In the 6th International Conference on Intelligent Environments (IE'10), Kuala Lumpur, Malaysia. 19-21st of July 2010

Decloaking Big Brother:

Demonstrating Intelligent Environments

J. Dooley, M. Davies, M. Ball, V. Callaghan, H. Hagras, M. Colley, M. Gardner
University of Essex
vic@essex.ac.uk

***Abstract*—In this short conceptual paper we explore the need for demonstrations of intelligent environments research that can convey what we as researchers think to potential users that have limited exposure to such ideas. This is especially important where physical and virtual worlds meet in the smart home context. We present several exemplars that are intended to promote user understanding through the use of mixed reality technologies.**

Keywords-component; intelligent environments, mixed reality, demonstrating science, public engagement, virtual worlds

I. Introduction

For many years now, the vision of ubiquitous computing research has aspired to augment the world around us with technologies that recede beyond human perception into the background of our everyday lives [1] [2]. This covers a multiplicity of problem domains too numerate to list, thus demanding that the successful *"ubicomp"* practitioner be skilled in hardware, software, networking, and overall systems engineering. Consequently, people that work in this area have a *"minds-eye"* that can conceptualise these intentionally invisible technologies and the relationships between physical, virtual and conceptual entities. Discussions with colleagues over a meal, coffee or a beer are typically sufficient to communicate the intricacies of certain problems, projects and musings; Common is the conversation that starts with *"wouldn't it be cool if…"*, or *"I've found an awesome way to…"*. However, end users that have not acquired this minds-eye view are ill equipped to understand these technologies and their consequences. Thus their ability to recognise the scope of application within their lives is reduced. This is especially true when their views are negatively skewed by media influenced preconceptions of "*Big Brother*" watching their every move [3] or free-thinking *"psychotic"* computers (e.g. *"The Tower"* or *"2001: A Space Odyssey"*) / malevolent robots (e.g. the works of Isaac Asimov, or the *"Terminator"* series), which take negative actions towards humanity.

Complex explanations are often required to illustrate scenarios that involve bespoke technologies, multiple components, or mechanisms that work over days, months or even years (e.g. intelligent agent learning). The problem of this technology being invisible is most strikingly communicated by the EU's *"Disappearing Computer"* initiative [4] that had the laudable aims, of making technology invisible to the user, but ironically made it more difficult to visualise (and promote).

For some time now, we have faced similar difficulties in effectively demonstrating our iDorm [5] and iSpace [6] [Fig. 1] based work to various audiences. Ranging from *ad-hoc* events that promote Science and Technology to the public, through high-ranking technologists from funding bodies and ambassadors from potential collaboration partners. More recently, in our group, a flurry of demonstrations to small groups of people (~10 in size) have prompted us, as active members of the Intelligent Inhabited Environments Group (and ubicomp community at large), to look more closely at the way in which we can make our research more readily accessible to people that have limited exposure to technology in general.

Figure 1. The iSpace.

Therein lies a recurring and fundamental problem: How can we, as ubicomp researchers, effectively demonstrate the invisible technologies on which we work? A demonstration / presentation must allow potential end users to quickly comprehend the basic paradigms behind our work and overcome any dystopian preconceptions they may have, all in a very short time frame (often little more than fifteen minutes).

The broad field of research and development has been plagued by this kind of problem for many years. For example Henry Ford is famously quoted as saying: *"If I had asked people what they wanted, they would have said faster horses"*, while Arthur C. Clarke eloquently states his third law: *"Any sufficiently advanced technology is indistinguishable from magic"*. More recently in the ubicomp area, Brian Johnson (of Intel) has been actively promoting the use of immersive science fiction stories as *"idea tools"* that prototype future technologies some 10-20 years away.

So how can the *"magic"* of these invisible technologies be *"decloaked"* to permit end users to peer into our worlds? This paper constitutes the product of our recent efforts and promotes mixed reality manifestations of concepts like agents and virtual appliance composition.

II. MODEL

The tangible computing devices, that populate the spaces we wish to demonstrate, are interconnected by a pervasive network and interact according to the protocols / abstractions of a common *"middleware"* software layer [Fig. 2]. Through this middleware, applications and agents can access physical and virtual worlds, while bindings are established that allow surrogates of physical entities to manifest in the virtual worlds.

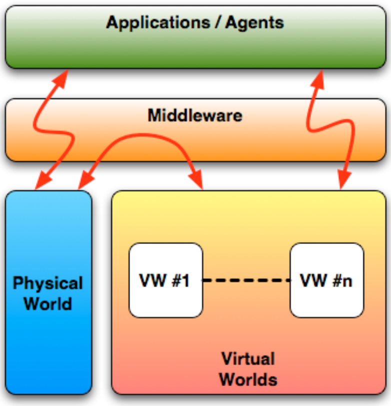

Figure 2. The interconnection of worlds.

The fidelity of worlds that model each other is achieved through the bi-directional flow of information through middleware that reflect changes (e.g. switching on a light in the physical world is reflected by a surrogate in the virtual world).

Virtual worlds have numerous advantages over physical worlds; a) As software, they are portable and so can be used in / from multiple locations b) they can be quickly modified to suit an experiment or demonstration, whereas high time / resource costs may be incurred to modify a real environment; c) Multiple instances can be created and run simultaneously to compare the effects of different technologies and / or agents; d) they can show information that would be otherwise invisible (e.g. the field-of-view of sensors, or a heater radiation area).

As part of our mixed reality architecture, the virtual worlds are constructed using *RealXtend (realxtend.org)* (a derivative of the *OpenSim* project: *opensimulator.org*) and are designed with simulated counterparts for every physical device in our iSpace test-bed, (some of which are based on models from the *Google 3D Warehouse*). When functioning together the two worlds create a *"Mixed Reality Intelligent Environment"*. We use the term *"mixed reality"* as, depending on the viewing perspective, we believe our system could be placed into either the augmented reality, or augmented virtuality sub-categories of Milgram's *"Reality-Virtuality Continuum"* [7] [Fig. 3]. Several exemplars are provided later in this paper for which Fig. 3 shows an approximate location.

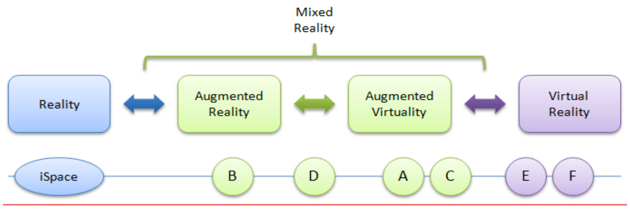

Figure 3. Milgram's Reality-Virtuality Continuum.

Additionally, our virtual world serves as a hub, providing access to different iSpace instances, each hosting a different array of technologies and / or agent designs. Users are free to focus on the individual research featured in a specific instance or roam around different instances and thus perspectives.

III. EXEMPLARS

Herein this section is a catalogue of lucid demonstrations, allowing audiences to experience some of our current and future ubicomp research concepts. These scenarios are intended to facilitate the comprehension of intelligent environments, by people with varying levels of previous exposure. The exemplars presented here can be adapted by the ubicomp community to present other elements of technology.

A. *Overcoming the Constraints of Physical Environments*

When a building is constructed an electrician is employed to install circuits throughout the environment, creating physical chains of related devices, sensors and actuators. These objects have no ability to control those on different circuits in the environment as there is no physical connection between them. For example; Switch A is on a circuit with Binary Light A, so can be used to control the state of this device. However, Switch A has neither control over the dimmable lights in the same room nor any other binary lights in the environment.

One of the key benefits of a virtual world is that it doesn't have to be limited by the constraints that naturally exist in a physical environment. This premise has recently been utilised in the demonstration of a virtual world that models our real iSpace [Fig. 4]. The mixed reality architecture was demonstrated to a group of potential end users in the iSpace, with the virtual components being displayed on large, wall-mounted, touch-screen displays.

Figure 4. The Virtual iSpace Demonstration World

The first stage of the demonstration focussed around a collection of eight dimmable spotlights that each existed in both the real and virtual worlds. Without the need for a physical switch, we demonstrated computer control of mixed reality devices; by *"clicking"* on a virtual spotlight, there is an incremental illumination of both physical and virtual lights.

Secondly, we presented a switch actuator that existed in both the physical and virtual worlds. The physical switch was connected to a circuit with two binary lights mounted on the ceiling of the iSpace, (amongst the spotlights). We demonstrated how the physical switch was able to change the state of these binary lights. We then returned to the virtual component of our mixed reality world and clicked on the counterpart switch, which caused both binary lights to turn on, along with all the previously used spotlights and a pair of X-10 controlled floor lamps that were also located in the room. We explained that despite the lights existing on three completely different and unrelated circuits, through our virtual world and some programs we had added, it was possible for a user to customise the environment to create controllers for chains of devices that would be impossible in the physical world. We also pointed out that the virtual world had remembered the individual spotlight levels that had been set in our earlier demonstration. Other devices could also have been included in the chain, such as a nearby HVAC unit and a television (these were independently demonstrated by *"clicking"* virtual world counterparts, in the same way as the spotlights).

B. Embodying Virtual Appliances & Applications

One vision for the nature of future appliances and applications is that they will be constructed from aggregations of elementary network services [8]. The vision is based on the possibility of *"deconstructing"*, logically, conventional home appliances such as TVs or Word-Processing packages into their elemental functions which may then be combined in novel ways with other deconstructed services to generate virtual-appliances and virtual applications of a person's own choosing. Further, the descriptions of these virtual entities are encoded in soft objects using ontology and rules. However, these concepts of virtual entities can be somewhat abstract and difficult for non-technical users to grasp. Hence, to aid people in understanding how virtual appliances can be constructed, we can use the iBox (described later in this section) to demonstrate this in the real world by allowing users to simply "*plug in"* different services to create a single appliance. Using a physical representation of a virtual appliance in this way can make it easier for many users to envision the disaggregation of more conventional appliances. We can also allow users to construct virtual appliances and applications in the simulated world by dragging-and-dropping devices into a virtual iBox (using traditional GUIs or more advanced touch screen / intelligent surface interfaces), thus encouraging people to experiment in their own creative way and come to terms with the concepts of virtual appliances.

The iBox is a physical representation of a virtual appliance and consists of a box that contains an embedded computer and has a large button situated on top. Four ports exist around the periphery of its upper surface that allow building blocks to be literally plugged in. When a block is plugged into a port, a unique block-id is communicated to the box by shorting electronic contacts (cheaper than using RFID or a microchip in each block). These block id's are associated with entities in the physical or virtual worlds (for example lights). By virtue of physically plugging a block into the box, the associated entity is plugged into the virtual appliance, thus providing a metaphor through which users can physically construct and reconfigure virtual appliances.

A fifth port (of different shape) exists on the box into which blocks that represent agent entities can be plugged. Upon pressing the inviting *"go"* button on the box, the virtual appliance is activated and the agent is configured with the four associated entities (that can be either inputs or outputs). Our basic example scenario is that of a light agent, where several agents of varying autonomy / learning ability can be plugged in and associated with either light sensors, light devices, human inputs (such as switches) or homogenous groups thereof (so a block that represents a light group can be plugged in).

C. Avatars as Methaphors for Embedded-Agents

How and by whom intelligent environments are managed and controlled is a critical issue that directly affects how users form their attitudes towards ubiquitous computing systems. Some researchers believe that embedded-agents controlling an intelligent environment should only act according to the explicit commands or programming issued by the user, while others maintain that equipping embedded-agents with autonomous learning capabilities is more beneficial to the user, as it greatly reduces cognitive load, and other researchers suggest that a more ideal approach is to provide a dynamic approach allowing the user to choose how their intelligent environments are managed [9]. We define an embedded-agent as being a software control process that includes some elements of reasoning, planning and learning that we associate with intelligence in people. Whether a system relies on embedded-agents completely or only exploits them to a certain degree, the notion of an invisible, intelligent creation being able to act and monitor us in such a personal environment as the home engenders fear in many people. To overcome such preconceptions, demonstrating the autonomous aspects of intelligent environments in an easily understandable way is vital. In previous experiences of explaining embedded-agents to others, we have found it very helpful to use the analogy that *"an embedded-agent can be regarded as a trusted and helpful friend, integrated into a system"*. An avatar is a perfect way to illustrate this helpful friend.

In our demonstration we allow users to witness the actions of agents in the virtual world rather than just effects of their actions in the physical environment. For example, if an embedded-agent was to turn on the heater on a cold day, this could be visualised with an avatar performing the action in the virtual environment (i.e. the agent would walk to the virtual heater and take an explicit action there, [Fig. 5]).

Furthermore, to demonstrate an agent's sensing capabilities an avatar could be used to visualise an embedded-agent monitoring the user and the current state of the environment; for example, an avatar could be seen to measure the temperature or imitate an action of the user (possibly visualised by the avatar reading the temperature off a thermometer in the virtual world and recording the data on a clipboard).

Figure 5. An avatar representing a heater controlling agent

D. Interpreting Sensor Networks

Another benefit of incorporating mixed reality technology into an intelligent environment is that it can augment the physical world by providing a visual reference for sensor information that is not directly perceivable. For example, the iSpace has been outfitted with a *"Ubisense"* radio-tracking system. Through this, the real-time three-dimensional position of *"tagged"* objects / inhabitants can be known. This sensor grid has been divided into several sub-spaces, each based around key areas of the household environment, (e.g. kitchen, living room, etc.). Each of these *"regions"* has a specified size and shape, whenever the system detects a radio tag enter or leave its bounds an event is triggered. With the virtual component of the mixed reality iSpace, we can visually display the position of each active region in the environment and its current state by precisely marking the boundaries. In addition to being able to demonstrate what regions are, where they exist and how they function in the environment, the mixed reality architecture also allows users to easily determine which region they're currently located in or moving to at any given moment, (something that might not be easy in a physical environment where regions aren't marked). Using a virtual world also eliminates the need to reduce the realistic presentation of the real household environment by placing physical reference markers that may cause damage or confuse potential users.

E. Revealing Middleware Connectivity and Protocols

Unlike the physical world, middleware abstractions permit entities in the virtual world to be decorated with a wealth of information that describes them and their state [11] (e.g. the conceptual groupings to which an entity belongs). There is a wide scope for providing many mixed reality queues to reflect such a wealth of information. For example *"virtual wires"* in the virtual world can be used to plug together compatible entities into virtual appliances. Colour and shape can be used to indicate compatible entities (as imposed by protocols) and virtual protocol adapters used in between entities. Message exchange / information flow can also be visualised.

F. Temporal Variance of Virtual Worlds

Originally intended as a way to prototype some processes and methods that in the real world take a long time (weeks, months or even years), the virtual world can be used to visualise time at a faster rate than it would occur in the physical world. For example the learning process of an agent over the past year (or as simulated and predicted for the future year) can be visualised in a few minutes [10]. Similarly this technique can be used to slow time down and allow the observation of things that in the real world occur too fast for human perception (e.g. seeing the actual event order when they appear simultaneous).

IV. SUMMARY

In this short paper we have discussed the problems that researchers face when trying to demonstrate the hidden and abstract technologies associated with Intelligent Environments. We explained that part of the difficulty lies in the goals of this research area which seeks deliberately to make the technology disappear; the most striking illustration of such intent being the EU's Disappearing Computer Programme whose name perfectly describes the dilemma being faced by those wishing to demonstrate the technology. We have proposed an approach to remove the cloak of invisibility by augmenting intelligent environments with a virtual reality lens, allowing hitherto invisible technological aspects of environments to be revealed which we hope will prove useful to the wider intelligent environments community, and help support the efforts of researchers to make their work accessible to the general public.

REFERENCES

[1] M. Weiser. "*The Computer for the Twenty-First Century*", Scientific American, pp. 94-10, September 1991.

[2] T. Hoare and R. Milner. *"Grand Challenges for Computing Research"*. The Computer Journal. Vol. 48, no. 1, pp. 49–52. The British Computer Society:London. 2005.

[3] G. Orwell. *"**Nineteen Eighty-Four",*** Secker and Warburg, 1949.

[4] N. Streitz and P. Nixon. *"The disappearing computer"*, Communications of the ACM archive, vol 48, no. 3, March 2005.

[5] A. Pounds-Cornish and A. Holmes. *"The iDorm - a Practical Deployment of Grid Technology"*, 2nd IEEE International Symposium on Cluster Computing and the Grid 2002 (CCGrid'02).

[6] V. Callaghan, G. Clark, M. Colley, H. Hagras, J. Chin and F. Doctor, *"Intelligent inhabited environments"*, BT Technology Journal, vol. 22, no. 3, Springer Netherlands, July 2004.

[7] P. Milgram and A.F. Kishino. *"Taxonomy of Mixed Reality Visual Displays"*, IEICE Transactions on Information and Systems, vol. E77-D, no. 12, pp. 1321-1329, December 1994.

[8] J. Chin, V. Call*aghan and G. Clarke. "Soft-appliances: A vision for user created networked appliances in digital homes*", Journal of Ambient Intelligence and Smart Environments (JAISE), vol. 1, no. 1, 2009.

[9] M. Ball, V. Callaghan, M. Gardner and D. Trossen. "*Achieving Human-Agent Teamwork In eHealth Based Pervasive Intelligent Environments*", Int. Conf. on Pervasive Computing Technologies for Healthcare 2010.

[10] M. Davies, V. Callaghan, and L. Shen. *"Modelling pervasive environments using bespoke & commercial game-based simulators"*, Int. Conf. on Life System Modelling and Simulation 2007 (LSMS '07).

[11] J. Dooley, V. Callaghan, H. Hagras and P. Bull, "Discovering the Home : Advanced Concepts". Int. Conf. on the Applications of Digital Information and Web Technologies (ICADIWT). August 2009