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XPlaces: An Open Framework to Support the Digital Living at Home

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***Abstract*— In this paper we describe our research in the design and evaluation of novel interaction techniques for pervasive computer technology at home. We particularly focus on supporting every day life by the means of an open source, multi-platform framework called XPlaces (eXtensible Places) designed to enable interactive applications for several environments. Its main aim is to give to the ambient the role of a medium able to hide technological complexity implicit in everyday objects and to make easier people activities encouraging interaction with services and applications. It is primarily concerned with the human aspects of ubiquitous computing, applied to enhance the possible interactions between people and the technologies blended with an ambient. This paper is organized as follows: first we present the idea and the motivation behind the framework. Then, the architecture and the models for interaction are described, followed by integration issues of the current XPlaces specification. Finally we discuss some observation and conclusions.**

Keywords-component; Multitouch, Tangible, Interactive, I-TV, Gesture, Bare-Hand, Mediacenter, Domotics.

I. Introduction

Digital home services are the most recent home environment in which people can receive various services including remote education, home automation and multimedia at any time and in any place by accessing all kinds of information and electronic devices through wired and wireless home networks [1]. These kinds of services can be inclusively understood as digital home services, but frequently present insuperable conflicts that must be addressed with ad-hoc solutions. We are constantly faced with challenges such as information overload, attention demanding tasks and unusable interfaces that frustrate the efforts made to achieve one's goals. While traditional HCI research deals with measurable quantities such as usability, error rate and task completion, new concepts like user satisfaction, social acceptability, emotional design, are imposing themselves to attention as they play a crucial role in the overall user experience [2,3,4]. Also the experience of designing real-world objects for everyday use has a lot to teach us about how to design usable interfaces. In our research the computer is regarded to as an augmenting element of the environment. It disappears as a device and is almost "invisible" but the functionality is ubiquitously available, and offers intuitive, personalized and unobtrusive interaction by providing seamless interoperability of services and applications. The use interface is blended with the ambient, the interaction among people and appliances takes place in the physical environment, is captured by specialized devices described below, and, if needed, processed before being routed to the appropriate actuators. This approach has implications on the design of the computing infrastructure since the Digital Home must easily and naturally integrate devices ranging from tiny sensors and actuators to hand-held information appliances. The connectivity between multiple devices in the home networks opens new distribution channels for content, services and applications. The diversity of devices in the home networks requires a new networking paradigm where the infrastructure is self-adapted to the needs of the devices. In the following sections the rationale behind XPlaces framework is explained in the context of Human-Computer symbiosis.

II. Motivation

A key aspect of our research is the design and evaluation of the interaction among people and appliances in the environment where they are installed, either if it a private or a public place, i. e. a house, an office, a museum and so on. These appliances grow in complexity and sophistication, they become harder to use, particularly because of their tiny display and limited keyboards. This involves rethinking the place in terms of a complex system of interconnected agents that cooperate continuously (and maybe unconsciously or instinctively) during everyday life. The challenge is to develop an intelligent environment which is at the same time "active" and "non invasive". Active because it has to effectively support the person, non invasive because the actions performed by the system should occur pro-actively and only when they are beneficial to the assisted person. We investigate how actions based user interaction can support and improve everyday life in an " eXtended Places".

The large majority of appliances expose to the user an interface modeled after one of the following:

1.switch based user interface: these include light switches and variable intensity switches like boiler and refrigerator regulators, water taps and gas knobs;

2.program based user interfaces: these include ovens, washing machines, and other appliances for which the user has to initialize a (usually small) set of parameters that define the behavior of the device;

3.WIMP like user interfaces: these include of course home computers, but also video recorders, TV sets, smart phones, etc. in which the pointing device is generally replaced by a 5 Way navigation key.

Although some have undergone more than a century long evolution, all these are far from perfect, as shown in [5]: the simplest switch based user interface often lacks the basic properties of visibility and functional mapping. Additionally, a higher complexity in the user interface often corresponds to a greater frustration on the user's part. Typically the user tend to ignore most of the functionalities offered by programmable appliances, and only rely on a combination of two discrete or continuous variables to set the behavior: temperature and timer for ovens and heating systems, load and water temperature for washing machines, etc. This behavior can be explained in terms of epistemic actions [6], i. e. actions that are executed on the environment in order to gather information about it and put the user in a better cognitive state for the achievement of a specific goal. By example consider a multiple light switch: in general there is no clear mapping that binds a switch to the corresponding light: people, even after years practice, will often rely on the simplest strategy: try all the switches until you find the right one. Several clever solutions to this problem can be imagined, arranging the switches to reflect the positions of the lights in the room (i. e. expose an explicit mapping), but in practice the simplest strategy happens to be the more effective for several reasons:

1. it works anywhere: that is, predictability is often better than efficiency;
2. it doesn't draw attention on the interface: the operation of turning all the lights off can be performed without thinking, just as a sequence of automatic actions;
3. it allows the formulation of goals in terms of vague and alternative configurations, that is: acting on a given switch may put the room in a state that, although not optimal, could be considered acceptable;
4. when a strategy to achieve the goal is not known, it helps to reach a convenient state from which one can foresee the solution of the problem, i. e. after trying all the switches the desired lamp doesn't turn on, it may be burned; if no one lamp turns on, may be due to a blackout.

By contrast, pragmatic actions are those executed according to a predetermined strategy as a sequence of steps towards a goal: pragmatic actions are planned in the head before being executed, where epistemic actions are performed in the world in order to get clues on its state and on the path that leads to one's goal. However there is a practical limit on the number of variables that can be considered: switch number & switch status, temperature & time, etc. When the number of variables grows, their possible combinations are too many to be explored and the strategy must be carefully planned, which in many cases requires a cognitive overload in terms of attention and memory, and leads to frustration on failure. The interaction model of XPlaces Framework is designed in order to give (whenever possible) a predominant role to epistemic actions (from here onwards simply actions). In our view this is the first step towards an eXtended Place, able to concert the functions of all kinds of standalone equipment and subsystems in the home so that mutual communication is possible. The second step would be to have the environment, in this case the (eXtended) Home, act as a facilitator for people's life instead of as a barrier. Encouraging communication among the different systems would greatly simplify many tasks that, as today, require time and mind consuming operations on the user's part. Integration also means that one and the same operating system can operate a variety of equipment.

III. Framework Architecture

The purpose of this framework is the design and the development of interactive living/working environment, provided with integrated information and communication technology to best satisfy people needs, thanks to an active and no-invasive synchronized orchestration. The eXtended Places could easily and naturally integrate devices ranging from tiny sensors and actuators to hand-held information appliances, able to configure, install, diagnose, maintain, and improve themselves. Technically xPlaces is a message oriented middleware written in ISO C++ based on linux distribution. Its main components are Box, Board and Device. More specifically an Device could be a Sensor, a Viewer or an Actuator, as a consequence box and board could have different purpose as it is better described below:

- Sensor Box [SBx]: is an hardware device provided with a minimal linux installation and IP connection. It is connected to a SBd or an S via /dev/tty.
- Sensor Board [SBd]: is a microcontroller board that hosts a sensor and provides its measurements in the proper format. It is connected to an SBx.
- Sensor [S]: is the component that convert physical parameters to electrical signals. It could be directly connected to a SBx or an SBd.
- View Box [VBx]: is an hardware device provided with a minimal linux installation and IP connection. It is connected to a VBd via /dev/tty.
- View Board: [VBd]: is a board that acquire and convert a video signal. VBd and V could be integrated in a single device.
- Viewer [V]: is a device able to play videos and images (e.g. TV, video projector, monitor). It could be directly connected to a VBx. V and VBd could be integrated in a single device.

- Actuator Box [ABx]: is an hardware device provided with a minimal linux installation and IP connection. It is connected to a ABd via /dev/tty.
- Actuator Board: [ABd]: ABd and A are usually integrated in a single device.
- Actuator [A]: is a device able to convert an electrical signal in a physical quantity that is usually meant to be an action in the physical world (e.g. a movement). ABd and A are usually integrated in a single device.

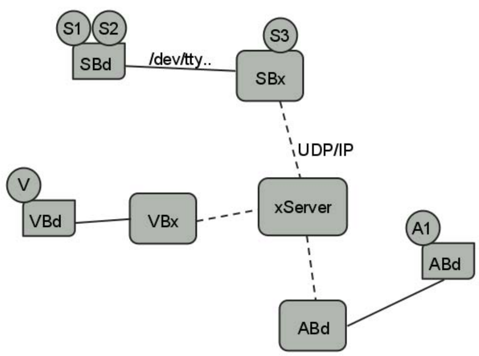

Figure 1. An Example XPlaces Architecture

Such technology enables data collection and processing in a variety of situations, for applications, which include environmental monitoring, home automation and entertainment, interactive showcase and so on. Building an XPlaces application just means to connect devices (sensor, actuator, viewer) and to implement most appropriate behaviour for a specific scenario.

IV. Implementing Alternative User Interfaces for Everyday Activities

We can identify many types of subsystems in a modern home, each one doing its own job, but with little (if any) mutual communication. They are all standalone systems. Finally, we note that the user friendliness of many systems and equipment leaves a lot to be desired. If we want to live flexibly and comfortably, we need something else that provides this flexibility, better comfort and greater ease of use. A possible solution to provide such flexibility are the Tangible User Interfaces (TUI) [7]. TUIs exploit physical objects to control the state of digital data: the physical control is coupled to its digital model to grant easy access to the model's functionalities. They represent a growing and increasingly popular research that encompass ergonomics, psychology and cognitive science, robotics and try to fill the gap among physical world and digital objects by letting the user manipulate directly the latter. The peculiarity of TUIs are that:

- the interaction takes place in the physical space; instead of manipulating graphical entities that represent digital objects, the user manipulates objects themselves;
- the interaction and its effects on an artifact happen at the same time and in the same place
- the interface encompasses the state of the model, i.e. the user interface is not meant to represent the state of the system, but rather the interface is the state of the system.

Into XPlaces framework, we focus these concepts exploring several kind of TUIs:

A. The House Cube

The "HouseCube" is a cubic tangible user interface developed for one-handed control of domotics appliances in a home environment. Cubic user interfaces have attracted many researchers in the field of pervasive computing. Cubes are largely exploited in the development of TUIs due to their properties of affordance, stability, symmetry (see for example [8] and Terrengi and Kranz [9]. Looking at the XPlaces architecture, the House Cube is a sensor box. It is a handy plastic cube, just big enough to contain a wireless sensor system, an embedded PIC microprocessor and a three orthogonal axis acceleration sensor. The system is networked with the environment with a unreliable RF communication channel (ZigBee). The data sets we used for classification were gathered with the three orthogonal axis acceleration sensor. The sensor readings are transferred via ZigBee to the actuators present into the eXtended Place. The sensor data we use as input for the classification system is captured from a user who performed gestures with the cube in his hand. By performing gestures, the user controls a set of lights, each face of the cube is related to a specific lights scenario, when the face is up the scenario is loaded by the framework. By example is possible to set up a romantic atmosphere dimming the lights and playing a soft music just rotating the right face, but it could also have more noble purpose in case of elderly people, making easier to access to the complex functionality of a video chat. See [10].

B. The House Booklet

Another experimental TUI powered by XPlaces, is the "House Booklet" a paper book who's pages act as controls for the playback of digital services in the house. In our prototype a digital camera hidden behind the TV screen the booklet and reacts to page changes. As shown in Fig. 2, each page of the book bears a visual tag that encodes the page number. The recognition of such tags is performed by means of the reacTIVision framework[11], which is capable of distinguishing several hundred different tags, their position in the frame and rotation on the plane. Whenever a new tag appears (the user turns a page) the related service starts. In the example of Fig. 2 a photo album from Flickr [12] is loaded into the Television screen. Looking at the XPlaces architecture, the Television screen a view box, and the camera is a Sensor Board. This approach minimizes the adoption barrier for people with limited IT knowledge.

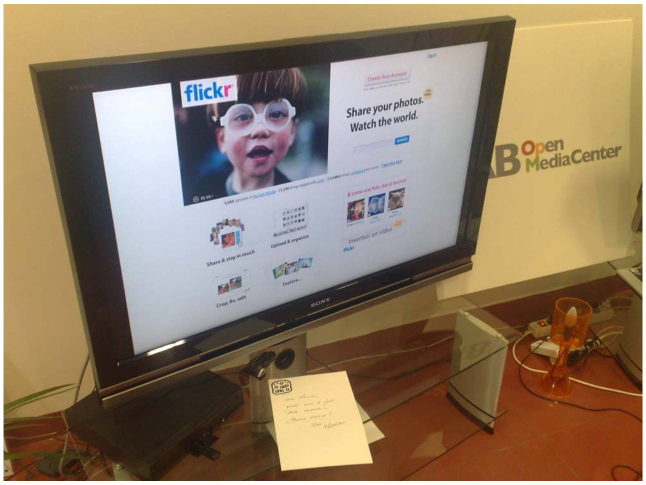

Figure 2. The House Booklet used to load a Flickr album into the Television Screen.

By example, elderly people will be able to follow at home the procedure established to obtain a service carried out through the TV Platform. Clearly, a constraint for the system to function is that the booklet must stay under the camera. But thanks its modularity the framework support several cameras into the house, so it is possible to implement different scenario and behaviour for the XPlaces Boxes.

V. Observation and Conclusion

Smart home's goal is to improve the quality of life but lacks play against it. The most relevant are incoherent and excessively complex metaphors (such as the adoption of WIMP style interfaces in TV sets), lack of interoperability among appliances, lack of visibility and predictability on the effects of controls. The purpose of XPlaces is to dismantle those barriers, giving to the home environment the role of a medium able to hide technological complexity implicit in everyday objects and to improve confidence of people with technology. We have shown how action based user interaction can successfully handle complex interaction tasks in the Digital Home. Actions are executed by the user on the environment in order do get a better understanding of the problem and reach a goal with less cognitive effort and with better satisfaction with respect to typical command based interaction. The user operate on digital objects through direct, bare hand manipulation, intuitively and with less cognitive effort with respect to analogous WIMP based applications. The underlying sentiment is often that the

added dimension of handling and touch will inherently lead to more

efficient and satisfying interfaces. Our work will consequently concentrate on understanding gestures as components of human (computer) interaction, in order to define practices and guidelines to inform our analysis of interactive systems. Facilitating the tedious activities in the use of Internet, enabling people to connect, navigate and consult any information just handling a familiar object, eliminating the use of the mouse and the need to open applications and introducing information in order to get where people want. However nowadays, the framework is still under development, and we are experiencing that the effect of

mediated touch can be positive or negative, depending on

context. Much as touch in the real world, mediated touch is a psychologically complex phenomenon, requiring careful consideration before use. More work is clearly

necessary before a set of guidelines for applying mediated

touch can be developed, but the prototypes we developed (House Cube and House Booklet) will serve as a

starting point for future investigation.

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