DAI Virtual Lab: a Virtual Laboratory for Testing Ambient Intelligence Digital Services

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Resumen

El soporte tecnológico de la Inteligencia Ambiental proporciona utilidades muy diversas de información de contexto y operación sobre el entorno.
Dichos sistemas ponen en juego una amplia diversidad de sensores, actuadores, organizados mediante redes de interconexión complejas, en las cuales coexisten diversos protocolos de comunicación y de operación, así como numerosos niveles de modularización.

La validación de nuevos desarrollos se realiza sobre prototipos físicos de viviendas inteligentes que hacen las veces de laboratorio. Las posibilidades de experimentación encuentran poderosas limitaciones debido a que el propio laboratorio se convierte en un recurso crítico que soporta un solo uso cada vez.

DAI VIRTUAL LAB es un entorno que recrea escenarios virtuales tridimensionales para ayuda al diseño de los sistemas digitales de inteligencia ambiental. Proporciona un nivel preliminar de validación virtual pero cercana a la realidad que soporta simulaciones en paralelo, sin gastos ni restricciones de tiempo y sin molestias para los usuarios.

Abstract

Ambient Intelligence technologies provide very diverse uses for context information and operation on the environment.

These systems bring into play a wide variety of sensors, actuators, organized in complex interconnection networks, in which different communication and operating protocols, as well as many levels of modularization, coexist.

The validation of new developments is performed on physical smart homes prototypes that serve as laboratories. Experimentation possibilities are quite limited because the laboratory itself becomes a critical resource that supports only a single use at a time.

DAI VIRTUAL LAB is an environment that recreates three-dimensional virtual environments to support the design of ambient intelligence digital systems. It provides a preliminary level for virtual validation but close to the reality that allows parallel simulations, without cost or time restrictions and inconvenience to users.

1. Introduction

One of the main issues in the design of Ambient Intelligence (AmI) services is testing the developments at different stages in conditions as similar as possible to the real ones. This is usually solved by using laboratories which are designed to resemble specific rooms or complete houses; incorporating very diverse devices (sensors, actuators, control networks...) what usually involves very high costs for a research centre. Only few centres can afford one of these smart living labs. In other cases, developments may be validated in real environments such as homes, nursing centres, hospitals... The main drawback of the latter is the inconvenience caused to users, which always suggests reducing real tests.

Recent computational and electronic advances have increased the capacity and functionality of AmI services. New interfaces enable people and devices to interact with each other and with the environment. Technology operates in the background while computing capabilities are everywhere, connected and always available. AmI provides a vision of the Information Society where the emphasis is on greater user-friendliness, more efficient services support, user-empowerment, and support for human interaction [1] [2] [3].

Anyone should be able to use digital services from home, regardless of their personal skills and capabilities. Therefore, the inclusion criteria must be considered as an essential design factor. The requirements that inclusive systems have to satisfy are much higher and the benefits to be provided are, correspondingly, of much greater magnitude. The confluence of AmI and inclusion criteria is part of the ambient assisted living (AAL) paradigm. There are intense advances in scientific domain (research projects, scientific journals, specific conferences, etc.) and technological field (equipment, systems and specialized environments) [4] [5] [6].

Inclusive design has implications in all the layers of a system. From a technological point of view, the characteristics of the sensors and actuators, and the structure and organization of the resulting system are affected. Features of the services that the solution must provide are also influenced. Therefore, the impact on the design of user interfaces is extremely important because they must be adapted to different functional skills; physical, sensory or intellectual disabilities; age… [7] [8] [9]. Besides the impact is also relevant for the designers and developers, the task-specific system managers, the installers, the maintenance engineers…

There are tools that automate the design of user interfaces in embedded systems using FPGAs. These tools allow to automatically generate code from UML specifications or other specification models, both hardware (usually VHDL) and software (C or similar) [10] [11] [12] [13]. However the number of tools to automate the interface design process is reduced. In [14] an automatic generator of user interfaces for multiple platforms using discourse models as a starting point is presented. In [15] Beale and Bordbar provide interface design support tools.

There are different simulators for AAL. Some simulate different services that a smart home can offer and provide a testing environment for those services using process choreography principles [16], it also provide the VAALID IDE [17] which is composed by an authoring tool and a virtual reality simulation environment. Another simulator, Virtual Valley [18] is integrated in an AAL environment for telerehabilitation, it integrates motion controllers and medical sensors and it is used to support physical rehabilitation, education, socialization and sharing of knowledge between users. In [19] a framework to develop interaction techniques for virtual worlds is presented.

2. Objectives

The inclusion skills could be established as follows. The inclusion of people in their environment is to facilitate communication between them through multimedia channels regardless of their personal skills.

Although this definition is concise, it provides a model of the problem (communication), identifies the entities involved: the people, in all their diversity of skills; the environment, with its richness of factors and processes; and the communication channel between them, which has to be bidirectional and with no restrictions initially on its nature.

The diversity of sectors, conditions and services (comfort, security, safety, energy management, communication and autonomy, health, administration, etc.) that make up the environment where people behave, qualify the definition of the inclusion problems with regards to the environmental aspects. Furthermore, the skills of each person impose the global conditions in which that communication will occur, particularly through sensory skills and perceptual attitudes. The phenomena that integrate the communication channel will be those potentially resulting from the compatibility between the characteristics of the environment and the people who inhabit it.

Inclusive interfaces for AAL implies both the design of homogeneous, intuitive and coherent user interfaces and the development of efficient AmI services. Therefore, the main aim of this research is to develop a generator of virtual environments intended to facilitate (ideally, automate) the design of interfaces for AAL. DAI VIRTUAL LAB generates 3D virtual environments that emulate the functionality of smart or automated homes, and has the following objectives:

- To create new interaction channels between users and the numerous and varied devices and services present at home. The developed system allows the automatic customization of the interfaces to access the functionality and state of the devices according to the needs and functional preferences of the user and the technological capabilities of the device to interact with;
- To serve as an aid tool for the designer of automated and smart homes, with different purposes: generation of the tridimensional virtual model of the environment, design of the installation, and simulation of its performance; and

- To provide a specialized, intuitive and powerful interface to end-users. This interface allows end-users to collaborate on design decisions by preliminary validations, through simulation using the virtual environment, recreating services and environments before proceeding to the final installation. Furthermore, the three-dimensional virtual model incorporates control panels for the different devices and services. These panels constitute the final interfaces that are installed in the real facilities.

DAI Virtual Lab is composed of a three-dimensional home generator and a simulation module.

The **three-dimensional virtual home generator** includes a home editor to allow the designer, in consensus with the end-user, set the equipment and the home services. The tasks in this phase are the following:

- Determine the installation structure, organization and division in modular sections,
- Characterize the technological elements of the system: sensors and actuators, and
- Establish the installation topology and the location of elements and components.

The **simulation module** emulates the constructive elements and allows simulating all kind of interactions and services that could be installed in a 3D environment. This virtual environment, once tested, becomes an interface adapted to the user that controls and monitors the services installed. The interface can be reconfigured according to the needs of the user and the evolution of the domotic system.

3. Principles and architecture

DAI VIRTUAL LAB generates a three dimensional environment which allows the simulation of services and the interaction with real devices. These two possibilities offered in a same platform increase the performance and support the designer to create assistive interfaces. Through the simulation, the designer can predict interactions patterns using a variety of input devices and allows reviewing and improving the performance. The three-dimensional environment allows the user to navigate through it and interact with the devices.

The communication between the virtual model and the real installation is done via web services using a control middleware (DAI middleware) [20]. This middleware completes the functionality of DAI VIRTUAL LAB and enables the integration and interoperability of all the installed systems. It offers an access interface, a set of web services and an API to develop services and applications (Fig. 1). It also includes a layer of services that can be used by the simulator module.

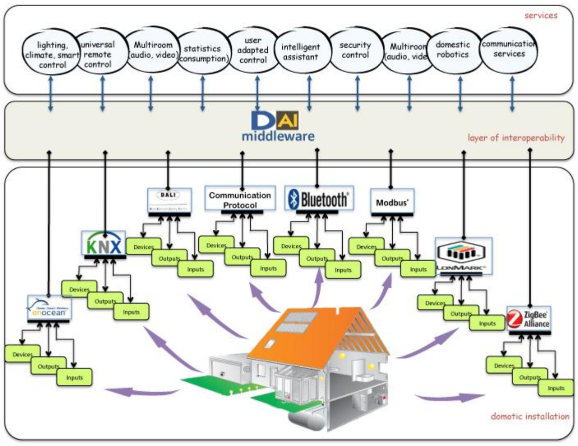

Fig. 1. DAI-middleware: control, integration and interoperability in heterogeneous systems

DAI middleware is based in an intranet that integrates control technologies and communication protocols (proprietary and standard) using gateways to Ethernet. The information and tasks assigned to the services are treated by a OSGI[1] (Open Services Gateway Initiative) based framework that can manage all the petitions from control devices or from the interfaces and applications. Its architecture (Fig. 2) is divided into three layers: device integration layer, task manager (OSGI) and services and applications layer.

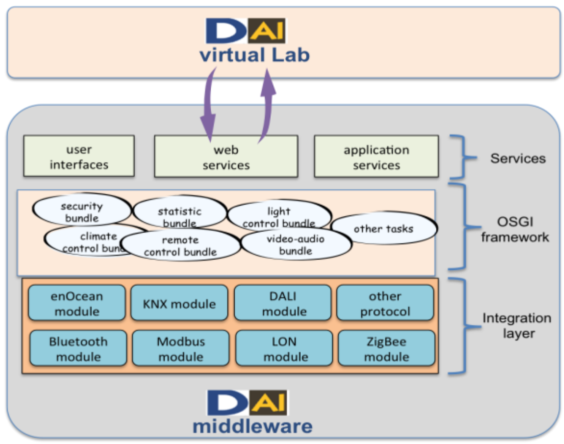

Fig. 2. DAI-Middleware: architecture and connection with DAI VIRTUAL LAB

3.1. DAI VIRTUAL LAB Architecture

The modules of DAI VIRTUAL LAB (editor and simulator) use a layered architecture (Fig. 3) that allows the abstraction of the functionalities of the lowest layers. At the lowest level there are the engines of graphics, audio and physics, which allow the rendering of the virtual models. These three

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[1] http://www.osgi.org/

engines are abstracted in the upper layer "Scene" where all the objects of the virtual environment are located. Above this layer there is the smart home devices layer. This layer virtualizes the home installation and associates the devices with the virtual objects of the scene. The upper layer includes the user interface and the web services modules. They both allow the interaction with the installation devices.

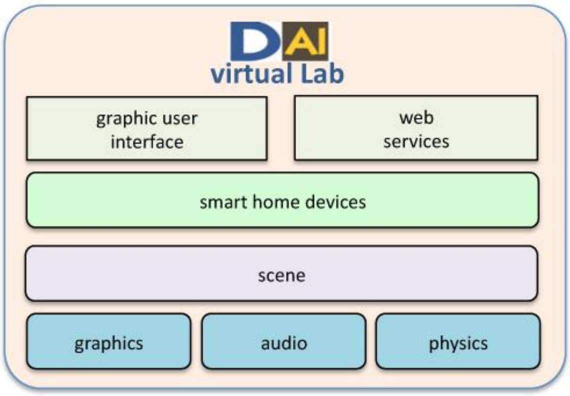

Fig. 3. DAI Virtual Lab architecture

3.1.1. Device programming. DAI VIRTUAL LAB incorporates a graphic language, DAI Device Macro Programming, that allows, in a simply but powerful way, to modify the behavior of the devices of the smart home installation, creating new macros (services). It is very intuitive and has been designed to offer an easy way to program the devices without the need of specialized knowledge about programming. This feature allows the end-user to program his smart home by adding new services or modifying existing ones.

Each device can have associated different macros that will be executed each time any of the functionalities of the device changes its value. This allows the incorporation of additional services by interconnecting the devices.

Fig. 4 shows a macro for the device "Light_1" with the following function:

```
while Light_1.switch {
  Sleep(10);
  Light_1.dimmer=(light_1.dimmer +
1) mod 256;
}
```

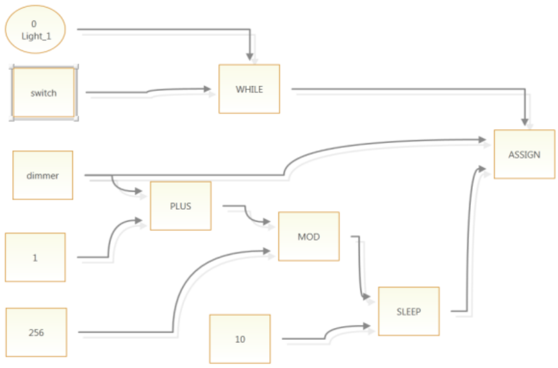

Fig. 4. Flow diagram of a macro

3.1.2. User Interface module. The upper layer is the user interface. It provides the user with a mechanism to interact with the devices in the home while viewing the results in the three-dimensional virtual environment.

There are two ways of interacting with the devices: selecting the device from a list, or selecting the device in the virtual environment itself. Fig. 5 shows a view of the interface with all the available options.

Fig. 5. DAI VIRTUAL LAB user interface: 1) open and save virtual labs, 2) options for the design, 3) help and support information, 4) viewing area, 5) detailed device information, 6) scene information: rooms, objects, devices…, 7) device information, 8) device actions, and 9) status bar

3.1.3. Interaction with the environment. After a scene is loaded, it is possible to interact with the devices. If the mouse is over a device it is highlighted. A device can be selected by clicking on it at the viewing area, or by selecting it from the list on the left.

Once selected, its information is shown in the right frame (5). Its functionalities are also accessible in (8) (i.e. if a door is selected it can be opened or closed).

The information shown and the available functionalities will depend on the device type. All the devices have a "Go To" button which focuses and moves the camera to its location. The functionalities categorized by device type are as follows:

- **Lights:** it permits to turn on/off the lights through a drop down list which contains the options OFF | ON. When the light is turned on/off, the scene will be illuminated with the respective color and intensity
- **Alarm:** it permits to turn on/off the alarm through a dropdown list which contains the options OFF | ON. When the alarm is turned on a sound will be played at the device location.
- **Blind**: it permits to close, open and set the blind with a scrollbar or a dropdown list which contains the options STOP | UP | DOWN. Any scrolling implies the corresponding movement of the blind at the viewing area.

3.1.4. Web service module. In order to communicate with the application, DAI VIRTUAL LAB implements a socket that can receive a set of commands in order to get information or modify the device status. The socket layer communicates with the devices just as the user interface does.

To make a common interface between virtual and real house, we have developed a web service that communicates with the virtual house socket offering exactly the same features as the original Web service of DAI middleware. Thus all interfaces designed for the virtual house can be used in the real house simply by changing the direction of the web service.

3.1.5. Home editor. The home editor provides a tool to modify the appearance of the virtual house by adding textures to objects, moving them to a specific position, or incorporating new devices and their characteristics. This tool is designed to retouch and add details to a virtual house modelled with a 3D modelling environment like Blender or 3D Studio and exported in COLLADA[2] format. Therefore, the original modelling of the house must be made with any of these environments and imported into the authoring tool. Later, the devices can be added and textures details or sound effects incorporated.

4. Use cases

DAI VIRTUAL LAB has been tested in two use cases. In each case a virtual 3D world that recreates each space has been designed and created offering the possibility to interact and simulate all the services provided by the middleware.

4.1. MetalTIC - Digital Home

This version shows the three-dimensional representation of MetalTIC – Digital Home[3], which is a smart laboratory and demonstrative facility for innovation, designed and developed by the Domotics and Ambient Intelligence research group for the Federation of Metal-working firms in the Province of Alicante [21].

This house has many interconnected devices from different brands and using different control protocols. The virtual representation simulates that interconnection and permits visualizing the devices behavior in a realistic way. These devices are placed virtually at this application, around the different rooms. The appearance offered at the virtual representation of the MetalTIC – Digital Home is quite similar to the real laboratory (Fig. 6).

Fig. 6. Real and virtual views of metalTIC – Digital Home: kitchen, bedroom and living room.

4.1.1. Use of MetalTIC - Digital Home in the validation of inclusive designs. This laboratory has been used as living lab in the tests carried out within the INREDIS project[4]. Its main aim is to develop basic technologies that will lead to the creation of communication channels and interaction among people with special needs and the ICT environment.

[2] http://collada.org/

[3] http://web.ua.es/en/dai/metaltic-digital-home.html

In particular, we validated different interfaces for elderly and deaf people (Fig. 7).

Fig.7. INREDIS project testing at MetalTIC – Digital Home

4.2. DAI Lab

DAI Lab[5] (Fig. 8) is the research laboratory that the DAI group is building at the University of Alicante. DAI Lab is aimed to the training and research in home automation and intelligent environments, paying special attention to the monitoring of people and analysis of its behavior in private spaces, and efficient use of energy.

Fig. 8. Different views of both the real and virtual DAI Lab.

5. Conclusions

The motivation for this work is based on the consideration that the electronic equipment of a home is composed of many, very diverse and complex devices. The difficulties of handling systems with such characteristics can make them unusable or prevent use them properly. The problem is especially acute in the case of persons with disabilities.

Given the obvious desirability of moving in the direction of normalizing operational interfaces in automated homes, the proposal we have developed in DAI VIRTUAL LAB considers all actors involved in the technology of these systems including the design engineer, the installation and maintenance technicians and users, regardless of their sensory, physical and intellectual skills. Another complicating factor is the diversity of industries, facilities and services (comfort, security, safety, energy management, communication, leisure, autonomy, health, administration, etc).

To conceive DAI VIRTUAL LAB, we started from a functional definition of the inclusion of people in their environment in terms of a communication system, which facilitates the characterization of the interface in order to obtain its functional specification. The design decisions were that the interface for home services consists of a virtual three-dimensional model of the dwelling that incorporates the control panels of the devices. This has allowed us to structurally specify the virtual models, i.e. determine the modules that make them up and which is the organization of these modules.

Taking into account that the structural specification of the models is precisely the output that DAI VIRTUAL LAB should produce, particularized for each dwelling, it has been possible to design the system for generating virtual models.

The main applications of DAI VIRTUAL LAB are:

- Support to the engineers of automated homes in making design decisions and simulating the installations in order to virtually validate the operating results before making the investment in equipment and install it;
- Provide a universal, consistent and intuitive user interface to manage and control the home through web services; and
- Create new channels of interaction between users and the various technological devices and services present at home. The developed system allows automatic customization of interfaces according to the needs, the functional preferences of the user and the technological capabilities of the device he/she wants to interact with.

Use cases discussed in this work demonstrate that DAI VIRTUAL LAB meets our expectations as a universal interface for the design and operation of inclusive automated homes.

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4 http://www.inredis.es/

5 http://web.ua.es/en/dai/dai-lab.html

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