (i) an approach to enable the universally accessible remote control of the TV set, (ii) an approach for the provision of universally accessible interactive services through TV sets, and (iii) an approach for the provision of universally accessible services in the TV user's real life context. We have implemented the contributing approaches for different use cases, and we have evaluated them with real users, achieving good results.

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User Interface Abstraction for enabling TV set based Inclusive Access to the Information Society

By

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Submitted to the Computer Architecture and Technology Department
in partial fulfillment of the requirements for the degree of
Doctor of Philosophy

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To Arbil, Mattin, and Ianire

Originality Statement

I hereby declare that this submission is my own work and to the best of my knowledge it contains no materials previously published or written by another person, or substantial proportions of material which have been accepted for the award of any other degree or diploma at The University of the Basque Country or any other educational institution, except where due acknowledgement is made in the thesis. Any contribution made to the research by others, with whom I have worked at The University of the Basque Country or elsewhere, is explicitly acknowledged in the thesis. I also declare that the intellectual content of this thesis is the product of my own work, except to the extent that assistance from others in the project's design and conception or in style, presentation and linguistic expression is acknowledged.

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Signed:____

"A little more persistence, a little more effort, and what seemed hopeless failure may turn to glorious success."

Elbert Green Hubbard, 1856–1915

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Tesi hau burutzea ez zen posible izango, hainbat pertsonen gidaritza, motibazioa eta ulermena izan ez banu. Tesi hau ez zen errealitate bilakatuko, zuen arlo tekniko zein pertsonaleko dedikazio eta ulermen gabe. Nire eskerrik beroenak eman nahi dizkizuet, tesia hasi aurretik eta tesiaren garapenean zehar emandako laguntza eta eskainitako denboragatik.

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Chapter 1

Introduction

This chapter is a general introduction to the PhD Thesis Report. The chapter is organised as follows. Section 1.1 introduces the motivation and context, Section 1.2 presents the objectives and Section 1.3 presents the structure of this dissertation.

1.1 Motivation

1.1.1 TV as the most widely used Information and Communication Technology

Television was invented in early 20th century. Ever since then its use has grown incrementally. Television is present in most homes worldwide and is the most used Information and Communication Technology (ICT). Furthermore, watching TV is one of the activities that take up most of our leisure time (Zillmann and Vorderer, 2000).

Despite the strong perception that younger age-ranges are dropping TV consumption caused by the rise of social media, mobile device usage, and other digital trends, this has proved to be happening in a rather slow fashion. According to latest analysis on cross-platform media consumption in Europe (Eurostat European Commission, 2013) and United States of America (Nielsen, 2014), TV remains by far being the dominant medium at all age ranges.

More in detail, in 2013 in the European Union, 85% of the population watched

TV through the TV set everyday or almost every day, and it went up to 95% if at least once a week use was considered. Compared to the reported daily use of Internet 56%, radio 50%, written press 33% or social networks 30%, TV set usage was the largest from all. Furthermore, if we consider the 55+ population, the everyday usage goes up to 93%. In Europe according to *OFCom* numbers for 2011, TV watching continued increasing, getting average minutes consumption of TV per day per person of 239 in Spain, 242 in the UK , 225 in Germany and 227 in France (2012).

Similarly, the statistics for the USA clearly show the dominance of traditional TV over game console, computer or mobile with regard to media consumption. The numbers reported by Nielsen for Q4 2013, present a 10 times higher consumption of traditional TV over all age ranges compared to watching time-shifted TV, using a DVD / Blu Ray device, using a game console, watching video on Internet or watching video on a mobile device. The only media consumption activity that shows a more considerable use over the different age-ranges is using the Internet on a computer, which is used 5 times less than the traditional TV.

As for the European citizens, older age-ranges make a higher consumption of traditional TV compared to the youngest age ranges. In the following Table 1.1 weekly consumption time for different age ranges is given to illustrates this difference.

Table 1.1: Weekly traditional TV consumption for the U.S.A. citizens for Q1 2013. TV in Hours : Minutes.

Age range	TV Consumption
2-11 years	24:37
12-17 years	21:22
18-24 years	23:24
25-34 years	28:53
35-49 years	34:18
50-64 years	44:09
65+ years	49:21

1.1.2 TV Potential for Interactive Services Provision

TV was designed and developed for entertainment, and its use has been mainly limited to render broadcasted content to the user. However, the TV sets' evolution from the analogue world to the digital world opened up a new range of possibilities.

Based on the favourable statistics regarding the penetration and use of the traditional TV, focus has been set on this ICT device to provide services from other mediums to a broad scope of population. As such, many studies and developments have tried to provide interactive services on TV sets.

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 in to TVs in many research projects (Cesar and Chorianopoulos, 2009).

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 Center solutions, to the TV set's themselves.

The level of interactivity of the implemented services has followed a likely path, from simpler to more complex services (i.e. 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 Smart TV (Yahoo! Inc., 2014) or Sony Applicast, and the so-called SmartTVs or ConnectedTVs.

This growing interest in providing interactive services through the TV can also be found in recent approval standards such as HbbTV. In HbbTV, regular broadcasts are complemented by interactive services available on-line. The aim is to provide those services seamlessly on a TV set (ETSI, 2010).

For many people, the integration of interactive services into a TV set means being able to access online banking, e-health services, having web presence or socialising via social networks. Otherwise, these services are inaccessible to them due to a lack of computer skills or other accessibility barriers (Technosite et al., 2011).

Moreover, the current trends of moving physically provided services into the cloud to save money in personal costs and to improve benefit margins, sharpens the need of providing interactive service in an accessible way to all. Otherwise, these user groups could be at risk of exclusion from the digital society.

1.1.3 Problems in Interactive Services on TV uptake

Despite the efforts to provide interactive services on television, no breakthrough deployment and use has been achieved until now. Integration with the information society has not been reached and TV nowadays continues mainly being an independent broadcast island. Only technical experts occasionally use the integrated interactive services.

Cesar and Chorianopoulus pointed out the following as the possible causes of the limited uptake: user interface design and evaluation methods issues (arguing that generic usability techniques cannot be directly applied to iTV applications), the pervasiveness of basic TV infrastructure, unrealistic expectations, slow evolution of iTV technologies, and conflicting viewpoints of stakeholders (2009).

Similarly, *Martin et al.* argue that the higher price of the interactive digital television hardware, and the lack of knowledge of the full features of the interactive television, make consumers to go for a less expensive hardware (2010). Additionally, they refer to patent and royalty issues as limiting factors.

From the state of art review, the main factors for the limited adoption of interactive services on TV sets have been identified, named as follows:

- Limited Human Computer Interaction.
- Lack of considering user's real life context in the dTV service integration strategy.
- Not all services can be deployed on a TV set.
- Regulatory framework limitations and conflicted interest of stakeholders.
- Lack of awareness – Lack of a killer application.

The identified main factors are analysed in the following subsections.

1.1.3.1 Limited Human Computer Interaction

Traditional remote control interaction is well suited for basic TV functionalities (volume up/down, channel up/down, moving to specific channel) and mainstream users. But it is limited for those with limitations to use the remote control to interact with the basic TV functionalities usage.

Even for those that can make use of this interaction concept with basic TV functionalities, it ends up in a limitation when it comes to the interaction with more complex services.

The following Figure 1.1 shows the interactivity capabilities of devices compared to the number of consumers they have.

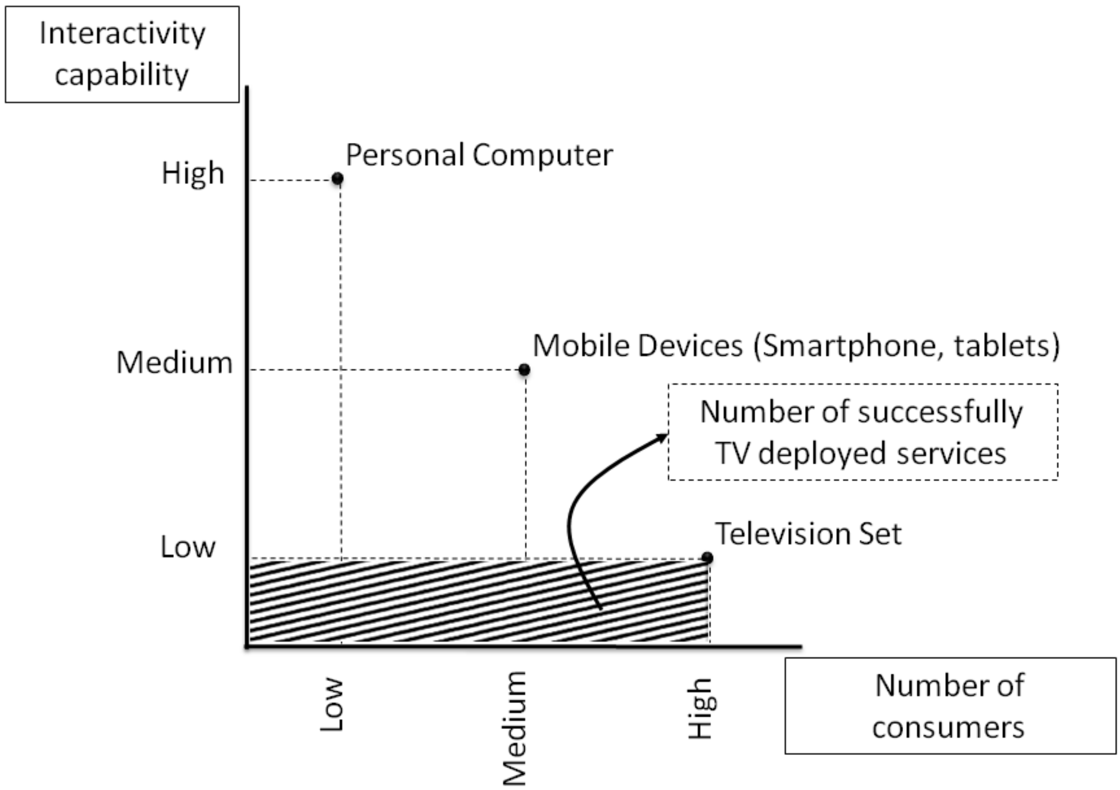

Figure 1.1: Interactivity capabilities of devices compared to the number of consumers they have

The diagram suggests that even if interactivity capabilities of TV are low, the large extension of the consumers makes this device an interesting device to provide solutions for. Advances on human computer interaction (HCI) technologies for TV (increasing the interactivity capability) can enable the number of successful TV deployed services to grow.

In recent years, TV manufacturers have started including natural user interfaces for TV sets (e.g. voice interaction), but solutions are still incipient and more natural and adapted interactions means are missing, especially for seniors and people with disabilities.

In addition to the limited interaction concept, commercial TV sets do not provide open and standardised interfaces to connect plug-and-play user interfaces or interaction means, limiting the development and deployment of new interaction technologies.

The presented interaction limitations of existing TV sets are especially a barrier for many people with disabilities. This limitation stops them from consuming interactive services on TV from the very beginning or are a major impediment for them.

1.1.3.2 Lack of considering user's real life context in the dTV service integration strategy

dTV interactive service integration developments have usually been done as independent developments and as add-ins to service portfolios in order to have representation on this extended platform. On the one hand, a strategy should consider that the user is not always in the same scenario. The user goes out, goes to work, goes on vacation and uses other devices to interact with those services that are being targeted to dTV. In addition, humans are part of a community and a society (relatives, caregivers, public / private service providers), which depending on the service to be provided, requires different actors' participation.

Therefore a successful strategy for integrating information society's services with the most used ICT device in society, should not only consider dTV solutions as separate developments. They should provide the user and its community with a global strategy and an architecture to support it.

The user should be able to continue the experience started on the TV sets in one context, on other contexts and vice versa. Additionally, the service provision should take into account the different actors involved from an integrated point of view.

1.1.3.3 Not all services can be deployed on a TV set

TV content and service consumption has been traditionally done in a lean back way (watch what is broadcasted) and shared among different home users. Even with the evolution of some users searching and choosing what they want see (lean forward) or users acting as producers, the TV set consumption context (posture, environment and group socialisation), limits some service deployments success.

As identified by *Cesar and Chorianopoulus* at the interactive TV application development methodologies need to take into account the specifics of the TV consumption environments (2009).

In this scenario, new advances on "second screen" experience can help starting a task in a device and moving to a second device which will enable high level of interactivity.

1.1.3.4 Regulatory framework limitations and conflicted interest of stakeholders

Each country has a different regulation with regards to the content and services that are offered, hardening common solutions uptake. Usually these regulations, limit broadcasting bandwidth, the type of content to be broadcasted (e.g. pornography), and the broadcasting time-frames for each content type. Broadcasters have to meet the legislation imposed by the regulatory framework, otherwise having to pay fines or even being banned or losing their broadcasting license.

Besides, the main source of financing for TV broadcaster is advertisement. The fear of launching external content that could contain out-of-regulation content or could lead to loss of advertisement consumers, has limited the development of seamless transitions among broadcasted content, interactive content and interactive services.

The lack of seamless transitions creates usability and accessibility barriers to users, whose main objective is entertainment, and slows down the adoption of the deployed interactive services. It is hard for them to switch from broadcast content to interactive services and to go back to broadcasted content.

Furthermore, broadcasters have limited as much as possible the exposure of their contents through other mediums such as the Internet, or they restrict their visualisations to be only through their web sites.

1.1.3.5 Lack of awareness – Lack of a killer application

Last but not least, the interactive TV services have not raised the awareness required for a large uptake by consumers. Many consumers have not understood the added value of buying an interactive TV hardware. This can be either caused by the interactive TV stakeholders failing to transmit their products or by the lack of a killer application for interactive services on TV.

Beside broadcast-only services such as the EPG, VOD or PVR, interactive TV has not found an application with a minimum use. The interactive TV is still lacking a killer application that would attract users to buy the required hardware and make use of such applications massively.

For times, videoconference has been identified as the one to be the killer app, but even videoconference on TV has not yet achieved a massive uptake.

1.1.4 Motivating User Scenario

Lynda (82 years old) was a very healthy person and autonomous person in her seventies, who widowed some years ago. Lately, she has begun to forget about recent things, like appointments with her friends. Her son John (60 years old), has asked her to move to their family's home, so she can be looked after. But she likes her independence and prefers living on her own.

John has recently early-retired from his work, due to the hand tremor his developing parkinson was causing on him. Neither John nor Lynda have computer skills and the ICT devices that they use are the fixed-line telephone and the TV-set in their living room. Peter (30 years old) is John's son, lives with him and is a technology enthusiast.

1.1.4.1 Sub-scenario 1: TV set Remote Control Universal Access

Lynda has a traditional TV set remote control configuration at home. John is quite sad because his hand tremor does not allow him to use her mother's traditional remote control, and he can't use the speech recognition system he has at home. John has to ask his mom to change channels and to perform related tasks.

At John's home, Peter is quite upset because the speech recognition system enabled TV set is quite slow for him. Moreover, the newly bought TV system is using closed software and he cannot control it using his multi-use smartphone. Peter keeps all his information and services on his smartphone.

Peter's work colleagues have talk to him about an innovative system that can be connected to a TV set and makes the TV set controllable through different user interaction technologies. This system can be configured manually (for expert users) or be managed by a service provider (for non-expert users).

Peter has decided to go for manual configuration for his home and for managed configuration for his grandmother's house.

For his grandmother house he has decided to enable the interaction through traditional remote control and through the speech recognition system used by his father. At his home, he has been playing around and he has configured speech recognition for his father and smartphone based gestures interaction for him.

After two years Lynda's sight has started worsening, so Peter has called the service provider to exchange her TV set UI with a simpler version containing larger fonts.

1.1.4.2 Sub-scenario 2: Interactive Services Universal Access through TV sets

John is quite angry because the bank office at his town has limited the retirement pension related task's office hours, to two hours per week. This generates excessive queues and it is frustrating him. Peter is telling him about the benefits of using the web version on PC, but John feels lost with the PC based complex UIs and he is afraid of making a mistake.

In addition, John sees his son using the videoconference system to communicate with his workmates, and he feels that it would be great if he could use it with his family members that went abroad to work.

John is also concerned about his mom forgetting appointments and the discussions she has with friends due to the forgotten appointments.

Peter has found in the Internet that the system that they had bought for remote controlling TV sets with alternate UIs, can be extended to use interactive services through their preferred TV UI configuration. He has installed the speech based bank and videoconference services' modules at his home system. John is really happy and telling all his friends about the benefits of this advanced TV set system.

Peter has recently read on scientific divulgation magazines that virtual human based UI are giving good interaction results with people with cognitive impairment. He has searched on the system's repository for an avatar based TV set UI, focussed in seniors with cognitive impairment. Next, he has asked the service provider to install the located UI for Lynda.

Lynda is really happy since she receives notifications of the appointments through a natural UI on TV. The appointments are set by herself through the speech recognition. She has improved her relationship with her friends and John is happy to see that his mom remains autonomous at the age of 82.

1.1.4.3 Sub-scenario 3: Interactive Services Universal Access in User's Real Life Context

John fell from the stairs and broke his knee. He had to undergo a knee replacement surgery. For the rehabilitation therapy, he was initially guided by a therapist, but then he moved to use a simplified PC based system rehabilitation system. Once finished the rehabilitation at the hospital, he has been given an instruction sheet to continue rehabilitation at home. John was active with the highly interactive PC based system and now he is under-motivated with the paper sheet based rehabilitation at home.

In less than a week, John reads in the newspaper about the innovative rehabilitation service his regional health department is offering. He has called to get informed and they have told him that it is compatible with his TV set system, but needs to install some modules for the services. John has asked Peter to help him, and Peter has installed the modules without further assistance.

Suddenly, John receives a telephone call telling him that he has won a travel to

Lanzarote. He is excited about the prize, but a bit upset since he will have to decide on going on travel or continuing with his rehabilitation.

Peter, aware of his fathers situation, looks for a tablet based solution for the rehabilitation service. Peter finds a UI with the same look and feel, but with larger fonts and speech recognition functionality.

Thanks to the PC based experience at the Hospital, John has become more open-minded and agrees to give a try to the tablet based UI. After a weekend with Peter's assistance, John decides to go on travel to Lanzarote himself and to continue rehabilitation while he is in Lanzarote.

Once back home, John goes to an out-patient revision. His therapist is amazed with the advance his knee has done and congratulates him, and programmes him new exercises using her PC based client. They discuss about the benefits of this new system, and the therapist tells John that she is also really happy.

She has been given more work hours flexibility, and they have provided her with a tablet with an expert UI, that allows her to continue her work while on the move. From the UIs developed for the rehabilitation service, she uses the ones with really small font and good organisation, since she feels that they maximised her work.

1.2 Thesis Objective

The motivation of this work has been the limited uptake of interactive services on TV sets, despite the potential TV has for their deployment and making such services accessible to a larger user base. This potential is due to the large deployment and use of TV sets worldwide.

From the identified problems in Section 1.1.3, this thesis focuses on the **(i) Limited Human Computer Interaction** and **(ii) Lack of considering user's real life context in the dTV service integration strategy.**

More specifically, this thesis tackles the limited capabilities of actual TV sets to connect alternative user interfaces or interaction means. The objective is to enable the development and deployment of new interaction technologies that meet each person's needs and preferences.

Additionally, this thesis considers those needs in the scope of user's real life context, with the aim of achieving user's acceptance and a breakthrough deployment.

1.2.1 Problem Statement – Research Objective

This PhD thesis's objective is to contribute to the state-of-art technologies for interactive services provision on TV with aim to enable an inclusive interaction (especially to vulnerable collectives), and to increase interactive TV uptake, with the aim to provide universal access to different services of the information society.

In addition, this thesis aims to contribute to the support of scenarios where parting from a TV centric environment, users can continue their experience in different environments using the controller device and the interaction technology that fits them best in each scenario.

Therefore for this thesis, the following specific objectives are defined:

1. To define an approach using user interface abstraction technologies to overcome the limited human computer interaction of interactive services on TV while enabling the provision of HCIs meeting each user's needs and preferences.
2. To define a user interface abstraction technology based approach to support TV user's in their real life multi-device context interaction needs and preferences.

1.2.2 Benefiting from defining solutions with people with disabilities in mind

This thesis acknowledges that many people with disabilities suffer most from the lack of solutions developed with diversity in mind. Some solutions developed for people with disabilities have demonstrated to be helpful for users that were not initially thought for. For example, captions were developed for deaf people, but are reused by people learning a new language or to follow a TV show in noisy environments.

In general, the development of solutions considering people with disabilities leads to more flexible solutions, and technologies that can enable access to other users under different context or impairments. Therefore this is considered an opportunity for achieving the objectives of this thesis.

1.2.3 Personalisation term usage in this thesis

This thesis is focussed on enabling the provision of HCI paradigms that fit best each TV set user. Therefore, in the context of this thesis, the "personalisation" term refers to the selection, adaptation and deployment of a HCI technology and the application, to meet per device and per context needs and preferences of each user.

1.2.4 Related Projects

This thesis was possible thanks to the participation of the author in different projects and research collaborations as a full time researcher at Vicomtech Research Centre in Donostia - San Sebastian, Spain and with the highly valuable support and guidance from Prof. Julio Abascal from the University of the Basque Country, Prof. Gottfried Zimmermann from the Stuttgart Media University, and Prof. Julian Florez from Vicomtech Research Centre.

The topics of this PhD were researched whilst participating in the following projects:

1. Intuitive Interaction for Everyone with Home Appliances based on Industry Standards (i2home): partially funded by the EU 6th Framework Program under grant FP6-033502.

2. Vital Assistance For The Elderly (Vital): partially funded by the EU 6th Framework Program under grant FP6-030600.

3. Ubiquitous Multidevice Personalised Telerehabilitation Platform (eRehab): Co-funded by the Basque Government under the ETORGAI program and the ICT companies Baleuko, STT, Ikusi, Vilau, Bilbomática and Teccon.

1.3 Structure of this thesis

The remaining of the PhD report is structured as follows:

1. Chapter 2 reviews the state-of-the-art related to this thesis. This review includes sections on TV accessibility, Abstract User Interface Description Languages, and Multi-Environment and Multi-Device Personalised Service Delivery Architectures, which are core to the contributions of this PhD work. This chapter also presents the user scenarios motivating this thesis.

2. Chapter 3 presents the approach defined for enabling the Universally Accessible TV set's Remote Control, together with the implemented case study to validate the defined approach.

3. Chapter 4 describes the approach defined to provide Universally Accessible Interactive Services through TV sets, together with the implemented case studies to validate the defined approach.

4. Chapter 5 presents the approach defined to enable Universally Accessible Services in TV user's real life context, together with the implemented case study to validate the defined approach.

5. Chapter 6 summarises the conclusions of this PhD research results. Main contributions and endorsing publications are described as part of it. Additionally, the future work planned and open challenges are introduced.

Chapter 2

Related Work

This chapter gives an overview of the current state-of-the-art of television accessibility, as well as the existing background on multi-device multi-environment service provision infrastructures. Abstract User Interface Description Languages will be analysed as the core part of the technology proposal for fulfilling the main objectives of the present thesis.

Section 2.1 reviews previous work on television accessibility. Section 2.2 analyses the different Abstract User Interface Description Languages. Section 2.3 presents the state of art approaches to Multi-Environment and Multi-Device Personalised Service Delivery Architectures. And the chapter finishes with the state of art review's conclusions in Section 2.4.

2.1 TV Accessibility

2.1.1 Introduction

The "Monitoring eAccessibility in Europe: 2011" report, funded by the European Commission, analyses both the accessibility of broadcast programs and end-user TV equipments. The report informs that TV accessibility is still far away from being implemented to its fullest extent (Technosite et al., 2011). In addition, it highlights the accessibility opportunities and challenges that the introduction of digital TV brings. This main challenge of not excluding people from accessing any digital TV's services was already underlined by the iTV research community at (Gill and Perera, 2003).

Given the political pressure to confront the poor design of accessibility and usability of interactive TV services and client devices, research has increasingly improved the state of art of this technology. Together with the technological research advances, guidelines that advise implementors over the existing solutions for making TVs accessible have been defined (Digital TV Group, 2013a,b; Olaf Looms, 2011).

From our point of view there are two main working areas directly related to making the TV interaction experience accessible, which are:

- Content accessibility.
- Access to the digital TV.

The state of art of these working areas is presented in the following sections.

2.1.2 Content Accessibility

This working area covers the initiatives that seek to provide alternative content means, which are synchronised with the original content. This way people with different disabilities can consume audio-visual content in an accessible way. This audio-visual content corresponds to the broadcasted TV content and to the iTV applications' media content.

The main accessibility services for providing accessible broadcast content according to (Olaf Looms, 2011), are:

- Audio-description / audio-captioning for the visually impaired.
- Captioning for the hearing impaired (and for people with language understanding problems).
- Sign language interpretation for the born deaf.

To ensure the availability of these services, it is necessary that all stakeholders comply with the legislation and the standards of production, distribution and display of such content.

The main efforts in this area have been made in the standardisation of the creation process of alternative content through regulatory agencies. At national level in Spain, UNE provides a standard reference on the creation of audio-description (UNE, 2005) and another standard reference on the creation of teletext subtitles (UNE, 2003). More recent standardisation efforts have led to the development of an international standard, providing guidance on the audio-description creation (ISO/IEC, 2013). Regarding the subtitling definition guidelines at international level the most used in many countries is the *BBC* subtitles editorial guideline (2009).

With the transition from analogue to digital television, ETSI has published a standard (ETSI, 2006) on how the subtitles should be managed in the Digital Video Broadcasting (DVB) technology.

It is remarkable, the ability of the DVB technology to transmit content composed of different streams of audio, video, and data. This enables the distribution of the audio-description, the sign language signing or the subtitles as additional channels. Thus, the user can select the combination of content streams to be rendered on their client device.

Targeting an improved level of access services over DVB, *Martin et al.* have researched on the provision of more personalised access services over the Multimedia Home Platform (MHP) technology (2010). Their solution provides subtitles whose appearance can be configured by the user targeting the deaf and the hard-of-hearing, and a spoken electronic programme guide (EPG) for the blind and the visually impaired. They send the human voice audio clips for the spoken EPG together with the guide.

In the content accessibility research area, different approaches have been tried to present solutions to adapt the content to the different user groups by making use of the multimedia framework provided by the MPEG-21 standard. *Yang et al.* propose an adaptation system based on the MPEG-21 standard, focused on visual disabilities (people with colour blindness) (2004). Opposed to disability specific efforts like this, *Vlachogiannis et al.* propose a content adaptation framework, also based on the MPEG-21 standard, that can adapt pre-authored content to the specifics of each user (2011).

The amount of accessible TV content produced is still well below 100% in traditional TV broadcasting. Due to the legislation change in many countries obligating to broadcast a higher level of accessible content, several initiatives like creating signed language through virtual characters, automatic captioning or translation of subtitles have been launched. The aim is to (fully or partially) automate the production of accessible content.

There is also a major challenge to ensure content accessibility in the current paradigm shift of TV content consumption, where the user is moving from being a mere consumer to produce content. This is happening in an environment where production, distribution and render are no longer in the hands of few parties and fixed set of technologies, as it has been so far.

2.1.3 Access to the Digital TV

Access to the digital TV comprises the purchase, installation, set-up and use stages. In this sense, a report on usability and accessible design of the TV analysed the following usage stages (Klein et al., 2003).

- Choosing and purchasing the TV set.
- Installing the TV set.
- Tuning the TV set.
- Setting the TV so that the DTV channel is convenient to access.
- Finding out what is on and selecting the desired channel, either by using the interactive on-screen guide, or by random surfing.
- Using subtitles, accessing additional settings, navigating the menu structure.
- Accessing interactive content (e.g. Teletext, BBCi).

More recent guidelines follow a similar approach for describing the different needs support (Digital TV Group, 2013b).

The focus of this thesis is on the accessibility of the user's interaction with the TV, so the information related to the product's acquisition and installation will be left out. Therefore, the remainder of this section is splitted into the accessible remote control of the TV and the accessible interactive services on TV.

2.1.3.1 Accessible Remote Control

The accessible remote control topic covers the efforts of providing a means of remotely controlling basic TV functionalities (e.g. channel up/down, volume up/down or turning the TV on/off) to all user groups.

The difficulties associated with the use of conventional handsets (unclear labels, insufficient tactile feedback, poor position and size of buttons) by the different user groups are well known (Costa et al., 2012).

Usability advances for different user groups have led to changes in the appearance of the TV remote controls. As introduced by *Rice et al.*, the usability improvement process has to be done taking care of the difficulties of simplifying the remote control, and getting it right (2008). An example of these difficulties is noted by *Carmichael* in (1999) as: fewer buttons may reduce demands on memory, but it can increase the workload when attempting to match more functions to fewer buttons.

The research community has also driven efforts to develop new remote control paradigms. These efforts are listed and classified by *Cesar and Chorianopoulus* (2009). Some of the interaction paradigms that could help making the TV remote control more accessible is the use of objects, such as pillows (Schiphorst et al., 2007), gesture recognisers (Kim et al., 2004), speech interaction and dialogue systems (Berglund and Johansson, 2004), and the use of other devices such as mobile phones and PDAs.

A notable work proposes to use a PDA with 3D visualisation based interaction paradigm, enabling the direct manipulation of physical environments, such as those composed by TV sets. Using this interaction paradigm, the user can control these devices or even drag and drop a presentation from a PDA to a TV set (Shirehjini, 2004). Furthermore, thanks to its UPnP network based architectural approach, it facilitates the user with a direct access to the control of the physical environment's appliances without having to know about IDs or IP numbers of specific devices (Shirehjini, 2005).

Nowadays, it is becoming common to find commercially available high end remotes with gyroscopes or microphones. Additionally the interaction technologies implemented in game console controllers like the Nintendo Wiimote or the Microsoft Kinect suggest that these new remote control paradigms could simplify some user's life in the future. Researchers are already investigating the use of these types of controllers in pointer based (Vatavu, 2011) or gesture based interactions with the TV set (Kim et al., 2004).

Figure 2.1 shows possible alternatives that can help ensuring the accessibility of the remote control of the TV.

Figure 2.1: TV set's remote control alternatives

The TV experience is usually shared among different users, and traditionally limited to watching broadcasted programmes. With the digitalisation of the TV technology and the introduction of iTV applications, a new challenge has appeared to enable the multi-user interaction of iTV services. Different studies, have analysed the multi-user interaction of TV sets, and have provided advanced solutions to allow the interaction with more than one remote control at the same time (Vatavu, 2011; Wang et al., 2011).

The initiatives presented in this subsection target specific use-case scenarios and specific developments for specific TV models, so the developments cannot be easily integrated in future implementations. Furthermore, they do not enable the use of alternate user interaction technologies in their approaches (which would allow meeting the needs and preferences of each person).

2.1.3.2 Accessible Interactive Services on TV

In recent years, several research projects have focused on the integration of interactive services into TV sets. This type of services can be categorised according to their level of interactivity (Peng, 2002):

- Broadcast-only services: Electronic program guides (EPG), Local games, Video on Demand, Personal Video Recording ...
- One-way interactive services: Advertisement direct response, opinion polling, voting ...
- Two-way interactive services: TV banking, interactive TV content, email, social networking ...

Apart from research projects, reacting to user interest in interactive services, manufacturers began including iTV applications in commercial products. These evolved gradually from Set-top boxes and PC based Media Center solutions, to the TV's themselves. The level of interactivity of the implemented services has followed a similar path, with successively more complex services being introduced.

With the advances in computation power, user interface technology has evolved from a simple on-screen display (OSD) to modern widget technology to improve the usability and user acceptance. A good example of these developments is the commercial availability of TV sets supporting advanced user interface technology like Yahoo Connected TV (Yahoo! Inc., 2014), Google TV (Google, 2014) or Philips Net TV (Philips, 2014).

This growing interest in providing interactive services through the TV can also be found in recent approval standards such as HbbTV (ETSI, 2010). This standard proposes to complement regular broadcasts with interactive services available online, with the aim of providing those services seamlessly on a TV set.

Once introduced a generic view of the interactive services on TV's evolution, the study will focus on research related to the usability and the accessibility of the interactive services on TV. In this sense, the initiatives are analysed from a product's life-cycle point of view:

- User requirement gathering methodologies.
- Design and development methodologies.
- Implementation of accessibility solutions for specific interactive services.
- iTV applications evaluation.

User Requirement Gathering Methodologies *Rice et al.* presented a research work centred on elderly users, where possible iTV applications are presented at theatrical sessions (2008). This allows audiences to empathise with the characters, and questioning their actions, they can think about the role of this technology. Once their needs, feelings, and requirements about the applications are gathered, the author proposes to follow up with paper prototyping and brainstorming sessions to understand how older people perceived using the targeted applications.

A related study, introduces various qualitative research methods applied to the field of design and evaluation of iTV applications (Eronen, 2006). She suggests that the application of these methods to the adaptation of applications to specific user groups, can help understanding their accessibility problems, while developing universally accessible interactive TV applications.

Following ethnographic methods, *Obrist et al.* (2008) and *Bernhaupt et al.* (2008) present studies, which investigate media consumption with TV as the focal point.

Design and Development Methodologies In (Springett and Griffiths, 2008), a methodology to develop accessible iTV applications is presented . This methodology divides the application's tasks into simpler tasks and the capacities needed to fulfil each task. To define the needed capacities, the authors evaluate each task with users, checking if they have any problem to carry out the defined task, annotating the capacities needed to fulfil the task.

In a following phase, they evaluate prototypes with users and they inspire creative thinking and gather suggestions by using check-lists that challenge the participant to think about questions and ideas that they may not have considered.

A notable guide offers detailed information on the appropriate design of digital services deployed on TV for the older people. The design information is based in their sensory and cognitive abilities, and the demands the system may place on them (Carmichael, 1999). For example, the importance of clear visual/spatial navigational support, such as suitable highlighting and lowlighting, is referenced as being important to relieve working memory load, minimise errors, and help guide attention through operations on screen.

Implementation of Accessibility Solutions for Specific Interactive Services
Most of the work done to date has been related to EPG applications. Some have extended the implemented text to speech capabilities for the basic TV interaction activities to EPG applications. There is an initiative that integrates a paper based remote for interacting with the EPG application (Berglund et al., 2006). *Carmichael et al.* developed a virtual assistant, providing a new interaction mean between the viewers and the content and functions of the EPG (2003).

With the explosion on the use of Internet based services, the development of TV based interactive services like the social networks, telemedicine or telerehabilitation has grown substantially, mostly focused on the mainstream users. Nevertheless, work is still missing on the provision of these services to less favourable user groups in an accessible way on their TV sets.

Concerning the available iTV platform implementations, the commercially available platforms like Yahoo Connected TV or Google TV are based in closed middleware implementations. They can't be easily extended to enable the interaction through more accessible or more advanced user interface technologies.

With regard to the work in the implementation of the adaptation of the graphical user interfaces to fit elderly user needs, *Rice and Alm* proposed and evaluated four prototypes layouts (carousel interface, flipper interface, transparency interface, standard iTV interface) and navigational strategies of communications systems (2008). These authors underlined the need of developing user interfaces, which follow a continuity concept, meaning that the users can relate them to concepts of their real life.

iTV Applications Evaluation In the context of the iTV applications evaluation, a research work proposed an affective UI evaluation methodology that takes into account usability and accessibility requirements, as well as the specific characteristics of the TV consumption context (Chorianopoulos and Spinellis, 2006). This is a step forward on providing accessible iTV UIs, making sure that the resulting UI competes with the established TV experience.

Rice presented the difficulties that visually disabled users face while consuming iTV services (2004). This work makes emphasis in parameters like screen size, font size and colour, icons' identification and screen layout. The main conclusion derived from the study is that the best way to approach the problem situation is personalisation, due to diverging requirements. A related study by *Springett et al.*, examines the applicability of the W3C web accessibility guidelines to interactive television focused on the visually impaired (2007). Regarding the elderly users, up to now, few studies have evaluated the design of iTV applications for older people, beyond the usability evaluation of existing services (Obrist et al., 2007).

2.2 Abstract User Interface Description Languages

2.2.1 Introduction

The separation of the user interface of an application or a service from the core functionality has been pursued since many years. Based on this user interface separation concept new scenarios are opened where specialist can develop user interfaces for specific context of use (user, device, environment). Following this concept user interfaces can be updated or upgraded independently from the functionalities implementation. What's more, these user interfaces can be automatically generated or adapted to enable universal access or enhance user experience.

Starting in the late 20th century, User Interface Management Systems (UIMS) for desktop based computer programs pursued decoupling the user interface code from the business logic of the application. Two of the most known and influencing contributions from that period are the largely used Model-View-Controller software design pattern (Krasner and Pope, 1988) and the Seeheim model (Green, 1985).

The separation of the UI from the application was initially motivated by the development of the user interface as an independent module of an interactive application. This motivation was later reinforced by the need to model a user interface as a set of specifications required by model-based development approaches.

The recent need to run user interfaces on a multiplicity of platforms, environments and by users with different needs, has led to the definition of many Abstract User Interface Description Languages (AUIDLs).

An AUIDL consists of a high-level computer language for describing characteristics of interest of a UI with respect to the rest of an interactive application (Souchon and Vanderdonckt, 2003). Depending on the aim of the AUIDL, the abstraction level and the implemented models vary.

The AUIDL specifications and the implementing platforms (section 2.3.2.3) are core part of the objective of this thesis. The objective is defined as to overcome the limited human computer interaction of interactive services on TV and to provide multi-device and multi-scenario support to their users through AUIDLs usage and the platforms implementing them.

In the following, the main XML-compliant AUIDLs that provide device-independence and modality-independence are analysed (Souchon and Vanderdonckt, 2003; Guerrero-Garcia et al., 2009; Trewin et al., 2004; Kuntner, 2012).

2.2.2 Classification

In order to make an initial classification of the AUIDLs, the reference framework defined by the CAMELEON project has been used (Calvary et al., 2003; Fonseca et al., 2010). This framework captures the processes, models, and methods involved in building multi-target user interfaces. This reference framework structures the development life cycle into four levels of abstraction: Task and Concepts, Abstract User Interface, Concrete User Interface and Final User Interface.

- The Task and Concepts considers: (a) the logical activities (tasks) that need to be performed in order to reach the users' goals and (b) the domain objects manipulated by these tasks. Often tasks are represented hierarchically along with indications of the temporal relations among them and their associated attributes.

- The Abstract User Interface (AUI) is an expression of the UI in terms of interaction spaces (or presentation units), independently of which interactors are available and even independently of the modality of interaction (graphical, vocal, haptic . . .). An interaction space is a grouping unit that supports the execution of a set of logically connected tasks.

- The Concrete User Interface (CUI) is an expression of the UI in terms of “concrete interactors”, that depend on the type of platform and media available and has a number of attributes that define more concretely how it should be perceived by the user. "Concrete interactors" are, in fact, an abstraction of actual UI components generally included in toolkits.

- The Final User Interface (FUI) consists of source code, in any programming language or mark-up language (e.g. Java, HTML5, VoiceXML, ...). It can then be interpreted or compiled. A given piece of code will not always be rendered on the same manner depending on the software environment (virtual machine, browser . . .). For this reason, CAMELEON considers two sub-levels of the FUI: the source code and the running interface.

A clarifying example of the instantiation of the CAMELEON Reference Framework is shown in Figure 2.2.

For the detailed analysis of AUIDLs done, the latter technologies have not been considered:

- Initiatives found in the AUIDL research focused on defining CUI level AUIDLs (e.g. XISL (Katsurada et al., 2003), XUL (Feldt, 2009), XAML (MacVittie, 2006), MXML (Adobe, 2004), CTU UIProtocol (Slováček et al., 2009) or VoiceXML (W3C, 2004c)).

- AUIDL specifications or parts of them that are not being openly available (e.g. AIUML (Merrick, 2001) or MXML(Adobe, 2004)).

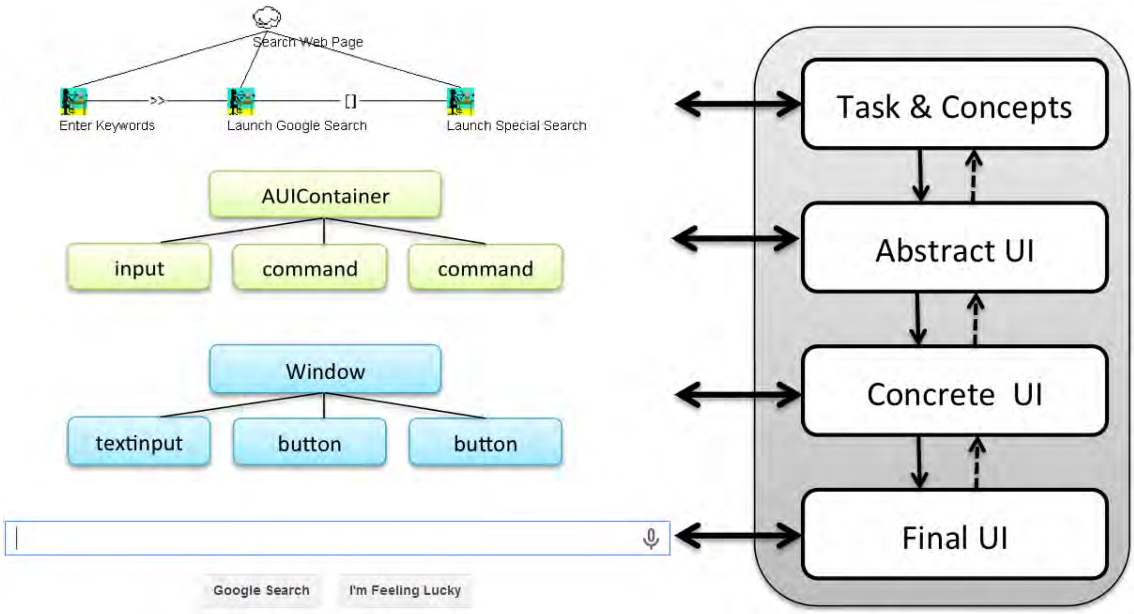

Figure 2.2: Instantiation example of the CAMELEON Reference Framework (Fonseca et al., 2010). On the left side, an example for each level defined by the CAMELEON Framework is given and identified to each corresponding level on the right side with arrows.

- Those AUIDL specifications that have a low level adoption or have not been updated in recent years.

2.2.3 User Interface Markup Language (UIML)

UIML is an XML-based language that provides: (1) a device-independent method to describe a UI, (2) a modality-independent method to specify a UI (Abrams et al., 1999). UIML allows describing the appearance, the interaction and the connection of the UI with the application logic. Following CAMELEON Reference Framework classification UIML is an AUI level AUIDL.

The following concepts underlie UIML:

1. UIML is a meta-language: UIML defines a small set of tags (e.g., used to describe a part of a UI) that are modality-independent, target platform-independent (e.g., PC, phone) and target language-independent (e.g., Java, VoiceXML). The specification of a UI is done through a toolkit vocabulary that specifies a set of classes of parts and properties of the classes. Different groups of people can define different vocabularies: one group might define a vocabulary whose

classes have a 1-to-1 correspondence to UI widgets in a particular language (e.g., Java Swing API), whereas another group might define a vocabulary whose classes match abstractions used by a UI designer.

2. UIML separates the elements of a UI and identifies: (a) which parts are composing the UI and the presentation style, (b) the content of each part (e.g., text, sounds, images) and binding of content to external resources, (c) the behaviour of parts expressed as a set of rules with conditions and actions, and (d) the definition of the vocabulary of part classes.

3. UIML groups logically the UI in a tree of UI parts that changes over the lifetime of the interface. During the lifetime of a UI the initial tree of parts may dynamically change shape by adding or deleting parts. UIML provides elements to describe the initial tree structure and to dynamically modify the structure.

4. UIML allows UI parts and part-trees to be packaged in templates: these templates may then be reused in various interface designs.

2.2.4 USer Interface eXtensible Markup Language (UsiXML)

UsiXML is structured according to the different levels of abstraction defined by the CAMELEON reference framework (Vanderdonckt, 2008) (Task and Concepts, AUI, CUI and FUI levels).

UsiXML relies on a transformational approach that progressively moves among levels to the FUI level. The transformational methodology of UsiXML allows the modification of the development sub-steps, thus ensuring various alternatives for the existing sub-steps to be explored and/or expanded with new sub-steps. UsiXML has a unique underlying abstract formalism represented under the form of a graph-based syntax.

1. Task and Concepts level: Describes the various interactive tasks to be carried out by the end user and the domain objects that are manipulated by these tasks. These objects are considered as instances of classes representing the

concepts. This step is supported by IdealXML (Stanciulescu et al., 2005). It is an extension of the CTT notation (Paternò, 2004) with new task types, attributes, and relationships.

2. AUI level: It provides a UI definition that is independent of any modality of interaction. The AUI is populated by Abstract Containers, Abstract Individual Components (AIC) and abstract relationships between. AIC represent basic system interactive functions, which are referred to as facets (input, output, navigation, control). Two AUI relationships that can be defined between AICs are the dialogue transition (navigation transition within an abstract container or across several abstract containers) and Spatio-temporal relationship (characterises the physical constraints between AICs as they are presented in time and space). This step is also supported by IdealXML (Stanciulescu et al., 2005).

3. CUI level: This level describes a potential user interface after a particular interaction modality has been selected (e.g., graphical, vocal, multimodal). This step is supported by several tools helping designers and developers to edit, build, or sketch a user interface. For instance, SketchiXML (Coyette and Vanderdonckt, 2005), GrafiXML (Michotte and Vanderdonckt, 2008), FormiXML, ComposiXML (Lepreux et al., 2007), PlastiXML (Collignon et al., 2008) and VisiXML are CUI level graphical user interfaces of UsiXML. It concretes an AUI for a given context of use into Concrete Interaction Objects (CIOs) so as to define widgets layout and interface navigation. It abstracts a FUI into a UI definition that is independent of any computing platform. Although a CUI makes explicit the final look and feel of a FUI, it is still a mock-up that runs only within a particular environment.

4. FUI level: This level is reached when the code of a user interface is produced from the previous levels. This code could be either interpreted or compiled. They hereby define a rendering engine as a) a software component (or set of components) that are able to interpret a UsiXML file expressed at the CUI level and to run it, or b) a code compiler that (semi-automatically) generates

code from a UsiXML file expressed at the CUI level.

2.2.5 The eXtensible Interface Markup Language (XIML)

XIML is a language for representing and manipulating interaction data at both Task and Concepts level, and at CUI level (Eisenstein et al., 2001) (following CAMELEON Reference Framework specification).

XIML interfaces are described using five categories of elements: task, domain, user, dialogue and presentation. Dialogue and presentation elements are CUI level, while task, domain and user elements are used at Task and Concepts level.

- Task elements capture the user tasks that the target supports. These are defined following a hierarchical composition containing task attributes and flow.
- The domain is a hierarchy of objects the user can view or manipulate. These objects are defined via attribute-value pairs.
- User elements also form a hierarchy, containing user classes and individuals.
- The presentation component is a hierarchy of CUI level interaction elements, and is unique to a particular widget set (e.g. the set of graphical interface controls provided on a controller platform).
- The final type of interface element is the dialogue. This is also a CUI level element, and it defines the interaction and navigation actions to be taken.

XIML also provides an 'intermediate' presentation component with predefined relations to specific controllers such as desktop PC, PDA and cell-phone. For example, the intermediate component would contain a button object that corresponds to 'button' objects specific to these platforms. This provides some degree of automated mapping.

Although the core XIML language has an abstract (at Task and Concepts level) and concrete level separation, it does not provide a modality-independent representation (AUI level representation). A new presentation component must be created manually for each additional modality to be supported. To alleviate this drawback and to automate this process, the concept of intermediate presentation is used at the CUI level.

2.2.6 XForms

The W3C XForms is a technology intended as the next generation of forms for the web. As such, it focuses on gathering input provided by the user. Some information display facilities are also included, but in general these are provided by a surrounding XHTML context or other host languages in which the form is embedded (W3C, 2009) (e.g. SVG, VoiceXML).

Despite its specialised scope, XForms contains many of the features necessary for a more general abstract language and may be appropriate for its application in a broader context.

XForms itself can be considered as an AUI level language (it is based on abstract interactors definition), which is embedded into a CUI level language (host language). Translators are available for different languages, even if the most popular is the HTML translation.

The XForms approach separates three aspects of a form interface:

1. The data model used by the target.

2. The presentation of the data model to the user. This is achieved by XForms form controls and associated style sheets. The XForms form controls are a set of abstract interactors for gathering the data in the data model.

3. The processing model. It defines the processing actions associated with user actions. These actions may be taken by the target, or may be local to the controller. The processing model is built on a set of standard XForms actions relating to initialisation, interaction, notification and error condition events.

2.2.7 Concurrent Task Trees (CTT) + MariaXML

The AUIDL approach defined by *Paternó et al.* also fulfils all the abstraction levels defined by the CAMELEON Reference Framework (2009b).

At the Task and Concepts level it defines the use of the Concurrent Task Tree (CTT) task model specification notation (Paternò, 2004). For the AUI and CUI levels it defines a multilevel UI logical description language called MariaXML (Paternò et al., 2009a). MariaXML is the successor of TeresaXML (Paternò and Santoro, 2003) which adds support for dynamic behaviours, events, rich internet applications, multi-target user interfaces. MariaXML is focused on web services.

1. Concurrent Task Tree: The main features of CTT are its hierarchical structure, graphical syntax and concurrent notation. CTT is used to model system task associated with a service. Once developed, the result is a structured model where the functionalities of the service are organised in a hierarchical task model and the service operations bindings are defined.

2. MariaXML - AUI level AUIDL: At AUI level, an interface is composed of a data model and one or more presentations. Each presentation is composed of name, a number of possible connections, elementary interactors (interaction object or an only output object), and interactor compositions (grouping or relation).
   The presentation is also associated with a dialogue model that provides information about the events that can be triggered at a given time. The dynamic behaviour of the events, and the associated handlers, are specified using the CTT temporal operators. A connection indicates the next active presentation when a given interaction takes place. All the interaction objects have associated events in order to manage the possibility for the user interface to model how to react after the occurrence of some events in their UI.

3. MariaXML - CUI level AUIDL: For this level, they define concrete platforms for modelling different type of devices. These platforms are defined by modelling the interaction events they support. Next, each interactor type defined at AUI level is refined by adding the specification of the concrete interactors. These concrete interactors contain the concrete platform specific events that can be used to interact with them.

2.2.8 The Universal Remote Console (URC) framework

The URC framework 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 (ISO/IEC, 2008). It can be seen as a user interface "model" that exposes the functions and current state of a target device or service. URC's technical framework includes an AUI level language intended to plug appropriate CUIs for specific contexts of use, either automatically generated or hand-coded.

A user interface for a target is described in three core component:

1. A target description provides pointers to a target's socket descriptions, and accompanying resource sheets. It may also contain pointers to external sources of resources, such as resource services.

2. The user interface socket (UISD) describes the data/interaction model of the target. A user interface socket description is composed of: a description of the functionality of the target as a set of typed variables, commands and notifications (exception-like states generated by the target).

3. Resource Sheets and Grouping Sheets define concrete resources and presentation structures for the UISD that can be used to generate or adapt the user interface to the specific context of use: A Resource Sheet can contain a variety of atomic resources, in different modalities (text, image, video, or any other digital medium that can be stored as a file with a known MIME type).

The URC standard does not support application's Task and Concept level modelling itself, but standard task modelling approximations have been successfully deployed on top of URC technologies (Murua et al., 2010).

2.2.9 AUIDL comparison

2.2.9.1 CAMELEON Reference Framework levels based comparison

The following Table 2.1 compares the AUIDLs under analysis, based on the CAMELEON Reference Framework. Columns refer to the AUIDLs and the rows are the different levels identified by the CAMELEON Reference Framework.

Table 2.1: AUIDL comparison table based on the CAMELEON Reference Framework

	UIML	UsiXML	XIML	XForms	CTT + Maria-XML	URC
Task and Concepts level	No	Yes	Yes	No	Yes	No
Abstract User Interface level	Yes	Yes	No	Yes	Yes	Yes
Concrete User Interface level	Yes	Yes	Yes	No	Yes	Yes
Final User Interface level	Yes	Yes	Yes	Yes	Yes	Yes

2.2.9.2 Comparison based on (Trewin et al., 2004) technical requirements

A reference study, analyses four AUIDLs (UIML, XIML, XForms, URC) for a scenario where the AUIDLs enable any user to access and control any compatible device or service in the environment (named as target), using any personal controller device (Trewin et al., 2004). We will extend this analysis to the rest of the AUIDLs considered for analysis in this subsection (UsiXML and MariaXML).

For the proposed scenario and for the AUIDLs being evaluated, the study defines the following properties as desirable: the applicability to any target and any context of use; personalisation; flexibility, extensibility and simplicity. These properties are specified as the following specific technical requirements that a language for AUI description must meet:

- Separation of data from presentation.
- Explicit machine interpretable representation of the target's user interface elements, commands, dependencies, relations and semantics.
- Flexibility in the inclusion of alternate resources and compatibility with CUIs.
- Support for different interaction styles.
- Support for remote control.

Separation of data from presentation All analysed abstract languages and their frameworks have clear architectures that separate different functional components of a user interface. UsiXML, XIML, MariaXML, XForms and URC are cleaner in their separation of data and presentation than UIML, whose architecture is designed with description of CUIs in mind. This emphasis is reflected in the lack of an explicit data model.

Explicit machine interpretable representation of the target's user interface elements, commands, dependencies, relations and semantics All of them provide an XML based document, but in the specific case of XIML (as analysed in the CAMELEON Reference Framework study), the description is not given in a modality and platform "agnostic" format (It is only given at CUI level). UIML, UsiXML, XIML, MariaXML and URC are all intended to cover a broad range of targets.

XForms has a narrower scope but can be supported through a framework to be equally flexible (e.g. XForms usage in the Persona / UniversAAL UI Framework (Tazari et al., 2010)). All these languages are also intended to represent interfaces for arbitrary contexts of use.

Flexibility in the inclusion of alternate resources and compatibility with CUIs Contribution of user interface resources by third parties (the extensibility property) is strongly supported by URC, fits well within the UIML, UsiXML and MariaXML architecture, reasonably well with XForms, and is not currently supported by XIML.

The precise mechanism by which alternative resources are provided has a significant impact on the flexibility of the resulting framework. If a user interface is built by referencing from a UI description to an external resource set, as followed in transformational approach (UIML, UsiXML, MariaXML and XForms), the pattern of referencing is fixed, including points where the user interface may reuse the same resource in multiple places in the user interface. Replacing the referenced resource set will replace all occurrences of that resource.

On the other hand, if resources are the ones that reference into the UI description (as in URC), then resource sharing is more flexible, and alternative resources need not follow the same sharing pattern. This may be a vital point in achieving usability for a specific language or user group.

Support for different interaction styles and Support for remote control
All AUIDLs under Trewin et al.'s technical requirements study support both different interaction styles and the remote control of the objective services and devices.

Table 2.2 compares the AUIDLs under analysis based on the technical requirement defined by (Trewin et al., 2004).

Table 2.2: AUIDL comparison table based on the technical requirements defined by *Trewin et al.* (2004)

	UIML	UsiXML	XIML	XForms	Maria-XML	URC
Separation of data from presentation	Yes. Limited	Yes	Yes	Yes	Yes	Yes
Machine interpretable representation at AUI level	Yes	Yes	No	Yes	Yes	Yes
Flexibility in the inclusion of alternate resources	Resource Set Fixed in UI desc.	Resource Set Fixed in UI desc.	No	Resource Set Fixed in UI desc.	Resource Set Fixed in UI desc.	Resources Points to UI desc. No Limit
Support for different interaction styles	Yes	Yes	Yes	Yes	Yes	Yes
Support for remote control	Yes	Yes	Yes	Yes	Yes	Yes

2.3 Multi-Environment and Multi-Device Personalised Service Delivery Architectures

2.3.1 Introduction

Our life is a multi-environment and multi-device experience. Decades of advances in miniaturisation of electronic devices and their portability, together with the provision of wireless networking (both in the inclusion in technological solutions and the supporting infrastructure deployment) have enabled a multi-controller device based interaction and a multi-environment experience. This type of intelligent devices have an affordable price, which has let to their mass market deployment.

In this line, recent studies have demonstrated that many users have various interaction devices available at home and in their working environment (Dearman and Pierce, 2008). Users that work with multiple devices want a seamless experience when interacting across them (Dearman and Pierce, 2008; Oulasvirta and Sumari, 2007). They want to access their resources, and services easily using any of their interaction devices.

They want to employ their interaction devices and enjoy a more personalised and integrated experience, rather than a collection of different independent experience in each interaction devices. Challenges are also triggered if we consider the access needs of diverse users.

Therefore, in this section we will analyse the different personalised multi-device service delivery approaches found in the literature. The analysis will be divided between the user interface and content personalisation approaches, and the advanced scenarios devised over them. User interface personalisation subsection will be analysed deeper, given its relationship with the thesis objectives.

2.3.2 User Interface Personalisation

2.3.2.1 Style Sheet based Web UI Personalisation

Traditionally, the user interface personalisation has been achieved by developing a different application per each different configuration need. In the web world, style sheets technology based solutions (Cascading Style Sheets – CSS (W3C, 2011) or Extensible Stylesheet Language Formatting Objects – XSL (W3C, 2006)) have been developed, which allow modifying the presentation of the user interface for different users and different interaction devices.

The main benefits of the style sheet technologies come from the separation of the structure and the content of the presentation's document. This technology allows more precise control (outside the tagging) over the spacing between characters, text alignment, the position of objects in a web page, the audio and voice output, text type characteristics, etc.

The main benefit of the web approach is that stylesheet supporting browser clients are available for almost any interaction device. Therefore, the multi-environment and multi-device support is only limited by the available network coverage.

The downside of this approach is that user interface personalisation is limited to style sheet personalisation capabilities, and user interface composition is limited to web technologies requirements. Web technologies do not facilitate for partial user interface resource substitution or complete user interface substitution to meet users' diverse needs and preferences. Additionally, web solutions do not allow access to many local devices control (despite the advances achieved by the W3C Device API Working Group (W3C, 2013)), such as those connected to the interaction device through Blueetooth.

2.3.2.2 Web Service and Service Oriented Architectures

Web Service and Service Oriented Architectures have enabled service composition and personalisation to be consumed by clients in different applications or business processes.

In this approach, services are defined following service interface definition standards such as Web Services Description Language (WSDL) (W3C, 2007b) or publicly given web APIs using RESTful (Richardson and Ruby, 2008). Service interfaces are accessed using standard protocols, such as SOAP (W3C, 2007a) or HTTP 1.1 (IETF, 1999).

This approximation allows building multi-device personalised user interfaces, but it lacks any user interface concept. It is rather focused in a machine to machine communication, which requires user interface developers to have service implementation's pre-knowledge.

2.3.2.3 Middleware based UI Frameworks

In recent years many different projects have developed middleware approach platforms to support the user interface personalisation and the composition of services mixing both local and remote services and devices.

AAL Domain In the Ambient Assisted Living (AAL) application domain, several European research projects have developed platforms with various specific objectives: OASIS (Bekiaris and Bonfiglio, 2009), PERSONA (Tazari et al., 2010), i2home (Alexandersson, 2008), MPower (Pitsillides et al., 2007), MonAMI (Kung and Jeanbart, 2010), Soprano (Wolf et al., 2008), Genesys Platform (Ovaska and Campos, 2011), VAALID (Kamieth et al., 2009), AALuis (Mayer et al., 2012), SmartAssist (Rothenpieler et al., 2013), UniversAAL (Ram et al., 2013), and Amigo (Thomson et al., 2008).

A reference paper analyses some of the approaches of the aforementioned projects and defines which features should be part of an integrated AAL platform (Fagerberg et al., 2010).

UniversAAL was an European project funded to integrate the various features developed in the aforementioned projects, providing the research and development community with an unified platform. Their deliverable D2.2C reports on their system architecture and the technology decisions made on each aspect of the middleware platform (UniversAAL Project, 2012).

Regarding the user interaction management, they considered that only Persona (Tazari et al., 2010), URC / UCH developed within i2home (Alexandersson, 2008), and the portable UI technology from Open Health tools provided a whole and consistent concept for user interaction in terms of a UI framework.

From those projects, Open Health's portable UI was discarded due to its unmatureness. Meanwhile, AALuis (Mayer et al., 2012), a project that was not considered by UniversAAL, has developed an alternative UI Framework based on Concurrent Task Trees (Paternò, 2004) and MariaXML (Paternò et al., 2009a).

The UI Frameworks considered to provide a complete user interaction concept are analysed in the following. These frameworks rely on different AUIDLs which have been analysed in a previous section (in Section 2.2).

The Universal Control Hub (UCH) The UCH architecture is an implementation of the Universal Remote Console (URC) (ISO/IEC, 2008) as a gateway.

It follows a centralised system approach, initially developed in the framework of the digital home (Zimmermann and Vanderheiden, 2007).

The URC standard by itself defines a UI Framework, which is based on the user interface socket and plug-and-play interfaces concept, and the UCH is an implementation option of it. The UCH architecture is shown in Figure 2.3.

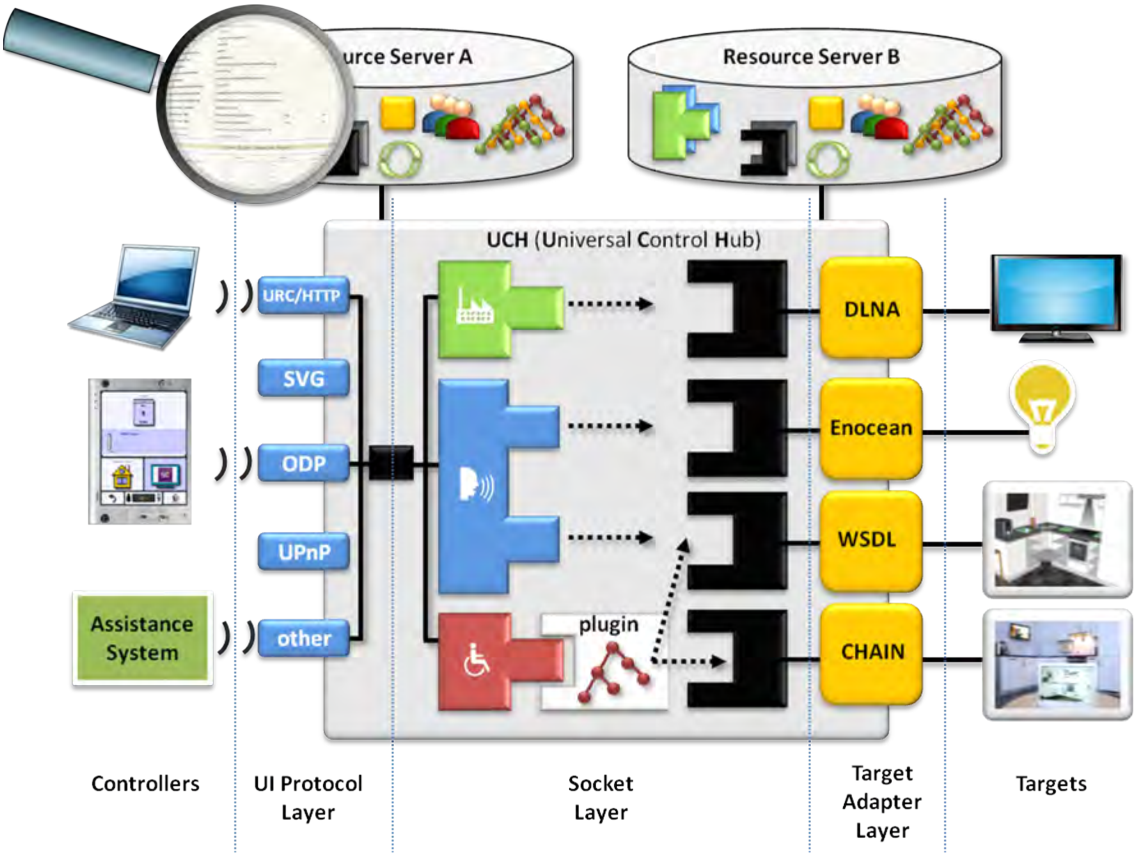

Figure 2.3: The Universal Control Hub Architecture and its UI Framework approach

The main features of the UCH are:

- It acts as a gateway between the target devices and services and the client controllers. Each of these communications can be done using different control protocol. Without a gateway, the different parts would not be able to talk to each other.

- The user interface socket is based on open standards. The UCH is based on the URC framework standard (ISO/IEC, 2008).

- It provides the option to use different user interface protocols. The UCH enables different user interface protocols' implementations and use by the client controllers (e.g. HTTP through DHTML, Flash, etc.).

- Globally available resource servers: The UCH can get resources, such as, target adapters, target discovery modules and user interfaces in a distributed manner.

In the UCH architecture, a User Interface Protocol Module (UIPM) is the responsible for presenting one or more sockets' functionalities to the user through a user interface that is rendered in a controller. Controllers and their software that is aware of this architecture, can access the socket of the target device or service and its atomic resources directly, to create an appropriate user interface based on the socket elements and their values.

The URC-HTTP protocol, which is a user interface protocol, provides remote controllers with direct access to the sockets that are running in the UCH. This protocol defines the messaging over HTTP, and the functions for a controller to access the sockets of a UCH. The implementation of this protocol in the UCH is optional, but once implemented, provides a standardised and powerful way for controllers to access the UCH.

The Persona / UniversAAL UI Framework The Persona / UniversAAL defines a distributed architecture for AAL Spaces (Tazari et al., 2010; UniversAAL Project, 2012).

The architecture is made of a set of communication buses namely input, output, context and services buses. Applications running in devices can register to one or more buses, being asynchronously notified as soon as events occur. Input and output buses are used to interact with users. The context bus is an event based bus on which are attached context sources, whose events can be re-elaborated and transformed in high level events by components subscribed to the bus. The service bus is used to group all the services available in AAL-spaces.

Persona UI framework (IEC, 2013) uses Xforms (W3C, 2009) as the user interface modelling technology for the dialogues that a service is going to present to the user, together with content-specific adaptation parameters. These adaptation parameters are later on enriched by a so called Dialog Manager, which adds information related to user and context profile. Finally, the system chooses the input/output interaction handler (I/O handler) that fits each user profile best.

Based on the modality and layout neutral representation given by the Xforms representation and the adaptation parameters, the selected I/O handler performs the transformations needed to adapt the content to each user. Whenever the user enters an input or calls for a service, this is sent to a service orchestrator which will call the correct AAL Space service through the service bus. Figure 2.4 present the Persona UI framework.

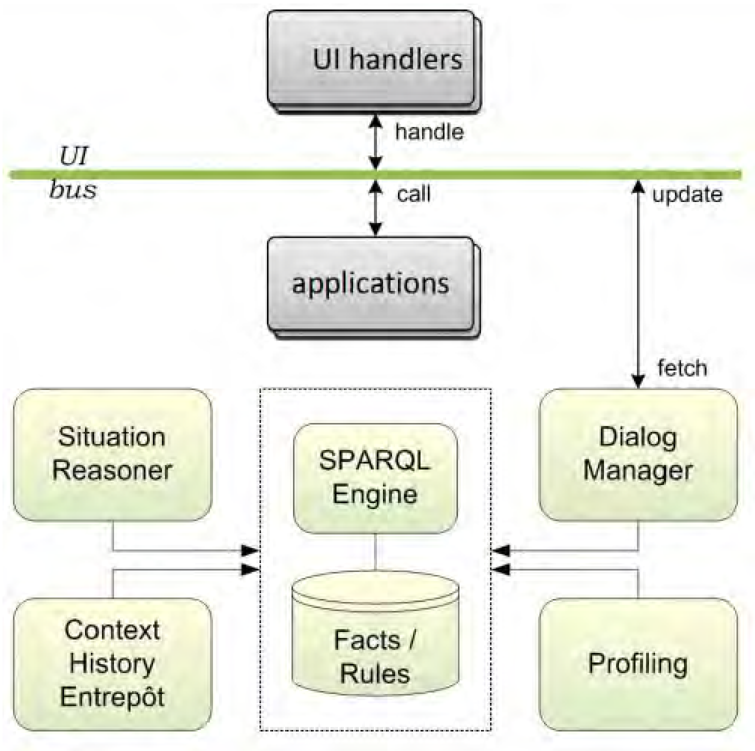

Figure 2.4: Persona / UniversAAL UI Framework approach

The Guide project is based on the PERSONA UI framework and targets hybrid TV platforms, such as the emerging connected TV standard HbbTV (Hamisu et al., 2011). The Guide project adds two innovative concepts to the Persona UI framework, which are the user simulation at design time and the UI adaptation during runtime through continuous evaluation of the context.

AALuis UI Framework The AALuis middleware is based on the OSGI service platform (OSGi Alliance, 2011), and follows a centralised approach.

According to the UI framework approach proposed by AALuis (Mayer et al., 2012), services connected to the AALuis platform provide a description of the interaction steps following the Concurrent Task Tree (CTT) notation (Paternò, 2004). Additionally, information on service method bindings has to be provided. These bindings are used by AALuis as instructions for service call-backs.

Based on the documents an AUI description is created. This root document is generated once after service registration. The result is a document that is described following the MariaXML notation (Paternò et al., 2009a).

A modality and device specific (Concrete) UI description is created based on the context information and the AUI description. Therefore, AALuis makes a sensible choice of output and input channels. This is done by applying a modality selection strategy utilising available context information. Depending on the adopted strategy the user's capabilities and preferences can be respected.

In the initial implementations, a fuzzy logic based strategy is being followed, but the implemented strategy can be updated thanks to AALuis' flexible architecture. For example, it may be replaced by a learning algorithm. From the selected modalities, the set of devices to be used for the interaction can be easily derived. If necessary, AALuis framework can transforms available content to different output modalities, e.g. text to speech, text to avatar, etc.

Based on the CUI description a representation that is directly renderable by an I/O device is created. In a first step this is an HTML5 document that can be displayed directly. Converters to other directly renderable technologies are possible, e.g. VoiceML which can be used by a specialised device.

The different interaction devices are connected via existing protocols (e.g. UPnP). The FUI rendering is done by the I/O devices. Those I/O devices collect the user input and send it back to the AALuis platform. The platform transforms data to a suitable representation for the service and it is sent to the corresponding service. The introduced UI Framework and its sequential steps are depicted in Figure 2.5.

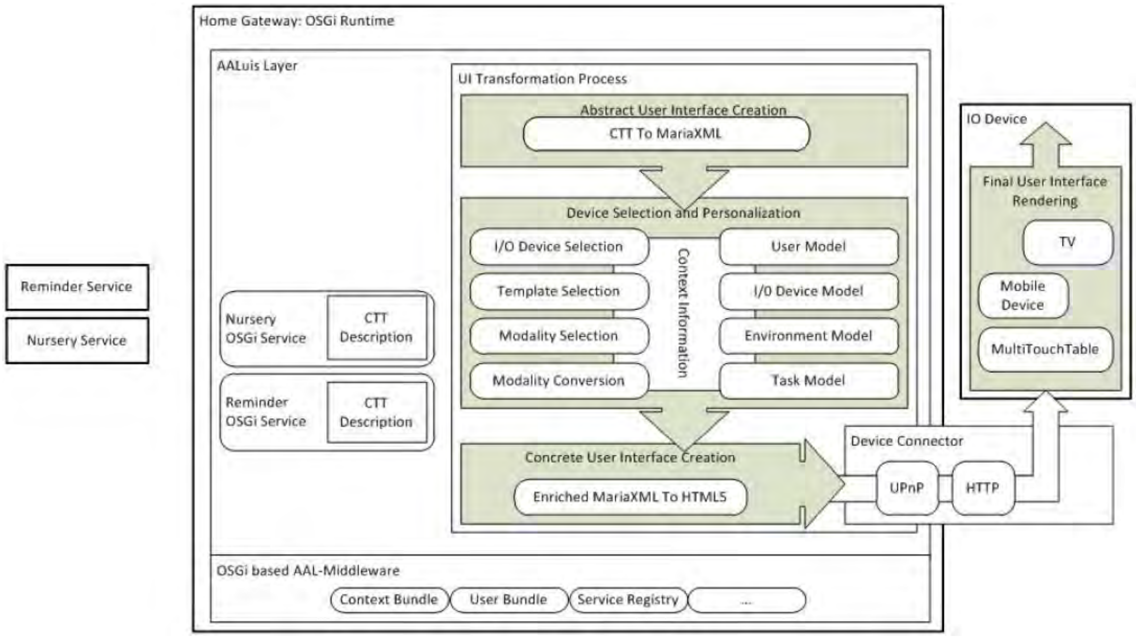

Figure 2.5: AALuis UI Framework approach and architecture

Health Domain In the health domain, multi-device and multi-scenario service delivery has been traditionally targeted by telemedicine applications and more specifically by telerehabilitation applications.

The evolution of applications, has been from simple communications, such as the email, to web solutions using Java applet/ActiveX (Reinkensmeyer et al., 2002), and more conceptual evolution towards Service Oriented Architectures (SOA) (Mougharbel et al., 2009).

Among telerehabilitation's main challenges, the provision of universal access and the user interaction that fits each user's need is considered one of the most important ones (Simpson, 2013).

In the past, *Feng et al.* have worked on the universality of the telerehabilitation architectures and have made use of a UI Framework (2007; 2005). Their work is based on the URC standard (ISO/IEC, 2008). Their approach has some limitations: the integration of new interaction device protocols is limited; it is not possible to deploy non-URC controllers; and solutions that access more than one service are not addressed.

Some other initiatives like OSAMI-D have tried to define a middleware platform approach for healthcare applications, but they not include any UI Framework concept (Lipprandt et al., 2009).

2.3.2.4 AUIDL approaches for Web Services

In parallel to the development of middleware initiatives integrating UI Frameworks, some authors have targeted AUI based approaches applied to the web services for the generation of multi-device user interfaces. They bring the existing service UI mash-up platforms (Casquero et al., 2008; Fagan, 2007; Song and Lee, 2008; Spillner et al., 2007) one step further.

This allows to extend the web services with a UI Framework or moving parts of the UI Framework logic to the web services, augmenting them through annotations.

One of initiatives in this line is the work done in the Servface project (Paternò et al., 2009b). They propose to augment the existing service WSDL file by creating a separate task grain level annotation using Concurrent Task Tree (Paternò, 2004). This task level annotation is used to generate and evolve the user interface description to implementation using the MariaXML language (Task => AUI => CUI => FUI).

Similarly, the OpenURC Alliance has proposed and developed an approach to annotate web services, so that the XML files (User Interface Socket and Target Description) required by the URC standard can be inherited from it (Alexandersson et al.). This work is being standardised as the part 6 of the ISO / IEC 24752 Universal Remote Console Framework, and it is expected to be an international standard in 2014.

These two initiatives would allow to simplify the middleware approaches that are based on the respective UI framework. Due to the shift of web services implementation from WSDL to Restful based Web APIs, the impact of these initiatives is limited.

2.3.3 Content Personalisation

Together with the user interface personalisation, a key technology for the multi-environment and multi-device service delivery is the content personalisation. Content personalisation can be given in terms of: (a) audiovisual stream transcoding to meet each environment's and device's requirements, (b) alternative content modalities provision to meet user's, environment's or device's specifics requirements, or by (c) generating personalised content taking as an input variable the user, environment and/or device.

2.3.3.1 Audiovisual Stream Transcoding

Different approaches have been defined for adapting the audiovisual streams to different network and device requirements (El-Khatib et al., 2004; Lum and Lau, 2002). The transcoded content can be produced beforehand or on real-time.

Considering the current home device's lack of 3D graphics rendering capabilities, and the need to adapt the 3D to video stream rendering and transcoding server resources to the fluctuating transcoding demand, *Zorrilla et al.* defined an end-to-end solution for interactive on demand 3D Media (2012).

Approaches that adapt the resolution, based on continuously monitored network quality-of-service have also been defined (Lum and Lau, 2002). The adapted content can be offered through alternative URIs or automatically offered based on the browser's user agent identification.

2.3.3.2 Alternate Content Modalities Provision

A good reference regarding the alternate content modalities needed for content accessibility is the Web Content Accessibility Guidelines recommendation, more specifically its section entitled as Perceivable (W3C, 2008). It is focussed on web content, but it provides a good insight for general content.

Even if it is defined with universal accessibility in mind, the implementation of these guidelines also enable people with no specific impairment to access such content under adverse scenarios.

In this context, the URC framework (ISO/IEC, 2008) has the capability to define resource externalisation for user interfaces using its resource sheets and resource server technology. This facilitates the user interface components' modality exchange.

2.3.3.3 Generation of Personalised Content

Personalised content can be generated based on the user, environment and device properties. A recent paper proposes a ubiquitous generation of personalised content (Kernchen et al., 2010). This article presents a novel multimedia adaptation and delivery process and its underlying framework, that focuses on mobile users in daily and dynamic situations.

The defined framework has functionalities such as the generation of the presentation schedule, the computation of the presentation environment matches, personalisation through situation learning, and device(s)-tailored presentation delivery. The novelty of this solution resides in its dynamism. Mobility aspects such as location and device changes are taken into account, while assuring optimal session continuity across different situation configurations.

Moving from a ubiquitous environment to a content production context, *Martin et al.* developed a web platform for automatic generation of rich media with dynamic multimedia content (2012). The dynamic multimedia content matching the semantic context is automatically retrieved from different content databases, including real-time information such us weather forecasts.

2.3.4 Advance Scenarios Over Multi-Scenario and Multi-Device Service Delivery Architectures

The provision of an infrastructure technology supporting multi-scenario and multi-device personalised services enables the evolution to ubiquitous computing. The Ubiquitous computing vision is defined by *Weiser* as the vision where the systems and devices with processing capabilities are seamlessly integrated with people's daily life and collaborate between them (1991).

Ubiquitous computing lead to the development of advanced scenarios as the context aware applications (Dey, 2001), distributed user interfaces (Dey et al., 2001) and the migratory user interfaces (Bandelloni and Paternò, 2004; Nickelsen et al., 2012).

In (Paternò and Santoro, 2012) they define a logical framework to analyse the features provided by different tools and applications for multi-device user interface support, within the ubiquitous computing research area. This logic framework considers the following dimensions: UI distribution, UI migration, UI Granularity, Trigger activation type, Device Sharing between multiple users, Timing, Interaction Modalities involved, UI Generation Phase, UI Adaptation Aspects and the type of Architecture.

An additional enabler of this type of applications can be the Preferences Server and the Matchmaker concept develop by the Cloud4All project (Vanderheiden et al., 2012) as part of building an Global Public Inclusive Infrastructure (Vanderheiden et al., 2013). The Preferences Server allows to store the user interaction settings (according to needs and preferences of each individual) for device, platform and applications in the cloud.

Additionally, the Matchmaker is capable of finding appropriate settings for a specific user in a specific context of use, either by using rule-based algorithms or machine learning based statistical algorithms.

In this context, (Abascal et al., 2011; Zimmermann and Jordan, 2013) are developing approaches to provide ubiquitous accessible services by the instantaneous generation of adapted accessible interfaces suited to the specific users.

2.4 Conclusions

One of the key features of the TV, the control interface, has not evolved at the same speed as the advances reported in the TV accessibility subsection. More usable TV remote controls have been developed, but the infrared remote control based interaction paradigm has remained unchanged for more than 30 years.

These remote controls are too complex to use for many people (e.g. a person lacking the required dexterity, a person not seeing the buttons, or a person that does not remember the functionality of the different buttons). A significant impact on accessibility has yet to be achieved.

Due to these barriers among others, advancements in Interactive TV, and the services offered via the TV set, are not reaching their full potential with all user groups, missing out on a great opportunity to bridge the digital divide for people with special needs (Technosite et al., 2011). Therefore, the development of an approach that would make TV sets' remote control universally accessible is needed. An AUI based approach seems the best option to fully reach universality.

From the literature review, we conclude that techniques exist from the iTV service's lifecycle development point of view (requirements gathering, design, implementation and evaluation). Additionally, there are specific implementations coming from the generic iTV research area, mostly EPG related, that provide accessibility solutions. Also, the availability of commercial iTV platforms targeted at mainstream users, shows the path of near future iTV services' usage scenario.

But in our opinion, it is necessary to define an approach that would allow the integration of services with different TV sets to meet different user needs. In order to guarantee the openness and the adaptability of the evolved scenario, an AUI based approach is needed.

The provision of an approach like this can foster the development of accessible TV interactive services' solutions, ensure the reusability of different modules and provide means of fast prototyping new TV set configurations (with new interactions technologies). The possibility of building fast prototypes can help filling the existing gap of studies and solutions on TV accessible interactive services research area.

In regards to the AUIDL analysis, UIML, UsiXML, XIML, XForms, MariaXML and URC have been identified to meet the required abstraction level (modality and platform independence), while having the required minimum adoption and updates.

In this sense, we have analysed the identified valid AUIDLs following the abstraction levels defined by the CAMELEON Framework, and the technical requirements defined by Trewin et al.

From this analysis, we see that UIML and XForms depend on third host languages for covering part of the requirements. UsiXML, MariaXML and URC offer similar functionalities from the established requirements point of view.

We have decided to use the URC AUI representation for our solution's technological base due to its external resource specification scheme. This specification scheme provides benefits for defining and updating the user interfaces with new resource sets in the future. This may be a vital point in achieving usability for a specific language or user group.

Moving to the Multi-Environment and Multi-Device Personalised Service Delivery, the presented web and middleware platform approaches cover well the personalisation of user interfaces for the different interaction devices, even in terms of universal access. But, they do not present conceptual architecture models to handle user's real life context, where the user moves among different scenarios and different actors intervene in the service delivery provision.

For the objective of enabling each user to be provided with a user interface that fits bets their needs and preferences, a middleware supporting AUI is foreseen to be running in each service consumption environment. The middleware will support each actor participating in the service.

Together with the UI personalisation approaches, the content personalisation has been analysed as a complementary part to achieve Multi-Environment and Multi-Device Personalised Service Delivery. The development of alternative modalities for the same content, as well as the availability of modality translators is understood as necessary for enabling the Multi-Environment and Multi-Device Personalised Service Delivery.

Chapter 3

Universally Accessible Remote Control

In the review of the state of the art presented on the previous chapter, TV remote control accessibility was found a limiting human computer interaction factor. In this chapter we describe an AUI technology based approach to make TV sets remote control accessible to all. In addition, a case study implemented to validate the proposed approach is detailed. This validation also reports on the evaluation with users.

We present and validate an approach that allows connecting and exchanging different user interaction technologies to remotely control TV sets. It bridges the gap between TV sets basic functionalities and diverse users' needs and preferences.

Section 3.1 gives some introductory remarks to the topic. Section 3.2 defines the approach. Section 3.3 presents a case study with the developments done to validate the approach. Section 3.4 gives some conclusions and discussion on the presented approach.

3.1 Introduction

In recent years, relevant research has been carried out in several fields related to television. Significant effort has been focused on developing TV receivers that provide multiple levels of interactivity whilst accessing diverse content and services over the network.

From an accessibility point of view, substantial effort has been made regarding broadcast content and how to convey this content through TV sets. Good examples of such efforts are the standardisation of the creation of subtitling for the hearing impaired (UNE, 2003) and audio descriptions for the visually impaired (UNE, 2005).

Despite these advances, one of the key features of the TV, the control interface, has not evolved at the same pace. By control interface we mean the TV remote control and the on-screen display (OSD).

TV remote controls have changed their appearance, advancements in usability have been achieved, but the interaction paradigm based on infrared remote control technology has remained unchanged. Effort have been made to make remote controls as user-friendly as possible (Falck Vital, 2009; Weemote, 2009), but a significant impact on accessibility has yet to be achieved.

Figure 3.1 presents some examples of the usability advances of remote controls.

Figure 3.1: Example of usable remote controls. The Weemote (Weemote, 2009) is shown on the left and the Falck Vital (Falck Vital, 2009) on the right.

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, as for example people with cognitive difficulties, require training on how to use the remote control. Even so, frequently they are unable to remember the location of the buttons on the remote control or how to use the TV's OSD menus.

Going beyond the remote control, other remote interaction technologies have been researched for remotely controlling the TV set: speech interaction (Berglund and Johansson, 2004), or the use of different interaction objects such as pillows (Schiphorst et al., 2007).

These implementations target-specific scenarios and their developments cannot be directly used in other scenarios. The development of an approach that would make TV sets' remote control universally accessible is still needed. A motivating scenario for this identified need has been described in Section 1.1.4.1. An AUI based approach seems to be the best option to fully reach universality enabling the use of alternate user interaction technologies to remotely control the TV set.

3.2 Approach

The objective of specifying this approach is to provide people with the remote control device plus a user interface that suits them best. As said in the introduction, not everyone feels comfortable with the regular IR remote controllers, which have evolved 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.

In our thesis we propose the use of AUI technology to make the TV set universally accessible. From the AUIDL technologies analysed in Section 2.2, we have decided to go for the URC Framework (ISO/IEC, 2008). Its pluggable user interface approach is preferred compared to the transformational approach of its main alternatives (UsiXML and MariaXML). Its external resource specification scheme is also found as a benefit over the alternatives.

In the URC Framework, the external resource specification is done pointing the AUI description nodes from the resources in contrast to the main AUIDL alternatives, which point to resource sets from the AUI description. On those cases, the pattern of referencing is fixed, and when a resource set is modified it replaces all occurrences of a resource .

The main advantage of the URC framework is that it allows the development of pluggable user interfaces. Given this fact, tailored user interfaces for any kind of user can be implemented to remotely control a TV set.

Figure 3.2 outlines our conceptual proposal in contrast to the current scenario. On the top half of the figure current scenario is shown. In this image a remotely operated TV set is shown, controlled by a remote control using a proprietary IR communication (Current Scenario). On the bottom half of the figure our proposal is presented (Proposed Scenario).

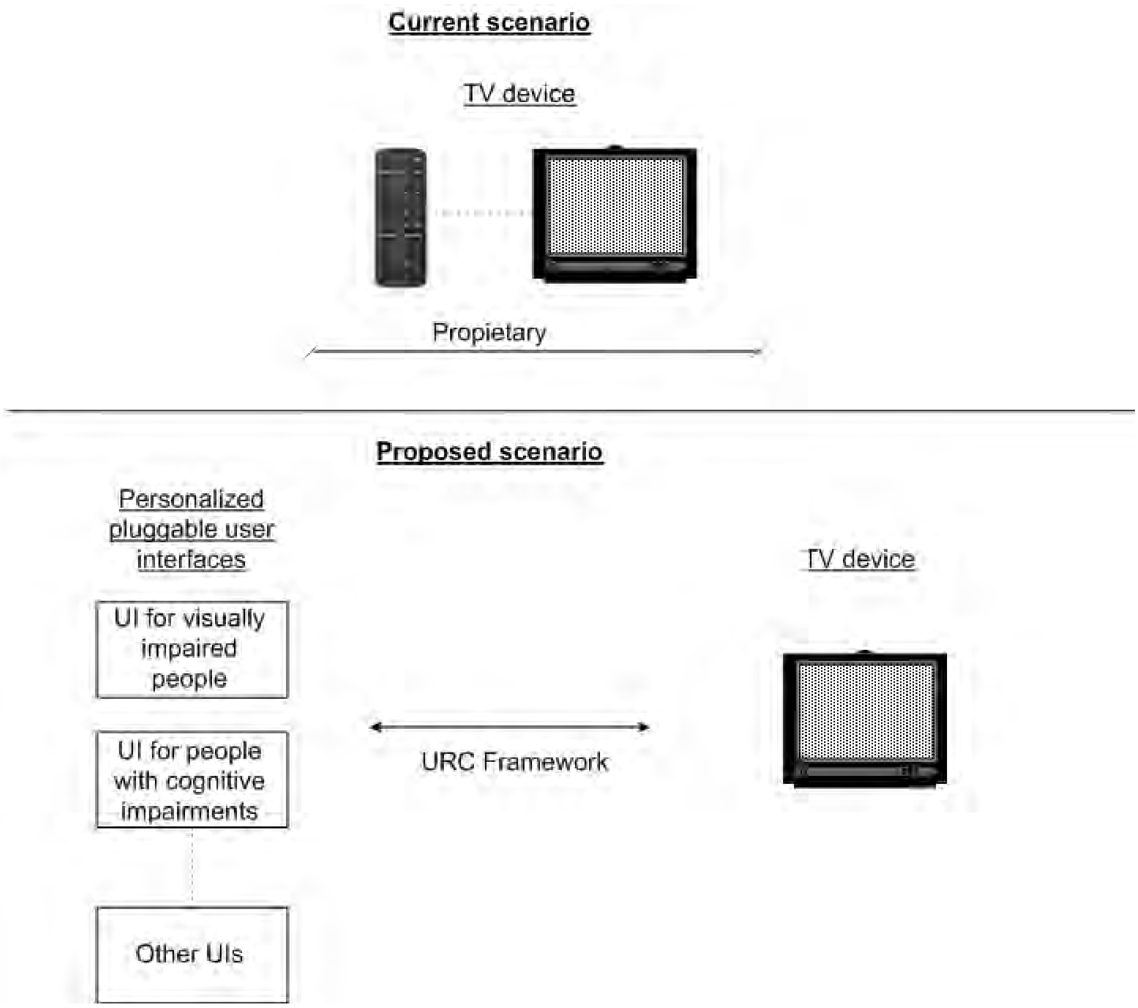

Figure 3.2: Current scenario vs. proposed architecture for accessible TV

We propose an approach where the URC Framework is used to provide an abstraction of the TV set's basic functionalities. Based on the AUI description developed for the TV set, different personalised pluggable user interfaces can be developed and deployed to meet each user's needs and preferences.

To show the openness of the approach, and the easiness to plug-and-play alternate user interfaces, Figure 3.2 shows a UI for visually impaired people, a UI for people with cognitive impairments as well as a box reflecting “Other UIs”.

3.2.1 URC framework document requirements analysis

As introduced in Section 2.2, the URC framework requires the definition of three core components in XML file format. For specifying the TV set's basic functionalities these documents would contain the following:

- Target Description (TD): This document is used to advertise the properties of the TV set to the client. The TD provides the information required by a client to connect to a TV's UI socket, in order to initiate a control session. A Target has exactly one TD.

- User Interface Socket Description (UISD): A User Interface Socket Description is a XML document with a machine-readable description of the TV's functionalities.

- Target Resource Sheet (RS): A resource sheet is a file that defines the resources that can be used in the construction of a user interface. For example, language specific strings, icons and other GUI elements.

The details of the URC framework required XML files for the TV set, can be found at the Appendix D.

In addition, the framework includes “resource servers” as global market and distribution places for resource sheets and pluggable user interfaces.

Today's devices and services do not come with a user interface socket built-in. However, many of them come with some kind of remote controllability through infrared, wired, or wireless communication technologies. It is possible to build a 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 (Zimmermann and Vanderheiden, 2007). Thus the UCH is the gateway between any target device/service and any controller. It exposes user interface sockets of all connected targets, and facilitates pluggable user interfaces that plug into the sockets.

3.2.2 UCH architecture integration requirements analysis

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 as follows:

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

In more detail, there are three requirement categories 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.

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 allows only a one-way communication. It allows us to operate the TV, but restricts us to receive any feedback on TV status.

With this known disadvantage, it's possible to integrate a TV in the UCH using IR signal. This can be achieved by using an IR transmitter in the machine the UCH runs on, or by using a master controller that has different IR outputs that can be accessed over an IP network (Global Caché, 2010). 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 that some of them have their own private protocol implementations. This means that an implementation for each communication technology should to be provided.

Therefore our recommendation for currently available marketed devices is to:

- Follow a limited IR technology based approach, which once done for one TV set, can be easily extended to other models leveraging IR code databases, or
- Develop UCH target integrations for mainstream device-technologies, as was the case in our Windows Media Center implementation, thus bringing the technology to a wider range of users.

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

The XML files required by the URC Framework have been described above, therefore we will concentrate on describing the code needed to implement the integration of the TV set in the UCH architecture:

- Target Discovery Module (TDM): The function of this module is to discover TV sets and any other related devices such as DVD players, Home Theatres, etc. One discovery module must exist for each communication protocol at least.
- Target Adapter (TA): A TA is a module that communicates with a specific Target (TV, DVD player, ...) in its native protocol,. TA interacts with the relevant socket instance via the Target Manager, to update the state of the socket values, or to receive commands from the controllers.

For more information see (OpenURC Alliance, 2012).

Once a TV set is integrated as a target in the UCH, we can both develop a UCH's User Interface Protocol Module (UIPM) or use an existing one. Through the available UIPMs we have the ability to plug-in the different pluggable UIs to remotely control the TV set, using the controller that we are most comfortable with.

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 3.3 outlines our proposal at technical level for the TV set's accessible remote control using the UCH middleware. This figure shows different pluggable user interfaces that can interact with a TV set that has been integrated with the UCH as a target.

The pluggable user interfaces can use the URC-HTTP protocol (which facilitates remote access by a controller to the sockets running in a UCH) defined by the *OpenURC Alliance* (2013b) or other user interface protocols (open or proprietary) implemented as UIPMs, to communicate with the UCH.

A resource server object reflects the option of using the pluggable user interfaces and integration modules downloaded directly from the Internet.

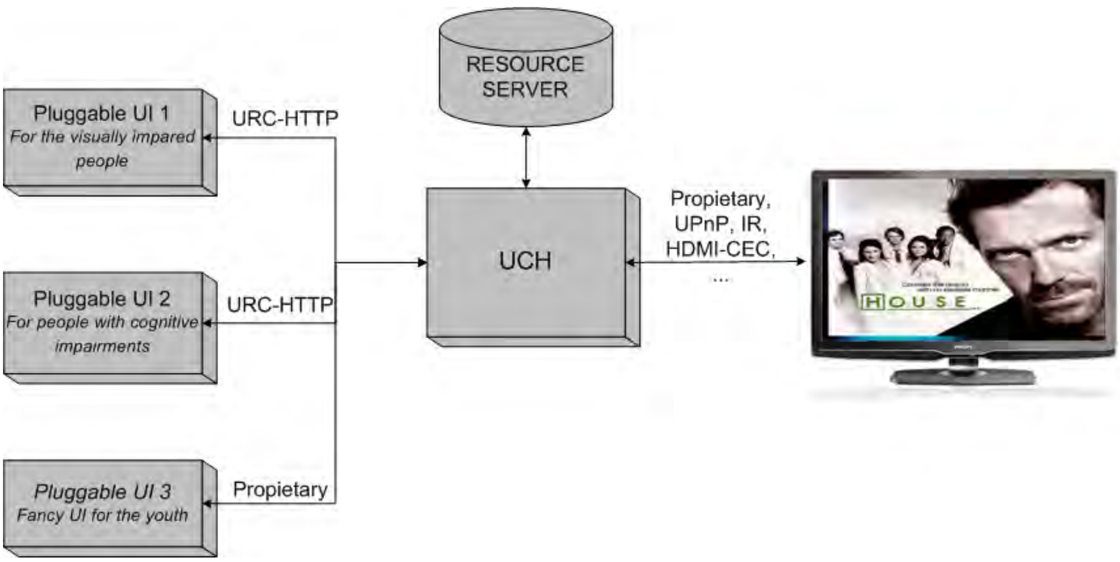

Figure 3.3: Proposed technical level solution for the TV set's accessible remote control

3.3 Approach Validation

In order to validate the proposed approach to make TV set's remote control universally accessible, first, we have integrated two different TV sets to the UCH, by defining the XML files required by the URC framework and by developing the code required for integrating them with the UCH.

Later on, we have developed two pluggable user interfaces (PUI) that meet two specific user groups' needs and preferences. The developed pluggable interfaces were then evaluated with the respective user groups.

The first subsection below introduces how the integration of the TV sets with the UCH was done. The second subsection presents the developed pluggable user interfaces and the results of the evaluation with the final users.

3.3.1 Integration of TV sets with the UCH as targets

For the validation of the solution, we have integrated two different TV sets 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.

The main reason for selecting these devices has been that they either offer a well documented Application Programming Interface (API) (for the WMC) or are based on open source code (Dreambox), thus making them easier to integrate.

Both solutions have IP connectivity and they fulfil the remote controllability requirements for a target device to be integrated with the UCH architecture (see Section 3.2).

We have defined a single UI socket for both TVs (available at Appendix D), 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, we developed the integration of the targets. In the case of WMC, we also included the time shifting functionality.

The integration of the Dreambox 7020 was done by parsing its web control interface as is depicted in Figure 3.4. Due to its open source nature, other alternatives as the implementation of standard control protocol over IP were analysed. Nevertheless, we decided to go for web parsing and the integration of the web based control interface, because the objective was a proof-of-concept prototype and the adopted approximation required less time to implement.

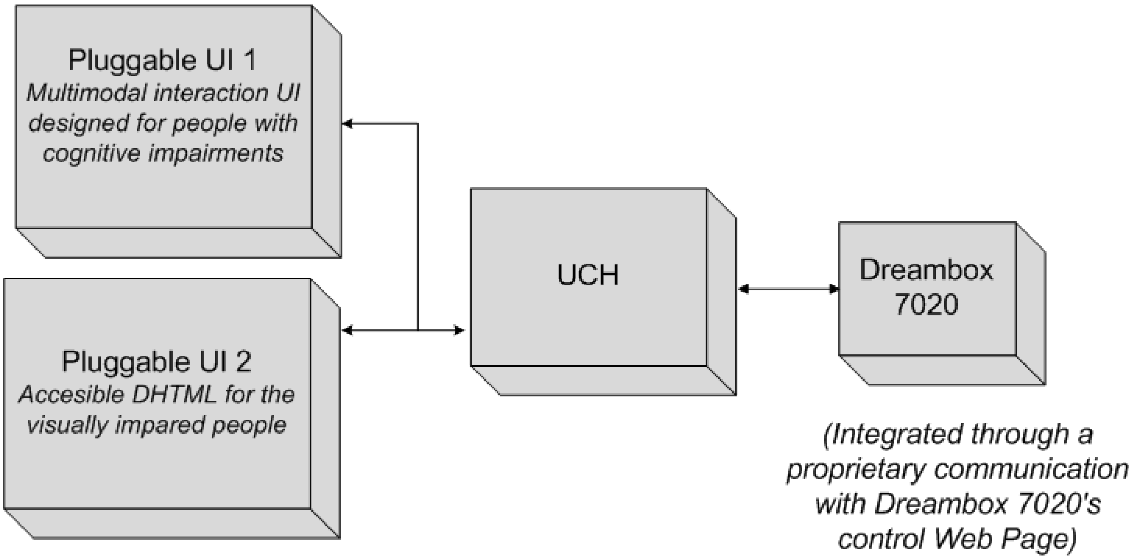

Figure 3.4: Solution implemented for the validation of the universal access remote control approach. Dreambox Integration.

The integration of the Windows Media Center target in the UCH has been done by integrating the UCH as a WMC add-in. The IP connection was analysed as part of this integration task, but the integration within the WMC using the API provided by the WMC, showed an improved performance over the IP based approach. The integration of the WMC with the UCH is depicted in Figure 3.5.

3.3.2 Pluggable User Interface 1: Multimodal UI on Smartphone

The first UI[1] 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 those people face are concentration problems and memory deficits.

The main ideas behind this UI are a large touch screen provided by a modern mainstream controller (HTC 7500 Advantage PDA) to prevent this user group

[1]This pluggable user interface was developed by DFKI in the i2home project framework (FP6-033502).

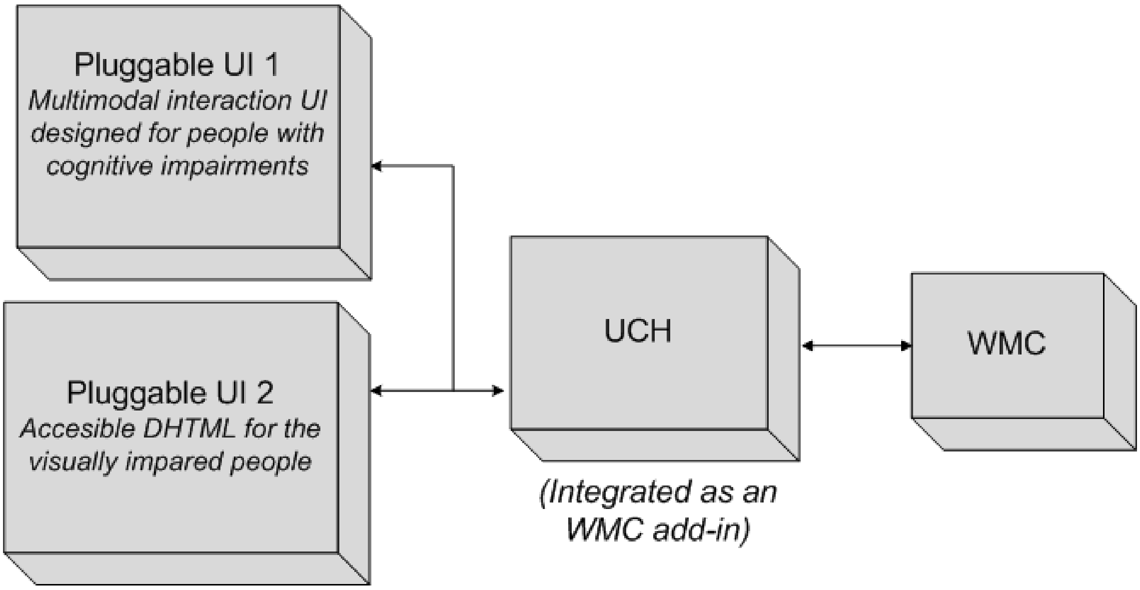

Figure 3.5: Solution implemented for the validation of the universal access remote control approach. Windows Media Center Integration.

becoming stigmatised, and a free choice of modalities or possible combination of them.

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 are these modalities are: speech, gesturing, mimicking, etc. For more detail, see (Schehl et al., 2008).

Figure 3.6 shows a depiction of the TV GUI. There, the bottom row contains artefacts 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 have been removed. The only functionalities left are on/off (top left), volume (bottom), mute (bottom left) and a scrollable 2x2 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 make the interaction simple and intuitive.

Figure 3.6: 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.

3.3.3 Pluggable User Interface 2: Accessible DHTML for the visually impaired

The second pluggable user interface[1] was developed for people with visual impairments and blind people. 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 (OpenURC Alliance, 2009) 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* (2014).

Figure 3.7 illustrates the developed accessible DHTML page. This DHTML page

[1]This pluggable user interface was developed by Siemens AG in the i2home project framework (FP6-033502).

was created in compliance with the WCAG 2.0 guidelines (W3C, 2008). 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.

Figure 3.7: Tablet PC rendering an accessible DHTML for people with low vision

3.3.4 Prototype Description

The prototypes implemented for the validation of the approach include two different implementations. The first implementation was based on the Dreambox set-top-box (Dream Property GmbH, 2014) (Figure 3.8), and the second one was based on the Windows Media Center (Microsoft, 2014) (Figure 3.9). The technologies used for the implementation of these prototypes are analysed in the following.

3.3.4.1 Dreambox set-top-box based approach implementation

- Equipment 1 - Dreambox STB

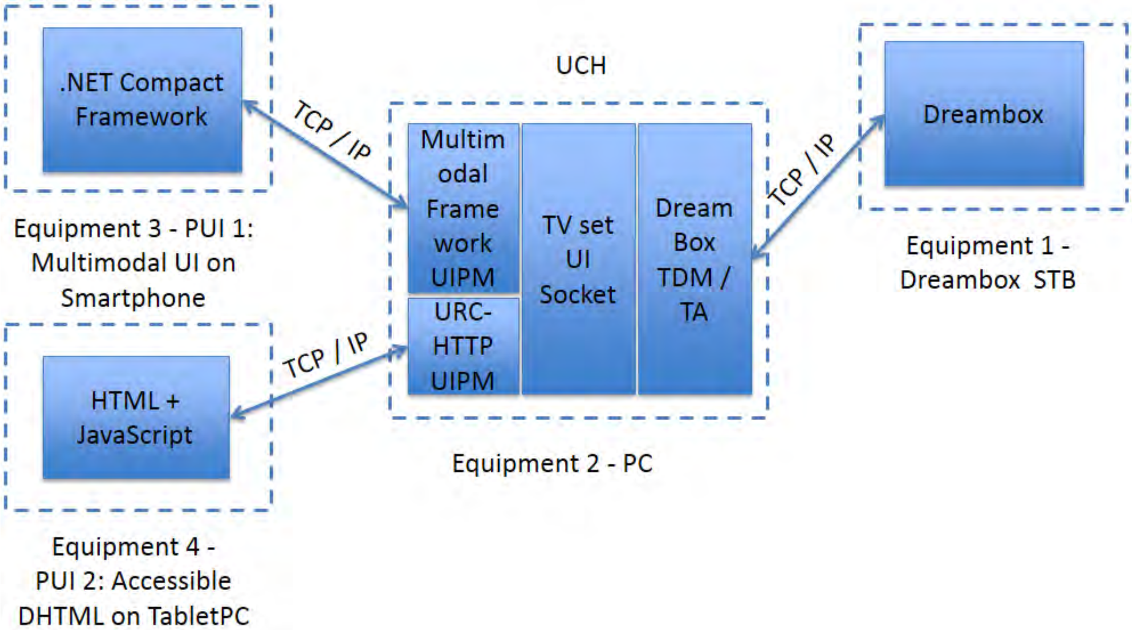

Figure 3.8: Dreambox based approach implementation technical details

  - Device: Dreambox 7020.

- Equipment 2 - UCH-enabled PC

  - Device: Intel Pentium D 945 @ 3.4 GHz, 2 GB RAM.
  - O.S: Windows Vista.
  - UCH implementation: .NET implementation by *Meticube* (2014) (Version 2.1).
  - Dreambox integration
    * TV set URC framework-required XML files (TD, UISD, RS). Details can be found in Appendix D.
    * TDM / TA.
      · TDM: Discovery done by specifying Dreambox IP address.
      · TA: Target is controlled by parsing its remote control web page. Communication is HTTP over TCP / IP.
  - UIPMs:
    * Multimodal framework UIPM (ODP) (Pfalzgraf et al., 2008).
    * URC-HTTP UIPM (OpenURC Alliance, 2013b).

- Equipment 3 - PUI1: Multimodal UI on Smartphone
  - Device: HTC 7500 Advantage.
  - O.S: Windows Mobile 5.
  - Input modalities: speech and touch / Output modalities: graphical and voice.
  - Client implementation in .Net Compact Framework 2.0.
  - Communication with Multimodal Framework UIPM with ODP required protocol over TCP / IP.
- Equipment 4 - PUI2: Accessible DHTML
  - Device: Toshiba M200.
  - O.S: Windows XP Tablet.
  - Client implementation based on Web technologies (HTML and JS), using URC-HTTP JavaScript implementation (OpenURC Alliance, 2009).
  - Jaws screen-reader for people with visual impairment (Jaws, 2014).

3.3.4.2 WMC based approach implementation

- Equipment 1 - PC containing UCH and WMC software
  - Device: Intel Pentium D 945 @ 3.4 GHz, 2 GB RAM.
  - O.S: Windows Vista.
  - UCH implementation: .NET implementation by *Meticube* (2014) (Version 2.1).
  - WMC integration:
    - UCH integrated as a WMC add-in.
    - TV set URC framework required XML files (TD, UISD, RS). Details can be found in Appendix D.
    - TDM / TA

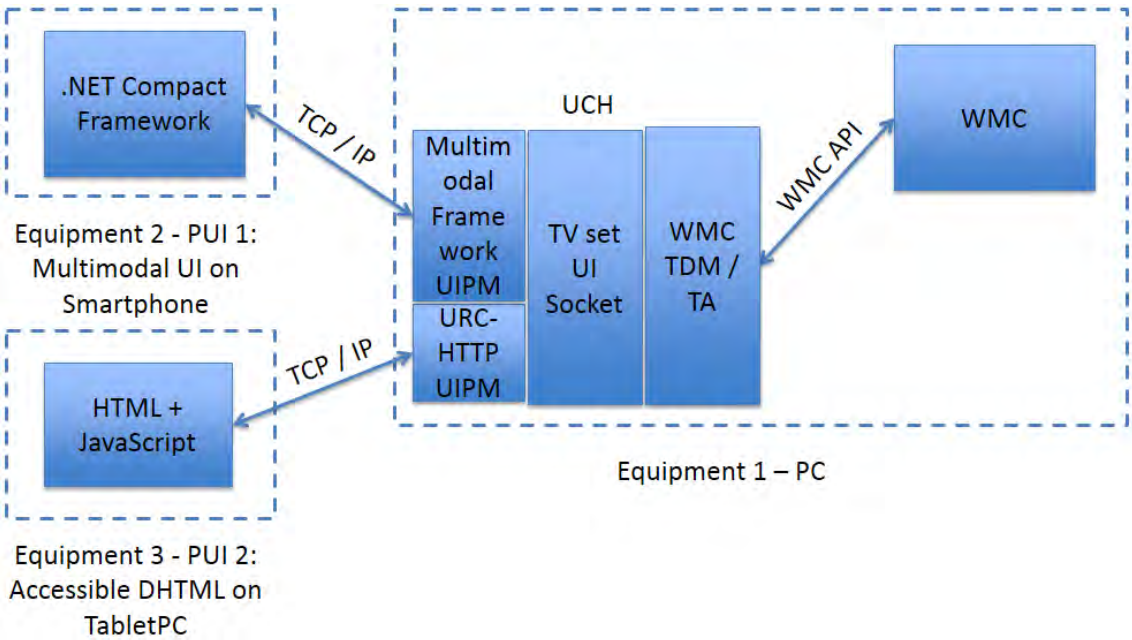

Figure 3.9: WMC based approach implementation technical details

  · TDM: Automatically launch since the UCH is being launched as a WMC add-in.
  · TA: Target is controlled by implementing WMC remote control API.

  - UIPMs:
    * Multimodal framework UIPM (ODP) (Pfalzgraf et al., 2008).
    * URC-HTTP UIPM (OpenURC Alliance, 2013b).

- Equipment 2 - PUI1: Multimodal UI on Smartphone
  - Device: HTC 7500 Advantage.
  - O.S: Windows Mobile 5.
  - Input modalities: speech and touch / Output modalities: graphical and voice.
  - Client implementation in .NET Compact Framework 2.0.
  - Communication with Multimodal Framework UIPM with ODP required protocol over TCP / IP.
- Equipment 3 - PUI2: Accessible DHTML

- Device: Toshiba M200.
- O.S: Windows XP Tablet.
- Client implementation based on Web technologies (HTML and JS), using URC-HTTP JavaScript implementation (OpenURC Alliance, 2009).
- Jaws screen-reader for people with visual impairment (Jaws, 2014).

3.3.5 Evaluation with users

Pluggable User Interface 1: Multimodal UI on Smartphone Evaluation was carried out with 10 people with mild cognitive impairments living in Sweden. The test participants' age distribution was: 9 in the age between 22 and 40 and one of age 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 valued as good, since all participants successfully completed the test. The result of the evaluations showed 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 (Neßelrath et al.).

Pluggable User Interface 2: Accessible DHTML for the visually impaired The tested tasks consisted of switching on/off the TV set, changing the volume and switching between different channels.

The tests were performed during two accessibility workshops in Horn Bad Meinberg, Germany. 42 elderly persons with their personal care taker (mostly relatives of the disabled persons) 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 results showed a good acceptance of the proposed interaction concept. The tests led to meaningful and sustainable information that will have an important influence on the accessibility design of the user interfaces.

3.4 Conclusions

In this chapter we have proposed a new concept that makes TV sets' remote control accessible for all. The proposal is based on the use of AUI technology to decouple the user interface from the TV set and to enable the use of user interaction technologies that fit best each user. In our proposal we have selected to use ISO/IEC 24752 Universal Remote Console (URC) standard as the AUI technology for the approach.

The presented architecture allows the deployment of Plug-and-Play user interfaces. In this sense, customisable pluggable UIs can be developed by third parties to address the needs of different user groups. This situation has opened the door to a new market of UIs. Business models for this new market are still a topic of research, but resource server based marketplaces may be the best approach.

Additionally, we developed an implementation of the proposed concept. In this prototype we used the UCH architecture as an implementation of the URC, and the Windows Media Center and the Dreambox 7020 set-top-box as TV set examples. In the same way, it is also possible to embed the UCH into an existing TV set or TV Set-Top box.

Furthermore, we implemented two pluggable UIs to demonstrate accessibility for people with visual impairments and people with mild cognitive impairments. The results of the validation with these target users has shown good acceptance.

Finally, we believe that this architecture will help to unleash the full potential of the TV by means of allowing: advanced UIs, natural language UIs, and UIs that seamlessly span over multiple devices such as DVD players, Home Theatres and Home Automation.

The contributions of this chapter were presented at a reference iTV conference (Epelde et al., 2009) and later published (an extended version) at a universal access topic journal (Epelde et al., 2013b).

Chapter 4

Provision of Universally Accessible Interactive Services through TV sets

In the previous chapter we have presented an approach to make TV sets' remote control accessible to diverse user needs and preferences, and probed the validity of the approach through a case study.

In this chapter we will focus on the TV potential to deliver Interactive services. TV is the most used ICT technology, which gives an opportunity to integrate a large community of users to the information society. But as introduced in previous chapters, the human computer interaction of the TV Sets is limited. Therefore, an approach to provide universally accessible interactive services in TV is needed for successfully exploiting the identified TV potential.

This chapter describes an approach using user interface abstraction technologies to overcome the limited human computer interaction of interactive services deployed in TV. This approach enables the use of TV set configurations that meet each user's HCI needs and preferences to access such services.

Section 4.1 gives some introductory remarks. Section 4.2 defines the approach. Sections 4.3, 4.4, and 4.5 present three different case studies with the developments done to validate the approach. Section 4.6 gives some conclusions and discussion on the given contribution.

4.1 Introduction

The TV set is one of the most common communication devices, present in most homes worldwide. Watching TV was time ago identified as one of the activities that was taking up most of people's leisure time (Zillmann and Vorderer, 2000). Social studies like this motivated the provision of one-way information services such as the teletext over analogue broadcasts, which even evolved to videotex based online shopping prototype on a TV set (Aldrich, 1984).

The transition from analogue to digital television has sped up the integration of different interactive services with the TV sets. In recent years, several research projects have focused on the integration of interactive services into TVs (Peng, 2002; Cesar and Chorianopoulos, 2009).

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 Center solutions, to the TVs themselves. The level of interactivity of the implemented services has followed a likely path, from simpler to more complex services, from integrating simple VOD applications to integrating latest social networking applications.

This growing interest in providing interactive services through the TV can also be found in recent approved standards such as HbbTV. In HbbTV regular broadcasts are complemented by interactive services available on-line, with the aim of providing those services seamlessly on a TV set (ETSI, 2010).

For many users, the integration of these services into a TV set provides the means for being able to access online banking, e-health services, socialising via available social networks or making use of the services provided by their environment, that otherwise would be inaccessible due to a lack of computer skills.

The current trends of moving physically provided services into the cloud to save money in personal costs, and to improve benefit margins, sharpens the need of providing interactive service in an accessible way. Otherwise, some user groups could be at risk of exclusion from the digital society.

Up to now, the majority of research carried out on inclusive TV has attempted to provide techniques for the interactive television (iTV) service's lifecycle development (requirements gathering, design, implementation and evaluation), or to make the content and remote control of the TV accessible to groups of users with specific disabilities.

Regarding the accessible interactive services in TV challenge, there are specific implementations coming from generic iTV research area, which are mostly electronic program guide (EPG) related. One of the results of providing specific solutions to specific user group's needs, instead of using an intermediary open user interface platform is that developed service adaptations are not reusable.

It is interesting that the greatest efforts to develop natural interfaces for the TV set come from the interactive television area. In recent years, the iTV research community has progressed through the integration of these interaction technologies for an improved interaction with TV deployed services.

There is also an industrial commitment, to include such interactive functionalities in commercial products that have already been brought to market. However, most research and industrial developments have been targeted to the mainstream user, generally ignoring the accessibility barriers experienced by people with disabilities and elderly people.

In our opinion, it is necessary to define an approach that would allow the integration of services with different TV sets to meet different user needs. A motivating scenario for this identified need has been described in 1.1.4.2. In order to guarantee the openness and the adaptability of the evolved scenario, an AUI based approach is needed.

The provision of an approach like this can foster the development of accessible TV interactive services' solutions, ensure the reusability of different modules and provide means of fast prototyping of new services or new TV set configurations (with new interaction technologies).

4.2 Approach

The objective of this section is to describe the approach of this thesis to enable different users to use the TV sets configuration that fits them best to consume interactive services in TV. In the introduction to this section, it has been noted that different initiatives from research and industrial worlds have provided the integration of different interactive services with the TV, but these developments have been focused on specific user profiles or on the mainstream user. This limits their reuse by other users and the provision of TV set configurations that fit each user best.

At the conceptual level, we propose to augment interactive services with an AUI representation. Against this AUI representation different TV set configurations can be deployed making the provision of interactive services in TV universally accessible.

Similarly to the previous section, we have chosen the URC Framework (ISO/IEC, 2008) due to its UI plug-and-play approach, in contrast to the transformational approach of alternative, which require to run the transformation logic on each execution. In addition, the concrete or final user interface development in the plug-and-play approach is targeted at UI designers and developers, while in the second case an expert in the transformational framework is required to develop transformation modules for new interaction technologies.

The main advantage of the URC framework is that it allows the development of pluggable user interfaces. Following this approach, different UI implementations for different TV set configurations can be implemented to access the given interactive service. Additionally, the resource server concept included in the URC Framework enables the deployment and the update of the UI implementations on the TV sets, through repositories on the Internet.

Figure 4.1 presents the evolution from the actual scenario to an AUI based evolved scenario. On the top half the actual scenario is shown. This image reflects the scenario where each TV UI is developed separately for each TV UI system by the solution provider. This is represented by independent blocks where individual TV UIs are tied to a individual interactive service and there is no possible reuse or alternate TV UI connection possible. On the bottom half of the image our proposed conceptual approach is represented and named as the evolved scenario.

In our approach, first, the interactive service is provided with an AUI description by the solution provider or integrator. Then, TV set UIs are personalised for different TV systems by the solution provider or by third parties (based on the open standard based interface definition).

We use the URC technology for the interactive service's AUI definition. Based on this definition, different TV UIs can be developed for specific interactive services ("TV UI 1 for Interactive Service 1" and "TV UI 2 for Interactive Service 2" depicted in Figure 4.1) or TV UIs that span across different interactive services ("TV UI 3 for Interactive Services 1+2" depicted in Figure 4.1) to answer the TV interaction needs of each user.

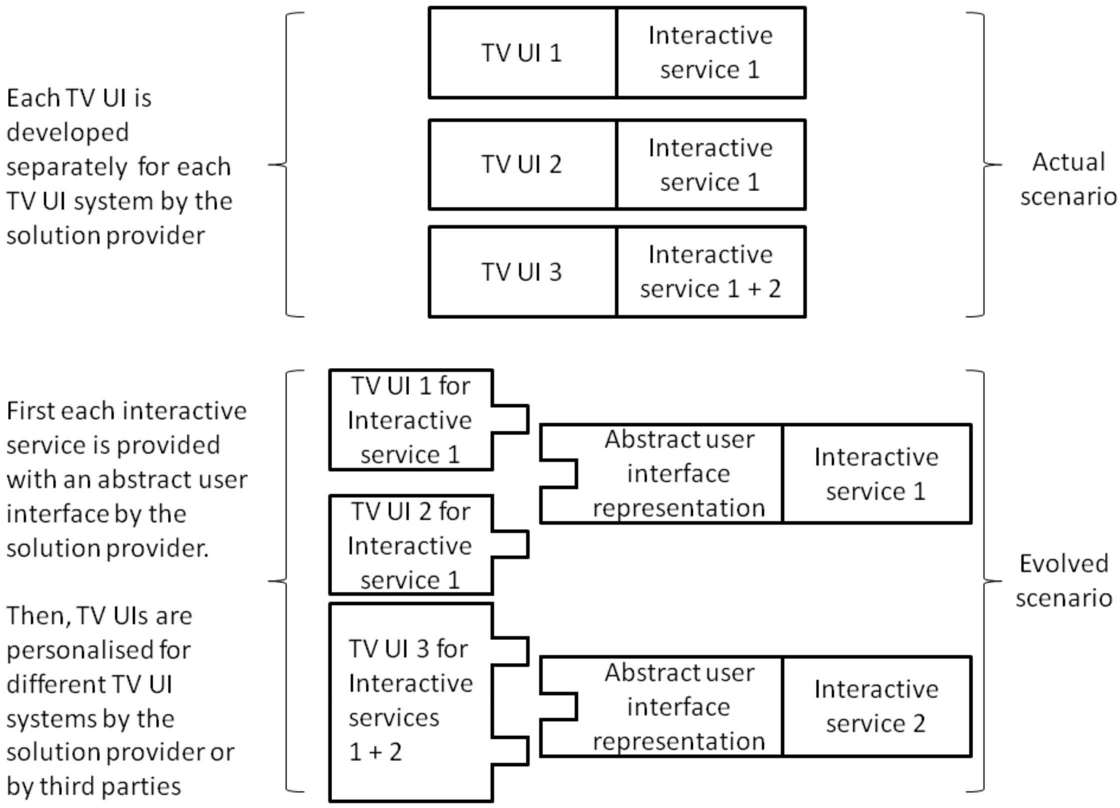

Figure 4.1: Actual iTV applications development in contrast to the proposed evolved scenario. The proposed evolved scenario allows the integration of services with different TV sets to meet different user needs

4.2.1 URC framework document requirements analysis

As introduced in Section 2.2, the URC framework requires the definition of three core components in XML file format. For specifying the interactive services AUI description, these documents should contain the following:

- Target Description (TD): This document is used to describe the properties of the interactive service to the clients. The TD provides the information required by a client to connect to a interactive service's UI socket in order to initiate a control session. A Target has exactly one TD.
- User Interface Socket Description (UISD): A User Interface Socket Description is a XML document with a machine-readable description of the interactive service's functionality.
- Target Resource Sheet (RS): A resource sheet is a file that defines the resources that can be used in the construction of a user interface. For example, language specific strings, icons and other GUI elements.

The details of the XML files defined for an example interactive service (video-conference), to meet the URC framework requirements can be found at Appendix E.

4.2.2 UCH architecture integration requirements analysis

As introduced in Section 3.3, today's devices and services do not come with a user interface socket built-in. Therefore, in this thesis we present an approach that proposes the use of the URC framework in the form of a gateway-oriented architecture, UCH (Zimmermann and Vanderheiden, 2007), to provide accessible interactive services to any TV set.

Regarding the services to be integrated, they can either be locally or remotely deployed, and they can have different levels of openness: they may have proprietary access protocols, defined access APIs or web service specifications.

Following the requirements to integrate a target to the UCH, an interactive service must have an interface for clients to remotely control the complete functionalities of the service. Next, the three requirement categories for the networking platform of a service to be integrated in the UCH are analysed:

- Discoverability: A target to be discoverable and identifiable on the home network. Translated to interactive services, this would either mean to have preknowledge of the location of the service's description files or service's URL. Advanced scenarios could include the use of query mechanisms to service registries such as the implementations of the Universal Description Discovery and Integration (UDDI) specification (OASIS, 2002). This technology has not been largely adopted.

- Controllability: A target must be controllable, i.e. a client must be able to invoke its commands remotely. Interactive services are defined to be controllable by their nature.

- Eventing: A target must send out events to inform a client about its state changes. Most common interactive services are web based, which do not usually provide eventing mechanisms. Even if a specification was defined for supporting eventing features on web services (Box et al., 2004), this has not been largely implementing in web service frameworks.

The services' integration into the UCH architecture is achieved by means of defining the XML files required by the URC Framework (TD, UISD and RS analysed above) and implementing the corresponding code for the target adapter layer requirements (Target Discovery Module and Target Adapter) for each interactive service. Following is provided some insight of the code needed to integrate such services with the UCH.

- Target Discovery Module (TDM): The function of this module is to discover interactive services. In the case of interactive services local deployment discovery protocols such bonjour or UPnP might be used. In the case of remote deployment of interactive services (most common), the code is limited to checking the availability of a service in a given URL and sending an event of a detected service if available. UDDI and similar technologies would require a bit more complex implementation that would include query and answer processing features.

- Target Adapter (TA): A TA is the module that communicates with a specific service in its native protocol, with the relevant socket instance via the Target Manager as to update the state of the socket values, or to receive commands from the controllers. For interactive services the native protocol would be mainly SOAP (W3C, 2007a) for WSDL based services, REST (Richardson and Ruby, 2008) for web API based services and proprietary communication protocol implementations for services working with proprietary protocols.

The TV set configurations that are used in this approach have to fulfil the following requirements: they must implement a communication technology and a programmable user interface system.

These TV sets can implement varying levels of accessibility features, depending on the user's requirements, and they may have different form factors, ranging from a TV, to a Set-top box, or a PC based media center solution.

Through the implementation of a UCH's User Interface Protocol Manager (UIPM) we can implement any TV set's compatible communication protocol. Using the UIPMs we have the ability to plug in different pluggable TV set UIs to the interactive services.

After achieving the integration of the services with the UCH and the required UIPM, we are able to create UIs for any service. The 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.

The Figure 4.2 outlines our proposal to provide accessible interactive services in TV sets at technical level.

This figure shows different target services integrated using their own protocols, that are accessed from different TV sets. The different TV set configurations make use of the URC-HTTP protocol defined by the *OpenURC Alliance* (2013b) or other user interface protocols (open or proprietary) implemented as UIPMs, to communicate with the UCH. The resource server reflects the option of using the UIs and integration modules downloaded directly from the Internet.

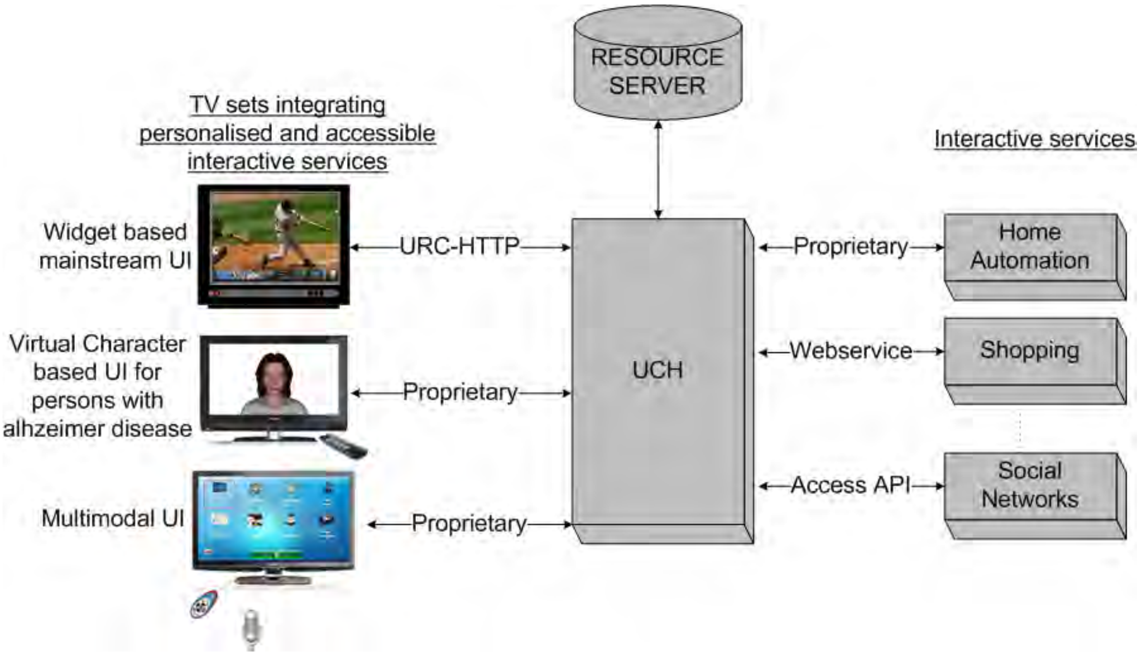

Figure 4.2: Provision of universally accessible interactive services in TV sets

4.3 Approach Validation 1: Multimodal TV UI configuration focussed on the elderly

On the first case study developed to validate our approach, we have focused on elderly users who are 60 years or older, with normal cognitive ageing, and have an active life. With this idea in mind, we integrated those services that could improve their quality of life, integrate them with mainstream society, and introduce them to new technologies through familiar interfaces.

The following services have been integrated to the UCH: video-conference as a social inclusion application, information service as a personalised information provider application, and audio book, educational content and p2p gaming (quizzes, chess) to enhance their leisure time and their cultural enjoyment.

The current elderly generations, as well as, less technical inclined people, adopt easier and with lesser rejection the traditional interaction paradigm of the TV set. On the contrary, the new services deployed on the traditional TV do not correspond with the elderly users' mental model (coming from the classic TV), which makes them get lost.

It's necessary to develop advanced multimodal user interfaces (Obrenovic et al., 2007), but using classical interaction resources so that the different user groups, and specially the elderly user is able to understand how to operate the provided applications.

Based on this, a multimodal (simplified remote control + speech interaction) TV set UI configuration has been developed. Figure 4.3 shows graphically the configuration of the integrated services and the developed TV set UI in the approach validation 1.

The first subsection below introduces how the integration of the interactive services with the UCH was done. The second subsection details the develop the TV UI concept. Finally, the last subsection reports on the results of the user evaluation.

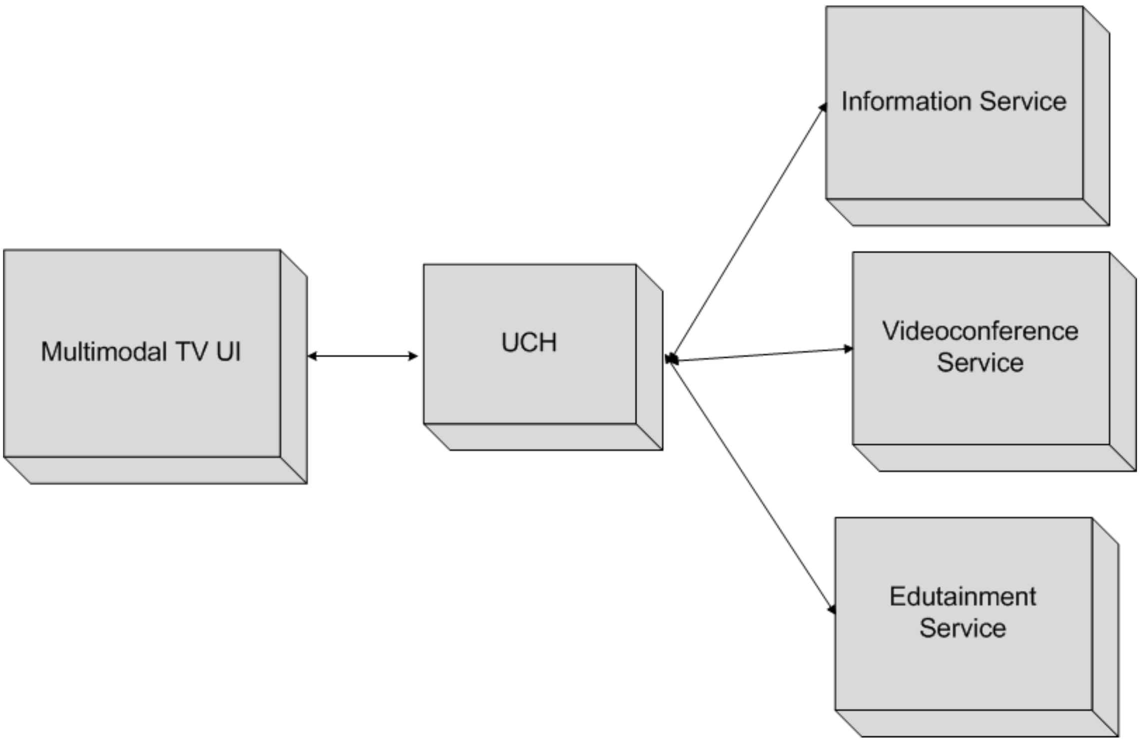

Figure 4.3: Configuration of the integrated services and the developed TV set UI for the approach validation 1. Multimodal TV UI configuration has been focused on the Elderly. Edutainment service block covers the audio book, educational content and the p2p games developed to enhance their leisure time and their cultural enjoyment.

4.3.1 Interactive services integrated with the UCH

The discussion of the user evaluation and its results will concentrate in the video-conference and the information service[1]. Therefore, this subsection concentrates on describing these two services in more detail.

4.3.1.1 Video-conference service

The main motivation for choosing to integrate the video-conference was that one of the biggest problems that the elderly suffer from is loneliness. To overcome this problem, connectivity applications are thought to improve the quality of their ageing. Using these connectivity applications the elderly can keep in touch with their family or friends, and make their life happier and more entertained.

Even if there are mainstream solutions in the market that integrate video-conference on a TV set like the Skype based solution, we felt that providing this functionality through a personalised and accessible UI, could improve the elderly's interest and adoption of this service.

The video-conference service has been provided through the integration of the open source Ekiga software as a target service to the UCH (through a proprietary control protocol defined over TCP-IP).

The details of the XML files defined to meet the URC framework requirements for the video-conference service, can be found at Appendix E.

The developed video-conference application's user interface for our TV UI system is composed of three interfaces.

- "Call Contacts" visualises the user's contacts and allows establishing a call with one of the contacts by pressing OK in the simplified remote.
- "Incoming Call" appears in the foreground when a new call arrives. This interface is composed of a picture of the caller contact and the options to take or reject the call. The users can choose one of the options by pressing on

[1] The information service was developed and integrated to the UCH by DFKI in the Vital project framework (FP6-030600).

the left and right arrow keys on the simplified remote, and they can run their option by pressing OK.

- "Ongoing Call" shows the video streams of the call and has a hang-up button that is activated by pressing OK in the simplified remote.

The video-conference service makes use of the platform's contact management service. These contacts can be easily managed on a PC through a user interface developed for the contact database's UI Socket.

Figure 4.4 shows the screenshots of the main menu and the three interfaces developed for the video-conference service.

Figure 4.4: Screenshots of the main menu and the three interfaces developed for the video-conference service (call contacts, incoming call and ongoing call).

4.3.1.2 Information service

An important concern we wanted to address was how to make the acquisition of information in the web easy to master. We believed that an application with such features integrated into the platform required less cognitive effort to the elderly. To this end, we decided to avoid the use of web browsers, direct access to search engines (instead, the information service invokes a query on behalf of the user), and even hide the fact that the user accesses the Internet at all.

In order to accomplish transparency of the content for the elderly, we encapsulated the knowledge about the web site into the project's ontology. Using this approach "web-surfing" is substituted by browsing through an ontology tree.

Here, the ontology defines the conceptual relations in the domain. Furthermore, it assigns web pages to concepts and specifies the rules to extract the documents. In a second step, the ontology provides a description of content related to specific web pages.

User preferences and interests of a specific user help to further restrict the space of concepts. Learning of users' interests is done by statistical evaluation of previous user behaviour. Combining a probability approach and a vector space model, a personal recommendation service provides interesting documents which are instances of the favoured concepts in the ontology tree.

For instance two instantiated concepts that have been established by the users' preferences are:

- TV: A personalised guide to the daily TV programme. The user can browse through all programmes split into categories (e.g. movies, sports, series, music and more). This category is displayed as the sixth icon in the information service's menu interface in Figure 4.5.

- Wellness: Information about a healthy life style, suggestions for staying in good shape, news about advanced techniques in medicine and so on; see the last icon in the information service's menu interface in Figure 4.5.

The information service has been integrated with the UCH, by publishing this service as a WSDL based web service and by developing the corresponding URC framework XML files and the UCH middleware binaries to discover the web service and to communicate with it.

Figure 4.5: Screenshots of the main menu and the three interfaces developed for the information service. On the top, a screenshot of the start page of the Information Service is displayed. Preselected topic areas are distinguished by big icons and ordered by users' preference that may change after usage. Below, two screenshots of the navigation through the content are shown.

4.3.2 Developed TV set UI concept

Concerning the specific needs of the seniors related to iTV platform's user interface, the requirements and the guidelines defined[1] for the development of the implemented platform are described in Appendix B.

With regard to the targeted TV set's UI, a multimodal interaction has been developed together with a simple and easy to navigate graphical user interface [2]. The multimodal interaction includes both a simplified remote control and speech interaction modalities. The dialog system technology used in the implementation is explained in Appendix C.

[1]The guidelines were defined by Ingema in the Vital project framework (FP6-030600).

[2]The multimodal TV UI's core was build by CTU (Graphical user interface technology) and DFKI (Ontology-based dialogue platform for enabling the multimodality) in the Vital project framework (FP6-030600).

The TV set's UI system is composed of a main menu with access to the different applications and the interfaces of the corresponding applications. Examples of the graphical UI of the developed TV set UI configuration are included in Section 4.3.1 and shown in figures 4.4 and 4.5.

4.3.3 Prototype Description

The prototype implemented for the approach's first validation is described from a technical point of view in Figure 4.6.

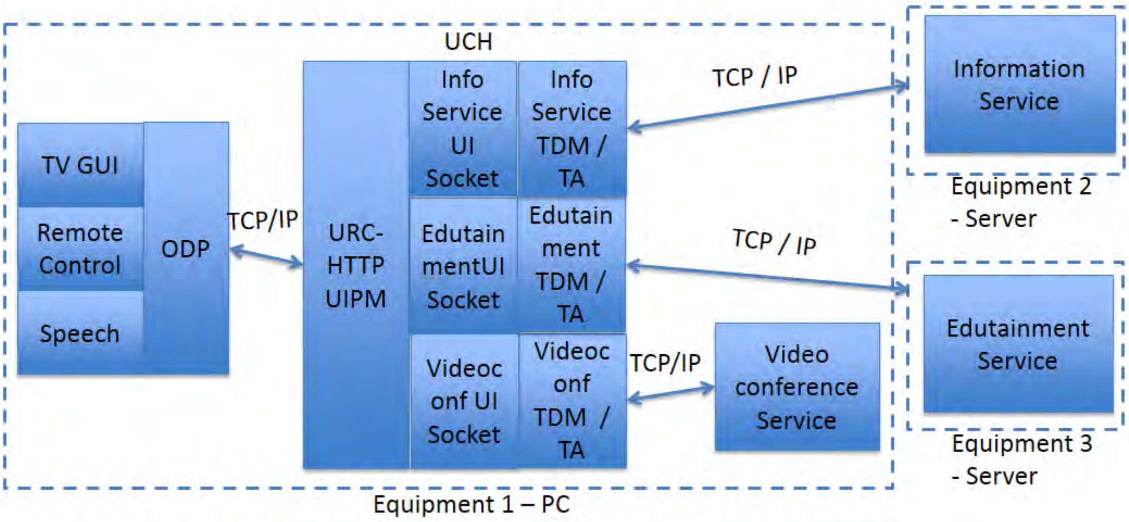

Figure 4.6: Older adult focussed accessible iTV setup

- Equipment 1 - PC (UCH and TV UI configuration)
  - Device: Intel Pentium D 945 @ 3.4 GHz, 2 GB RAM.
  - O.S: Windows Vista.
  - UCH implementation: .NET implementation by *Meticube* (2014) (Version 2.1).
  - Locally running services
    - Videoconference service based on the *Ekiga* software (2014) (Version 3.2.7), modified to be remotely controllable by the UCH.
  - Service Integration
    - Information Service

- URC framework-required XML files (TD, UISD, RS).
- TDM: Discovery done by specifying Information Service's server IP address.
- TA: Services are controlled using their WSDL description and SOAP for the remote control.

* Edutainment Service
  - URC framework-required XML files (TD, UISD, RS).
  - TDM: Discovery done by specifying Edutainment Service's server IP address.
  - TA: Services are controlled using their WSDL description and SOAP for the remote control.
* Videoconference Service
  - URC framework-required XML files (TD, UISD, RS). Details can be found in Appendix E.
  - TDM: Specifying the IP, and port to communicate with the modified Ekiga software.
  - TA: Target controlled by using a simple proprietary protocol, implemented in the modified Ekiga software.

- UIPMs
  * URC-HTTP UIPM (OpenURC Alliance, 2013b).
- UI implementation
  * Windows Presentation Foundation-based TV graphical user interface.
  * Infra-red based remote control. *Weemote* (2009).
  * Speech based interaction. *Nuance* Dragon SDK Client (DSC) Edition (2014) (Version 10).
  * Multimodal interaction supported by the ODP framework (Pfalzgraf et al., 2008).

    * The ODP framework connects to the URC-HTTP UIPM, using the .NET URC-HTTP implementation included in the *Meticube* .NET UCH bundle (2014).

- Equipment 2 - Server (Information Service)
  - O.S: Linux - Ubuntu Server 7.04.
  - Web-service software: Apache Tomcat 6.
- Equipment 3 - Server (Edutainment Service)
  - O.S: Linux - Microsoft Windows 2003 Server.
  - Web-service software: Microsoft Internet Information Services (IIS).
  - Database management system: MySQL Server.

4.3.4 Evaluation with users

4.3.4.1 Evaluation method

The development of the platform was done following the user centred design approach. Following this approach, the platform was evaluated at the end of each iteration. The results of the first evaluations served as an input for the second iteration's developments.

For the initial user test the platform was tested in labs by 10 users in Spain and by 30 users in the United Kingdom. The tests included interaction with the initial prototypes, together with personal interviews and focus groups to capture the user's experience and to compile the input for the upcoming development period.

For the final test of the platform, the system was tested by 16 users at homes in the United Kingdom, and by 4 users at home in Spain for a period of 3-4 weeks. The platform's final prototype was also tested in elder associations in Spain with a meaningful amount of users.

The reporting that is detailed in the following subsection is concentrated in the final evaluation of the platform done in the north of Spain in different older people associations. The system was shown and discussed with an amount of users large enough to enable the performance of subsequent quantitative statistical analyses.

Participants The sample recruited for the final evaluation of platform was composed of 83 participants. After the revision of the answered questionnaire and subsequent refinement of the data, the final sample from whom the results have been compiled, was composed of 47 participants, 13 male and 34 female, with an age ranging from 52 to 89 (x=71.11; sd=7.12) from the town of Zarautz (n=23) and the city of San Sebastian (n=24), in the North of Spain.

All users were attending elder associations in their respective locations. They had been living in their current location a mean of 46.58 years (sd=19.04), which identifies them as stable participants in their respective communities. Only 27.7% had no studies, while 46.8% had completed primary studies, 8.5% secondary studies, 12.8% had higher education studies and 4.3% had completed university studies. They had been active workers throughout their lives, with a mean working life of 36.08 years (sd=12.22). 51.1% of the people from the sample were married, while 38.3% were widows.

Technical Set Up Two laptops with a headset, a simplified remote control, and their corresponding signal receptors were set in a room where the demonstration would take place on a group basis, connecting the main computer running the platform to a slide projector. One evaluator and one observer explained the whole procedure to the users in each testing site, gathered as a group in the room.

Users were administered a consent form, thus showing their acceptance to participate in the evaluation session. Afterwards, they were given a questionnaire, which included the following sections: i) socio-demographical data; ii) quality of family and social contacts; ii) leisure activities; iv) satisfaction with life, and v) specific evaluation of the platform's services (here, questions about the system in general and individual applications in particular were asked).

Figure 4.7 shows the technical set up of the evaluation sessions.

Tests steps After an approximate time of 30 minutes to fulfil sections 1 to 4 from the questionnaire, the main menu was presented, and a brief explanation of its usage was given to the participants. Users were required to give written answers to questions related to the main menu, as well as to provide specific verbal feedback to what they were seeing on the screen and consulting the staff at any time.

The same procedure was followed for each application (from video-conference to information service), thus showing the interface and the functioning (via a simplified remote control) of each application. A demonstration of the interaction via voice (in English) was done.

After all the services were presented, users were asked to discuss aloud any additional comments or feedback they would like to add. Then, the questionnaires were collected and users were thanked for their participation.

Figure 4.7: Technical setup of the evaluations in an elderly association

4.3.4.2 Results

Overall impression about the system and main menu The opinions about the system were divided among those not having a clear statement, those thinking that it was a good application, and those reporting from the beginning that "this application may isolate people... it might isolate them in their homes".

However, a majority of 68.2% thought it would be helpful in improving their social relationships. 71.4% thought it would help them to keep closer contact to their relatives. 73.7% thought it would help them to get closer with friends, and 84.2% were confident in the idea that it would improve their quality of life.

Regarding the main menu interface, most of the sample (53.3%) found it pleasant or very pleasant, not being tiring for the eyes. All of them considered the interface was readable, with appropriate font size and colour. The voice control demonstration worked well and participants were impressed. They expressed concerns regarding the use of headsets, the provision of the technology in other languages and the accuracy of the voice interaction with elderly users.

A table summarising the results from the evaluation with users is included in Table 4.1.

Table 4.1: Summary of evaluation results

Overall Impression about the system
68.2% found it helpful in improving their social relationships
84.2% were confident it would improve their quality of life
53.3% of the sample found the main menu interface pleasant
Video-conference service
48% found the layout as pleasant (48% were neutral)
81.3% thought was a useful application
50% would regularly use it
Information service
50% described the layout as pleasant
87.5% considered it was useful
50% would regularly use it

Video-conference Service The layout of the video-conference was described as pleasant by 48% of the sample (48% said it was neutral, neither pleasant nor unpleasant). When they saw the way it worked on the demonstration session, 81.3% thought it was a useful application, and 50% would regularly use it (the others would rather continue with the regular phone). 54.5% would use it to talk to family, and 36.4% to both family and friends. It was a very well rated application ("it helps you keep in touch easier... it brings you closer to your relatives... in this way, I can see them").

Some of the participants were familiar with this form of communication through Skype on a PC. However, it was considered an advantage that the video-conference system allowed being using the TV set for other purposes (watching a film, etc.) while it runs in the background; the user could be just watching the TV and, in case of receiving an incoming call, the call would pop-up on the TV screen. This simplicity of use was highly appreciated by the users.

Moreover, some of the opinions stated by the users were related to their perception of the video-conference service. More specifically, there was a significant relationship between feeling happy with the frequency of family contacts and perceiving video-conference as a device that could improve their quality of life ($\chi 2(3) = 12.058$, $p<0.01$), thus resulting in 63.15% of users (who were already happy because they met their relatives as much as they wanted to) who thought that video-conference would improve their quality of life.

In addition, 66.66% of the users who had social relationships mainly outside home were the ones who precisely described video-conference as a device that could improve their social relationships ($\chi 2(1) = 4.421$, $p<0.05$).

These results suggest that a device like this, rather than improving quality of life of those with less social relationships, is more likely to be accepted by those who can perceive it as a complement to their already existing successful social network.

Information Service 50% described the layout as pleasant. After being exposed to its use, 87.5% considered it was useful, but only 50% would use it regularly. They liked the fact that local content was available, but stressed that the content would have to be updated regularly in order for it to be useful.

Many stated that they would continue with regular newspaper, and this kind of technologies may be good “for younger people”. Some complained that the layout contrast was not good and that fonts should be made bigger, but they were told that this may be adjusted when using it on a TV set.

More details on the evaluation and result of the applications developed to validate our approach can be found at (Diaz-Orueta et al., 2011).

4.4 Approach Validation 2: Virtual Human based TV set UI configuration for the guidance of persons with Alzheimer disease.

On the second case study developed to validate our approach, we have implemented a TV UI system for people with cognitive impairments such as the 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 usually affects those over 65.

The services integrated with the UCH for the development of this approach validation, have been those providing reminder events (either calendar notifications or home appliances' alarm notifications). The aim was to support users in with impaired memory and concentration abilities.

The developed TV UI system is composed of an avatar together with the logic to provide interaction (simplified remote control). Figure 4.8 shows graphically the configuration of the integrated services and the developed TV set UI in the approach validation 2.

The first subsection below introduces how the integration of the interactive services with the UCH was done. The second subsection details the developed TV UI concept. Finally, the last subsection reports on the results of the user evaluation.

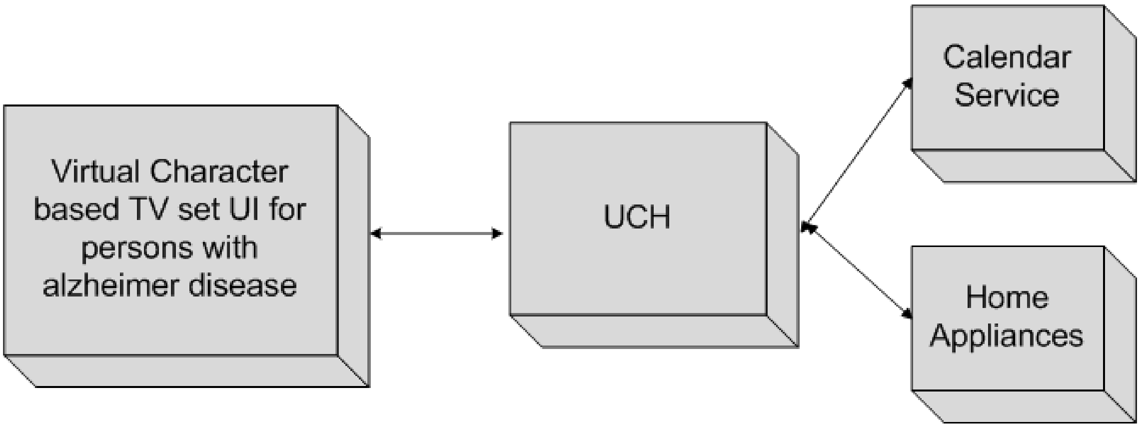

Figure 4.8: Configuration of the integrated services and the developed TV set UI for the approach validation 2. Virtual Human based TV set UI configuration deployed for persons with Alzheimer disease to inform them about calendar of home appliances notifications.

4.4.1 Interactive services integrated with the UCH

For the validation of the solution we have integrated two different services: i) a calendar service with the aim to provide calendar event notifications[1], and ii) home appliances targeting their alarms as event notifications[2].

Additionally, the WMC's TV profile integration was used for providing regular TV experience while no event is happening. Regular TV shows are shown before and after the Avatar has conveyed the event notification. The integration details of the WMC's TV profile have been given in Section 3.3.1.

With regard to the calendar service, a reminder service locally running within the UCH was used. The reminder service allows the synchronisation with Google Calendar. The reminder service running locally has four different user interface sockets defined, one per each different functionality (contact management, calendar edit, calendars management and reminder notification).

From these functionalities, the reminder notification functionality was integrated within the UCH. The aim of this functionality integration is to convey the user, reminders that their relatives managing their calendar or themselves have set (e.g. "Make up, your daughter is visiting you", "Be ready, we are going to the dentist").

[1]This service was developed and integrated by Meticube in the i2home project framework (FP6-033502).

[2]These appliances were integrated by Siemens AG in the i2home project framework (FP6-033502).

The home appliances (Heating, Ventilation and Air Conditioning (HVAC), Fridge, Oven,...) are Siemens serve@Home compatible. The communication with the serve@Home devices is done over powerline. The serve@Home gateway handles the "Network of Household Appliances" and is the gateway between ethernet and the powerline networks. It offers a basic web interface to configure devices, network and security. By means of this implementation the CHAIN (CECED, 2003) based appliances become controllable via the UCH.

For each appliance the different XML files required by the URC framework were defined. Additionally a TDM was developed to discover devices over powerline and a TA for each integrated appliance. The aim of integrating home appliances, is to convey users with cognitive impairment with appliances misuse notifications (e.g. “You have left the oven on”, “The fridge’s door is open”).

4.4.2 Developed TV set UI concept

The developed TV set UI concept works as the following: the user of this controller is usually watching the TV set functionality provided by the WMC target. Whenever a notification is generated, the avatar pop-ups and establishes a dialogue with the person using the system.

For the development of this TV set UI, on the one hand, WMC has been used to provide the user with live TV experience. On the pure UI side, a UIPM module for UCH has been developed, which is in charge of putting UIs into the foreground and switching between the WMC and an external application that renders the avatar. The avatar is rendered using *OpenSceneGraph* (2013) for graphical, and Loquendo (Nuance, 2013) (acquired by Nuance) for speech output.

Additionally the UIPM implements the logic for receiving and interpreting the remote control IR signals. For the remote control, both the *Weemote* (2009) and the *Falck Vital* (2009) simplified remote controls were tested, with basic commands (YES, NO, +, -, arrow up, arrow down).

For the user evaluations, the Falck Vital remote control was used, because it offered an easier way to press buttons and it leaves less room to make mistakes. The developed TV UI concept is presented in Figure 4.9.

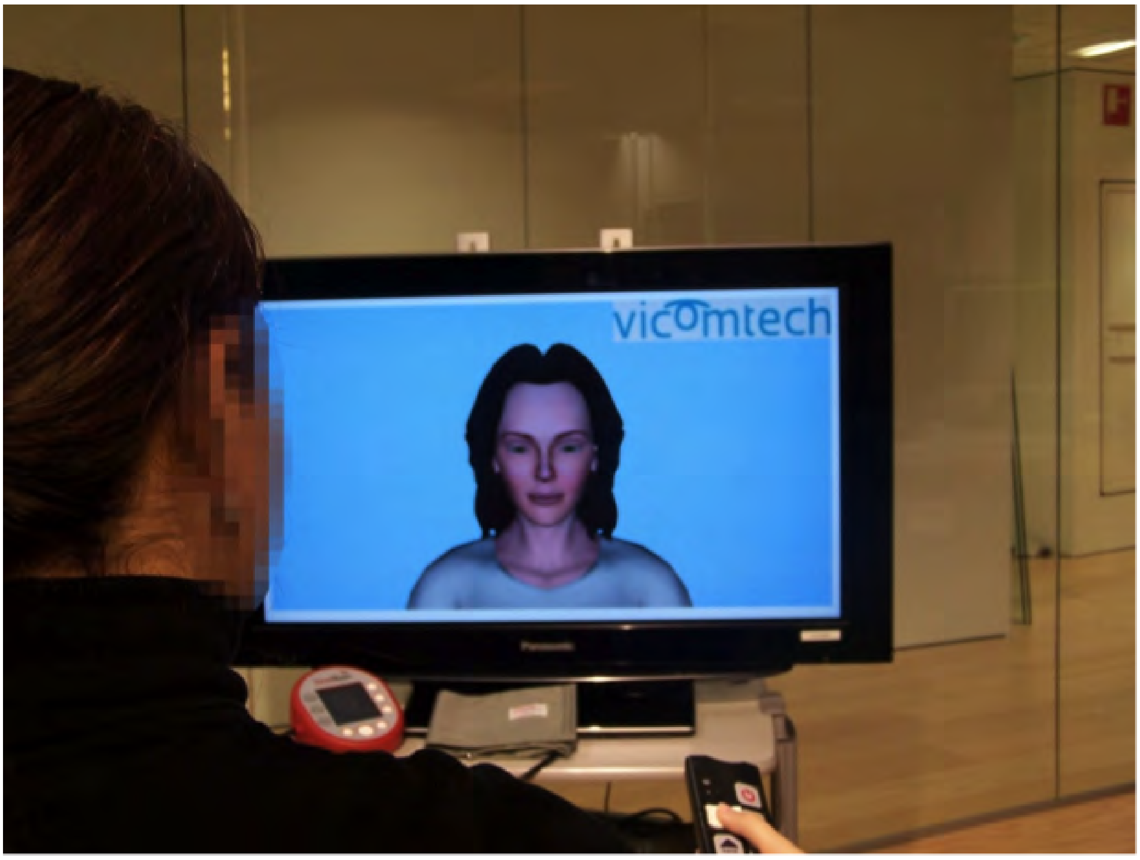

Figure 4.9: A person interacting with an avatar displayed on a TV set

A previous version of this development for set-top-boxes was done by transcoding avatar audio-visual content and streaming it into the set-top-box. Details of this development can be found at (Carrasco et al., 2008).

4.4.3 Prototype Description

The prototype implemented for the approach's second validation is described from technical point of view in Figure 4.10.

- Equipment 1 - PC (UCH and TV UI configuration)
  - Device: Intel Pentium D 945 @ 3.4 GHz, 2 GB RAM.
  - O.S: Windows Vista.
  - UCH implementation: .NET implementation by *Meticube* (2014) (Version 2.1).
  - Services running locally

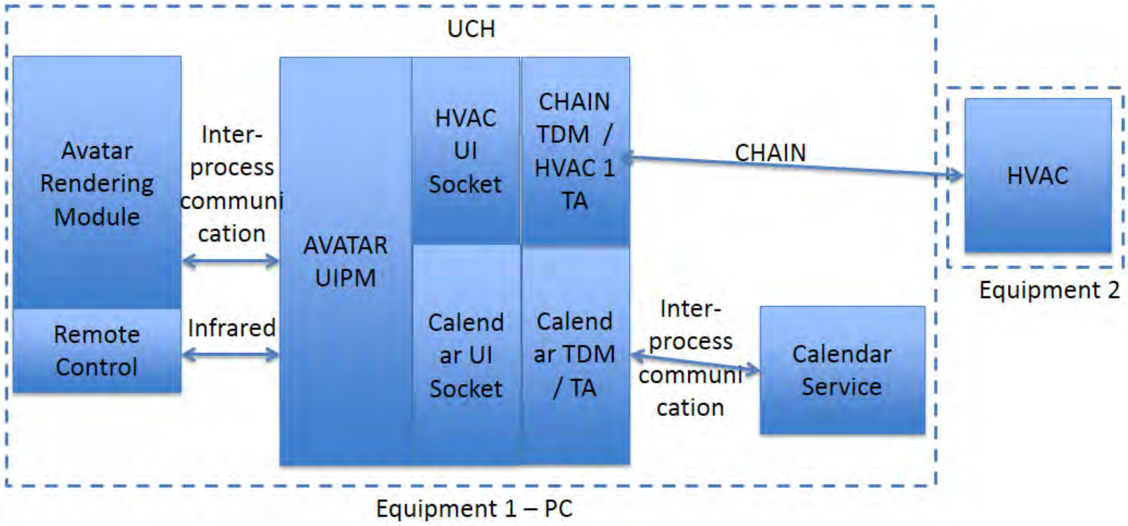

Figure 4.10: Avatar based accessible iTV setup focussed on people with cognitive impairment

    * Calendar Service, part of the *Meticube* .NET UCH bundle (2014).

- Service Integration
    * Calendar Service
        · URC framework-required XML files (TD, UISD, RS).
        · TDM: Checks wether the calendar service process is running in the system.
        · TA: Service controlled using inter-process communication.
    * HVAC (serve@Home)
        · URC framework required XML files (TD, UISD, RS).
        · The communication with the serve@Home devices is done over powerline (CHAIN protocol). The serve@Home gateway handles the "Network of Household Appliances", and it is the gateway between ethernet and the powerline networks.
        · TDM: Using IP communication, the serve@Home gateway is queried about the available serve@Home devices.
        · TA: Specific TA developed for the HVAC. Remotely controls the HVAC device through the serve@home gateway.
- UIPMs

      * Avatar UIPM: Implements the integration with the UCH, and the Avatar rendering module. Additionally, interprets the captured infra-red signals.
  - UI implementation
      * Avatar rendering module: External application that renders the avatar. It connects to the Avatar UIPM through inter-process communication.
          · Graphical rendering using *OpenSceneGraph* (OSG) SDK technology (2013) (Version 2.4).
          · Loquendo Text to Speech (TTS) for speech generation (Nuance, 2013) (Version 7).
      * Infra-red based remote control. *Weemote* (2009).

- Equipment 2 - HVAC (heating, ventilation, and air conditioning)
  - Siemens@home HVAC. Remotely controllable through the CHAIN protocol (CECED, 2003).

4.4.4 Evaluation with users

4.4.4.1 Evaluation Method

The validation tests were performed at the Matia Foundation IZA Day Care Center, San Sebastian, Spain. In order to control external variables, a homogeneous focus group was required. For this reason an initial neuropsychological screening was carried out on each candidate user. The aim of the evaluation was to assess perception, language and memory capabilities.

Participants After the neuropsychological evaluation, the final 21 members of the focus group were selected. All suffered from Alzheimer's disease with a Global Deterioration Scale (GDS) [23] measure ranging from 3 to 5 (from mild to moderate). More specifically, a score of GDS=3 in 10, GDS=4 in 9, and GDS=5 in 2 participants was obtained. In addition, our group showed a mild functional dependency as measured with the Barthel Scale [24] (x=69.3, sd=22.4).

Technical Set Up For the tests two simple pre-defined dialogues were executed. 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. The Basque Handball match scenario was chosen as it is the most popular spectator sport amongst the focus group.

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.

Test steps The user validations were done on a one-to-one basis. Each user was at first briefed by the interviewers in the same room that the validations took place. The goal of the briefing was to make the user aware that the avatar was going to appear on the television, and that they would be presented with various questions, to which they should respond by using the remote control.

The instructions given by the interviewer previously to the application were as follows: *You are going to watch a TV programme. At any moment while you are watching TV a young woman will appear on the screen and will ask you some questions. You will have to answer her by using the remote control. Are you ready? [...] Is the TV loud enough for you?*

The user was then placed watching a normal broadcast television programme. Several minutes later, the avatar appeared and dialogue 1 was run (”A handball match is going to start. If you want to see it, press ’Yes’ on the remote control”). Once dialogue 1 was concluded, the user resumed watching the selected programme until several minutes later dialogue 2 was run (”Please write your name on the piece of paper placed in front of you”).

The interviewers observed the user during the entire validation process and noted their observations in the usability reports. The usability reports showed whether a button had been pressed or not, whether the answer in dialogue 2 was correct or not, how often the avatar needed to repeat the message, the time elapsed between the question and a response, and other general observations. Additional information about when users gave a verbal response to the avatar was also registered.

Finally, both qualitative and quantitative data analysis have been performed. From a qualitative perspective, the analysis will help to determine why the participant answered incorrectly, what are their feelings toward the avatar, whether they understood the avatar voice/meaning, etc.

From a quantitative perspective, the rates of correct and incorrect answers, and response latency, have been measured.

4.4.4.2 Results

From a **qualitative point of view**, a remarkable result of the tests was how well the focus 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.

More importantly, it was observed that the avatar's appearance seemed natural to the focus group and they readily accepted it speaking to them. Only one member of the group showed surprise to the fact that the avatar greeted him using his first name. Nevertheless, after the initial surprise, this user engaged with the avatar in the same terms as the other group members.

Yet another remarkable result of the tests was that after the avatar initially spoke to the users, they first attempted to respond in kind, that is to say, by speaking. Even though the users were not given specific instructions regarding oral responses, 80% of the sample group responded verbally to the avatar. This suggests that a verbal response is a priori a more natural way of interaction for people with mild to moderate cognitive impairment, than the use of a remote control.

However, the users easily adjusted to using the remote control to respond to the avatar, once it gave instructions on how to respond by pressing the corresponding buttons.

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. Afterwards, they continued watching television as before.

Finally, a variance in the time taken to respond to the avatar was observed during the validation testing. More specifically, a total of 86.7% immediately responded to the avatar's first question ("Are you there?"). To the avatar's second question ("Would you like to watch a handball match?"), 80% responded immediately. 73.3% responded immediately to the final question ("Have you written your name on the piece of paper?"). This steady decrease in the response rate may be attributable to a declining level of attention after successive tasks.

More details on can be found in (Diaz-Orueta et al., 2014).

4.5 Approach Validation 3: URC-MCML based applications on Windows Media Center

On the last case study we have developed a proof-of-concept prototype to validate our approach. No specific user group has been targeted by the developed TV set UI concept. This case study was developed as a confirmation of the approach, taking advantage of the experience gotten from the previous developments with WMC and the services integrated for the two previous case studies.

This prototype's TV set UI is based on the Windows Media Center (WMC) technology. The interactive services integrated with the UCH are: HVAC, the calendar service and the video-conference service.

Figure 4.11 shows graphically the configuration of the integrated services and the developed TV set UI in the approach validation 3.

The first subsection below introduces how the integration of the interactive services with the UCH was done. Next, the second subsection details the developed

TV UI concept.

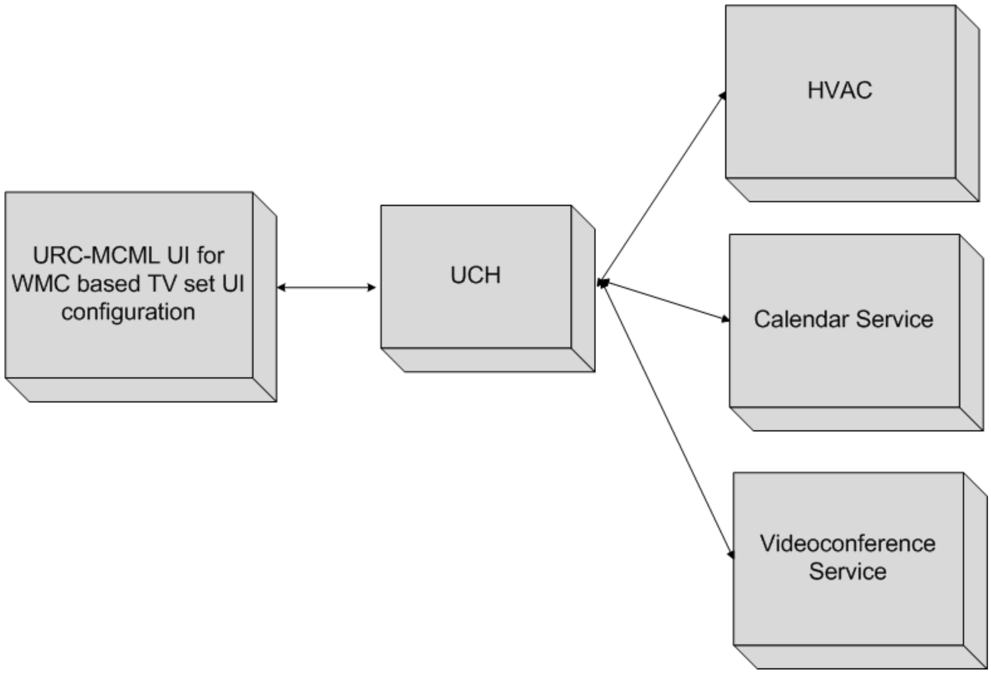

Figure 4.11: Configuration of the integrated services and the developed TV set UI for the approach validation 3. URC-MCML UI for WMC based TV set UI configuration deployed for controlling HVAC and the videoconference service, and receiving notifications from the calendar service.

4.5.1 Interactive Services integrated with the UCH

For this prototype previously integrated services were reused. The reusability is direct, involving no extra implementation, just the new TV set UI concept (introduced in next subsection).

HVAC (Siemens serve@home appliance) and the calendar service integration were introduced in Section 4.4.1. Video-conference service integration was introduced in Section 4.3.1.

4.5.2 Developed TV set UI concept

This TV set UI is based on the Windows Media Center (WMC) technology. 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 (OpenURC Alliance, 2013b) has been used to develop URC-MCML applications. This development has not been tested with real users.

Figure 4.12 shows a screenshot of the URC-MCML UI implementation for remotely controlling a HVAC device, Figure 4.13 shows a URC-MCML UI for receiving reminder notifications, and Figure 4.14 shows the incoming call notification UI for the developed TV set UI concept.

Figure 4.12: URC-MCML UI for remotely controlling a HVAC device

Figure 4.13: URC-MCML UI for receiving reminder notifications

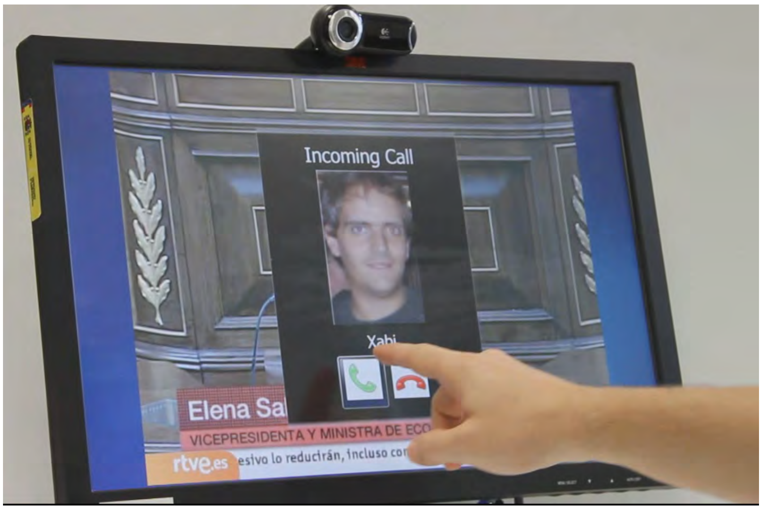

Figure 4.14: URC-MCML UI receiving an incoming call notification

4.5.3 Prototype Description

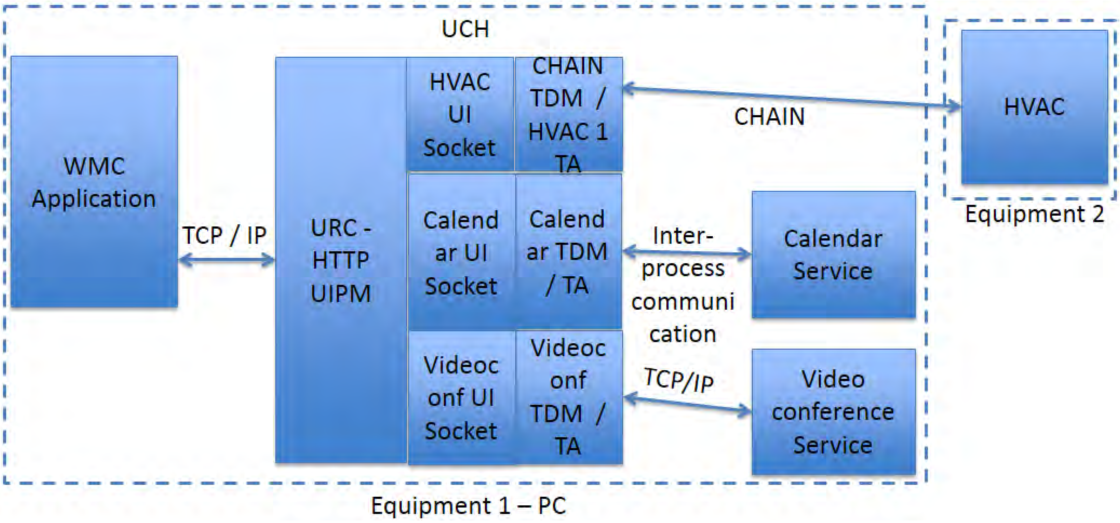

Figure 4.15: WMC based accessible iTV setup

- Equipment 1 - PC (UCH and TV UI configuration)
  - Device: Intel Pentium D 945 @ 3.4 GHz, 2 GB RAM.
  - O.S: Windows Vista.
  - UCH implementation: .NET implementation by *Meticube* (2014) (Version 3.0).
  - Locally running services

    * Calendar Service, part of the .NET UCH bundle *by Meticube* (2014).
    * Videoconference Service based on the *Ekiga* software (2014), modified to be remotely controllable through the UCH.

  - Service integration
    * Calendar service
      · URC framework-required XML files (TD, UISD, RS).
      · TDM: Checks if the calendar service process is running in the system.
      · TA: Service controlled using inter-process communication.
    * Videoconference service
      · URC framework-required XML files (TD, UISD, RS). Details can be found in Appendix E.
      · TDM: Specifying the IP, and port to communicate with the modified Ekiga software.
      · TA: Target controlled by using a simple proprietary protocol, implemented at the modified Ekiga software.
    * HVAC (serve@Home)
      · URC framework-required XML files (TD, UISD, RS).
      · The communication with the serve@Home devices is done over powerline (CHAIN protocol). The serve@Home gateway handles the "Network of Household Appliances", and it is the gateway between ethernet and the powerline networks.
      · TDM: Using IP communication, the serve@Home gateway is queried about the available serve@Home devices.
      · TA: Specific TA developed for the HVAC. Remotely controls the HVAC device through the serve@Home gateway.

  - UIPMs
    * URC-HTTP UIPM (OpenURC Alliance, 2013b).

  - UI implementation

        * Windows Media Center Application based as a TV GUI application.
        * Deployed in a touch screen, so that touch interaction is enabled.
        * Connected to the URC-HTTP UIPM, through a .NET URC-HTTP implementation available in the *Meticube* .NET UCH bundle (2014).

- Equipment 2 - HVAC (heating, ventilation, and air conditioning)
    - Siemens@home HVAC. Remotely controllable through the CHAIN protocol (CECED, 2003).

4.6 Conclusions

4.6.1 Section conclusions

In this chapter we have presented a new approach to integrate all kinds of interactive services with the TV set, in a way that allows personalising the TV UI to the needs of each user group. The proposed approach is based on the ISO/IEC 24752 Universal Remote Console (URC) standard and its implementation in the UCH architecture.

Our proposal for an "ordinary" TV user interface is based on the contributions provided by the interactive TV research. This approach allows to access interactive services from common TV sets, through the provision of personalised plug and play user interfaces that are rendered on the TV set.

This approach permits an easy integration of new accessible services into our TV sets, including the services locally provided by intelligent environments. At the same time, this approach allows the consumption of these interactive services in new TV set configurations with their corresponding interaction paradigms. These interaction paradigms include advanced UIs, natural language UIs, assistive technologies, and multimodal UIs.

Moreover, having the required modules available on a resource server on the Internet, allows us to deploy and update our systems easily, and opens a new market for service integrators and UI developers.

The presented approach has been validated through three case studies.

- The first implementation of this approach has been carried out focused on the elderly. Services targeted on improving the elderly people's quality of life were integrated (video-conference, information service, audio book, educational content and p2p gaming (quizzes, chess)). With regard to the targeted TV set's pluggable UI, a multimodal interaction (remote control + speech interaction) was developed together with a simple, and easy to navigate graphical user interface.

- The second implementation of the approach has been centred in people with mild to moderate cognitive impairment. In this case, apart from interactive services (calendar service), home appliances remote control was integrated. The developed TV UI concept for the second approach validation was a virtual human combined with speech synthesis for the output, and a simplified remote control for the input. Additionally, in combination with the developed TV UI concept, WMC target was used to provide the user with a regular TV experience while there was no notification to show.

- The third and last case study was developed with no specific user in mind and was implemented for testing the reusability of previously integrated interactive service and targets (home appliance, video-conference and calendar service). WMC applications SDK (MCML + .NET) was used for building the TV set user interface.

The first two case studies were evaluated with representative amount of users, while the third case study implementation was not tested with real users. The user tests showed that the developed UIs were well accepted.

The senior users of the first case study thought that the developed concept could improve their social relationship and their quality of life, especially for those who already perceived themselves as having an adequate social network and had close contact with their relatives. With regard to the second case study users (people with mild to moderate cognitive impairment) they showed to be able to interact adequately with the developed TV UI concept.

From the implementers perspective what is remarkable is the easiness to integrate existing modules like the dialog system or the presented services. The simplicity to develop user interface instances of the selected TV UI solution for new services or devices from different environments is also remarkable. Additionally, service integrations have been completely reused from approach validation to approach validation without further modification.

The provision of an approach like this fosters the development of accessible TV interactive services' solutions and provides a means of fast prototyping of new services or new TV set configurations (with new interactions technologies) thus filling the existing gap of studies and solutions on accessible interactive services in TV research.

The UCH implementation can be embedded into a consumer broadband router, into the TV itself, or with a more powerful UCH that has extended functionality such as a dedicated PC.

Additionally, the ongoing initiatives to provide the web services with native URC interface, as well as, providing a URC interface directly on devices in the environment, can reduce the implementation complexity of the URC solution, making it simpler to embed in devices like the TV in the future.

The author of this thesis has contributed through an active participation, and a candidate approach implementation to the upcoming part 6 of the ISO / IEC 24752, which is an annotation approach for web services. It is based on following a naming convention for defining the WSDL web service description, in order to be able to generate automatically the XML files required by the URC framework.

The contributions of this chapter were presented at a reference multimedia conference (Epelde et al., 2011) (technological perspective), at a universal access focused conference (Diaz-Orueta et al., 2011) (user perspective) and later published (an extended version) at a multimedia topic journal (Epelde et al., 2013c).

4.6.2 TV set mixed use case

In chapters 3 and 4 we have introduced two complementary approaches for making TV experience universally accessible: one for making TV remote control universally accessible and the other one for providing universal access to interactive services through TV set configurations that fits each user best. In each of these approaches, 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 interactive services access 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 Centers ...) and these devices can implement a target use case, a controller use case or contain both use cases presented in these chapters.

Figure 4.16 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.

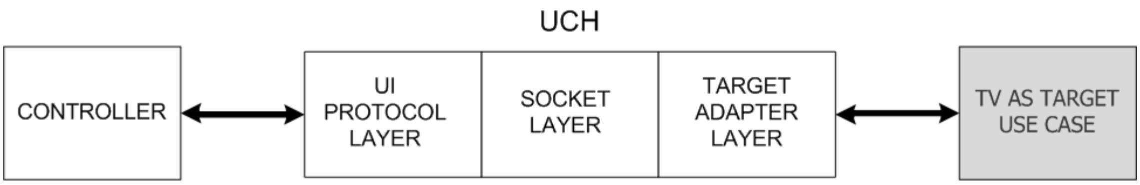

Figure 4.16: TV as Target Use case

Figure 4.17 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.

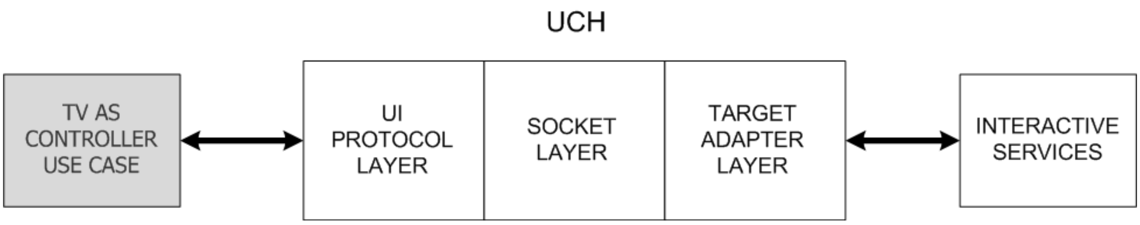

Figure 4.17: TV as Controller Use case

In the case of Figure 4.18, 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 our 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.

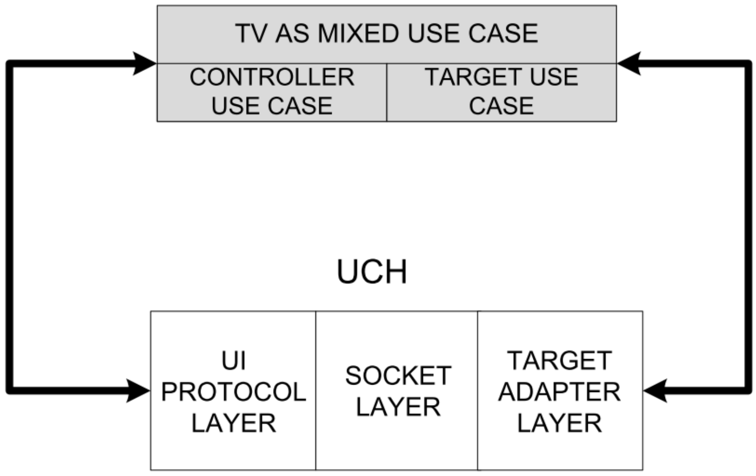

Figure 4.18: TV as Mixed Use case

Each TV set use case approximation was presented separately in different conference papers: Chapter 3 in (Epelde et al., 2009), and Chapter 4 in (Epelde et al., 2011). A complete use case approximation was published in an extended version in (Epelde et al., 2013b).

Chapter 5

Universally Accessible Services in TV User's Real Life Context

In the two preceding chapters we have defined and validated a complete approach to make current and future television sets accessible to all. We have provided universal access approaches for both the remote control of TV sets and the provision of interactive services through TV sets.

In this chapter, we will tackle the limiting factor "lack of considering user's real life context in the DTV service integration strategy" introduced in Chapter 1 (see Section 1.1.3.2). Therefore, this chapter will focus on presenting an approach to support the users' universal access to services in the different contexts they move through, in terms of the interaction devices and technologies used. We will also consider the different actors that participate in the provision of such services.

Section 5.1 gives introductory remarks to the topic. Section 5.2 defines the approach. Section 5.3 presents a case study of the defined approach on telerehabilitation. In Section 5.4 conclusions are outlined and the corresponding discussion on the given contribution is developed.

5.1 Introduction

In the last decades, several initiatives have targeted the integration of interactive services with TV sets. The number of initiatives trying to achieve such integration has grown since the transition from analogue broadcast to digital broadcast, and specially with the introduction of connected or smart TVs. The main services that have been integrated are on-demand audio-visual contents (either movies, music or thematic contents) and social network related services.

Despite these specific service implementations, not many other service types have been integrated, and those that have been integrated have not had a large adoption. The different factors for such limited uptake were analysed in Section 1.1.3. Besides the limited human computer interaction, in this thesis we focus on the lack of considering user's real life context in the DTV service integration strategy as one of the main barriers for the interactive services on TV uptake.

In this thesis, a user's real life context is considered from two points of view. On the one hand, we need to tak into account that the user is not always in front of his TV set. The user moves from place to place, and changes the device used to interact with the environment and the services provided. On the other hand, we need to consider that services are accessed by different actors: i) for the service's same use cases (e.g. a relative is allowed to do certain tasks), ii) for different use cases (i.e. each actor has a differentiated role within the service) or iii) for shared use cases (i.e. actors collaborate to reach a goal).

Our life is a multi-environment and multi-device experience. Recent studies have demonstrated that many users have various interaction devices available at home and in their working environment (Dearman and Pierce, 2008).

Users that work with multiple devices want a seamless experience when interacting across them (Dearman and Pierce, 2008; Oulasvirta and Sumari, 2007). They want to access their resources and services easily, using any of their interaction devices. They want to employ their interaction devices to enjoy a more personalised and integrated experience, rather than a collection of different independent experiences in each interaction device.

In addition, statistical studies on European citizens' ICT usage (Eurostat European Commission, 2013) evidence the need for an architecture that supports user's real life context and its multi-device usage nature. Figure 5.1 shows a representation of the user's multi-environment and multi-device reality.

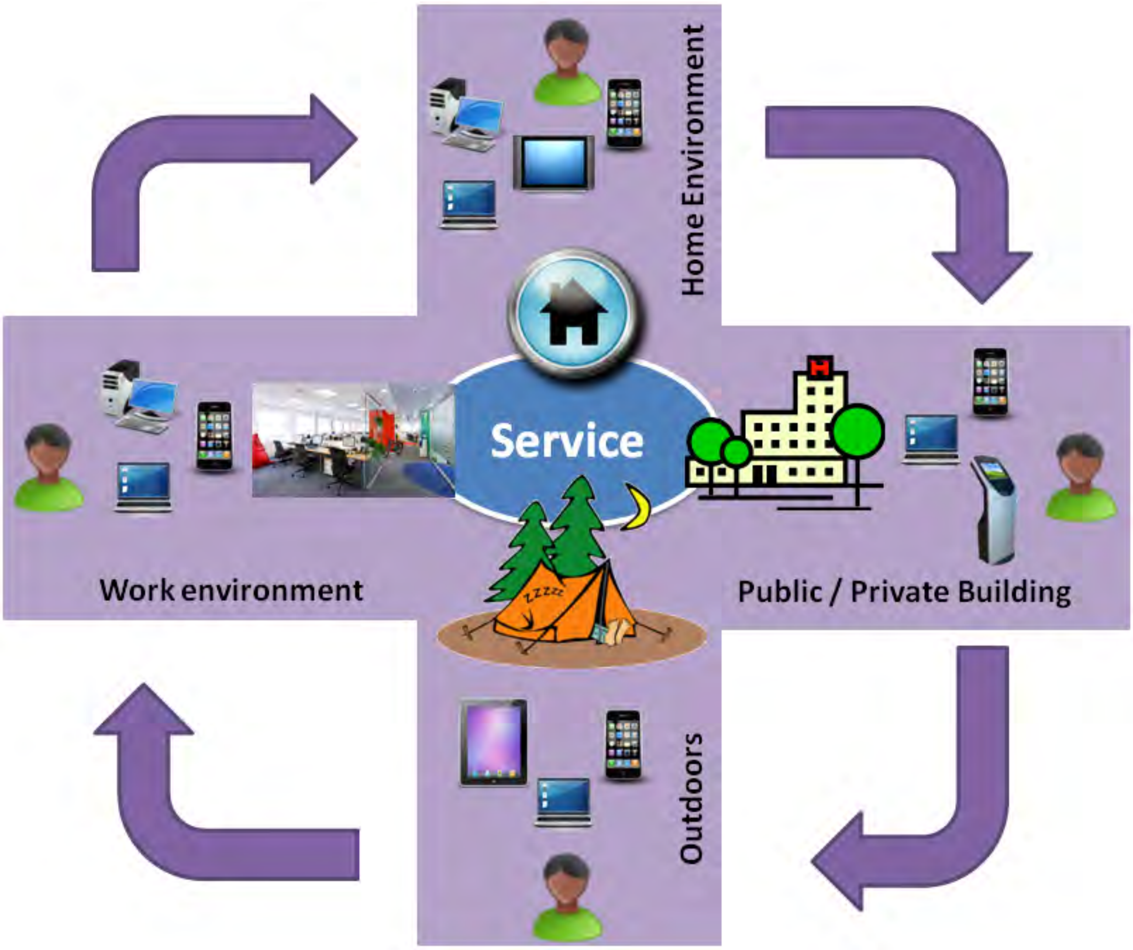

Figure 5.1: User's multi-environment and multi-device reality. The user can move around different environments and use different controller devices in each environment.

Concerning the multi-actor interaction with a service, different users have different needs and preferences for interacting services. Figure 5.2 shows a telecare service example where different interacting actors can be identified.

This multi-actor reality has been captured by different software development processes, such as the Unified Process. Unified Process defines steps to identify the different actors that interact with a system, in a notation such as the UML Use Cases (Larman, 2002).

In this multi-actor scenario, *Zimmermann and Vanderheiden* described some guidelines to apply in the software development processes, for ensuring the accessibility of the developments (2008). An example of such guidelines is the use of Persona profiles (Cooper, 1999) to identify and test the accessibility needs per each actor.

Based on the two concepts of the user's real life context introduced, and taking

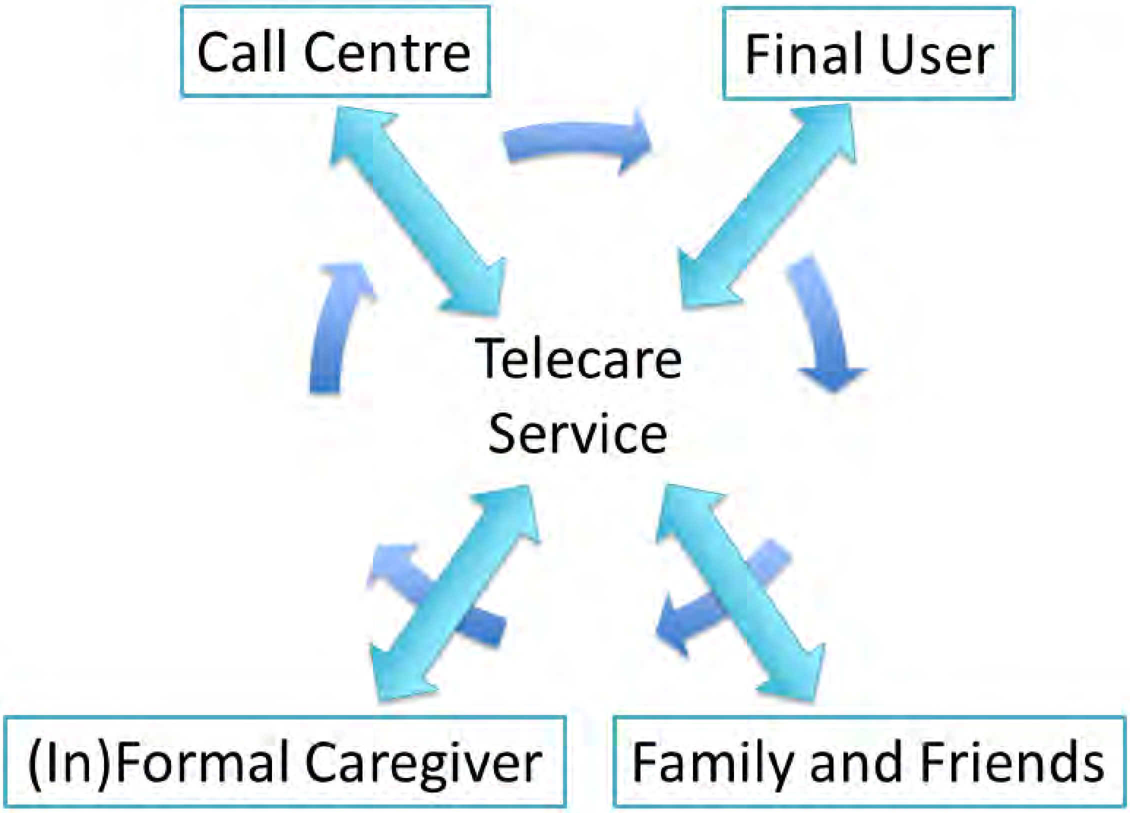

Figure 5.2: Multiple actors taking part in an example telecare service

into account the interaction needs and preferences per each user, an approach that considers interactive service provision on TV as part of an integrated approach is needed. This approach should enable the universal access to the service for different users, environments and controller devices. A motivating scenario for this identified need has been described in Section 1.1.4.3.

5.2 Approach

In this subsection, the approach defined to provide universally accessible services in TV user's real life context will be described. As mentioned in the introduction of this section, one of the limiting factors of the adoption of TV based interactive services is the lack of continuum of these services in different environments and devices, and the lack of integration of the different actors that consume the service.

At the conceptual level, we propose to augment the different interactive service's per actor use case, with an abstract user interface (AUI) description. On the users' side, we propose to have an AUI based middleware for each of the interaction devices. This would allow to personalise the user interface for each user, context and device. Finally, in order to support the introduced personalisation, a cloud-based repository containing UI building parts and multimodal content (for supporting different content accessibility requirements), as well as a translator service are proposed.

Figure 5.3 presents a diagram comparing the current scenario as opposed to the proposed scenario. At the top half the current scenario is shown. This scenario reflects an interactive service which has two different use cases targeted at two different actors. Then, for each of these use cases pre-defined UIs are provided. In the best-case scenario, a different UI is provided for each device (e.g. through web style sheets). At the bottom half, the proposed evolved scenario is depicted.

In our approach, each interactive service's use case is provided first with an AUI (either by the service provider or by an integrator). These interactive services are recommended to be provided through cloud services supporting scalable resource allocation. Then, each interaction device is deployed with an AUI based middleware (Depicted as AUI MW in the figure). The aim of using this middleware is to be able to integrate non-URC enabled services and UI technologies, and to be able to deploy cross-service user interfaces.

Next, this middleware enabled device is used to load or personalise the user interface to the different environments and users. The cloud based support for loading different UIs or UI parts is depicted as the "Cloud based UI and Content Resources" block, which is composed of a "UI Resources" repository, a "Multimodal Content" repository and a "UI Resource and Content translators" service.

Example scenarios enabled by the approach are described in the following: User 1 can be using the interactive service's Use Case 1 through the same interaction device (Dev 1) in two different contexts (Context 1 and Context 2) through two different UIs (UI 1 and UI 3); User 1 could also be using two different devices in those contexts using a different UI per device (UI 2 and UI 4); User 1 could also be using two different use cases (Use Case 1 and Use Case 2) in the same context (Context 1), through the same device (Dev 1) using different UIs (UI 1 and UI 5); Finally a use case (Use Case 2) could be shared among two users (User 1 and User

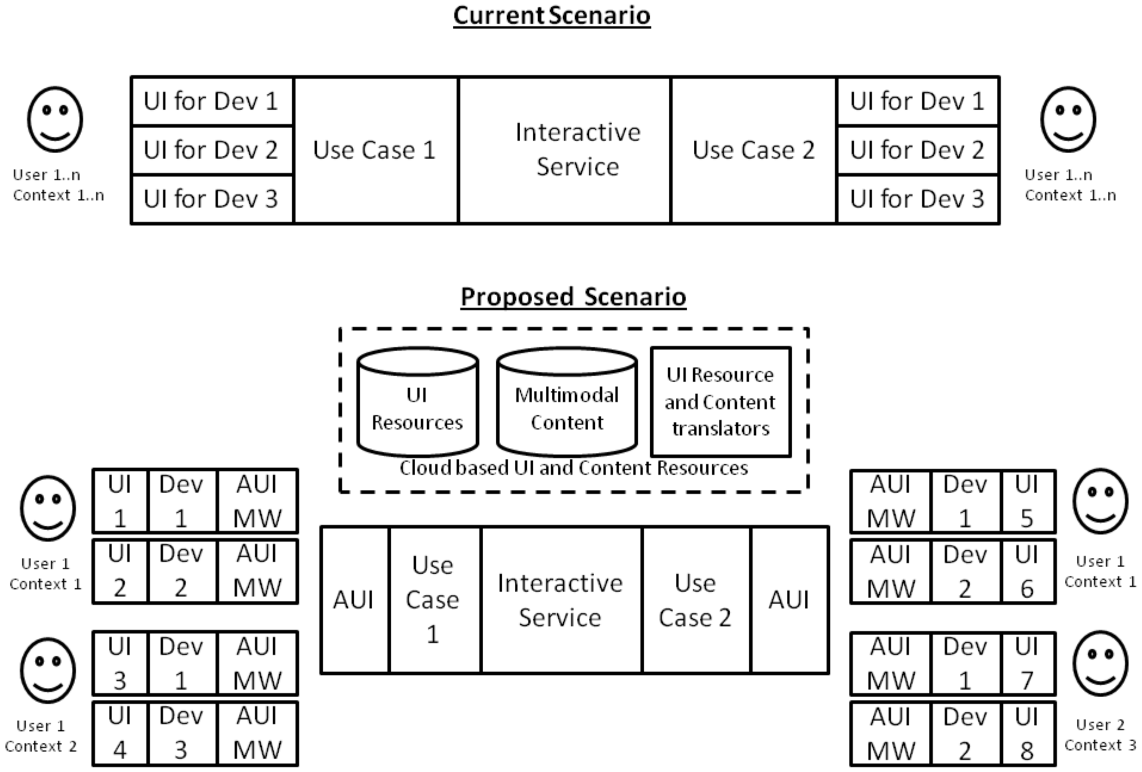

Figure 5.3: Current scenario vs proposed approach for the provision of universally accessible services in TV user's real life context

2) and could be interacted through the same device (Dev 1), using personalised user interfaces for each user (UI 5 and UI 7).

For the AUI technology, the URC technology has been selected (ISO/IEC, 2008). This choice has been motivated by the plug-and-play user interface approach defined by this technology, and the independence that is given to the UI developer to develop completely new user interfaces or personalising parts of existing ones, through the definition of alternate UI resources.

This independence is provided through an open standard based interface definition and the support of publicly available and well defined specifications for the whole URC ecosystem (OpenURC Alliance, 2012).

In contrast, transformation based approaches require a larger scripting logic to be run, and the development of new input / output modules for different interaction device technologies requires the expert knowledge of such systems.

As introduced in Section 2.2 the URC framework requires the definition of three core components in XML file format (Target Description, User Interface Socket

Description and Target Resource Sheet). For more information on the interactive services AUI description specifying task, the reader is referred to Section 4.2.1.

For the AUI based middleware, the UCH middleware has been selected (Zimmermann and Vanderheiden, 2007). The UCH is a gateway-oriented architecture of the URC Framework. This gateway-oriented implementation allows for connecting and integrating non-URC services and devices, and the connection of different user interface technologies. In addition, it allows the use of user interfaces that span across different service and devices.

Regarding the services to be integrated, they can either be locally or remotely deployed, and they can have different levels of openness: they may have proprietary access protocols, defined access APIs or web service specifications.

The requirement specifics of integrating an interactive service with the UCH have been given in Section 4.2.2 of the previous chapter. The reader is referred to that section for the networking (discoverability, controllability and eventing) and code implementation (target discovery module and target adapter) in-detail requirements analysis for interactive services.

For the cloud based UI and content resources module, the URC ecosystem resource server has been selected. *Zimmermann and Wassermann* introduced the benefits and details of the URC ecosystem's Resource Server in (2009).

Besides the role of hosting and organising complete UI or UI parts, in this thesis we define the use of such a resource server: i) to organise the alternate content modalities, and ii) to do the translations among the required modalities of both interactive services UI and content (transparently to the user).

After achieving a UCH middleware implementation per interaction device (or provision through an alternative machine in the environment), and services integration with the UCH, the different personalised UI or UI parts can be downloaded and deployed for each environment, user and device.

Figure 5.4 sketches at technical level our proposal to provide continuum to TV based interactive service consumption, as part of a multi-actor, multi-environment and multi-device personalised UI delivery. This figure shows two different use cases corresponding to interactive services, defined for the different actors (identified as user roles in the figure), and services locally deployed. These services can be integrated with the UCH using their own control protocols (e.g. SOAP, HTTP against Web APIs or proprietary protocols).

Next, the different actors can access those services' use cases through the preferred device, using the UI technology of their choice. The UI will communicate with the UCH using the default UI protocol (URC-HTTP) or other user interface protocols (e.g. VoiceXML) that fits best each scenario. The resource server is responsible for hosting and organising the UI parts and multimodal contents of the interactive services for the different actors, environments and devices.

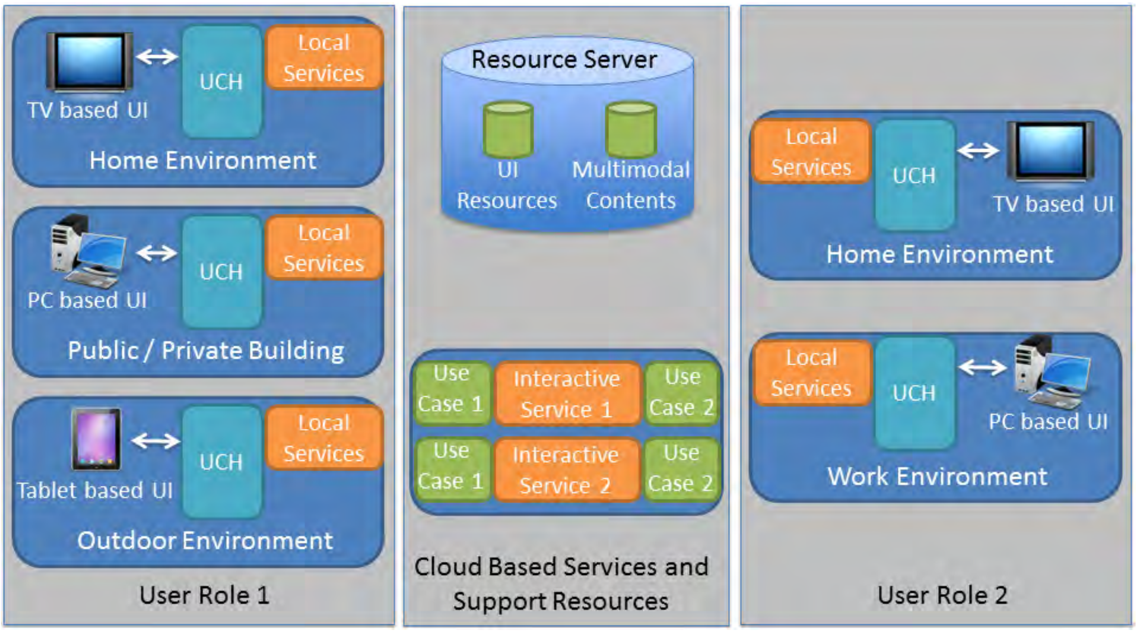

Figure 5.4: UCH and Resource server based technical level approach for integrating TV based interactive service consumption with multi-actor, multi-environment and multi-device personalised UI delivery

5.3 Approach Validation 1: Telerehabilitation

On our approach validation, we have focused on a telerehabilitation service. The aim of this development was to develop a universal remote rehabilitation delivery solution. The objective was to achieve a larger user's acceptance and adherence to the therapy, by providing further support to the final users' flexibility in terms of location, client device, interaction means and content.

The architecture proposed for the universal remote rehabilitation delivery is an instantiation of the approach introduce in Section 5.2. It is made up of three layers: the user layer (relative to the final user role), the cloud layer and the hospital layer (relative to the medical professional role). The proposed architecture is depicted in Figure 5.5.

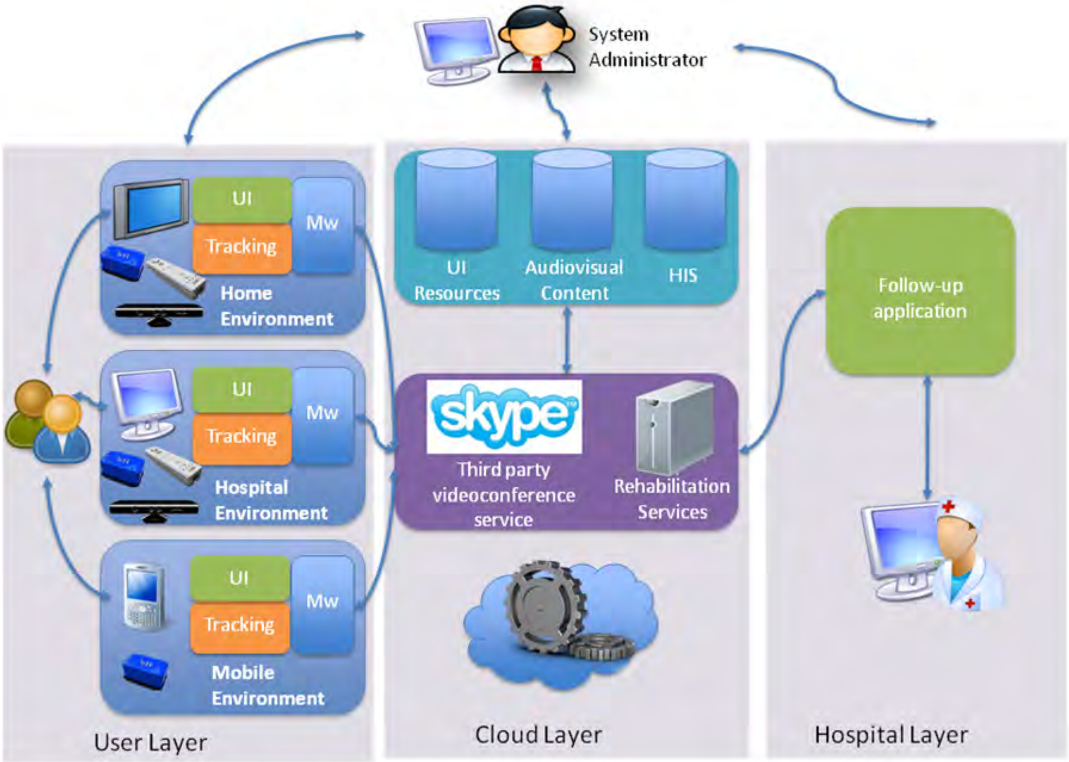

Figure 5.5: Instantiation of the approach proposed for the telerehabilitation service

The **user layer** defines a common approximation for the different service consumption contexts users are exposed to in their real lives (e.g. home context, hospital context or on the go). Each service consumption context client is composed of a UCH middleware, a tracking solution and a user interface.

The UCH enables UI personalisation and easy upgrading through its UI plug-and-play feature. Also, the definition of a common interface specification for the different tracking systems in the UCH enables the seamless exchange of the tracking systems.

Having followed a UCH middleware based architecture approach, the system can be easily extended with new services (e.g. health services, home control) and user interfaces that span across several services or targets can be deployed.

The **cloud layer** is responsible of ensuring the scalability of the services, and it is composed of the following blocks: the UI resources repository, the audio-visual content repository, the rehabilitation services, and the Hospital Information System (HIS).

The UI repository follows the resource server concept introduced as part of the URC ecosystem (OpenURC Alliance, 2012), and implements the interface and guidelines provided by the *OpenURC Alliance* in (2013a). This technology enables to incrementally support users with different needs and preferences, and to upgrade UI elements or complete UIs, based on the user's capabilities and context evolution, or maintenance tasks.

The developed audio-visual content repository supports different modalities, in order to meet all user's needs and preferences. Apart from a static repository, the most advanced scenario targets the fusion of the prescribed exercise content with the user's exercise tracking representation in the same audio-visual content.

The rehabilitation services can include basic or complex services. The baseline services must include the support for therapy prescription and results assessment functionalities for the medical professional, and the therapy load and results submission functionalities for the patient. These services can be extended to include other actors involved in care cycle or provide new functionalities to the involved actors.

In order to provide open interfaces for third-party developments, and to make sure that the implementation is HIS independent, the rehabilitation services must be defined following the Web Services Description Language (WSDL) specification. The integration of video-conference can be provided as part of the rehabilitation services or externally, as depicted in Figure 5.5.

The main element of the **hospital layer** is the follow-up application, which implements the medical professionals' client to access rehabilitation services. The functionalities to be implemented in such a client include rehabilitation therapy prescription and patient's therapy execution's tracking results revision.

Due to a special focus on the final user and due to budget constraints, the approach's universal access features were implemented only for the final user. The medical professional's UI was developed using .NET C# technology against the web-services.

In summary, the inclusion of the UCH and Resource Server technology in the architecture approach: i) enables the easy personalisation of UIs, ii) allows using URC and non-URC controller technologies (choice of client device), iii) maximises available interaction capabilities, and iv) provides a platform for adding new services in the future.

The approach proposes an architecture for service provision in users' real life context (starting from rehabilitation at hospital, moving home, to giving the chance to continue outdoors or on travel). Apart from the localisation choice, the solution allows having different service functionalities in each UI, providing the required service functionalities per scenarios.

5.3.1 Implementation

The case study's implementation has been done for the Total Knee Replacement (TKR) rehabilitation, and more specifically for the post-surgical teletraining of body joints. The implementation has been focused on seniors, the user group greatly affected by this.

On the service layer, the initial rehabilitation services implementation includes four web-services (WS): (WS1) Rehabilitation therapy prescription, (WS2) Load Therapy Exercises, (WS3) Send Exercise Monitoring, and (WS4) Load Therapy Monitoring and Historical.

Rehabilitation's work-flow is detailed in the following: First, a medical professional (medical doctor or therapist) prescribes a therapy through the WS1 service. Later, the patient loads the therapy and the assigned multimedia content using the WS2 service, and performs the exercises while his / her joint movements are being monitored. The monitoring data is uploaded to the cloud through the WS3 service. Finally, the medical proffessional loads the therapy monitoring for assessing patient evolution using the WS4 service. Figure 5.6 shows a conceptual diagram of the developed web services.

Furthermore, the Skype video-conferencing system was selected as a third party video-conference service, and it has been integrated through the SkypeKit API directly into the clients (Zivkov et al., 2012).

Figure 5.6: Conceptual diagram with the developed rehabilitation services

In the user layer, the following services have been integrated with the UCH middleware: (WS2) Load Therapy Exercises, and (WS3) Send Exercise Monitoring. In addition, the inertial sensor based tracking system, and the required modules for the virtual human based user interaction technology have been integrated with the UCH.

In the hospital layer, a patient follow-up application has been implemented. This application has integrated with the (WS1) Rehabilitation therapy prescription service, and the (WS4) Load Therapy Monitoring and Historical service. The implementation of the cloud layer was done on locally hosted servers. Porting to a cloud service, such as Amazon EC2, is planned to provide scalability, high availability and decrease system's maintenance tasks.

The following subsections provide details about the UI concept developed for the seniors and the selected tracking solution.

5.3.1.1 Virtual Human Guided Rehabilitation Therapy

A realistic virtual human deployed on TV was selected as the user interface interaction paradigm (see Section 4.4.2 for technical integration details). In order to achieve older adults' acceptance, and have them follow virtual therapist's instructions, a familiar and convincing look was designed in collaboration with medical professionals. The voice of the virtual therapist was selected from a casting to meet the therapist's profile[1].

For the dummy virtual human reproducing the exercises, a simple model was selected to avoid stigmatisation. The developed virtual therapist and dummy concepts are shown in Figure 5.7.

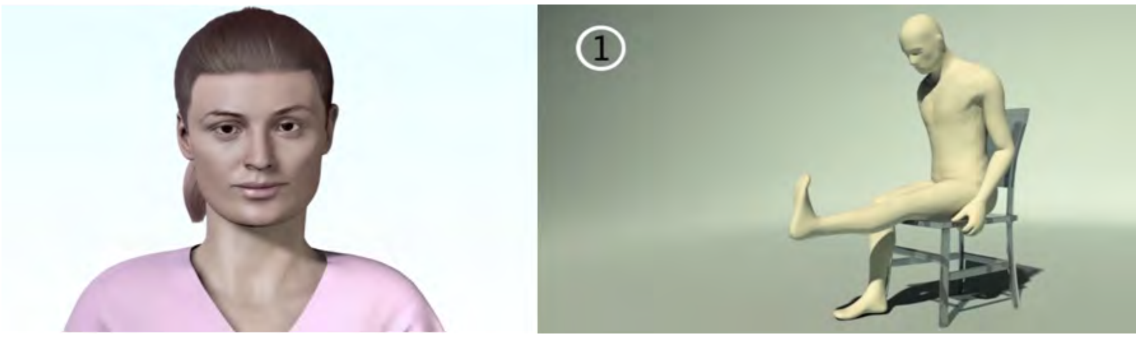

Figure 5.7: Virtual human based rehabilitation therapy guiding

In addition to the developed virtual human-based main interface, a user interface for Android tablets was developed using text and icon based UI and content. The aim of developing an alternate UI was to test the validity of the approach.

At the time of the development, there was no UCH implementation for Android, therefore the URC-HTTP protocol was used to connect the Android client to a UCH instance running in the environment. The developed textual UI is shown in Figure 5.8

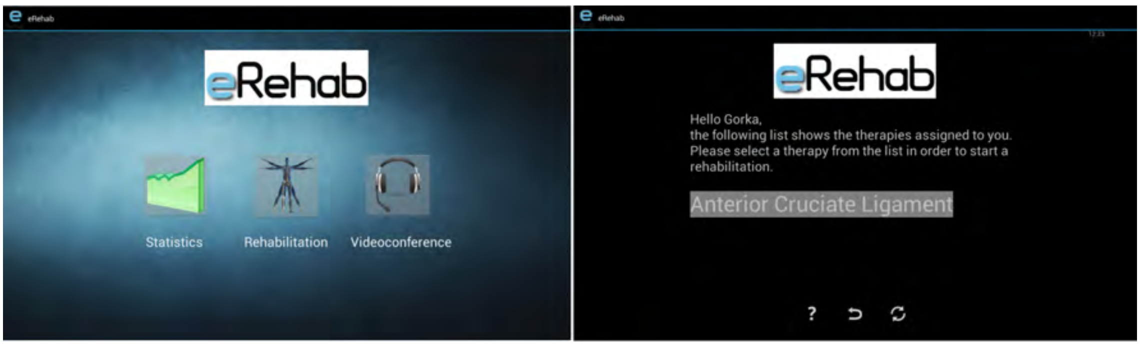

Figure 5.8: Alternative text based UI implementation for therapy guiding

[1]The virtual human visual model and voices were developed by Baleuko in the e-Rehab project framework.

5.3.1.2 Portable inertial sensors for joint angle assessment

Precise joint (elbow, shoulder...) angle measurement is required for specific rehabilitation therapy assessment. In addition to a precise and reliable solution, a home rehabilitation deployment should keep at the minimum the amount of device technologies used, the configuration needs and the costs.

As suggested by the literature analysis, the implementation has made use of a device that integrates the inertial sensors with magnetometers (STT, 2013). The selected solution provides precise orientations, angular velocities and accelerations in real time, and has been integrated with the UCH middleware through its Bluetooth connectivity and serial port profile implementation.

Information received from the inertial sensors is locally processed to calculate each flexion / extension angle for the selected biomechanical model. For the implementation, left and right knee biomechanical models have been used.

Then, the prescribed exercise repetition is assigned with the processed joint angle time-history dataset, and uploaded to the cloud using the defined rehabilitation service.

Alarms per maximum / minimum joint angle flexion / extension can be defined currently to ease rehabilitation assessment by the therapist. Additionally, work is being carried out to identify under-activity and the recognition of evolution trends to suggest the medical professional a therapy / rehabilitation phase change.

5.3.2 Prototype Description

The approach defined for services multi-actor, multi-environment and multi-device personalised UI delivery, has been implemented only for the rehabilitation service consumer actor (due to budget and timing restrictions). The technologies implied in the implementation of the prototype for the rehabilitation service consumers are depicted in Figure 5.9, and analysed in the following section. For the medical professionals, a direct integration of developed web-services (WSDL) has been implemented in a standalone application.

- Equipment 1 - Server (Rehabilitation Services)

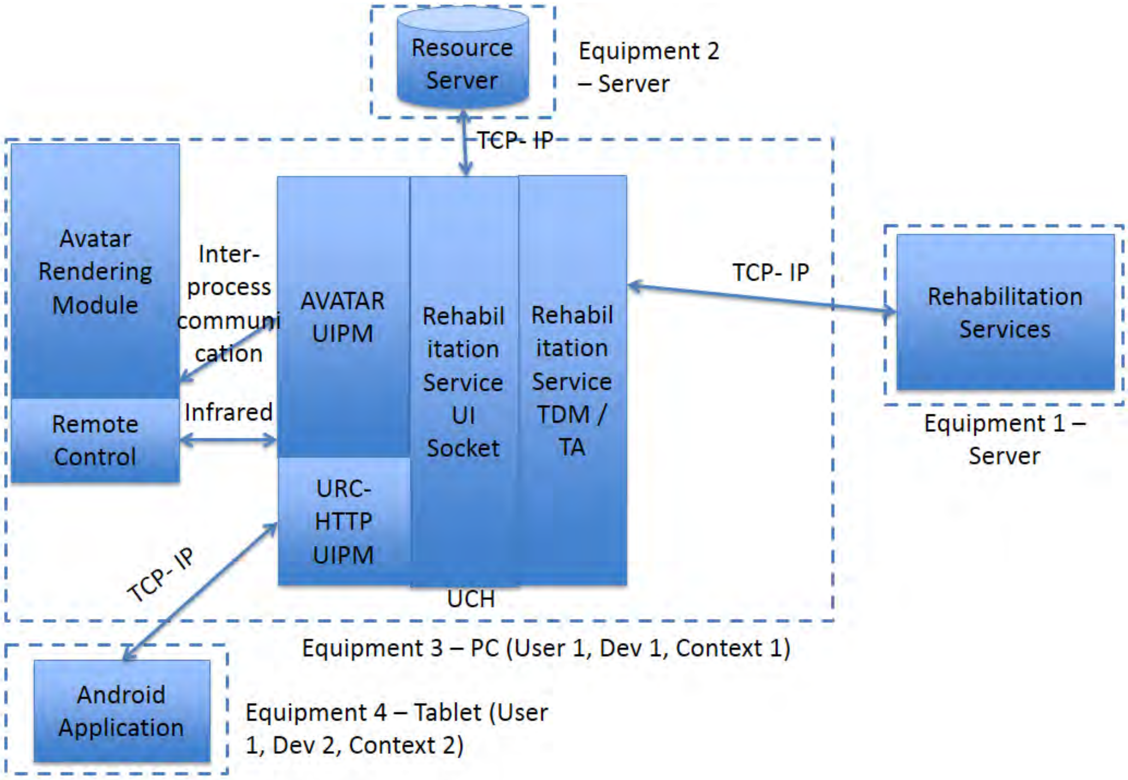

Figure 5.9: Rehabilitation service based approach implementation setup

- Device: Intel Core 2 Quad CPU Q8300 @ 2.5 GHz, 3 GB RAM.
- O.S: Linux - Ubuntu Server 11.10.
- Web-service software: Apache Tomcat 6.
- Database management system: MySQL Server.

- Equipment 2 - Server (Resource Server)
  - Trace Center Resource Server Implementation.
  - Provided through Amazon Cloud technologies at http://res.myurc.org.
- Equipment 3 - PC based client (User 1, Dev 1, Context 1).
  - Device: Intel Pentium D @ 3.4 GHz, 2 GB RAM.
  - O.S: Windows Vista.
  - UCH implementation: .NET implementation by *Meticube* (2014) (Version 3.0).

- Rehabilitation services integration (WS2: Load Therapy Exercises, WS3: Send Exercise Monitoring)
    - URC framework required XML files for the rehabilitation services (TD, UISD, RS).
    - TDM / TA
        - TDM: Discovery done by specifying Rehabilitation Services' server IP address.
        - TA: Services are controlled using their WSDL description and SOAP for the remote control.
- UIPMs:
    - Avatar UIPM: It implements the integration with the UCH, and the Avatar rendering module. Additionally, interprets the captured infra-red signals.
    - URC-HTTP UIPM (OpenURC Alliance, 2013b).
- UI implementation
    - Avatar rendering module (external application that renders the avatar). It connects to the Avatar UIPM through inter-process communication.
        - Graphical rendering using *OpenSceneGraph* (OSG) SDK technology (2013) (Version 2.4).
        - Loquendo TTS for speech generation (Nuance, 2013) (Version 7).
    - Infra-red based remote control. *Weemote* (2009).
    - UI parts and multimedia resources downloaded from the resource server.
- Resource server access:
    - Resource server URL, user, and password provided through UCH configuration files.
    - Resource server communication following the Resource Server HTTP Interface (OpenURC Alliance, 2013a).

- Equipment 4 - Tablet based client (User 1, Dev 2, Context 2)
  - Device: Asus TF101.
  - OS: Android 4.0.3.
  - Input modality: touch / Output modality: graphical.
  - Client implementation done using Android SDK.
  - At the time of this client implementation, there was no UCH version for Android, that is why the developed client has to rely on an external UCH. Equipment 3 - PC was used for this purpose. It connects to the URC-HTTP UIPM using the Java implementation of the URC-HTTP protocol, available in the open source version of the UCH (OpenURC Alliance, 2014).

5.3.3 Evaluation with users

5.3.3.1 Evaluation Method

Participants The developed system has been evaluated with 13 medical professionals and 19 patients in the period between January 2013 to July 2013. The recruited medical professionals' profile was rehabilitation specific, evenly distributed between medical doctors and physiotherapists. Their experience was quite diverse, ranging from low (1-2 years), medium (5-10 years) and high (20-30 years).

Concerning patients, the sample was composed of 10 males and 9 females with an ages ranging from 50 to 79 (x=69.31; sd=7.38), from the city of Donostia / San Sebastián (Spain) and its surroundings. The sample was built with patients that had undergone a Total Knee Replacement (TKR) at the Donostia University Hospital.

15.79% had no formal education, while 57.89% had completed primary education, and 26.32% had finished secondary education. Regarding the technology usage habits, 52.63% did not make use of connected devices, 21.05% used computers, 15.79% used tablets and 26.32% reported having smart TVs but not making much use of its advanced features.

Technical setup The technical setup on the patient's side was composed of a TV set with the virtual therapist content as the HCI technology, and with inertial sensors for therapy execution monitoring. The sensors were identified with stickers containing numbers 1 and 2, and an instructions paper with clarifying pictures on how to put them on was provided to the patient. The therapist viewed patient's visual information on a laptop, composed of a 3D representation of the exercises' execution, and 2D plot of the achieved joint angles on a time scale.

Test steps A meeting was arranged with the therapists where the system was introduced. Therapists were then presented a prototype of the client application. After some minutes, they were asked to fulfil a usability questionnaire. Additionally, focus groups were set up to collect more information, and detect improvement areas.

The technical set-up was similar for the patients. Nevertheless, the system was tested by the patient him / herself, and the monitoring results were reviewed by a therapist. The evaluation procedure was explained to them by the therapist, and they were administered a consent form for capturing their acceptance to participate in the evaluation session.

Afterwards, required socio-demographical data was captured, and patients were allowed to practise the system. Once the patients had completed four (4) therapy sessions programmed for different days, they were asked to fill in a usability questionnaire. The questionnaire asked on the designed audiovisual content paradigm and look, the tracking system, and the overall acceptance of the developed system.

5.3.3.2 Results

Medical professionals were very positive on the virtual therapist for therapy guiding. The simplicity of the dummy virtual human representing the exercises was found as a possible limiting factor for patients adherence to the therapy. One of the main comments about the virtual therapist was why recordings of real people could not be used instead. Some of the professionals also stated that the virtual therapist looked too serious, and lacked empathy with the patient.

Regarding the dummy virtual human, the therapists said that it should reflect the user's effort and pain, it should be dressed, and the areas used in each exercise should be highlighted. Regarding the inertial sensors, the therapists identified them as providing precise information, but therapists were afraid of senior patients not being able to put them on correctly. In general the therapists conceived the solution as valid, motivating and as a complementary tool to outpatient rehabilitation at clinical facilities.

Patients showed a good acceptance of both evaluated virtual humans (therapist and dummy). Virtual therapist's design acceptance was confirmed with comments considering it a serious and adequate character, or patients requesting for more exercises of the presented paradigm. Concerning the dummy virtual human, patients expressed the easiness to follow its movements, but it was considered too simple to engage with. Regarding the inertial sensors, the patients had almost no problem wearing them on, following the provided instructions flyer.

Concerning the marketability of the product (attitude towards product consumption), the therapists clearly understood the evaluated system as complementary, and noted its potential to improve patient's progress. Additionally, the patients reported that this system could improve their motivation towards the exercise execution.

5.4 Conclusions

In this chapter we have described the approach defined in this thesis for providing Universally Accessible Services in TV User's Real Life Context. This approach has been proved to overcome the limited consumption of interactive services on TV sets. More specifically, it addresses the limiting factor identified in Section 1.1.3.2 as the lack of considering user's real life context in the DTV service integration.

This limiting factor is understood in terms of the need to provide the user with a service consumption continuum in different environments (multi-environment and multi-device preference fitting UIs), and in terms of providing the same facilities to the different actors involved in an interactive service provision and consumption (multi-actor provision).

Our approach starts by describing the per-actor use cases of an interactive service by means of AUI descriptions. Then, at each interaction device, an AUI based middleware is deployed with the aim to allow loading different modules: i) to control services and devices, and ii) to provide the user interfaces that meet each user's preferences for each environment and device.

The AUI based middleware enabled interaction devices, are defined to be provided for the different actors. Finally, in order to support the complete or partial UI substitution, and the universal access to content, cloud based UI and content resource repositories are defined.

The technologies chosen for providing a technical level approximation have been those of the URC ecosystem (OpenURC Alliance, 2012). For the AUIDL the URC Framework is used (ISO/IEC, 2008). For the AUI based middleware, the UCH architecture has been chosen (Zimmermann and Vanderheiden, 2007). Finally, for the cloud based UI and content repositories, the Resource Server concept has been selected (Zimmermann and Wassermann, 2009). The main reasons for selecting this technology are: i) the UI's plug-and-play approach, ii) open standard-based interface descriptions, and iii) the integration of new UI interaction technologies by non-experts.

In the defined approach, the AUI description XML files were locally provided at the UCHs, but in the future these could be provided directly on the web services description, through the upcoming Part 6 of the URC standard. Thus, enabling lighter AUI-based middleware implementation.

The provision of this approach overcomes the limitations of providing continuum to TV users on interactive services consumption, and enables the different participating actors to consume such services in different environments and on different interaction devices, through UIs and content modalities fitting their needs and preferences.

This approach opens the door to more advance scenarios identified at Section 2.3.4 (e.g. UI migration, UI distribution, continuing content consumption in different devices and environments), by implementing the required logic on top of the presented approach.

The presented approach has been validated through a validation developed for telerehabilitation. A universal remote rehabilitation delivery system has been developed, which considers users' real life context. UCH middleware deployment was limited to patients' client controllers due to budget restrictions. Rehabilitation services and a tracking system were integrated with the UCH.

The implementation of the main user interface has been developed for the older adults' joint rehabilitation therapy. Following state of art research results, a TV-based virtual human has been selected for rehabilitation therapy guiding of the seniors. A high fidelity virtual therapist (visual model and voice) and a dummy avatar reproducing the prescribed exercises have been developed in tight collaboration with the therapists. Additionally, for testing the approach validity a simple textual UI for Android tablets was developed with no specific target user.

Concerning the therapy progress assessment, the literature review on tracking devices for precisely measuring joint angles revealed two main options from which the magnetometers integration with inertial sensors has been selected. This decision was taken because they require the least amount of devices, configuration needs and home rehabilitation system's costs. The definition of a common interface specification for the different tracking systems in the UCH enables the seamless exchange of the tracking systems.

The resource server available in the cloud has allowed to organise the multimodal (audio-visual and textual) content, and the required modules for the developed UIs.

In regards to the evaluation with users, both medical professionals and patients have positively rated the approach's implementation. Enhancements were asked concerning to the dummy virtual human reproducing the exercises. Its simplicity was identified as a possible limiting factor on patients' engagement. Some therapists also requested that the expression of the virtual therapist should be relaxed, in order to improve its empathy with the patient.

The development and deployment of the approach, together with the acceptance of the implementation by the patients, confirms the proposed approach and its implementation. The contributions of this chapter focused on the telerehabilitation case study were presented at a medical informatics conference (Epelde et al., 2013a) and later published in an extended version on a computer systems topic journal

(Epelde et al., 2014).

Chapter 6

Conclusions

This chapter summarises the work done in this thesis by revisiting the original objectives outlined in Chapter 1, and by analysing their accomplishment.

Section 6.1 begins by developing such analysis, and describing the main contributions done to knowledge. This is followed by a list of endorsing publications, that support the presented contributions. Next, in Section 6.2 a summary of the general conclusions is presented. Finally in Section 6.3, the chapter is concluded with future work and open challenges discussion.

6.1 Research question and objectives accomplishment

The research objective was stated in Section 1.2.1 as: "*to contribute to the state-of-art technologies for interactive services provision on TV with aim to enable an inclusive interaction (especially to vulnerable collectives), and to increase interactive TV uptake, with the aim to provide universal access to different services of the information society*". The core work of the presented thesis has been to achieve these contributions through the use of AUI technologies.

Regarding the accomplishment of the specific objectives detailed in Section 1.2.1, the first specific objective was defined as: "*to define an approach using user interface abstraction technologies to overcome the limited human computer interaction of interactive services on TV while enabling the provision of HCIs meeting each user's* *needs and preferences*".

Objective 1 has been tackled divided in two separate use cases of the TV sets:

- In Chapter 3 an AUI technology based approach has been described for the universal access to the TV sets remote control.
- In Chapter 4 an AUI technology based approach has been described for the provision of universally accessible interactive services on TV sets.

Through the work presented in these two chapters, the objective to overcome the human computer interaction limitations of interactive services on TV sets have been attained.

The second specific objective was defined as: "*to define a user interface abstraction technology based approach to support TV user's in their real life multi-device context interaction needs and preferences*".

This objective has been gained through the definition of an AUI technology and its ecosystem solutions' based approach, to provide universally accessible services in the TV user's real life context.

In this thesis we have described the approach, the validation case studies and the user evaluation results for each of the thesis contributing area. Based on the reported work, we consider that our research objectives have been achieved.

6.1.1 Summary of the main contributions

The following is the summary of the contributions done on this thesis to the enable the inclusive interactive services provision on TV sets, and to increase its uptake as a path to foster the universal access to the information society.

Methodological contributions

1. An approach to enable the universally accessible remote control of the TV set.
2. An approach for the provision of universally accessible interactive services through TV sets.

3. An approach for the provision of universally accessible services in the TV user's real life context.

Technical contributions

1. Contributions to the natural and realistic user interfaces for therapy and daily activities guiding, focused on older adults.

2. Contributions to the upcoming ISO 24752 standard's Part 6 - Universal remote console — Part 6: Web service integration.

3. Contributions to the multi-environment and multi-device personalised service delivery architectures interoperability requirements analysis.

6.1.2 Endorsing publications

Universally accessible TV set remote control

- **Epelde, G.**, Carrasco, E., Zimmermann, G., Bund, J., Dubielzig, M., and Alexandersson, J. (2009). URC based accessible TV. *In Proceedings of the 7th European conference on Interactive Television (EuroITV 2009)*, pages 111–114. ACM, New York, NY, USA.

- **Epelde, G.**, Carrasco, E., Zimmermann, G., Alexandersson, J., Neßelrath, R., and Dubielzig, M. (2013). Universal Remote Console-based next-generation accessible television. *Universal Access in the Information Society*, 12(1):73–87.

Provision of universally accessible interactive services through TV sets

- **Epelde, G.**, Valencia, X., Abascal, J., Diaz-Orueta, U., Zinnikus, I., and Husodo- Schulz, C. (2011). TV as a human interface for Ambient Intelligence environments. *In IEEE International Conference on Multimedia and Expo (ICME) 2011*, pages 1–6. IEEE, New York, NY, USA.

- Diaz-Orueta, U., Etxaniz, A., Urdaneta, E., **Epelde, G.**, and Valencia, X. (2011). A TV platform to improve older people's quality of life: lessons learned from the evaluation of the VITAL project with Spanish elderly users. *In Proceedings of the 4th International Conference on PErvasive Technologies Related to Assistive Environments, PETRA '11*, pages 24:1—-24:6. ACM, New York, NY, USA.

- **Epelde, G.**, Valencia, X., Carrasco, E., Posada, J., Abascal, J., Diaz-Orueta, U., Zinnikus, I., and Husodo-Schulz, C. (2013). Providing universally accessible interactive services through TV sets: implementation and validation with elderly users. *Multimedia Tools and Applications*, 67(2):497–528.

- **Epelde, G.**, Carrasco, E., Zimmermann, G., Alexandersson, J., Neßelrath, R., and Dubielzig, M. (2013). Universal Remote Console-based next-generation accessible television. *Universal Access in the Information Society*, 12(1):73–87.

Provision of an approach to integrate universally accessible services on TV with user's real life context

- **Epelde, G.**, Carrasco, E., Rajasekharan, S., Abascal, J., Jimenez, J. M., Vivanco, K., Gomez-Fraga, I., and Valencia, X. (2013). Smart Medical System for the Universal Remote Delivery of Rehabilitation. *InImpact: The Journal of Innovation Impact*, 6(1):98–109.

- **Epelde, G.,** Carrasco, E., Rajasekharan, S., Jimenez, J. M., Vivanco, K., Gomez- Fraga, I., Valencia, X., Florez, J., and Abascal, J. (2014). Universal Remote Delivery of Rehabilitation: Validation with seniors' joint rehabilitation therapy. Cybernetics and Systems, 45(2):109–122.

Development of natural and realistic user interfaces for therapy and daily activities guiding focused on older adults

- Carrasco, E., **Epelde, G.**, Moreno, A., Ortiz, A., Garcia, I., Buiza, C., Urdaneta, E., Etxaniz, A., González, M. F., and Arruti, A. (2008). Natural Interaction between Avatars and Persons with Alzheimer's Disease. In Computers Helping People with Special Needs, Lecture Notes in Computer Science, volume 5105, pages 38–45. Springer, Berlin - Heidelberg, Germany.

- Carrasco, E., Murua, A., **Epelde, G.**, Valencia, X., Buiza, C., Urdaneta, E., Etxaniz, A. and Diaz-Orueta, U. (2009). Videoconference System for Alzheimer's Patients at Home. *Roots for the Future of Ambient Intelligence. Adjunct Proceedings 3rd European Conference on Ambient Intelligence (AmI09)*, pages 316–321. Salzburg, Austria.

- Diaz-Orueta, U., Etxaniz, A., Gonzalez, M., Buiza, C., Urdaneta, E., Yanguas, J., Carrasco, E., and **Epelde, G**. (2014). Erratum to: Role of cognitive and functional performance in the interactions between elderly people with cognitive decline and an avatar on tv. Universal Access in the Information Society, 13(1):99–99.

- **Epelde, G.**, Carrasco, E., Rajasekharan, S., Abascal, J., Jimenez, J. M., Vivanco, K., Gomez-Fraga, I., and Valencia, X. (2013). Smart Medical System for the Universal Remote Delivery of Rehabilitation. *InImpact: The Journal of Innovation Impact*, 6(1):98–109.

- **Epelde, G.,** Carrasco, E., Rajasekharan, S., Jimenez, J. M., Vivanco, K., Gomez- Fraga, I., Valencia, X., Florez, J., and Abascal, J. (2014). Universal Remote Delivery of Rehabilitation: Validation with seniors' joint rehabilitation therapy. Cybernetics and Systems, 45(2):109–122.

Multi-environment and multi-device personalised service delivery architectures interoperability

- Fagerberg, G., Kung, A., Wichert, R., Tazari, M.-R., Jean-Bart, B., Bauer, G., Zimmermann, G., Furfari, F., Potortì, F., Chessa, S., Hellenschmidt, M., Gorman, J., Alexandersson, J., Bund, J., Carrasco, E., **Epelde, G.**, Klima, M., Urdaneta, E., Vanderheiden, G., and Zinnikus, I. (2010). Platforms for AAL Applications. *In Smart Sensing and Context, Lecture Notes in Computer Science, volume 6446*, pages 177–201. Springer, Berlin - Heidelberg, Germany.

- Alexandersson, J., Zinnikus, I., Frey, J., Zimmermann, G., **Epelde, G.**, and Rosa, B. (2010). Convergence of Internet of Services and Internet of Appliances : Extending the Universal Remote Console to Web Services URC / UCH

: Projects and Business. *In Workshop on Future Standards for Model-Based User Interfaces*, Rome, Italy.

- **Epelde, G.**, Carrasco, E., Rajasekharan, S., Zimmermann, G., Alexandersson, J., Bund, J., and Vanderheiden, G. (2012). Open standards based public procurement policy for large market uptake and new entrants barrier lowering. *AAL SUMMIT 2012,* Bilbao, Spain.

- Klima, M., Macik, M., Urdaneta, E., Buiza, C., Carrasco, E., **Epelde, G.**, and Alexandersson, J. (2009). User Interfaces for the Digital Home on the basis of Open Industrial Standards. *Ambient Intelligence Perspectives. Selected Papers from the first International Ambient Intelligence Forum 2008.* pages 144–152. IOS Press, Amsterdam, The Netherlands.

- Alexandersson, J., Bund, J., Carrasco, E., **Epelde, G.**, Klima, M., Urdaneta, E., Vanderheiden, G., Zimmermann, G. and Zinnikus, I. (2011). openURC: Standardisation towards "User Interfaces for Everyone, Everywhere, on Anything". AAL-Kongress 2011. pages 117–125. Springer, Berlin - Heidelberg, Germany.

6.2 General conclusions

This section summarises the main conclusions of the work presented in this thesis. These conclusions reflect the achievement of the aforementioned contributions. For more detailed conclusions the reader is referred to each contributing chapter's conclusions.

The work developed in this thesis proposes an AUI technology based approaches: i) to overcome the limitations of human computer interaction for integrating interactive services on TV sets, and ii) to overcome the lack of considering user's real life context for the development and deployment of such services.

For the development of the this thesis, firstly a deep analysis of the state of art has been done on the areas of: i) TV sets accessibility, ii) user interface description languages, and iii) on the multi-environment and multi-device personalised service delivery architectures.

Regarding the specific AUI technology, the URC ecosystem technologies: URC Framework (ISO/IEC, 2008), UCH Architecture (Zimmermann and Vanderheiden, 2007) and Resource Server (Zimmermann and Wassermann, 2009)) have been selected.

The following characteristics have motivated the URC technologies adoption: UI plug-and-play approach, open standard based interface descriptions and the integration of new UI interaction technologies by non-experts.

In Chapter 3 we have introduced an approach (**the first methodological contribution**) to overcome the limitations found on the human computer interaction of the TV sets remote control use case.

The proposal is based on the use of AUI technology to decouple the user interface from the TV set, and to enable the use of user interaction technologies that fit best each user. The presented architecture allows the deployment of plug-and-play user interfaces.

We have developed an implementation of the approach taking the Windows Media Center and the Dreambox 7020 set-top-box as examples of a TV set, and two pluggable UIs to demonstrate the universal access for people with different impairments.

In Chapter 4 we have defined a complementary approach to the one presented in Chapter 3. This approach (**the second methodological contribution**) has been defined to overcome the human computer interaction limitations of accessing interactive services through a TV set.

The approach proposes to augment the interactive services with AUIs, on top of which, personalised plug and play user interfaces that are rendered on a TV set can be deployed, to provide the user with the services in the TV UI configuration that fits their needs and preferences best. The presented approach has been validated through three case studies.

A first implementation was focused on the elderly, integrating services targeted on improving the elderly people's quality of life (video-conference, information service, audio book, educational content and p2p gaming). The developed TV set's pluggable UI, was composed of a multimodal interaction (remote control + speech interaction), together with a simple and easy to navigate graphical user interface.

The second implementation of the approach was centred in people with mild to moderate cognitive impairment. In this case, a calendar service and home appliances remote control were integrated. The developed TV UI concept for the second approach validation was a virtual human combined with speech synthesis for the output and a simplified remote control for the input.

The third and last approach validation was developed with no specific user in mind, and was implemented for testing the reusability of previously integrated interactive service and targets (home appliance, video-conference and calendar service). WMC application's SDK (MCML + .NET) was used for building the TV user interface.

The **last methodological contribution** has been reported in Chapter 5. In this chapter we have introduced an approach to provide universally accessible services in TV user's real life context.

Our approach starts by describing the per actor use cases of an interactive service by means of AUIDLs. Then, at each interaction device, an AUI compatible middleware is deployed with the aim to allow loading different modules to control services and devices, and the user interfaces that meet each users preferences for each environment and device.

The AUI based middleware enabled interaction devices, are defined to be provided for the different actors participating in the service. Finally, in order to support the complete or partial UI substitution and the universal access to content, cloud based UI and content resource repositories are deployed.

The presented approach has been validated through a case study developed for telerehabilitation. A universal remote rehabilitation delivery system has been developed, which considers user's real life context. Middleware deployment was limited to patients' client controllers due to budget restrictions.

The implementation of the main user interface has been developed for the older adults joint rehabilitation therapy. Following state of art research results, a TV based virtual human has been selected for rehabilitation therapy guiding of the seniors.

A high fidelity virtual therapist (visual model and voice) and a dummy avatar reproducing the prescribed exercises have been defined, and developed in tight collaboration with therapists. Additionaly, for testing the approach validity, a simple textual UI for Android tablets was developed with no specific user in mind.

One of the strengths of this thesis is that beside the definition of the approaches to overcome the identified limitations, an important amount of case studies have been developed to validate those approaches. Additionally they have been evaluated real users.

In regards to the technical contributions, the context of the research projects supporting the thesis have allowed the conception, development and evaluation of new natural user (virtual human based) interface approaches. This natural user interface paradigm has been tested for therapy and daily activities guiding focused on older adults, even for those with mild-to-moderate cognitive impairments. The evaluation of the developed prototypes have shown a good acceptance and engagement with the targeted users.

The context of the research projects, as well as the active participation on the alliance supporting the selected AUI technology, has allowed the author of this thesis to contribute to the revision of the ISO / IEC standard, which is in charge of augmenting web services with the selected AUI technology. The author of this thesis developed an alternate approach for it, and participated in the new part's conception.

Additionaly, this work context has allowed the author of this thesis to contribute to the discussion on interoperability of the different multi-environment and multi-device personalised service delivery architecture approaches, at different AAL UI workshops and at the EIP-AHA C2 interoperability action group.

6.3 Future Work and Open Challenges

The work developed in this thesis has advanced the state of art of the universal access HCI for interactives services provision on TV sets, and the provision of such services in the users' real life context. This thesis contributions have been mainly focussed on the definition of universal access enabling approaches.

Future work is mainly foreseen in:

- The implementation of the approaches to make TV sets universally accessible in commercial TV sets.
- The implementation of plug-and-play user interfaces for different users.
- The (full or partial) automatic generation of such user interfaces.
- The development of the logic required for the advanced scenarios identified at Section 2.3.4.

Opportunities for the described HCI approaches implementation in commercial TV sets are seen on the recent integration of complete operative systems in commercial TV systems. The main challenge is the restricted access to modify the existing firmware, and to have a manufacturer including such modifications on their distributions for a large scale deployment.

Concerning the mainstream adoption of the proposed HCI approaches, implementation of final user interfaces that meet different users needs and preferences are needed (or at least to supply them to the main user groups suffering HCI limitations).

The integration and the evolution of automatic UI generation technologies for the TV sets, has been identified as a possible path to achieve impact, due to the high costs of developing a complete new UI for each user.

In this thesis, an approach has been defined for overcoming the limitations of providing continuum to TV users on interactive services consumption, and enabling the different participating actors to consume such services. This approach opens the door to more advance scenarios (e.g. UI migration, UI distribution, continuing content consumption in a different device and environment) identified at Section

2.3.4. These scenarios require the implementation of specific logic on top of the presented approach.

These advanced scenario developments are foreseen to be developed by taking advantage of complementary modules such as the user needs and preferences server developed by the Global Public Inclusive Infrastructure (GPII) initiative (Vanderheiden et al., 2013).

In addition to the technological approaches, guidelines and methologies are needed for the development and validation processes of these advanced scenarios user interfaces.

Finally, the problems identified in Section 1.1.3 for the interactive services on TV uptake that have not been tackled in this thesis, should be considered as open challenges. These untacled problems are:

- The identification of deployable services in the TV set consumption posture, environment and group socialisation.
- The regulatory framework interests and the conflicted interests of stakeholders.
- The awareness of the benefits of the consumptions of interactive services through the TV set as part of the universal access to the information society.

Appendix A

The URC Framework

The Universal Remote Console (URC) framework (ISO/IEC, 2008) 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 its 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 Figure A.1) 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).

- 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's 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 received currently. 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 part is needed that "plugs" into the socket to "render" the socket, i.e. present it to the user and allow 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 Figure A.1).

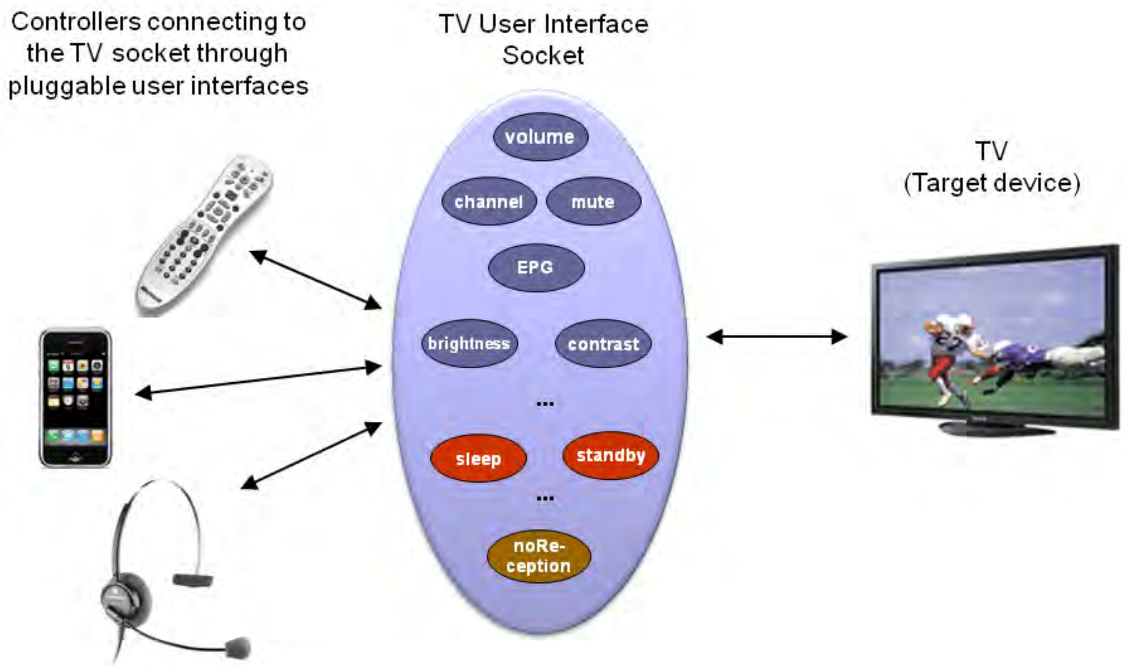

Figure A.1: Sample user interface socket for the TV

Pluggable user interfaces allow a high degree of individualization and personalization. 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.

A.1 UCH Architecture

The Universal Control Hub (UCH) is a gateway oriented architecture for implementing the Universal Remote Console (URC) framework in the digital home (Zimmermann and Vanderheiden, 2007). 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:

- 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 A.2 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 (OpenURC Alliance, 2013b), 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.

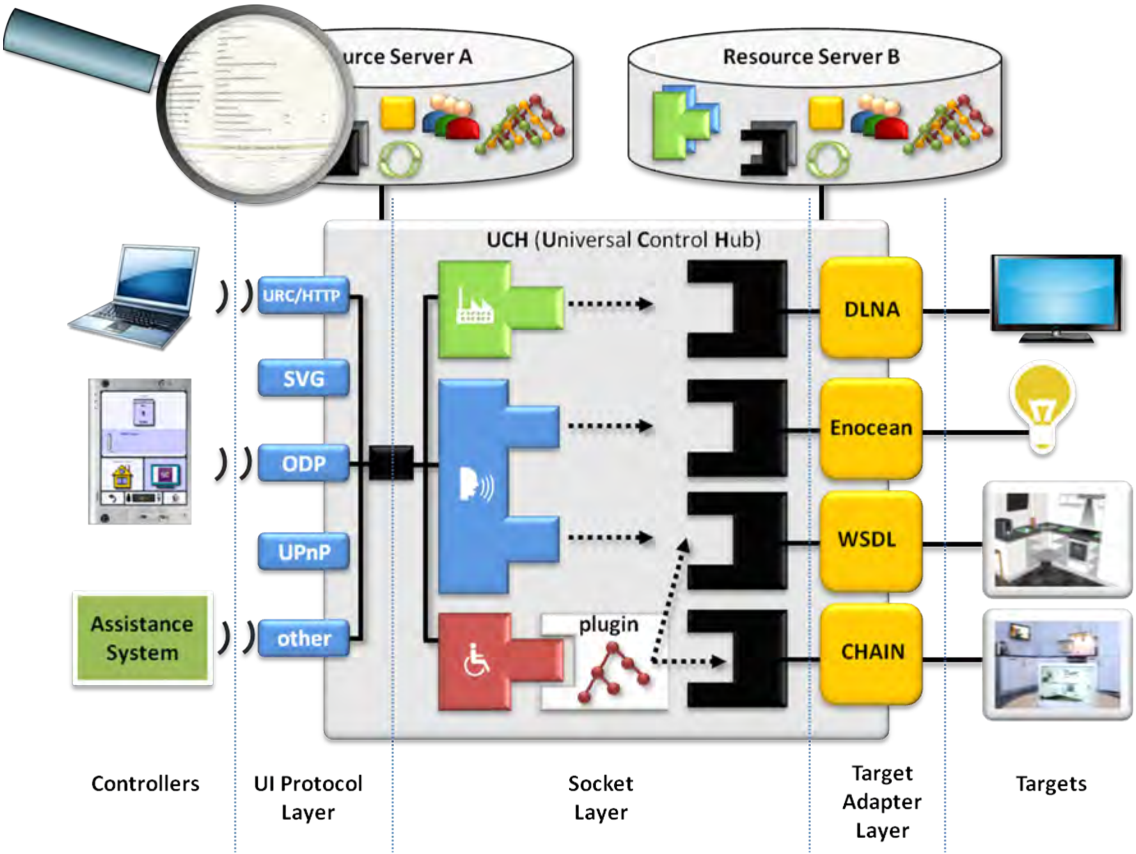

Figure A.2: The Universal Control Hub Architecture

Appendix B

Elderly user needs and followed design guidelines for the developed Multimodal TV UI

Visual domain needs Among the elderly, the impairment of visual functions is a process of normal ageing. Ageing process implies a decrease of visual functions, including a reduction of visual acuity, sensibility to contrast (when trying to determine brightness differences) and loss of the ability to detect fine details (Echt, 2002).

Adopted visual domain design guidelines As it has been presented, changes in vision that occur with age can make it more difficult to read computer or TV screens. Considering the previously described features of elderly people in visual domain, the following recommendations are adopted for the design of user interfaces in the targeted platform:
Use of icons/graphics:

- Concepts in application screens must be presented using an adequate combination of text, graphics and when considered appropriate audio.
- Graphics should be relevant and not for decoration.
- Icons should be simple and meaningful.

- Animation should be reduced to the minimum as necessary, to minimise users' distraction.

Use of text, font type and size:

- Fonts in the application screens must be resizeable.
- Condensed letters should be avoided.
- Take into account text presentation in TV terminals is poorer than in PC monitors.
- Upper case only fonts are preferred in application messages and text. Upper case fonts are easier to read. Italics are not recommended since italics text is easily degraded in TV terminals.
- Boldface can be used to emphasise important texts or to increase the readability.

Use of colours:

- Following different authors' guidelines for interface design, background screens should not be pure white or change rapidly in brightness between screens (Kurniawan and Zaphiris, 2005). High contrast between the foreground and background should exist.
- Colour must be used to attract the attention of the users to the most important elements of an application screen (i.e. the currently selected element). The contrast is the most important factor to keep in mind when considering colours to be implemented in the applications.
- Take into account the colour performance of TV and PC terminals is absolutely different.

Screen titles:

- Every application screen must have a text title identifying the purpose of the screen.
- Every application screen must offer a help option to the user.

Auditory domain needs Auditory functions in the elderly may include the presence of tinnitus, which is characterised by continuous sounds in the ear (buzzing, softly singings or little bells). These can be caused by small abnormalities in blood flow reaching the ear (Segal, 1996).

Presbicusis, also known as the loss of ability to discriminate between medium and high frequency sounds, can mask peripheral sounds and make difficult the detection of a concomitant tinnitus.

Overall, the declines described above, together with excessive accumulations of ear wax, make it difficult for older people to deal with their daily tasks in some way. Sometimes words are hard to understand, another person's speech may sound slurred or mumbled, especially with background noise. Certain sounds can be annoying or loud, and TV shows, concerts or parties may be less enjoyable because of hearing difficulties.

Adopted auditory domain design guidelines

Use of audio feedback:

- Background noise should be minimised.
- For each possible state of an application, the user can be informed as to where they are in the interaction, and which actions are possible at this point.
- Audio feedback must be used with great care since it can become annoying and frustrating when it is too insisting. It might also affect the privacy of the users since other persons in the same room may get access to private information.
- Speech rates should be kept to 140 words per minute or less (Fisk et al., 2004). Artificial (synthesised) speech messages that do not closely imitate natural speech should be avoided.
- For acoustic signals to attract attention, a frequency between 300Hz and 3000Hz should be used (Fisk et al., 2004). Moreover, older adults miss attention getting sounds with peaks over 2500 Hz (Hawthorn, 2000).

Cognitive domain needs In normal ageing, some functions stay stable: Automatic and over learned responses, remote memory, semantic memory (memory for the meaning of words and concepts) and verbal reasoning and comprehension.

In contrast, some other functions decline: Decrease in information processing speed, including slower reactions, slower reasoning, and thinking capacity. The ageing person may experience a decline in working memory (Hawthorn, 2000). This is defined as "the temporary storage and manipulation of information that is assumed to be necessary for a wide range of complex cognitive abilities" (Baddeley, 2003) , in other words, the capacity for maintaining some information and mentally operate with it at the same time.

According to *Zajicek et al.* (2000), 82% of their elderly users were unable to build useful conceptual models of the workings of the Web. Their confidence in making the decisions needed for the construction of conceptual models was low and they became confused and frustrated.

In this sense, information and UI navigation should be provided in an easy way to master, and should seek to increase users' confidence, avoiding unexpected behaviours.

Adopted cognitive domain design guidelines

- Language used should be simple and clear, avoiding irrelevant information on the screen.
- Important information should be highlighted, and concentrated mainly on the centre of the screen.
- Screen layout, navigation, and terminology used should be simple, clear, and consistent.
- Ample time should be provided to read information. Time critical processes must be avoided. Feedback information must be also adapted to the expected slow responsiveness of the users.
- When a critical action has been selected by the user (i.e. exit an application),

the system must always clearly notify this circumstance to the user, and must request his explicit confirmation.

- Web-based interfaces must provide backward, and forward navigation.
- Whenever possible, processes must be sequential, and one way.
- The presence of parallel or simultaneous tasks must be avoided at all cost.
- It must also be avoided the use of complex navigation structures composed of multiple tree-like levels.
- The demand on working memory should be reduced by supporting recognition rather than recall, and providing fewer choices to the user.
- Use new objects with new appearances for new interface behaviours, to avoid interference with the user's previous knowledge.
- The same actions must be implemented using exactly the same procedures in all applications.

Motor domain needs Within the ageing, different joint diseases together with different bone fractures occur more frequently. These diseases significantly restrict movement in joints and increase the pain in the realisation of daily live tasks.

People with these pathologies make slower movements. The lack of precision of movements limits their dexterity to realise those daily tasks, and to interact with mainstream technology through provided controls.

Adopted motor domain design guidelines

- For users with different forms of motor dysfunctions, the graphical interface should be made less sensitive to erratic hand movements.
- The slowness, and lack of precision of movements associated to the pathologies described above could affect the use of scroll bars or image maps.

- The enlargement of interface does not only have implications for the visual domain. Allowing the user to adapt the size of user interface elements as much as they want, the need for fine-motor coordination can be reduced.
- The remote controller must be extremely simple, and must have as few keys as possible.
- The size of the remote must be adequate to its planned use by the target users.
- The remote must have big, individual, and well separated keys.
- The design of the remote must be ergonomic, it must adapt to the shape of the hand, and must have volume.
- Every key must present a drawing representing its function on its surface.

Appendix C

Developed Multimodal TV UI's Dialog System

We conceive the multimodal dialog system[1] as a scalable and modular unit, which provides voice control over the applications integrated in the targeted platform. The core component of the multimodal dialog system is constituted by the Ontology-based Dialog Platform framework (ODP). It provides an open architecture for building multimodal, task-oriented user interfaces that is in concordance with large parts in W3C's multimodal architecture proposal (W3C, 2004a).

The ODP framework itself is built up on blocks (see Figure C.1) which stand for the basic dialogue system modules:

- The Extended Typed Feature Structures (eTFS) represents a data representation format which unifies the properties of RDF/RDFS (Resource Description Framework (W3C, 2004b), and typed feature structures (Carpenter, 1992)). The encoding of the internal data as eTFS is accordant to the approach of ontology design in general, such that we use an <object> tag in order to denote a complex object of a certain type.
- PATE (Pfleger and Schehl, 2006) provides a framework that supports the development of applications for multimodal dialogue systems. PATE's archi-

[1] This section describes the Ontology-based dialogue platform developed by DFKI for enabling the multimodality of the TV UI in the Vital project framework (FP6-030600).

tecture is centred on the idea of three separated data storage facilities: (i) the goal stack, (ii) the working memory, and (iii) the long-term memory.

The working memory is responsible for the activated instances so-called Working Memory Elements (WMEs), which are accessible for processing, i.e., rule applications.

The long-term memory is responsible for the persistent storage for all instances of the type hierarchy the system has in the background.

The purpose of the goal-stack is to represent the focus of attention within the process of the system (Anderson and Lebiere, 1998). The placing of WMEs between the three data storage parts is organised by the activation value, which changes in the processing flow and the effects taken by rule applications.

- The Ontology-based Middleware Platform for Multimodal Dialogue Systems (OBM) is a middleware platform and application-programming framework for building multimodal dialogue systems. It is based on the eTFS API for system-wide data representation and PATE for implementing rule-based message routing.

  The OBM core functions as a server component that ties all modules and services together and maintains their interoperability. At run-time the server is responsible for managing the deployment of system modules.

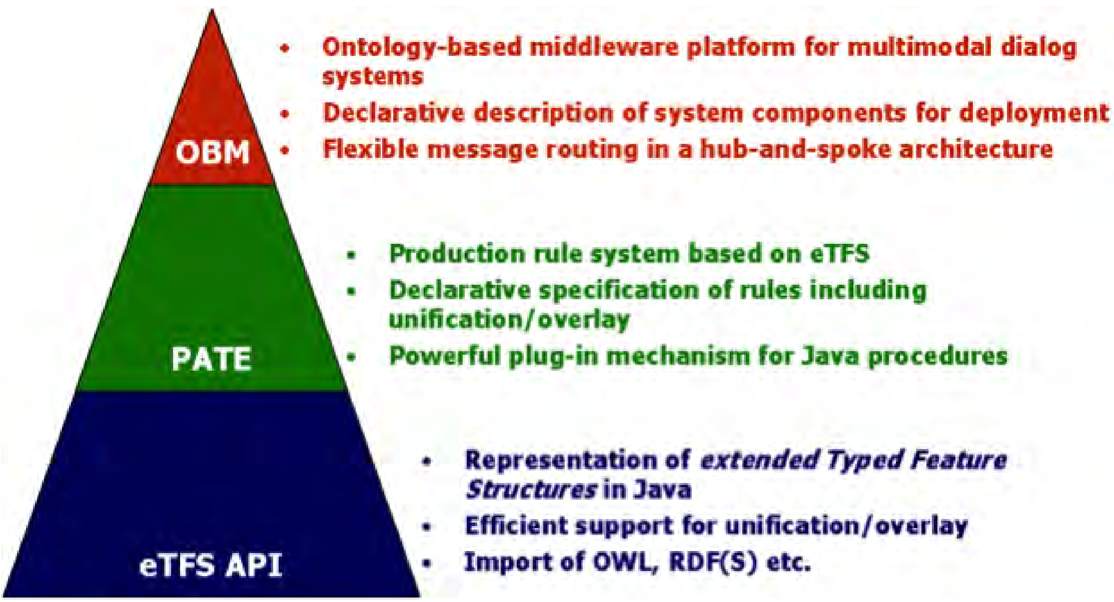

Figure C.1: The core building blocks of the ODP framework

As to enable voice interaction for the applications, the technical challenge was to first integrate the ODP framework into the UCH, and second to provide the TV with the abstract presentation encoding the graphical content.

In order to achieve a consistent context within the dialog system with respect to what is happening on the target side (e.g. Information Service Target), and on the User Interface side (TV), the internal state of the dialog system has to keep track and administrate the actions taken place at both ends.

As we can see in Figure C.2, the ODP docks by means of the two different services at the UIPM Layer that speaks the URC-HTTP protocol (i.e., receiving and posting socket modifications from/to the targets and the protocol that can be interpreted by the TV client):

- The Function Modeler Service supplies the ODP with the information returned by the target that are converted into TFS objects and serve the Information State Module to update its own state.
- The Presentation Planner Service implements a service that invokes event handling on the UIPM. The TV client exclusively processes rendering information, which is made ready by the UIPM. Also, in case the context information is not fully covered by the information retrieved from the target, the dialog system uses the rendering information as complementary input.

Besides the services, which are dealing with the communication to the TV and the back-end services, different tasks within the multimodal dialog platform along the speech processing are allocated across multiple modules (see Figure C.2):

- The Interpretation Manager carries out natural language interpretation. For that purpose it processes the word lattice reflecting the user's vocal-utterance with its semantic interpretation of the utterance. In particular, the natural language understanding component interprets the recognised spoken input of the user, and converts it into instances of the ontology.
- The Information State stores, and manages the ontology-based representation of all targets that represents the appropriate services on the back-end side.

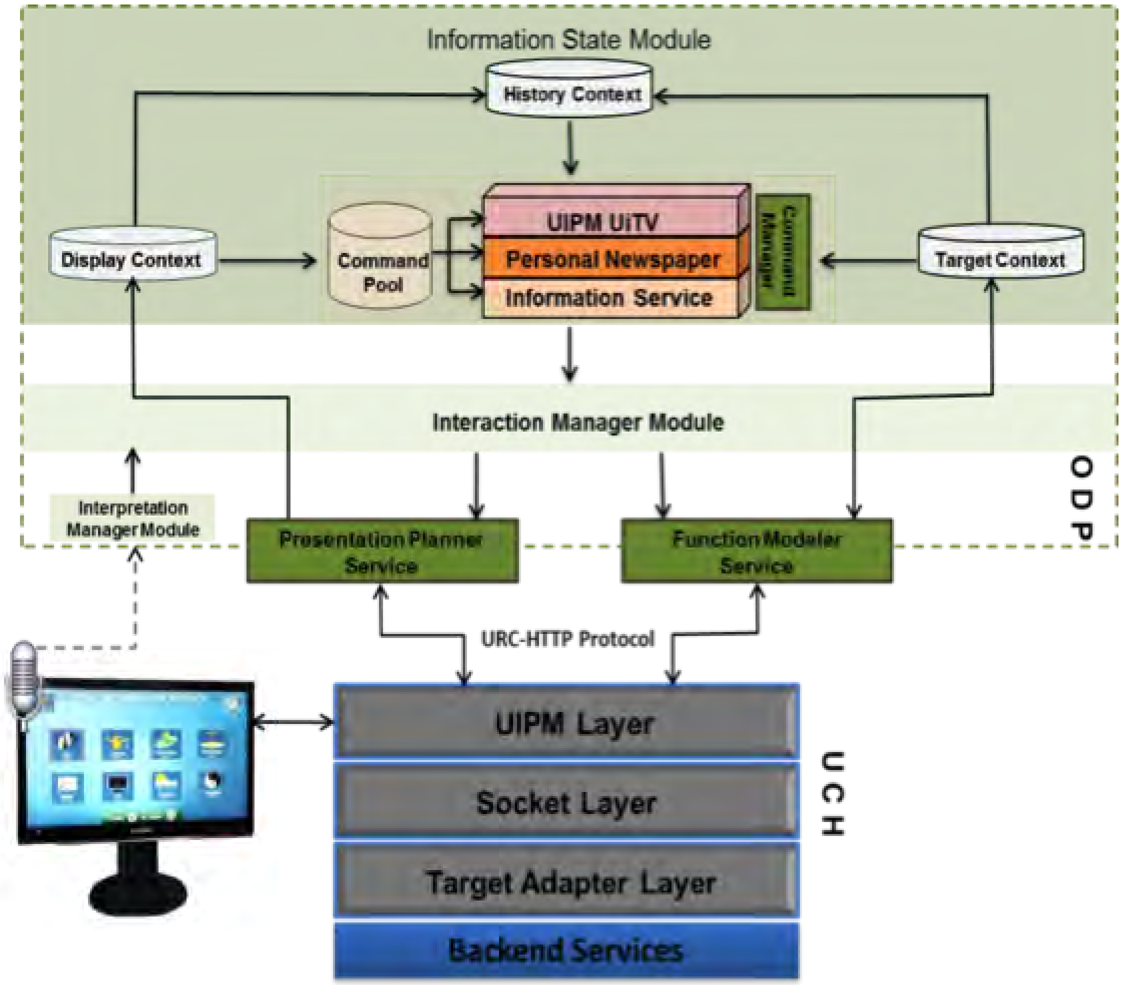

Figure C.2: Dialog systems data flow diagram. The data flow in the dialog system's architecture demonstrates how the Information State Module together with its building blocks is synchronised via two channels dedicated to the input coming from the User Interface (TV) and the back-end services.

Additionally, the Information State administrates, and makes available a coherent representation of the displayed graphical content. The synchronisation between the internal state of the dialog system and the back-end components together with the content on the screen builds the basis for enabling access to multimodal interactive services.

Depending on the state configuration, the Command Manager of the Information State Module retrieves the required commands assigned to manipulate the states of the back-end services or/and the graphical user interface (GUI).

- The Interaction Manager has the task to propagate these commands and invoke the adapters that are able to speak the language of the URC-HTTP protocol, hence takes care of the information exchange with the target layer (back-end services) and the presentation layer (TV).

Typically when the user utters commands specific to the presentation layer, i.e., "Go to the Main Menu", first an ontological concept SwitchApplication is instantiated, and then the interaction manager invokes the presentation planner to build and send the appropriate message to the UIPM.

Within the context of the tested prototype we can change between two input modalities, and allow the user to alternate between voice interaction and the remote control.

Possible utterances by the user are described by a grammar, maintained in a W3C standard compliant format. However, not only predefined speech input is accepted; the framework allows for loading new grammar entities on the fly. This is useful in the context of dynamic concept names (e.g. the title of a movie), which are created using information available from the web at runtime.

Appendix D

URC User Interface Description for the TV set

The following subsections contain the XML file instances (Target Description, User Interface Socket Description and Target Resource Sheet) required by the URC Framework, defined for the TV set.

For space and comprehensibility issues, the User Interface Socket Description, and the Target Resource Sheet have been cut to only represent the live TV functionalities of the TV set. The Target Resource Sheet is presented only for the English language.

The complete version of the files are available at the target templates repository of the OpenURC Alliance (http://www.openurc.org/TPL).

- TV set Target Description: `http://www.openurc.org/TPL/tv-1.0-yyyymmdd/mce.td`
- TV set User Interface Socket Description: `http://www.openurc.org/TPL/tv-1.0-yyyymmdd/mce.uis`
- TV set Target Resource Sheet: `http://www.openurc.org/TPL/tv-1.0-yyyymmdd/mce.en.rsheet`

D.1 Target Description

```xml
<?xml version="1.0" encoding="utf-8"?>
<target about="http://res.i2home.org/tv/mce" id="target"
hidden="false" xmlns="http://myurc.org/ns/targetdesc"
xmlns:td="http://myurc.org/ns/targetdesc"
xmlns:dc="http://purl.org/dc/elements/1.1/"
xmlns:dcterms="http://purl.org/dc/terms/"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://myurc.org/ns/targetdesc http://myurc.org/ns/targetdesc http://purl.org/dc/elements/1.1/
    http://dublincore.org/schemas/xmls/qdc/2006/01/06/dc.xsd http://purl.org/dc/terms/ http://dublincore.org/schemas/
    xmls/qdc/2006/01/06/dcterms.xsd">
  <dc:creator>Gorka Epelde, VICOMTech</dc:creator>
  <dc:publisher>VICOMTech, Spain</dc:publisher>
  <dc:rights>Copyright 2008, VICOMTech</dc:rights>
  <dcterms:conformsTo>http://myurc.org/iso24752-4/2007</dcterms:conformsTo>
  <dcterms:modified>2008-09-04</dcterms:modified>

  <socket id="mceSocket" name="http://res.i2home.org/tv/mce.uis" sharedSessions="true">
    <socketDescriptionLocalAt>../targets/tv/mce.uis</socketDescriptionLocalAt>
  </socket>

  <!--Description of the root Resource Directory-->
  <rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#" xmlns="http://myurc.org/ns/res#">
    <ResDir>
      <dirItems rdf:parseType="Collection">
        <ResSheet rdf:about="http://res.i2home.org/tv/mce/mce.en.rsheet">
          <forLang>en</forLang>
          <dcterms:conformsTo>http://myurc.org/iso24752-5/2007</dcterms:conformsTo>
          <localAt>../targets/tv/mce.en.rsheet</localAt>
```

```xml
        <dc:type>Text</dc:type>
        <aResDescForDomain rdf:resource="http://res.i2home.org/tv/mce" />
      </ResSheet>
    </dirItems>
  </ResDir>
 </rdf:RDF>
</target>
```

D.2 User Interface Socket Description

```xml
<?xml version="1.0" encoding="utf-8"?>
<uiSocket about="http://res.i2home.org/tv/mce.uis" id="socket"
xmlns="http://myurc.org/ns/uisocketdesc"
xmlns:uis="http://myurc.org/ns/uisocketdesc"
xmlns:dc="http://purl.org/dc/elements/1.1/"
xmlns:dcterms="http://purl.org/dc/terms/"
xmlns:xsd="http://www.w3.org/2001/XMLSchema"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://myurc.org/ns/uisocketdesc http://myurc.org/ns/uisocketdesc http://purl.org/dc/elements/1.1/
    http://dublincore.org/schemas/xmls/qdc/2006/01/06/dc.xsd http://purl.org/dc/terms/ http://dublincore.org/schemas/
    xmls/qdc/2006/01/06/dcterms.xsd">
  <dc:description xml:lang="en">UI socket for the TV functionalities provided by Windows Vista Media Center.</
     dc:description>
  <dc:creator>Gorka Epelde, Vicomtech</dc:creator>
  <dc:contributor>Eduardo Carrasco, Vicomtech</dc:contributor>
  <dc:contributor>Gottfried Zimmermann, Access Technologies Group</dc:contributor>
  <dc:publisher>Vicomtech, Spain</dc:publisher>
  <dcterms:conformsTo>http://myurc.org/iso24752-2/2007</dcterms:conformsTo>
```

```
<dcterms:modified>2008-09-30</dcterms:modified>

<set id="liveTVControls">
  <variable id="activeChannel" type="channelType">
    <dc:description xml:lang="en">
   This variable may be used to set the active channel shown by the TV.
   </dc:description>
    <selection closed="true">
      <selectionSetDynamic id="currentChannels" varRef="channelList" />
    </selection>
  </variable>
  <variable id="channelList" type="channelListType" final="true">
    <dc:description xml:lang="en">
   This variable holds a space-separated list of ids of channel that the user may select as active channel. The UI may
        also show numbers to the
    users, using an index into this list. The variable is marked as final, since the channel list may not be modified
        at runtime. Example: "ARD ZDF SAT-1 ARTE"
   </dc:description>
    <dependency>
      <relevant>true()</relevant>
      <write>false()</write>
    </dependency>
  </variable>
</set>

<schema xmlns="http://www.w3.org/2001/XMLSchema">
  <xsd:simpleType name="channelType" id="channelTypeId">
    <xsd:annotation>
      <xsd:documentation>
    Codes for channels - no whitespaces allowed as part of the codes. Dynamic labels should be provided.
    </xsd:documentation>
```

```
      </xsd:annotation>
      <xsd:restriction base="uis:stringListItem"></xsd:restriction>
    </xsd:simpleType>
    <xsd:simpleType name="channelListType" id="channelListTypeId">
      <xsd:annotation>
        <xsd:documentation>
      List of channel codes.
      </xsd:documentation>
      </xsd:annotation>
      <xsd:list itemType="channelType" />
    </xsd:simpleType>
  </schema>
</uiSocket>
```

D.3 Target Resource Sheet

```
<?xml version="1.0" encoding="utf-8"?>
<ResSheet rdf:about="http://res.i2home.org/tv/mce/mce.en.rsheet"
xmlns="http://myurc.org/ns/res#"
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:dc="http://purl.org/dc/elements/1.1/"
xmlns:dcterms="http://purl.org/dc/terms/"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://purl.org/dc/elements/1.1/ http://dublincore.org/schemas/xmls/qdc/2006/01/06/dc.xsd http://
    purl.org/dc/terms/ http://dublincore.org/schemas/xmls/qdc/2006/01/06/dcterms.xsd">
  <dc:creator>Gorka Epelde, VICOMTech</dc:creator>
  <dc:publisher>VICOMTech, Spain</dc:publisher>
  <dc:rights>Copyright 2008, VICOMTech</dc:rights>
```

```
<dcterms:modified>2008-09-17</dcterms:modified>
<dc:title xml:lang="en">Resource Sheet for the mce socket.</dc:title>
<dcterms:conformsTo>http://myurc.org/iso24752-5/2007</dcterms:conformsTo>
<dc:type>Text</dc:type>
<dc:format>text/xml</dc:format>
<aResDescForDomain rdf:resource="http://res.i2home.org/tv/mce.uis" />
<groupingForDomain rdf:resource="http://res.i2home.org/tv/mce.uis" />
<forLang>en</forLang>

<!-- Description of the contained Resources -->
<resItems rdf:parseType="Collection">
  <AResDesc rdf:about="http://res.i2home.org/tv/mce/mce.en.rsheet#socketLabel">
    <dc:type>Text</dc:type>
    <dc:format>text/plain</dc:format>
    <content rdf:parseType="Literal" xml:lang="en">Vista MCE Socket</content>
    <useFor rdf:parseType="Collection">
      <Context>
        <eltRef rdf:resource="http://res.i2home.org/tv/mce.uis#socket" />
        <role rdf:resource="http://myurc.org/ns/res#label" />
      </Context>
    </useFor>
  </AResDesc>
  <!-- Atomic Resources: labels for sets -->
  <AResDesc rdf:about="http://res.i2home.org/tv/mce/mce.en.rsheet#liveTVControlsLabel">
    <dc:type>Text</dc:type>
    <dc:format>text/plain</dc:format>
    <content rdf:parseType="Literal" xml:lang="en">- Live TV controls</content>
    <useFor rdf:parseType="Collection">
      <Context>
        <eltRef rdf:resource="http://res.i2home.org/tv/mce.uis#liveTVControls" />
        <role rdf:resource="http://myurc.org/ns/res#label" />
```

```
      </Context>
    </useFor>
  </AResDesc>
  <!-- Atomic Resources: labels tvControls sets labels -->
  <AResDesc rdf:about="http://res.i2home.org/tv/mce/mce.en.rsheet#activeChannelLabel">
    <dc:type>Text</dc:type>
    <dc:format>text/plain</dc:format>
    <content rdf:parseType="Literal" xml:lang="en">Active channel</content>
    <useFor rdf:parseType="Collection">
      <Context>
        <eltRef rdf:resource="http://res.i2home.org/tv/mce.uis#activeChannel" />
        <role rdf:resource="http://myurc.org/ns/res#label" />
      </Context>
    </useFor>
  </AResDesc>
  <AResDesc rdf:about="http://res.i2home.org/tv/mce/mce.en.rsheet#channelListLabel">
    <dc:type>Text</dc:type>
    <dc:format>text/plain</dc:format>
    <content rdf:parseType="Literal" xml:lang="en">Channel list</content>
    <useFor rdf:parseType="Collection">
      <Context>
        <eltRef rdf:resource="http://res.i2home.org/tv/mce.uis#channelList" />
        <role rdf:resource="http://myurc.org/ns/res#label" />
      </Context>
    </useFor>
  </AResDesc>
 </resItems>
</ResSheet>
```

Appendix E

URC User Interface Description for a videoconference service

The following subsections contain the XML file instances (Target Description, User Interface Socket Description and Target Resource Sheet) required by the URC Framework, defined for the videoconference iteractive service.

For space and comprehensibility issues, the User Interface Socket Description, and the Target Resource Sheet have been cut to only represent the makecall / takecall functionalities of the service. The Target Resource Sheet is presented only for the English language.

The complete version of the files are available at the target templates repository of the OpenURC Alliance (http://www.openurc.org/TPL).

- Videoconference Service Target Description: `http://www.openurc.org/TPL/socialnetworking-1.0-yyyymmdd/Ekiga.td`
- Videoconference Service User Interface Socket Description: `http://www.openurc.org/TPL/socialnetworking-1.0-yyyymmdd/videoconference.uis`
- Videoconference Service Target Resource Sheet: `http://www.openurc.org/TPL/socialnetworking-1.0-yyyymmdd/videoconference.en.rsheet`

E.1 Target Description

```
<?xml version="1.0" encoding="utf-8"?>
<target about="http://res.i2home.org/socialNetworking/videoconference"
  id="target" hidden="false"
  xmlns="http://myurc.org/ns/targetdesc"
  xmlns:td="http://myurc.org/ns/targetdesc"
  xmlns:dc="http://purl.org/dc/elements/1.1/"
  xmlns:dcterms="http://purl.org/dc/terms/"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://myurc.org/ns/targetdesc http://myurc.org/ns/targetdesc
    http://purl.org/dc/elements/1.1/ http://dublincore.org/schemas/xmls/qdc/2006/01/06/dc.xsd
    http://purl.org/dc/terms/ http://dublincore.org/schemas/xmls/qdc/2006/01/06/dcterms.xsd">
  <dc:creator>Gorka Epelde, VICOMTech</dc:creator>
  <dc:publisher>VICOMTech, Spain</dc:publisher>
  <dc:rights>Copyright 2008, VICOMTech</dc:rights>
  <dcterms:conformsTo>http://myurc.org/iso24752-4/2007</dcterms:conformsTo>
  <dcterms:modified>2008-12-19</dcterms:modified>

  <socket id="videoconferenceSocket"
    name="http://res.i2home.org/socialNetworking/videoconference.uis"
    sharedSessions="true">
    <socketDescriptionLocalAt>../targets/socialNetworking/videoconference.uis</socketDescriptionLocalAt>
  </socket>

  <!--Description of the root Resource Directory-->
  <rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns="http://myurc.org/ns/res#">
    <ResDir>
      <dirItems rdf:parseType="Collection">
```

```xml
          <ResSheet rdf:about="http://res.i2home.org/socialNetworking/videoconference.en.rsheet">
            <forLang>en</forLang>
            <dcterms:conformsTo>http://myurc.org/iso24752-5/2007</dcterms:conformsTo>
            <localAt>../targets/socialNetworking/videoconference.en.rsheet</localAt>
            <dc:type>Text</dc:type>
            <aResDescForDomain rdf:resource="http://res.i2home.org/socialNetworking/videoconference"/>
          </ResSheet>
        </dirItems>
      </ResDir>
    </rdf:RDF>
</target>
```

E.2 User Interface Socket Description

```xml
<?xml version="1.0" encoding="UTF-8" ?>
<uiSocket about="http://res.i2home.org/socialNetworking/videoconference.uis" id="socket"
  xmlns="http://myurc.org/ns/uisocketdesc" xmlns:uis="http://myurc.org/ns/uisocketdesc"
  xmlns:dc="http://purl.org/dc/elements/1.1/" xmlns:dcterms="http://purl.org/dc/terms/"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://myurc.org/ns/uisocketdesc http://myurc.org/ns/uisocketdesc
  http://purl.org/dc/elements/1.1/ http://dublincore.org/schemas/xmls/qdc/2006/01/06/dc.xsd
  http://purl.org/dc/terms/ http://dublincore.org/schemas/xmls/qdc/2006/01/06/dcterms.xsd">
  <dc:description xml:lang="en">UI socket for the functionalities of videoconference, exchange of archives, exchange
     of messages, and to know the connection status of other users.</dc:description>
  <dc:creator>Gorka Epelde, VICOMTech</dc:creator>
   <dc:contributor>Xabier Valencia, VICOMTech</dc:contributor>
  <dc:contributor>Gottfried Zimmermann, Access Technologies Group</dc:contributor>
  <dc:publisher>VICOMTech, Spain</dc:publisher>
```

```xml
<dcterms:conformsTo>http://myurc.org/iso24752-2/2007</dcterms:conformsTo>
<dcterms:modified>2008-10-09</dcterms:modified>

<set id="connections">
  <dc:description xml:lang="en">
  This set contains the functionalities to make/receive calls. Reception of calls is done via a notification plus a
      command to accept or reject the offer
  </dc:description>
  <notify id="incomingCall" category="alert">
    <dc:description xml:lang="en">
    This notification notifies us that there is an incoming call. The behaviour would be that notification would be
        active for x seconds. If there is no response after those x second, it would treated as rejected.
    </dc:description>
    <dependency>
      <explicitAck>false()</explicitAck>
    </dependency>
  </notify>
  <command id="rejectCall" type="uis:basicCommand">
    <dc:description xml:lang="en">
    This command rejects the incoming call.
    </dc:description>
    <dependency>
      <write>value('incomingCall') eq 'active'</write>
    </dependency>
  </command>
  <command id="takeCall" type="uis:basicCommand">
    <dc:description xml:lang="en">
    This command accepts the incoming call.
    </dc:description>
    <dependency>
      <write> value('incomingCall') eq 'active'</write>
```

```
      </dependency>
      <param id="incomingCallType" dir="in" type="callType"/>
    </command>
    <command id="makeCall" type="uis:basicCommand">
      <dc:description xml:lang="en">
      This command is to start a call with a user.
      </dc:description>
      <param id="outgoingCallType" dir="in" type="callType"/>
    </command>
    <command id="endCall" type="uis:basicCommand">
      <dc:description xml:lang="en">
      This would end up, any established call, not only for this connection.
      </dc:description>
    </command>
  </set>

  <schema xmlns="http://www.w3.org/2001/XMLSchema">
    <simpleType name="callType" id="callTypeId">
      <annotation>
        <documentation>
        This type represent the different call types that can be established. Only audio or audio and video
        </documentation>
      </annotation>
      <restriction base="xsd:string">
        <xsd:enumeration value="audioOnly"/>
        <xsd:enumeration value="audioAndVideo"/>
        <xsd:enumeration value="videoOnly"/>
      </restriction>
    </simpleType>
  </schema>
</uiSocket>
```

E.3 Target Resource Sheet

```xml
<?xml version="1.0" encoding="utf-8"?>
<ResSheet
    rdf:about= "http://res.i2home.org/socialNetworking/videoconference.en.rsheet"
    xmlns= "http://myurc.org/ns/res#"
    xmlns:rdf= "http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:dc= "http://purl.org/dc/elements/1.1/"
    xmlns:dcterms= "http://purl.org/dc/terms/"
    xmlns:xsi= "http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation= "http://myurc.org/ns/res# http://myurc.org/ns/res#
    http://purl.org/dc/elements/1.1/ http://dublincore.org/schemas/xmls/qdc/2006/01/06/dc.xsd
    http://purl.org/dc/terms/ http://dublincore.org/schemas/xmls/qdc/2006/01/06/dcterms.xsd">
   <dc:creator>Xabier Valencia, VICOMTech</dc:creator>
   <dc:contributor>Gorka Epelde, VICOMTech</dc:contributor>
   <dc:contributor>Gottfried Zimmermann, Access Technologies Group</dc:contributor>
   <dc:publisher>VICOMTech, Spain</dc:publisher>
   <dcterms:conformsTo>http://myurc.org/iso24752-2/2007</dcterms:conformsTo>
   <dcterms:modified>2008-10-09</dcterms:modified>
   <dc:title xml:lang="en">Resource Sheet for videoconference socket.</dc:title>
   <dcterms:conformsTo>http://myurc.org/iso24752-5/2007</dcterms:conformsTo>/>
    <dc:type>Text</dc:type>
    <dc:format>text/xml</dc:format>

   <aResDescForDomain rdf:resource="http://res.i2home.org/socialNetworking/videoconference.uis"/>
    <groupingForDomain rdf:resource="http://res.i2home.org/socialNetworking/videoconference.uis"/>
    <forLang>en</forLang>
    <!-- Description of the contained Resources -->
   <resItems rdf:parseType="Collection">
     <AResDesc rdf:about="http://res.i2home.org/socialNetworking/videoconference.en.rsheet#socketLabel">
```

```
          <dc:type>Text</dc:type>
          <dc:format>text/plain</dc:format>
          <content rdf:parseType="Literal" xml:lang="en">Videoconference Socket</content>
          <useFor rdf:parseType="Collection">
              <Context>
                  <eltRef rdf:resource="http://res.i2home.org/socialNetworking/videoconference.uis#socket"/>
                  <role rdf:resource="http://myurc.org/ns/res#label"/>
              </Context>
          </useFor>
  </AResDesc>
<AResDesc rdf:about="http://res.i2home.org/socialNetworking/videoconference.en.rsheet#makeCall">
          <dc:type>Text</dc:type>
          <dc:format>text/plain</dc:format>
          <content rdf:parseType="Literal" xml:lang="en">makeCall</content>
          <useFor rdf:parseType="Collection">
              <Context>
                  <eltRef rdf:resource="http://res.i2home.org/socialNetworking/videoconference.uis#makeCall"/>
                  <role rdf:resource="http://myurc.org/ns/res#label"/>
              </Context>
          </useFor>
</AResDesc>
<AResDesc rdf:about="http://res.i2home.org/socialNetworking/videoconference.en.rsheet#rejectCall">
          <dc:type>Text</dc:type>
          <dc:format>text/plain</dc:format>
          <content rdf:parseType="Literal" xml:lang="en">rejectCall</content>
          <useFor rdf:parseType="Collection">
              <Context>
                  <eltRef rdf:resource="http://res.i2home.org/socialNetworking/videoconference.uis#rejectCall"/>
                  <role rdf:resource="http://myurc.org/ns/res#label"/>
              </Context>
          </useFor>
```

```
  </AResDesc>
<AResDesc rdf:about="http://res.i2home.org/socialNetworking/videoconference.en.rsheet#takeCall">
         <dc:type>Text</dc:type>
         <dc:format>text/plain</dc:format>
         <content rdf:parseType="Literal" xml:lang="en">takeCall</content>
         <useFor rdf:parseType="Collection">
             <Context>
                 <eltRef rdf:resource="http://res.i2home.org/socialNetworking/videoconference.uis#takeCall"/>
                 <role rdf:resource="http://myurc.org/ns/res#label"/>
             </Context>
         </useFor>
  </AResDesc>
<AResDesc rdf:about="http://res.i2home.org/socialNetworking/videoconference.en.rsheet#endCall">
         <dc:type>Text</dc:type>
         <dc:format>text/plain</dc:format>
         <content rdf:parseType="Literal" xml:lang="en">endCall</content>
         <useFor rdf:parseType="Collection">
             <Context>
                 <eltRef rdf:resource="http://res.i2home.org/socialNetworking/videoconference.uis#endCall"/>
                 <role rdf:resource="http://myurc.org/ns/res#label"/>
             </Context>
         </useFor>
</AResDesc>
 <AResDesc rdf:about="http://res.i2home.org/socialNetworking/videoconference.en.rsheet#incomingCallType">
     <dc:type>Text</dc:type>
     <dc:format>text/plain</dc:format>
     <content rdf:parseType="Literal" xml:lang="en">incomingCallType</content>
     <useFor rdf:parseType="Collection">
         <Context>
             <eltRef rdf:resource="http://res.i2home.org/socialNetworking/videoconference.uis#incomingCallType"/>
             <role rdf:resource="http://myurc.org/ns/res#label"/>
```

```
            </Context>
        </useFor>
    </AResDesc>
    <AResDesc rdf:about="http://res.i2home.org/socialNetworking/videoconference.en.rsheet#outgoingCallType">
        <dc:type>Text</dc:type>
        <dc:format>text/plain</dc:format>
        <content rdf:parseType="Literal" xml:lang="en">outgoingCallType</content>
        <useFor rdf:parseType="Collection">
            <Context>
                <eltRef rdf:resource="http://res.i2home.org/socialNetworking/videoconference.uis#outgoingCallType"/>
                <role rdf:resource="http://myurc.org/ns/res#label"/>
            </Context>
        </useFor>
    </AResDesc>
</resItems>
</ResSheet>
```

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