Towards Producing Artificial Humans for Intelligent Environments Research

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

***Abstract*— This paper and the accompanying video, (which can be viewed at http://www.youtube.com/watch?v=hW_xLSzrHjQ) present the current findings of a project researching how computer games and their related technologies could be adapted to create virtual and mixed reality intelligent environments. After describing the developed strategy and the methods of deployment used by the project, a new research focus for the project is introduced. A new mechanism, still under development, aims to produce artificial intelligence controllers for human non-player character avatars, which would be usable within a virtual or mixed reality intelligent environment to provide an alternative to real people during evaluations.**

Keywords- virtual worlds; mixed reality; intelligent households; artificial intelligence; research tools

I. Introduction

This paper reports on the current progress of an ongoing project. We start by briefly highlighting the major conclusions drawn from our investigations into how computer games and their related technologies can be used to create prototype and full-scale virtual intelligent environments. These iWorlds can also be further augmented by incorporating physical devices in a real intelligent environment in a mixed reality context and by exploiting inherited multi-user functionality from the computer game technologies used as a base for the virtual worlds.

A duel-threaded approach has been employed during the phase of this project focussing on virtual intelligent environments and their functionality. Firstly, several of the iWorlds developed have been used by different projects as tools for researching intelligent environments, including eLearning [7] [20] and web-based interface design for smart homes [8]. Additionally, the iWorlds were developed to provide an infrastructure to allow human-computer interaction within different intelligent environments to be observed and to evaluate designs for a new artificial intelligence system aimed at computer-controlled human characters in computer games.

Following our overview of the different categories of virtual intelligent environment developed during this project, we discuss our primary research focus, namely the artificial intelligence mechanism. Despite being aimed towards computer games the project mechanism may also possess potential applications to generate tools for aiding researchers of intelligent environments and designers of agent programs.

II. Virtual Intelligent Environments

A. *Modifying Computer Games*

Initially this ongoing project sought to answer whether it was possible to create realistic simulations of intelligent environments by modifying 'off-the-shelf' computer game software, which could be used as tools by researchers [7] [9]. The aim was to investigate a hypothesis that high-quality three dimensional virtual worlds created for modern computer games could be modified to allow the construction of realistic simulations of intelligent environments (iWorlds), which could be used to test agent programs and evaluate system architectures. The major benefit of such a strategy would be allowing detailed virtual worlds capable of exhibiting intelligent functionality to be created with a fraction of the time and/or budget required to build a completely bespoke simulation, such as those used by other projects (e.g. [3] [4] [5]). The strategy could also potentially allow researchers of intelligent environments, who may lack graphical programming skills, to build and customise worlds for their experiments. An investigation showed that although it is possible to create intelligent virtual worlds using this strategy, there are several drawbacks to using an existing commercial product as a base for such a system, for example;

- Modifications to the existing virtual world were mostly limited by the constraints used by the original game architecture, (i.e. available graphics models and included programming API methods).
- Being a off-the-shelf commercial product the original game contained several security measures such as encrypted data that greatly restricted how much code could be altered.

B. *Massive Virtual Intelligent Environments*

The next investigation of this project sought to overcome the limitations discovered when attempting to modify an off-the-shelf computer game [6] [8]. Here the focus also shifted from software designed to be run offline on a single computer to web-based alternatives, including Massively Multi-User Online (MMO) Virtual Worlds. Several different software packages are available online to freely download, each capable of building and hosting independent large-scale three dimensional virtual worlds using software originally developed for running computer games.

RealXtend [19] allows virtual worlds to be created using an augmented version of the code created by the Open Simulator (OpenSim) project, which itself was built from a modified version of the popular online community Second Life [16]. Programmed using a combination of the C# and Python languages RealXtend virtual worlds are accessed via a bespoke viewer application which is run on a client machine and used to connect to the central server for the world. An alternative to this approach is offered by the Open Wonderland, (formerly known as Project Wonderland) software [18]. Programmed entirely in Java, Wonderland virtual worlds can be accessed directly through a web-browser and run using Java Web-start.

Each of these pieces of software has its own merits, some better at performing particular tasks than others and vice versa. For example, when using Open Wonderland perhaps the most noticeable trade-off for the convenience of not requiring potential users to download and install a viewer application on their machines before being able to access the virtual world is a reduced graphical quality compared to RealXtend. Both pieces of software are capable of importing freely available three-dimensional graphics models from the popular online repository Google's 3D Warehouse [10], plus additional bespoke models can easily be created using the associated free Google SketchUp graphics editing software.

Originally the project virtual worlds focussed on single intelligent household environments. However, this was soon expanded to allow multiple instances of an intelligent household building to exist in a single iWorld. This set-up has the potential of allowing multiple different researchers to simultaneously use the same virtual world for their individual projects with each 'owning' a specific building that they can customise to suit their project requirements [8]. The possibility of collaboration between projects hosted within the same virtual world also exists as researchers effectively work alongside each other, despite not necessarily being part of the same institution or perhaps even located in different countries.

III. Mixed Reality Intelligent Environments

A. *What is Mixed Reality?*

For the purposes of this project, the term mixed reality reflects the category of Milgram's Reality-Virtuality (RV) Continuum, (Fig. 1) [17], which collectively describes any world featuring simultaneous elements of real and virtual content.

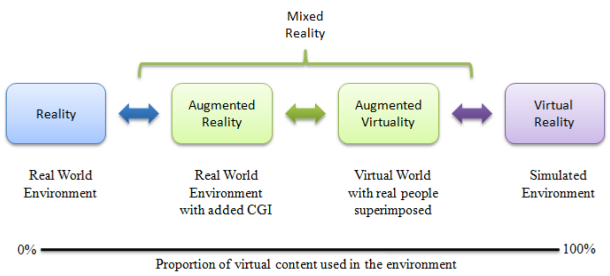

Figure 1. Milgram's Reality Virtuality Continuum

The Mixed Reality Intelligent Environment from this project could effectively be placed into either of the mixed reality sub-categories highlighted by the RV Continuum, (namely Augmented Reality and Augmented Virtuality), depending on how the world was being used and viewed. If a user was primarily interacting with the physical environment, but also used content that only existed in the virtual world, (e.g. fictitious intelligent devices), this is akin to augmented reality. The opposite of this, where the user interacts primarily with the virtual component of the environment, but also uses content from the real world, follows the augmented virtuality concept. Additionally, if both the virtual and physical components are designed to function in parallel with each other, possessing exactly the same layout and contents (i.e. with no objects being exclusive to either world) the Mixed Reality Intelligent Environment can operate in a 'Duel Reality' context, similar to the MavHome project's ResiSim world [5]. Other variations of Augmented Reality and Augmented Virtuality could also be utilised. For example, a system based upon the 'Blended Reality' premise [11], where users interact with an environment via a wand-like device, such as a remote control from Nintendo's Wii games console.

B. *The Physical Component*

The University of Essex iSpace is a purpose-built four room facility designed to replicate a typical household and be used as a test-bed for intelligent environments research projects [1] [2]. Consisting of a lounge / kitchen, study, bedroom and a bathroom each connected by a central hall the environment has been outfitted with all the furniture and devices one would expect, plus a number of sensors and other embedded technologies, which have been mounted within hollow walls and ceilings located throughout the facility. A number of computer-controllable devices have also been added to augment the physical environment including; X10 appliance modules, Echelon LonWorks controlled HVAC units and motorised curtain rails. All sensors and intelligent devices installed throughout the iSpace can be accessed by computer, via a server containing OSGI UPnP wrappers for each device.

C. *The Virtual Component*

Using the RealXtend software and a combination of bespoke three dimensional models and others modified from selected 3D Warehouse content, a virtual world (iWorld) replicating the physical iSpace environment was created. An additional piece of middleware software was implemented to provide a bridge between the simulated intelligent devices and their real-world counterparts in the physical iSpace. Once deployed in the iSpace, the virtual world is visible on selected 40" LCD screens throughout the environment or any computer connected to the network that has the RealXtend viewer application installed. The simulated devices featured in the virtual world can be used in conjunction with counterparts in the physical iSpace to augment the real-world by creating a mixed reality intelligent environment. Using the middleware software to associate virtual objects with a single or collection of physical devices, the real and simulated worlds can interact with each other. By clicking on an intelligent virtual device, it is possible to change the state of any associated physical equipment, (e.g. clicking on a virtual light switch to turn on / off a collection of lights). This process can also be reversed, with physical actuators and / or third party agent programs capable of altering the state of virtual devices. Whether interaction occurs in the real or virtual world, (or a combination of both), the two components are designed to mirror each other, with any changes made being updated in pseudo real-time in both sides of the mixed reality environment. Furthermore, as already stated, some intelligent devices may exist in only one component of the world. For example, the virtual world could contain a stereo system that can play music files either streamed from the internet or stored in a local repository. A set of OSGI UPnP control wrappers can be created and attached to the virtual object, allowing it to be controlled like any other intelligent device. From the perspective of the network the stereo would be indistinguishable from any other linked intelligent device in the environment, but only exists virtually so has no physical presence in the real world.

As RealXtend retains many of the attributes it inherited from Second Life, including the MMO functionality of an online virtual world, multiple users can be present in the simulated iSpace simultaneously however not these individuals may not all necessarily be present in the physical environment at the time. Clients can login to the virtual world servers from anywhere in the world where there is access to a computer with the viewer software installed and an internet connection.

IV. Creating Artificial Humans

A. A New Artificial Intelligence Mechanism

The virtual and mixed reality iWorlds mentioned in this paper were primarily developed to provide platforms for gathering usage data and performing evaluation testing for the main research focus of this project, a new artificial intelligence mechanism. The developed project mechanism is designed to allow computer-controlled avatars in computer games (NPCs) to exhibit a more human-like appearance, in terms of their decisions and actions, by using controllers generated from mimicked behavioural data taken from real people that has been modified using genetic programming [12] [13] [14] [15]. Using the mechanism a single person can potentially generate multiple new artificial behaviour profiles, which can each be used as an artificial 'persona' or 'brain' to control one or more NPC inhabitants in a virtual world of a computer game. This could potentially allow large crowds of computer-controlled characters to be present in a densely populated world, each possessing their own unique set of appropriately realistic behaviours, without the need for large amounts of additional programming by the game developer.

The various virtual worlds and mixed reality environments created for this project are primarily being used as a means of gathering the necessary mimicry data by observing how real people interact with intelligent devices in an iWorld during a number of different scenarios. The project artificial intelligence mechanism is designed to generate behavioural profiles for each user in the intelligent environment(s). These are subsequently used by the mechanism as a base when generating new artificial profiles. As the artificial behaviours are based on data captured from real humans the resulting actions and decisions generated using the mechanism should remain of a similar integrity to the performance exhibited by the original user(s), but different enough to give the appearance of another person. Richer environments, in terms of the number and variety of intelligent devices and sensors, can allow more detailed behavioural data to be collected. By using detailed three dimensional graphics for virtual worlds and mixed reality environments, it was hoped that users would be able to feel more at ease during evaluations due to the more immersive atmosphere, allowing them to behave in a more natural manner.

B. Artificial Humans for Intelligent Environments

Although the artificial intelligence mechanism was designed with the intention of being used in computer games and related software, the development of the mixed reality intelligent environment with the University of Essex iSpace presented an opportunity for this project to explore additional alternative uses. The existing mechanism could be used to capture user interaction with the household layout of the iSpace and associated virtual world of the mixed reality intelligent environment, observing user interactions to create sets of behaviours via mimicry. Artificial behaviour profiles could be generated from this data by the project mechanism, which subsequently could be used as controllers installed into NPCs placed in the virtual component. Using the mixed reality bridge NPC avatars would be able to interact with both virtual and physical intelligent devices as if they were real people inhabiting the environment. This strategy could potentially offer various new evaluation possibilities for intelligent environments researchers, such as;

- Performing testing using one or more artificial users rather than real people.
- Having a combination of real and virtual inhabitants co-existing in the world simultaneously.
- Having agents installed in an intelligent environment each represented by their own avatar on the virtual component, allowing a visualisation of each running program and exhibiting how it influences the world and its contents by performing actions.

V. The Next Step

To allow further evaluation into the potential of using artificial humans generated using the project mechanism, as tools for researching intelligent environments, a new virtual iWorld is currently under construction. Currently dubbed the iTown, the new world is intended to be of a much larger scale than the previous household-type environments. As the name suggests the virtual world is intended to model a small fictional town, with designated residential, commercial and industrial sectors, each hosting a number of associated services related to a typical daily lifestyle. Residential buildings are modelled from an expanded version of the previous iSpace simulations, with multiple instances of the virtual intelligent environment being present, which can each be 'owned' by different individuals who are using the world. The commercial sector is divided between a collection of typical shops, (e.g. a butcher, backer, restaurants and a supermarket), and administrative buildings, (e.g. a bank, library, health centre and civic centre). The industrial sector consists of 'factory' buildings where users of the world can go and play mini-games contained within the environment to 'earn currency' to spend on residential and commercial services. The iTown has been designed to encourage users to explore the virtual world and hopefully interact with the intelligent devices they encounter along the way to provide mimicry data to profile their behaviour. Additionally as the iTown has been created using MMO virtual world technologies, the environment will be accessible by users located around the world via the internet. By collecting a varied set of results the investigate hopes to assess whether the project artificial intelligence mechanism and its associated artificial humans, could be of potential use to intelligent environments research. The investigation will also continue to make use of the mixed reality iSpace system when focussing specifically on intelligent household environments.

VI. Conclusions

This paper has discussed how intelligent environments can be modelled using three dimensional virtual worlds created from software and related technologies used by professional computer games. Firstly, an overview is provided of the initial investigation performed as part of this ongoing project and the conclusions drawn from the results collected.

Limitations found when creating virtual intelligent environments from pre-existing computer game software was overcome in subsequent investigations, which eventually came focus on freely available MMO worlds and their associated functionality. By taking advantage of the available virtual worlds and editing tools, plus the vast array of free models available from the Google 3D Warehouse this paper has shown how a lack of graphics programming skills need not restrict the quality of a virtual world produced to visualise a project. Continuing on the paper then describes how such virtual world can be attached to a real-world intelligent household environment to create a mixed reality system.

The following discussion reveals that the virtual worlds and mixed reality environments created during this project are all being used as testing platforms to evaluate the primary research focus, namely a new artificial intelligence mechanism. The project mechanism is designed to take behavioural data gathered by monitoring the interactions of real people in an intelligent environment then use that information to generate a number of similar artificial behaviour-sets to be used as controllers for computer-controlled avatars featured in virtual worlds. Finally, the paper explains how although the project mechanism has been designed with the intention of being used as part of a computer game system, the construction of a mixed reality household has provided an opportunity to investigate whether artificial humans could be used as intelligent environments research tools. The under construction iTown virtual world is described, which will be used as one of the main evaluation tools during this investigation, offering the ability to gather behavioural data from a number of different scenarios.

References

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

[2] Callaghan V., Clark G., Colley M., Hagras H., Chin J., Doctor F., "Intelligent inhabited environments," BT Technology Journal , vol. 22, no. 3, Klywer Academic Publishers, Dordrecht, Netherlands, July 2004.

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

[4] Campuzano F., Garcia-Valverde T., Garcia-Sola A., Botia J. A., "Flexible simulation of ubiquitous computing environments," The 2010 workshop on the Reliability of Intelligent Environments (WoRIE '10), 2010.

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

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

[7] Davies M., Callaghan V., Shen L., 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] Davies M., Callaghan V., "iWorlds: Building Mixed Reality Intelligent Environments using Customisable 3D Virtual Worlds," The 6th IEEE International Conference on Intelligent Environments (IE '10), Kular Lumpur, Malaysia. 19th – 21st July 2010.

[9] Forbus, K. D., Wright, W. "Some notes on programming objects in The Sims™." Northwestern University, 2001.

[10] Google, 3D Warehouse, http://sketchup.google.com/3dwarehouse, Retrieved: 26th February 2011.

[11] Huynh D. F., Xu Y., Wang S., "Exploring user experience in "Blended Reality": moving interactions out of the screen", Proceedings of the conference on Human Factors in Computing Systems (CHI '06), Montreal, Canada, pages 893 – 898, 2006.

[12] Koza J. R., "Genetically Breeding Populations of Computer Programs to Solve Problems in Artificial Intelligence", Proceedings of the Second International Conference on Tools for A.I., IEEE Computer Society Press, Herndon, Virginia, pages 819 – 827, November 1990.

[13] Koza J. R., "Genetic Programming: A Paradigm for Genetically Breeding Populations of Computer Programs to Solve Problems", Stanford University Computer Science Depart-ment Technical Report STAN-CS-90-1314, 1990.

[14] Koza, J. R., "Evolution and co-evolution of computer pro-grams to control independent-acting agents", From Animals to Animats: Proceedings of the First International Conference on Simulation of Adaptive Behavior, Eds. Meyer J., Wilson S. W., Paris, pages 366 – 375, September 1990.

[15] Koza J. R., "Introduction to Genetic Programming", Proceedings of the 2007 GECCO Conference Companion on Genetic and Evolutionary Computation, London, UK, pages 3323 – 3365, 2007.

[16] Linden Lab., Second Life, http://secondlife.com/, Retrieved: 24th February 2011.

[17] Milgram P., Kishino A.F., "Taxonomy of Mixed Reality Visual Displays", IEICE transactions on Information and Systems, Vol. E77-D, No. 12, pages 1321 – 1329, 1994.

[18] Open Wonderland, Open source 3D virtual collabaration toolkit | Open Wonderland, "http://openwonderland.org", Retrieved: 1st March 2011.

[19] RealXtend, realXtend – Open source platform for interconnected virtual worlds, http://www.realxtend.org, Retrieved: 26th February 2011.

[20] Shen L, Leon E, Callaghan V, Shen R "Exploratory Research on an Affective eLearning Model", International Workshop on Blended Learning 2007 (WBL '07), Edinburgh, UK, 15 – 17 August 2007