iWorlds: Building Mixed Reality Intelligent Environments using Customisable 3D Virtual Worlds

Marc Davies, Vic Callaghan

Digital Lifestyles Centre
University of Essex
Colchester, United Kingdom
{midavi, vic}@essex.ac.uk

Abstract—**This paper summarises our research into creating mixed reality intelligent environments, specifically focussing on the quality and realism of the virtual components. We start with a description of the benefits of using virtual worlds as tools for intelligent environment research, highlighting the various categories of virtual world used by recent projects. We then provide a strategy for creating a high-detail three-dimensional world, to use as the virtual component of a mixed reality intelligent environment, resolving restrictive issues such as cost and experience in programming detailed graphics. Finally, we discuss the potential benefits of incorporating technologies from online computer games into the simulations.**

Keywords- virtual worlds, simulators, mixed reality, video games, pervasive computing, intelligent environments.

I. INTRODUCTION

A. Virtual Intelligent Environments

Virtual Worlds have long-since become a common tool for researchers of intelligent environments. Often used in a mixed reality context, they provide a convenient mechanism interfacing with real-world devices and/or exhibiting the influence of agents. A virtual world doesn't have to follow the same rules as a real environment, meaning they can be used to augment the functionality of physical devices to allow actions, or reveal relationships that otherwise would be impossible, (e.g. turning on a light using a switch wired to a completely different circuit, showing a virtual appliance, etc).

The quality of the virtual world used in a project is often determined by its function in the intelligent environment. While technically not a virtual world, some projects may limit the computer-generated component of their mixed reality test-bed to a collection of windows on a computer desktop, each representing specific real-world devices, (as seen in [8]). Others such as the University of Texas' MavHome [5] and the MiRTLE project [3] have created complete digital reproductions of physical environments, with virtual counterparts to real-world devices. The visualisation of such simulations can vary greatly, according to the level of texture detail and number of dimensions used by the graphics modelling the environment and virtual devices.

B. How many dimensions?

Many virtual worlds simulating an intelligent environment use two-dimensional graphics, usually providing a top-down view of a building and its devices [7] [15]. However, the lack of a height dimension can restrict the range of environment devices that can be visualised realistically. Devices such as those fixed on walls or ceiling lights are rendered at the same level as objects on the ground, potentially creating issues such as hiding environment features, (e.g. through overlapping), or promoting misinterpretation by a user.

Using virtual worlds built with three-dimensional graphics clearly has advantages when modelling an intelligent environment. In the case of an intelligent building, using a three-dimensional simulation allows users to view the virtual world from a first-person perspective, rather than a top-down third-person view [5]. Alternatively a three-dimensional world could be viewed from a third-person perspective but from an angle placing the observer inside the environment, (as used worlds such as virtual meeting rooms [12]). Both methods take advantage of the immersive properties of a three-dimensional virtual world, increasing realism by providing the sensation of being in a physical intelligent environment. A realistic virtual world design could promote more natural interaction from users, allowing them to connect with the environment more easily, (e.g. because a chair looks like a chair). Naturally this assumption is contingent on the virtual world and any included three-dimensional devices all possessing a high level of realism, so even uncommon objects could be easily identified, as in a real-world environment. This principle creates several new issues, most notably that while a computer scientist may be accomplished in the field of intelligent environments they may lack the necessary skills to program an entire world of detailed three-dimensional graphics. Additionally, the time that would be required to individually program the graphics for each intelligent device and the world itself could become extensive, especially for complex environments.

Due to the added complexity when designing and building a three-dimensional virtual intelligent environment, it is understandable why researchers might choose the simpler two-dimensional graphics approach for their project. However, as will be described in the following section, it is possible to avoid all of the issues described above and rapidly create a realistic virtual intelligent environment with a minimal cost in terms of time and resources.

II. THE BEST OF BOTH WORLDS

When it comes to three-dimensional computer graphics perhaps some of the best examples can be found within the videogames industry. Popular modern videogames often have development budgets running into millions of dollars, with teams of programmers working on a title for several years before it is finally released. As we have highlighted in previous papers [6] [7] it is possible to take off-the-shelf copies of a videogame and re-program the software to represent an intelligent household environment. We also discovered several drawbacks such as much of the original game code being encrypted for security reasons making it impossible to edit. This problem was resolved using an open-source videogame graphics engine to create our own intelligent virtual world [6], but caused us to lose the ability to use the professionally designed device models, included in the original videogame, in our environment. A solution to this issue has since been found.

RealXtend [14] is open-source virtual world software, (programmed mainly using C# and Python), which we have modified to act as a platform for our latest intelligent environment simulation. A derivative of the *OpenSim* (a.k.a. *Open Simulator*) project [13], *RealXtend* is based on the code from *Second Life* [11], allowing us to benefit from the detailed graphics (i.e. realistic avatars and landscaping) of the popular online virtual world. As *RealXtend* is open-source we have complete access to modify any part of the software code.

While *RealXtend* by itself solved our problems for landscaping worlds and avatars, it didn't contain models for creating realistic three-dimensional intelligent devices to outfit our new environment. Nor did it possess a sophisticated enough set of editing tools to create a realistic building structure, (i.e. adding spaces for doors and windows). To overcome these issues we turned to two free services provided by *Google*, specifically the *Google SketchUp 7* graphics editing suite, and *Google 3D Warehouse*, a vast online repository of three-dimensional models created by people using *SketchUp*, most of which are also free to use [9]. The three-dimensional models from the warehouse could be converted into the OGRE mesh format used by *RealXtend* using a plug-in for *SketchUp*, (several are freely available online to download). The converted model files could then be imported into our *RealXtend* virtual world.

III. A MIXED REALITY INTELLIGENT HOUSEHOLD

Using *RealXtend* and a number of modified device models from the *Google 3D Warehouse*, we designed and built a three-dimensional virtual world to act as half of a mixed reality intelligent environment (Fig. 2). The virtual world layout was designed to replicate the University of Essex *iSpace* (Fig. 1), a purpose-built test-bed for pervasive computing research and the other half of our mixed reality environment [1] [2] [10].

The *iSpace* features a lounge, study, bedroom, and bathroom containing all the furniture and devices commonly found in a normal household environment. Additionally, numerous hollow walls and ceilings have been outfitted with a myriad of embedded-computer based technologies, including both sensors and effectors. All of the technologies used in the iSpace are wrapped into a generic OSGI UPnP framework.

Figure 1. The University of Essex *iSpace*

Figure 2. The Intelligent Household Virtual World

The contents of the virtual household were intended to appear as similar to the physical *iSpace* as possible. However this wasn't a requirement for the mixed reality world, as virtual object models could be almost any design. Therefore, a virtual device could appear completely different to a real counterpart, (e.g. a real telephone could be represented in the virtual world by a floating orb). Some devices in our world were a different design to real counterparts and/or positioned slightly differently to improve the appearance of the virtual environment.

RealXtend can be augmented through the addition of Python scripts adding advanced features into the default world. Most of these function by being attached to specific prims (objects) in the virtual world. Whenever the prim is interacted with it then automatically runs any part of the attached script code associated with the interaction method. Several sub-projects have arisen for creating these Python scripts, including a bridge allowing real-world X-10 enabled devices to be remotely controlled using virtual counterparts and vice versa. While the *iSpace* does contain X-10 devices they too are wrapped into and controlled by the generic OSGI UPnP framework. For this project it was necessary to develop an alternative bridge (based around a Socket client-server system), allowing us to remotely control *iSpace* devices using their associated wrapper commands, rather than through a direct interface. Our new bridge allowed us to manipulate and gain information from several different devices and sensors found in the real-world *iSpace*, (X-10s, Echelon LonWorks, Phidgets, etc.), through their virtual counterparts, using Python scripts.

Fig. 3 below shows the mixed reality set-up of the *iSpace* lounge area, (the large image of the virtual world is being displayed on the screen of the real touch-screen television in the two smaller pictures). Dimmable spotlights in the real lounge could be controlled individually, by clicking directly on their virtual counterpart, or collectively using the light switch model shown. In the real-world *iSpace* the counterpart to the light switch shown below actually controls the two large globe ceiling lamps, which are on a completely different circuit to the dimmable spotlights. The augmented functionality provided by the virtual components of the mixed reality world changed this, making it possible to control both sets of lights.

Figure 3. The Mixed Reality *iSpace* Environment

As *RealXtend* is based on *Second Life* the software has inherited the multi-user properties of an online virtual world, which have now been passed on to the virtual intelligent household environment. By allocating each occupant of the environment with their own client avatar the *iSpace* can be simultaneously inhabited by a collection of real and remote occupants, both of whom can manipulate the various intelligent devices on the network. By using the virtual world as a gateway, users could access and control intelligent devices in the real-world *iSpace* and see the state of the environment from anywhere in the world (via a computer with an internet connection). Additionally, third party agent programs could be attached to our bridge, connecting the *RealXtend* simulation with the OSGI UPnP framework of the real *iSpace*, allowing researchers to perform testing in the mixed reality environment.

IV. MASSIVE VIRTUAL INTELLIGENT ENVIRONMENTS

Massive Multiuser Online (MMO) virtual worlds have become increasingly popular in recent times. Online virtual communities, built around MMO architectures, have attracted audiences of several millions, (over 18 million registered subscriptions for *Second Life* as of January 2010 [11]). While many of these worlds are videogames with established plotlines others, such as *Second Life*, are strongly based around user customisation, where the world is built by people who use it.

Making a virtual intelligent environment accessible from across the internet would have numerous benefits. Depending on the size of the environment, it could allow hundreds of users to simultaneously access and interact with the world and its devices, allowing the creation of an intelligent community. These users could be based anywhere in the real-world, potentially allowing users from multiple age-groups and/or culture access to the environment.

In the case of our virtual intelligent household, users could each 'own' their own instance of the environment. Starting with a default empty house shell, users could customise their world by adding furniture and other devices from a provided catalogue or importing their own models from the *Google 3D Warehouse* or another source. Using mimicry researchers could store and then later import environment designs created by external users into test-beds for their projects, either by using the simulation in a stand-alone format or by linking the virtual objects to those in a physical *iSpace*-style environment using our bridge. The real-world environment could be modified to appear similar to the customised virtual world layout, or the physical devices could simply be used as an interface to their virtual counterparts, (the reverse of the set-up in many mixed reality projects). Additionally, real-world environments such as the *iSpace* could be augmented by including new devices, created from user customisation, which don't physically exist in the real-world test-bed. Virtual or soft appliances [4], composed of aggregated groups of real embedded computer services, which normally don't have a monolithic physical manifestation in real intelligent spaces, could be given one using virtual environments. By adding a set of OSGI UPnP wrappers to the *iSpace* system to control the new device it can be treated the same as any physical object on the mixed reality environment network, but executed only on the virtual-side.

V. THE NEXT STEP

Following further trials of a single mixed reality intelligent environment it is our intention to expand the world to incorporate multiple instances of the *iSpace* on the virtual-side, creating a community of online environments we refer to as an iWorld, (Fig. 4 shows an early prototype building). Each of these *iSpace* instances will contain an independently generated layout and inventory of devices, mimicked from a user of our MMO system, inherited from *RealXtend* and *Second Life*. The expanded world will be presented in the form of an iCommunity, with zones dedicated to different aspects of human life relevant to pervasive computer science research, (e.g. home-life, work environments, recreation, etc). Researchers, both locally and remotely will be able to work in this online space, 'owning' their own environments and, if they wish, collaborating with shared benchmarks, objects and other research oriented facilities, such as online code repositories, library resources or discussion rooms.

Figure 4.   An iCommunity building contining multiple *iSpace* instances

We also intend to continue taking inspiration from the videogames industry and its related technologies. We believe adapting videogame technologies into tools for researching intelligent environments shows great potential, offering multiple resources such as access to high quality three-dimensional virtual worlds and vast MMO communities of people who through their use and enjoyment of this technology could create a vast and valuable archive of evaluation data.

VI. CONCLUSIONS

In this paper we have discussed issues surrounding the use of three-dimensional graphics in the virtual worlds of mixed reality intelligent environments. We have presented a methodology for allowing researchers of pervasive computer science to easily create low-cost mixed reality intelligent environments utilising realistic three-dimensional graphics. This technology can be used to provide a low cost and highly flexible test-bed for prototyping pervasive computing technology, demonstrating pervasive computing concepts or for remote control. We described our previous research leading to the usage of this technique and how it was employed to add mixed-reality functionality to the real-world University of Essex *iSpace* environment. We have also described the bridging mechanism we used to connect our new *RealXtend*-based virtual environment with the physical *iSpace* devices.

Continuing on from the methodology description, we described how the underlying videogame technologies used by the *RealXtend* virtual world software could be exploited by a mixed reality intelligent environment. By providing individual users with their own personal copy of the virtual environment, different world designs could be generated. Using mimicry these designs could be stored and imported into the test-bed used by pervasive computer science researchers. This potentially provides the ability to perform research in a variety of different environments, or a set generated by a specific target group of users. We also described how mimicked intelligent environments could be used to augment real-world test-beds by introducing devices to the mixed reality world that had no physical presence and how the virtual environment could give a virtual embodiment to abstract or hidden entities.

Finally, we outlined our plans for the near-future, including the expansion of the virtual-side of the mixed reality environment into an iCommunity by putting the iWorld online.

REFERENCES

[1] V. Callaghan, G. Clarke, and J. Chin, "Some socio-technical aspects of intelligent buildings and pervasive computing research," Intelligent Buildings International Journal, vol. 1, no. 1, 2007.

[2] 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.

[3] V. Callaghan, M. Gardner, B. Horan, J. Scott, L. Shen, and M. Wang, A mixed reality teaching and learning environment, *Proceedings of the international conference on Hybrid Learning 2008 (ICHL '08)*, Hong Kong, Springer LNCS 5169, pp. 54 – 65, 2008.

[4] J. Chin, V. Callaghan and G. Clarke, "*Soft-appliances: A vision for user created networked appliances in digital homes*", Journal of Ambient Intelligence and Smart Environments (JAISE) Volume 1, Number 1 / 2009, pp. 69-75, ISSN 1876-1364, IOS Press.

[5] D. J. Cook, M. Youngblood, E. Heierman, K. Gopalratnam, S. Rao, A. Litvin, and F. Khawaja, MavHome: an agent-based smart home, *Proceedings of the IEEE international conference on Pervasive computing and communications*, pp. 521 – 524, 2003.

[6] M. Davies, V. Callaghan, and M. Gardner, Towards a mixed reality intelligent campus, *Proceedings of the 2008 international conference on Intelligent Environments (IE '08)*, Seattle, USA.

[7] M. Davies, V. Callaghan, and L. Shen, Modelling pervasive environments using bespoke & commercial game-based simulators, *Proceedings of the 2007 international conference on Life System Modelling and Simulation (LSMS '07)*, Shanghai, China, Springer, September 2007.

[8] M. Duller, R. Tamosevicius, G. Alonso, and D. Kossmann, XTream: personal data streams, *Proceedings of the 2007 ACM SIGMOD international conference on Management of data*, Beijing, China, ACM, pp. 1088 – 1090, 2007.

[9] Google, 3D Warehouse, *http://sketchup.google.com/3dwarehouse*, Retrieved: 22nd February 2010.

[10] IIEG, iSpace, *http://dces.essex.ac.uk/Research/iieg/idorm2/index.htm*, Retrieved: 20th February 2010.

[11] Linden Lab., Second Life, *http://secondlife.com/*, Retrieved: 15th February 2010.

[12] A. Nijholt, J. Zwiers, and J. Peciva, "Mixed reality participants in smart meeting rooms and smart home environments," Personal and Ubiquitous Computing, vol. 13, no. 1, Springer-Verlag, London, pp. 85 – 94, 2009.

[13] OpenSim, Main Page – OpenSim, *http://opensimulator.org*, Retrieved: 22nd February 2010.

[14] RealXtend, realXtend – Open source platform for interconnected virtual worlds, *http://www.realxtend.org*, Retrieved: 1st March 2010.

[15] T. Van Kasteren, A. Noulas, G. Englebienne, and B. Kröse, Accurate activity recognition in a home setting, *Proceedings of the 10th international conference on Ubiquitous computing (UbiComp)*, Seoul, Korea, ACM, pp. 1 – 9, 2008.