An Adaptive Integrated Environment for Assisted Living

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***Abstract*—The aging population together with increased incidence of chronic disease, technological advances and rapidly escalating health-care costs lead to Assisted Living and the development and usage of new technologies and services. Assisted Living aims to facilitate older adults and people with disabilities through life by offering technological advancements and equipment (among other). In this paper we describe an integrated environment of platforms and services that facilitates older adults with disabilities. We describe our solution both technologically, as well as from the user perspective through use case scenarios. The paper focuses in particular to two integration methods followed between the platforms and the different communication routes these offer, allowing for different user interfaces to be utilized.**

Keywords— integrated environment; assisted living; assistive technologies; adaptive interfaces

I. INTRODUCTION

The combination of reduced infant mortality and increased life expectancy has led to a restructuring of population demographics across the developed world [1, 2]. Therefore, population aging together with increased incidence of chronic disease, technological advances and rapidly escalating health-care costs are driving health-care into the home. Elders commonly suffer from chronic conditions or advanced chronic illness, which include above all mobility restrictions that make it impractical to provide them with frequent, intense oversight in an office setting. As a result, increasing healthy life expectancy requires the introduction of support in the form of technological products and services.

In effect, technological developments have increased viability of homecare due to the miniaturization and portability of diagnostic and information technologies, remote monitoring, and long-distance care [3, 4]. Actually, this population is highly likely to want and need medical care that could be enhanced by the use of such tools. Despite the fact that so many technological solutions and services are available, the ability of older adults to find, but most importantly utilise such tools and services is a critical issue.

On another dimension, a significant number of people with disabilities worldwide are supported by Assistive Technologies (AT) [5, 6]. Available AT devices and systems provide a wide range of assistive functionality, improving thus the quality of life of people with disabilities. However, AT devices often require adaptation, since they have been designed for explicit applications, and thus cannot be used in slightly different environments without serious customizations. In this respect, routine activities of people with disabilities may be restricted, either because AT devices cannot be adapted based on their needs, or because the device itself or its adaptations introduce unaffordable costs.

The AsTeRICS (Assistive Technology Rapid Integration & Construction Set) project [7] has built a hardware and software framework, which targets to reduce the time, effort and costs of developing Assistive Technology applications. It offers a flexible and affordable components set that enables building assistive functionalities, which can be highly adapted to the dynamically changing needs of each individual. The system is scalable and extensible and allows easy integration of new functionalities without major changes. It enables people with disabilities to gain access to the standard desktop computer, as well as to embedded and mobile services that did not offer highly specialised user interfaces until present. By using its scalable and extensible architecture, it provides easy means for designing and running specialized AT applications, which can simplify and assist the daily routine of people with disabilities.

A key limitation of the AsTeRICS platform was that it did not permit reuse and quick integration of the functions offered by its assistive components to an existing application developed using another technology. The work presented in [8] simplifies and expedites integration of assistive functionalities in existing software applications built using different technologies, as well as improving the accessibility of the application. Moreover, the refined runtime middleware environment presented in [8] offers exploitation of the capabilities offered by sensors, actuators and other mobile devices deployed on different machines for the development of assistive applications. The AsTeRICS Runtime Environment (ARE) was re-designed and developed as a Java-OSGi middleware, which offers assistive functionalities via the pool of existing OSGi components (sensors, actuators, etc.), which were now exposed as *REST services*. In specific, REST functionality was introduced within the AsTeRICS architecture as a means of communication of external devices and services with the AsTeRICS Runtime Environment for exchange of information, data and resources. Through the two described use cases it was demonstrated that new ways of AT interaction can be easily and rapidly integrated into existing software applications.

Moreover, in [9] a prototype developed during the Prosperity4all FP7 project [10] is presented that incorporates adaptive user interfaces and AT middlewares for device overarching use cases. The paper presents the four technologies/platforms combined under Prosperity4all in order to provide a system for adaptive user interfaces in distributed environments: (i), the Global Public Inclusive Infrastructure (GPII) [11] is used as a means to transfer platform independent user preferences from one application to another and to infer appropriate settings to adapt the target system's user interface according to the user's needs. The adaptive user interface layer is formed by a cooperation of the (ii), MyUI framework [12] and (iii), AsTeRICS. MyUI provides an adaptive graphical user interface and enables device overarching user interfaces, while AsTeRICS accommodates people with special motoric needs in AT applications. Finally, (iv), the Universal Remote Console (URC) runtime [13] is used to mediate between the user interface layer and the devices and services that shall be controlled. It is also used to give third parties, e.g., assistive technology experts, the possibility to make their own contributions.

In this paper we discuss the abovementioned integrated technologies from another dimension: the facilitation and provision of Assisted Living services to elderly people with special needs. We specifically describe two integration methods followed between the platforms AsTeRICS, MyUI and URC, and, more importantly, we show specific usage scenarios involving elderly people that the two integration methods implement. In specific, the two integration methods offer different communication routes between the three platforms, allowing thus for different user interfaces to be utilized. The integration methods are dynamic in the sense that the user can switch between the two by rebooting the system and initiate the desired interaction method.

The rest of the paper is structured as follows: Section 2 presents related work. Section 3, after a brief introduction to the platforms, describes the two integration methods between them. Section 4 provides an introduction to the use case scenario "Assisted Living", discussing the personas, the environment and the technology used. Sections 5 and 6 discuss the different User-System interaction formats that result from the two distinct integration methods followed between the platforms. Section 7 concludes the paper.

II. RELATED WORK

A number of AT systems have been developed, mainly in European Projects. The TOBI project [14] focuses on the design of non-invasive BNCI prototypes that combine existing Assistive Technologies and rehabilitation protocols. The aim is to improve people's communication by supporting access to devices such as virtual keyboards, internet, email, telephony, fax, SMS and environmental control. The BRAIN [15] project enhances intercommunication and interaction skills of disabled people via the development and integration of Brain-Computer Interfaces into practical assistive tools. The aim of the BRAIN system is at improving interaction of the user with people, home appliances, assistive devices, personal computers, internet technologies, and more. BrainAble's [16] main objective is to assist people with disabilities on overcoming exclusion from home and social activities by providing an ICT-based Human Computer Interface (HCI), as well as producing a set of technologies suitable for assisting people with physical disabilities regardless of cause.

A project with many similarities with AsTeRICS both in terms of the concept, the implementation and the system architecture is OpenHAB [17]. It provides a scalable and modular architecture that integrates components and technologies in a single solution. OpenHAB is open-source with an active community, which enables new features and functionalities to be added, as with AsTeRICS. It is also based on JAVA OSGi [18] and provides APIs for integration with other systems. In addition, it provides remote communication with a REST API and intra communication. The "new thing" that OpenHAB introduces is that it gives the ability to the user to define the interaction of things and devices. The restriction of OpenHAB, in comparison to the AsTeRICS framework, is that an expert developer is needed to define in the form of text-based scripts the interactions amongst the components even for a simple AT scenario in the Smart Home. In contrast, the AsTeRICS system enables a non-expert AT designer to use a simple modelling interface to easily model or reuse existing models to provide the necessary functionality to the user.

An adaptive Ambient Assisted Living system developed for elderly people is the PIAPNE Environment [19]. It is based on three models: A user model (capabilities, permissions), a task model (user activity) and a context (environment) model. The system has several layers. The middleware layer bridges different network technologies and the intelligent service layer can be used to connect intelligent applications interfaces (only software).

The DomoEsi Project [20] is carried out at the Escuela Superior de Ingenieros de Sevilla and focuses on interoperability problems but uses also some simple, adjustable hardware controller devices. Universal Plug and Play (UPnP) serves as common interface from which software bridges to other Smart Home technologies can be built. The system can be accessed via web browser, a Nintendo Wiimote controller or a voice interface. The different input modalities of the Wii controller (infrared camera, buttons, accelerometers) can be used to provide a simple adaptable interface for people with disabilities and with other, special needs.

III. INTEGRATION BETWEEN ASTERICS, MYUI AND URC

The AsTeRICS platform was described in Section 1; in this section, before going over the integration methods between the three platforms, we will briefly describe MyUI and URC.

A. MyUI

MyUI provides an environment to render and adapt a user interface to the user context during runtime. All knowledge on various user interface design solutions and adaptations is contained in design patterns. MyUI provides also an abstract format to define the interaction possibilities of a user with the application called AAIM (Abstract Application Interaction Model), which is based on UML2 State Machine Diagrams. Instead of developing many variants of the user interface in order to meet the individual needs of the diverse end users, the application developers can focus on implementing the application logic. The knowledge about the user interface adaption lies in the pattern repository.

B. URC

The overall purpose of the URC framework (standardized in ISO/IEC 24752) [21] is to provide a mechanism, enabling users to control any target with any controller devices fitting best the user's needs. Targets can be devices or services, usually such that can be found in the Smart Home or Ambient Assisted Living domain. Controllers can range from User interfaces running on PCs, Smart Phones over traditional Remote Controls to regular or specialized hardware. In order to realize such a system, every target provides an abstract description of its operating interface. In URC terms this is called Socket Description. Socket Descriptions contain all information about a device's properties, which can be accessed by a user. Basically, these are variables that can be controlled by the user, commands that can be send to the target, and finally notifications that the device can send to a user interface. Based on the concept of Socket Descriptions, third party user interface developers can create personalized user interfaces, and publish them via a dedicated Resource Server. At runtime, users can select a user interface that fits best their needs, download it from the Resource Server and virtually plug it into a target. This is why they are referred as pluggable User Interfaces. To enable the communication between any user interface and the URC, the URC-HTTP protocol was developed.

In the described scenarios all three platforms, namely AsTeRICS, MyUI and URC are integrated via two integration methods.

C. Integration Method I: ARE → MyUI → URC

In this scenario, the communication between the AsTeRICS and MyUI is being conducted over the operating system. AsTeRICS provides accessibility and AT interfaces to control default operating system events, such as mouse or keyboard interaction, in order to control the MyUI Adaptive User Interface. The URC-HTTP protocol is being used to enable communication between MyUI runtime and URC. To simplify the communication between MyUI runtime and UCH, the JavaScript Library implementing the client side of the URC-HTTP protocol is used.

D. Integration Method II: MyUI → ARE → URC

This scenario requires that an appropriate MyUI Adaptive User Interface exists that manages the AsTeRICS ARE through a RESTful based communication. Through this integration, MyUI Adaptive User Interface is able, on one hand to initiate REST calls to the ARE to handle models, such as "Start Model", "Stop Model", "Pause Model", "Load Model", etc., and on the other hand to receive (and display if needed) relevant updates of the ARE's application state and runtime information.

When an AsTeRICS model has been started and is running, a RESTful communication between the ARE model components and the remote URC sensors/actuators is being established. The AsTeRICS model is then able to retrieve and/or push information from/to the remote URC components. This functionality is provided through a URC plugin component built on AsTeRICS and used within the AsTeRICS model. The URC plugin component is designed and developed for use with any URC remote sensor/actuator, and can be used by any AsTeRICS model, provided that the corresponding model component interconnections are being properly defined. This serves as an example of Software and Hardware reuse, where a URC plugin component (that handles a remote URC sensor) is designed and built once on AsTeRICS, but is reused in many AsTeRICS models of different purposes without further coding needed. In addition, as the AsTeRICS platform enables a non-expert AT designer to easily model or reuse existing AsTeRICS models to provide the necessary functionality to the user, it can be easily inferred that having URC plugin components available to be freely used within AsTeRICS models provides added value to the platform, and the ability to the non-expert AT designer to freely access remote URC sensors/actuators.

Fig. 1 shows the overall integration schema between the three platforms. AsTeRICS needs to run on the same machine as MyUI in order to interact through the operating system (route *AsTeRICS → MyUI*). On the opposite direction (route *MyUI → AsTeRICS*) this is not needed, as interaction is conducted through the AsTeRICS RESTful API.

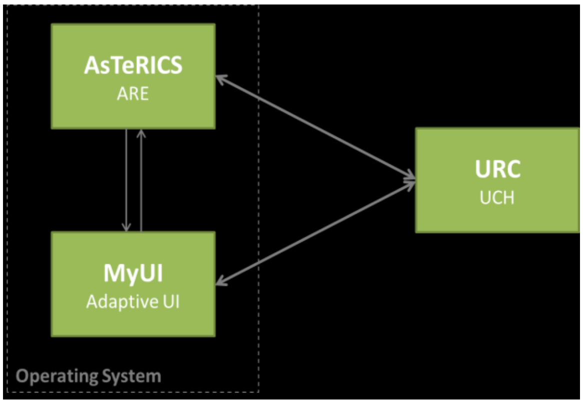

Fig. 1: Overall integration Schema

IV. INTRODUCTION OF USE CASE SCENARIO “ASSISTED LIVING”

The use case scenario describes how the integrated platform can be used effectively in real life situations of Assisted Living. The scenario was successfully implemented in our labs in Cyprus and Germany by involving laboratory staff. No real users were involved at the time.

A. Personas

The selected personas aim to reveal the behaviour of elderly people with disabilities while using the system.

1) Mrs Moroz

Mrs Moroz, a 73 year woman, has had a stroke a year ago, which paralyzed the right side of her body and took her speech away. Fortunately, she still has good head control which enables her to use a variety of different technologies. For example she is competent in using a headmouse control, a mouth stick and a chin control for her electric wheel chair. She spends a lot of her time in an Assisted Living dormitory.

2) Nicholas

Nicholas is 71 years old. He moves around in an electric wheelchair, which he controls via a joystick. His hands need to be placed on the joystick by a care-person and then he can use it with very small movements of his fingers. However, using the joystick is exhausting for him. That’s why he prefers to control the mouse with (limited) head movement whenever possible. Nicholas also spends time in the Assisted Living dormitory.

3) Vasili Moroz (Care Giver)

Vasili Moroz is Mrs Moroz husband, 78 years old and is also the care giver of Mrs Moroz in the dormitory.

B. Environment/Available Technology

Mrs Moroz and Nicholas spend much of their time in Assisted Living, a really nice and warm dormitory that provides accessibility. Specifically, Mrs Moroz spends her weekdays there, while Nicholas spends only a few hours on most of the week days. The dormitory has a separate bedroom for every resident and a common room for getting in contact with other people. The common room has two different areas, one is equipped with a TV set and the other one with tables so that people can sit together.

The common room, as well as each bedroom, is equipped with the following:

- Philips HUE lights, a lamp that changes colours that is remotely controlled by URC (it is a remote URC actuator) so that it can be illuminated to individual colour wishes.
- An electricity outlet, the Wöhlke Websteckdose that is remotely controlled by URC (it is a remote URC actuator as well) connected with a fan heater that can be turned on/off from the network.
- Both Philips HUE lights and the electricity outlet in a room can be controlled from a central control panel within the room, a computer screen that can adapt to users’ preferences.

C. Personalized Technology Control

The central Philips HUE light and the fan heater can be controlled via the computer screen with AsTeRICS, MyUI Adaptive Interfaces and URC installed. All three people, Mrs Moroz, Nicholas and Vasili should be supported in controlling the devices as follows:

1) Mrs Moroz:

- Needs to use the headmouse feature (controlling the mouse via head movement) with sensitivity set to *“normal”*: requires normal head movements to operate the mouse (keeping still for four seconds over something selects it).
- Due to her wheelchair the distance between her and the control panel is about 1.0m to 1.5m. Furthermore, due to her age, her eyesight is not perfect.

For Mrs Moroz the following is needed: *“normal” headmouse control + very large button/font size*.

2) Nicholas

- Needs to use the headmouse feature with sensitivity set to *“increased”*: even with limited head movements the mouse can be operated. Keeping still for four seconds over something selects it.
- Due to his wheelchair the distance between him and the control panel is about 1.0m to 1.5m

For Nicholas the following is needed: *“sensitive” headmouse control + large button/font size*.

3) Vasili Moroz

- Wants to use a mouse or touchscreen
- Needs to see as many information as possible concerning the lights and the fan heater.

For Vasili Moroz *no assistive technologies are needed + normal button/font size*.

D. General requirements

- Large font size and less information displayed for bedridden people due to increased distance between display and user, as well as bad eyesight.
- Different input technologies: “sensitive” headmouse control, “normal” headmouse control.

Every room has its own control panel which must adjust to each resident’s preferences for that room. The control panel in the room enables controlling the Philips HUE lights and the fan heater in a personalized manner.

V. INTEGRATION METHOD 1

A. Scenario Part 1

1) Introduction

Mrs Moroz is sitting in her bedroom where she has set the Philips HUE lights and fan heater according to her current needs: “green” light and fan heater “on”. At some point she uses her electric wheel chair to move to the common room to watch TV. Since nobody has been there for a while, the temperature is lower and the lights are out, so Mrs Moroz needs to switch on the fan heater, as well as control the lights in the common room. She uses the control panel in the common room to make the necessary changes so she needs to use very large button size (to be able to read characters from a distance) along with "normal headmouse control". The system makes the necessary adjustments to assist Mrs Moroz.

2) Scenario

As Mrs Moroz enters the common room, GPII detects her entering the room. Mrs Moroz needs to switch on the fan heater and control the lights, therefore she uses the control panel (screen) to make these changes. Based on Mrs Moroz's needs and preferences, "very large button size" is adjusted by MyUI so that she is able to read characters from a distance. Moreover, AsTeRICS initiates operation with the "normal" headmouse control model. Via the headmouse control Mrs Moroz can use normal head movements to interact with the very large button size UI of MyUI (Fig. 2) to control the remote URC actuators: change the colour of the Philips HUE lights (see Fig. 3 and 4) and switch on the fan heater (Fig. 5 depicts the electricity outlet Wöhlke Websteckdose that controls the fan heater).

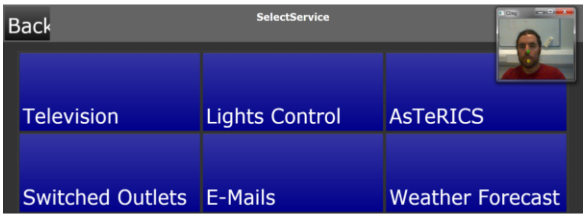

Fig. 2: MyUI very large button size UI: in usage with AsTeRICS headmouse

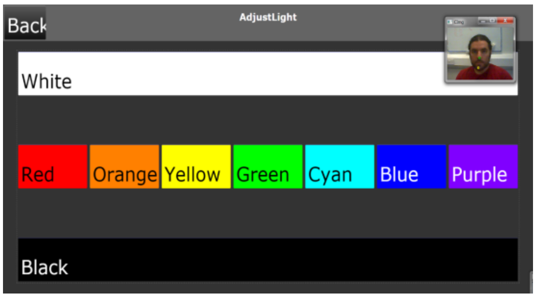

Fig. 3: Changing the lights through MyUI UI via head movement (AsTeRICS)

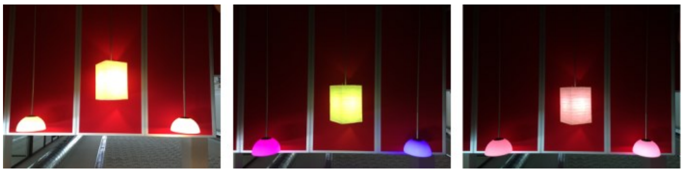

Fig. 4: The Philips HUE lights in different colours

Fig. 5: The electricity outlet Wöhlke Websteckdose controls the fan heater

B. Scenario Part 2

1) Introduction

After some period of time, Nicholas also enters the common room. He has been out with his brother. He feels hot so he thinks of switching off the fan heater. Also, he wants to read a new book his brother gave him, so he asks Mrs Moroz's permission to make the room a little bit brighter by changing the colour of the lights to something brighter, as well as less hot by switching off the fan heater. Mrs Moroz doesn't mind so Nicholas approaches the control screen. Due to his wheelchair the distance between him and the control panel is about 1.0m to 1.5m, so the system increases the font size to "large" and enables "sensitive headmouse control".

2) Scenario

Nicholas enters the common room and approaches the touch screen. Based on Nicholas's needs and preferences, large font size is selected and "sensitive" headmouse control is enabled. MyUI initiates "large button size" UIs, while AsTeRICS enables "sensitive" headmouse control for Nicholas to use. Nicholas is now able to use very limited head movement (as a limitation of his illness) to control the mouse and interact with the large button size UI of MyUI to control the remote URC actuators: change the colour of the Philips HUE light and switch off the fan heater.

C. Scenario Part 3

1) Introduction

When Vasili Moroz enters the common room 2 hours later, he feels the room is a bit cold. He approaches the control screen in the common room and through the device normal interface he switches the fan heater to "on".

2) Scenario

When Vasili enters the common room, MyUI sets common font size, while AsTeRICS remains idle since AT services are not needed in Vasili's case. Vasili is able to turn on the fan heater via accessing the remote URC actuator through MyUI interaction.

VI. INTEGRATION METHOD 2

A. Scenario Part 1

As Mrs Moroz enters the common room, GPII detects her entering the room. Mrs Moroz needs to switch on the fan heater and control the lights, therefore she uses the control panel (screen) to make these changes. Based on Mrs Moroz's needs and preferences, "very large button size" is specified by MyUI so that Mrs Moroz is able to read characters from a distance. Moreover, AsTeRICS enables the "normal" headmouse control actuator. Via the headmouse control Mrs Moroz can use head movements to interact with the very large button size UI of MyUI to change the AsTeRICS model via a simple click of a button so that she is able to handle the remote URC sensors/actuators needed by using AT. Now, Mrs Moroz can handle the remote URC sensors via head movement as follows:

- Philips HUE light: head movement continuously changes between available colours, e.g. turning head to the right makes lights towards blue, while turning head to the left makes lights towards green. All colour variations are supported via head movement. By keeping still for 4 seconds Mrs Moroz can return to the headmouse control model – normal head movement now controls the mouse - to continue with other tasks. The colour of the lamp is then the last selected colour.

- Switch on the fan heater: repetitive mouth movement (opening) changes between "switch on" and "switch off". When the fan heater is set to the desired state, Mrs Moroz can return to the headmouse control model – normal head movement now controls the mouse - to continue with other tasks. Returning to headmouse control can be done via a specific head movement: turning head to the right.

B. Scenario Part 2

When Nicholas enters the common room, he needs to switch off the fan heater and also to change the colour of the lights to something brighter. Nicholas approaches the control panel. Based on Nicholas's needs and preferences, the system increases MyUI font size and enables "sensitive" headmouse control. Nicholas will then use "sensitive" headmouse control to interact with the large button size UI of MyUI to change the AsTeRICS model via a click of a button so that he is able to handle the remote URC sensors/actuators needed by using AT. Now, Nicholas can handle the remote URC sensors via head movements as described above for Mrs Moroz, although the headmouse control will be set to "sensitive" instead of "normal".

C. Scenario Part 3

Vasili Moroz does not need AT, he would prefer to control the fan heater via the MyUI interface by using the touch screen, rather than via head movements through AsTeRICS.

VII. CONCLUSIONS AND FUTURE WORK

The adaptive integrated environment described in this work is targeted for use with elderly in Assisted Living scenarios. Had they been real people, Mrs Moroz and Nicholas would have been excited with the many interaction possibilities the environment provides. They would have liked the very easy and straightforward way one can handle the lights and the fan heater to suit their needs and preferences. They would have also felt excided knowing that even more devices can connect to the integrated system in the future to provide even more cool solutions, making their lives at the dormitory easier.

Future work involves testing with real users. In specific we plan to conduct experiments with elderly people in the lab, as well as at their homes. The evaluation will include the services described in this work, as well as additional Assisted Living services based on the needs and wishes of the elderly. The added services will be evaluated as well. Evaluation will include focus groups and interviews.

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