Michael Anderson

Putting the "Reality" in Virtual Reality: New Advances through Game Engine Technology

Abstract: During the past four years, a number of projects have begun to realise the cost-effectiveness of using software and hardware designed for the purposes of the computer game industry in production of academically acceptable and archaeologically accurate 3D virtual realities. However, these tools present advantages for academic reconstruction beyond simply reducing costs. Computer game virtual realities are enhanced by sound, changing daylight conditions, environmental effects, realistic physics and, most importantly, are populated by a number of different inhabitants. This paper argues that archaeological virtual reality must continue to follow in the footsteps of game designers, taking advantage of the unique opportunities presented by game engines and continuing to increase the immersive effect and functional utility of scientific reconstructions. To this end, continued work on the recreation of a single house from the ancient city of Pompeii is presented, demonstrating the unique advantages of computer game engines and tools.

Computer Games as Academic Resources

In 2003 the CAA in Vienna saw the initial suggestion that computer game engines might provide a useful substitute for virtual reality reconstruction in archaeology (Anderson 2004; Meister / Boss 2004). My own contribution provided an initial appraisal of the advantages and disadvantages of using technology designed for 3D computer games, known in the business as "first-person shooters", for the creation of accurate and academically valid reconstructions of archaeological monuments and ancient spaces. The results of my initial assessment strongly suggested that there were indeed considerable advantages to using computer game engine technology, not least of all being that of relative costs. Whilst professional 3D rendering software and immersive technology hardware often require budgets of many thousands of pounds and a significant investment of time with highly trained labour – the bottom line for the research which I had carried out was less than ten British pounds. Furthermore, the necessary software and the real-time virtual model itself could run smoothly on a simple, low-end laptop without the need for professional video cards, significant processor speed or additional immersive equipment.

Computer game engines are accessible to sympathetically-minded academics due to a number of developments in the industry itself. For many years, game designers have realised that including tools for the creation of additional "levels" for use in the game would extend the longevity of their product and increase sales – especially with the growth of the Internet and gaming based in this environment. However, more recently some companies have begun to focus nearly exclusively on the production of the game engine itself, which controls lighting, physics, game play and the interface along with a comprehensive set of tools, source code and documentation for its modification and extension, known generally as an SDK (software developer's kit). Thereafter, the game engine may be licensed to other companies who, through modifications to the system, make their own individual games for sale. This means that a large number of free resources already exist, both for the creation of additional "levels" and for the extension and modification of the original game engine. Academic researchers may use these resources, releasing their reconstructions in the form of a new "level" within a given game engine, or may extensively alter the game itself (known colloquially as "mods"), giving it greater academic functionality. Anyone with a legal copy of the original game engine (at the cost of roughly 30 British pounds) can thereafter gain access to these academic resources for private use at no additional cost. Given this situation, there can be no doubt that game engines can provide a useful resource and a valuable and inexpensive tool for budget archaeological reconstruction and merit serious consideration as an academic resource with a variety of potential applications.

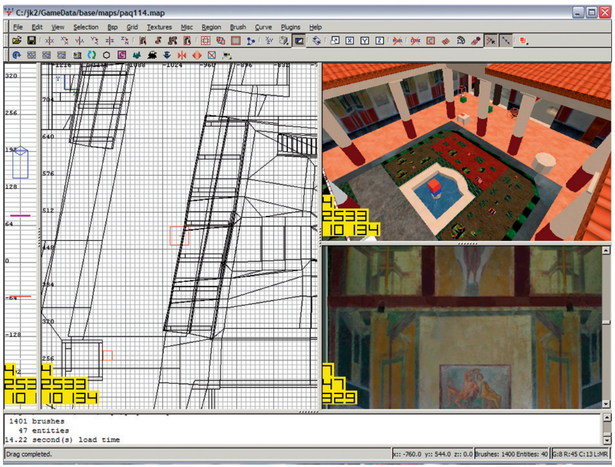

Fig. 1. Editing the model in Gtk-Radiant.

Fig. 2. The *Casa di Paquius Proculus* reconstructed.

A More "Realistic" Virtual Reality

Not only are game engines capable of competing with professional rendering packages in the creation of immersive virtual realities, but in a number of important ways they are actually more successful than their more serious counterparts. The virtual realities created by game engines present a more complete and immersive environment than is generally produced by academic researchers. More than simply asking whether computer game engines can keep pace with the accuracy of professional rendering packages, we should also weigh the effect of academic reconstructions against the results produced by the computer gaming industry. In many cases, much can be learned from this comparison, and the results ought to be taken as a model for archaeological reconstructions, whatever software is used for their creation. Because they are attempting to create worlds that are entirely fantastical and make-believe, computer game designers tend to consider a number of aspects of the real world which academic reconstructions frequently do not. These include important components of the experience of our surroundings such as sound, changing environmental conditions, weather, dynamic lighting, shadows that change with the passage of time, atmospherics, gravity, and of course the presence of sentient actors and the associated possibilities of social interaction or the necessities for its avoidance.

These qualities are just as important for the accurate recreation of archaeologically recovered remains as they are for producing a believable fantasy environment. In order for true immersion to be effected they are necessary components of human experience of the world. Their absence undermines not only the illusion of realism but more importantly denies the importance of these aspects in the past and overlooks their potential use for explaining and understanding past environments and architecture. Academic reconstructions must begin to learn from computer game designers in the production of 3D immersive virtual realities.

Gravity and Real-Time Experience

Some of the most important aspects of reality imitated by game engines are also the easiest to overlook. Game engines universally permit a virtual reconstruction to be experienced interactively and in real-time, just as we experience the physical environment around us. The viewer is not restricted to a given path, but may move through and around it, spending longer in one area than another if desired. This serves to not only increase the realism of the experience but is particularly effective because the viewer is in control of the movement and direction of view. Even more important is the presence of physical limitations such as gravity and solid walls – important real world limitations that play a significant role in human experience of the world. Whilst the fly-through films created by many high-end reconstructions do an excellent job of showcasing the particular details of a given archaeological structure or space, they do not reproduce the manner in which real people would have experienced them.

A game engine requires that in experiencing the model one must obey the laws of gravity. Included in this effect is the so-called "head bob", in which the viewing frame moves up and down slightly in order to mimic walking or running. It is impossible to overemphasize the importance of these features for the creation of realism. However, more than this, they augment the potential of a reconstruction as a means of analysis, for instance making upstairs reachable only via reconstructed stairways. Since no ancient person was able to fly though their world, if we are to appreciate fully the spatio-visual impact of our reconstructions, neither should we.

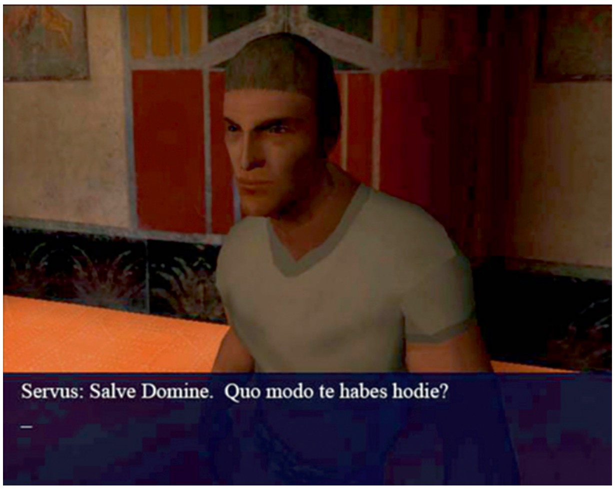

Fig. 3. Interaction with computer controlled inhabitants.

Sound, Light, and Environment

Another major component of the realism of computer game engines involves the inclusion of sounds, both as a result of actions and as ambient background noise. Most game engines provide for the ability to situate and control the placement of sound sources, be they a fountain, the noise from a busy ancient thoroughfare, the conversation of house residents or the sounds of footsteps and the opening and closing of doors as people move about the house. Although reconstructed environments are not yet modelled with complete acoustic accuracy, sounds do attenuate naturally with distance from the source. The true challenge in sound is multilayered since one must not only record appropriate sounds but consider the potential for sound sources in one's reconstruction. Because of this, some finesse is still necessary for the accurate recreation of sounds, but the additional information given to the viewer via stereo effects (so that a source can be identified as behind or in front of the viewer for instance) are well worth this additional effort. Furthermore, the consideration of these features in reconstructing an ancient environment is of significant value for research, pointing to the importance of phenomenological effects that have been examined relatively infrequently in archaeology (Sanders 1990; Devereux 2002).

Further augmenting the ability to appreciate a reconstruction is the play of light and shadow at different times of the day, in changing weather conditions or through the course of the year. Any reconstruction which hopes to understand an ancient architectural or natural environment must consider the vastly different circumstances that result from altered light, environment, and the direction of the sun. Integration of these aspects into game engines has been relatively slow because of the difference between true ray tracing, which is only possible from a single point of view, and "radiosity" lighting which is a global method of lighting employed by most real-time 3D rendering systems. The demands placed upon a system attempting to ray trace from a particular viewpoint would not allow for real-time movement. Nevertheless, changing day lighting, the effects of contrast and backlighting and volumetric shadows cast by moving objects have seen greatly increased implementation in recent years.[1] It should be expected to become a more common feature of game engines in the near future. It goes without saying that the incorporation of dynamic and temporal considerations into archaeological reconstructions will greatly increase their utility as a way of experiencing our reconstructed past, relating our understandings to changes in the use of space over time at a variety of different temporal scales.

The Importance of Inhabitants

However, the most important aspect that may be found in computer game virtual realities but is absent from nearly all academic reconstructions is the presence of socially interactive inhabitants. Ancient buildings were not the glossy, empty structures that

[1] To date, dynamic changes in daylight are particularly noteworthy only in Bethesda Software's "Elder Scrolls" series.

are generally reconstructed, but rather were inhabited. It is therefore vital to repopulate the spaces archaeology reconstructs with actors in order to understand the ancient spaces themselves. It is an aspect of recreation that is no less important than the accurate modelling of architectural features or decoration. This is especially true of the houses of Pompeii which are my main focus, but is no less true of a Greek agora, of an Egyptian temple or indeed, any building which we may seek to reconstruct. Architectural theorists have long argued that the population and their social interaction is what makes a building a building, and to leave it out is not only to ignore a vital component in its recreation but to overlook a chance at understanding how it truly functioned (Hillier / Hanson 1984; Hillier 1996; Hanson et al. 1998).

Furthermore, the repopulation of our reconstructions provides for an extension of the use of 3D architectural reconstruction. Actors may be "programmed" to interact with those experiencing the space. A house owner or slave may speak, demanding to know who has just entered his or her house. The actors furthermore might perform didactic roles, teaching the visitor about the reconstruction or about the culture to which it pertains. Therefore the repopulation of reconstructions is not simply an interesting exercise or flashy showpiece, it represents a significant advance in what our reconstructions are able to do, both for analysis and academic research as well as for public presentation, outreach, and didactic purposes. Potential uses of such a tool would include the production of experiential courses in ancient culture, for instance a living Latin course involving computer experience of life within a Roman household. The creation of a reconstructed ancient environment that is populated with dynamic actors controlled via built in artificial intelligence (AI) and scripted to interact, perform duties and generally inhabit the virtual reality is something that at this stage can be achieved only via computer game technology. It has also been taken as the primary goal of the case study presented below.

The Need for Greater Realism in Reconstruction

But why should "realism" and immersion be the goal of reconstruction? Frequently this important question is omitted and the goal of realistic immersive 3D reconstructions is taken as a goal in and of itself, but there are a number of reasons why increased realism and immersion are important. Not least is the fact that the very creation of as realistic a 3D environment as possible is in itself, a manner of analysis. To understand the environment of the ancient world, even through the lens of our own recreations is to approach the experiences of the past and to understand the past world more completely – surely one of the primary goals of archaeology. Furthermore, to examine our own reconstructions from inside and out, with accurate lighting, physical and experiential qualities is to understand the ramifications and implications suggested by our reconstructions. This is not merely a device for controlling errors (though this is also an important result) but is also an introspective journey in the process of hypothetical reconstruction. One cannot appreciate the full implications of architectural or environmental reconstructions simply on paper.

A second role of reconstruction is to communicate ideas, both to other academic researchers and to the general public. Reconstructions allow for the transmission of a particularly rich type of description between fellow researchers that is not possible via non-computerised or standard 2D methods. Furthermore, it is the responsibility of academia to ensure that the results of research reach a useful end. The modern public is accustomed to having the ancient world reconstructed via television, computer games, the Internet or film. Whilst we may never be able to compete with these reconstructions of the past, the production of our own, equally immersive worlds must speak loudly in the same language lest our message be lost in a cacophony of competing voices.

Case study: Inhabitants for the Casa di Paquius Proculus

In order to evaluate and assess the potential of these features of computer game engines, a case study was undertaken to add sound, dynamic daylight effects, atmospherics and computer controlled inhabitants to the *Casa di Paquius Proculus* (I,7.1.20), a house situated half way down the *via dell'Abbondanza* at the ancient site of Pompeii. In essence, these features were added to the model that was produced as a test of the scientific accuracy and utility of game engines as presented at the CAA in 2003. This case study therefore also represents a test of the ease and process of data migration as a newer game engine was employed for the current research.

Production of the House Model

In order to be able to populate the house model with ancient inhabitants, it was necessary to move the data from the older Quake III engine, which does not permit the addition of computer controlled actors, to the newer version of this game engine as implemented in Jedi Knight II. The process of upgrading the older model involved the retracing and thorough rebuilding of the model within software designed for the creation of game "levels" for the Quake/Jedi Knight game engine in the appropriate format. The use of a Binary Space Partition (.bsp) format of storing three-dimensional data for the model is one of the most notable features that distinguishes game engine rendering from many high-end rendering packages such as 3DStudio Max (Autodesk), Lightwave 3D, Softimage XSI or even Blender. Though several freeware editing packages were available,[2] Gtk-Radiant (1.4.0: Raven) was chosen in the end because it was the most straightforward. The model of the *Casa di Paquius Proculus* comprises a slim 1257 solid convex shapes (confusingly known as "brushes" in level creation lingo). These polygons present the house as it is hypothesized to have appeared at the time of the eruption of Vesuvius in AD 79 according to previous researchers (Spinazzola 1953, Fig. 60–61; Erhardt 1997) and my own, on site investigations. Further detail could have been added to the model via the addition of smaller "brushes" and meshes for complex objects, 3D models for furniture, fittings or topographic features. Revisiting the model also provided the opportunity to attempt to solve some of the problems discovered during the first case study such as the leakage of light between seams in the model.

Inhabitants for the Casa di Paquius Proculus

The method for creating inhabitants for a reconstruction naturally varies depending on the game engine employed. In the case of the Quake III/Jedi Knight II game engine, numerous freeware tools were available to assist in the task. The greatest challenge in this was the creation of the 3D mesh-models which could populate the reconstruction. Character models function within the Quake III engine by means of the combination of a 3D mesh model with a series of animations that provide the movement of the "skeleton" within the model. The mesh is connected to the "bones" of this skeleton at specific points and therefore deforms to accommodate their movement during the animation. This means that every model can perform a large number of different actions. Both animations and models may be altered within the game engine, but models are far easier to work with than animations. Additionally, whilst the creation of new models is not a terribly difficult process, it can be rather time consuming. In repopulating the Pompeian house, there were moreover a large number of potential inhabitants and visitors from which to choose. These might have included the house owner and his family, children, male and female servants, freedmen, clients and high-ranking visitors. Because the immediate goal of this research was to repopulate the house during the daytime, when many of these actors would have been at the Forum or otherwise engaged, it was felt that the most vital inhabitant to begin with was the slave, a type of inhabitant known widely from the ancient sources. In order to save time at the present stage of work, a pre-existing character model was simply given new textures by reworking an image file in editing software providing the appropriate colouring and detail. This process, which is known as "re-skinning" in level editing lingo, allowed the creation of several appropriately Roman characters from models that were originally designed to function within the game, but only was possible in cases in which an appropriate model already existed. In order to create the house owner or his wife for instance, it would have been necessary to create a new model from scratch.

Once the models and skins were ready to be placed into the house, it was necessary to provide them with appropriate behaviours. This is surprisingly easy to do since the entire system is coordinated via small "snippets" of computer code called scripts in a system known as ICARUS. Tools which had been made available via the Internet such as "BehavEd" and various model viewers provide easy access to this functionality. The activities and behaviour of the computer controlled characters (frequently known as NPC's) may be loosely organised according to a combination of tasks, rules, context specific instructions, and infinitely repeat-

[2] These included the Hammer Editor by Valve, GMax: Tempest by Autodesk et al.

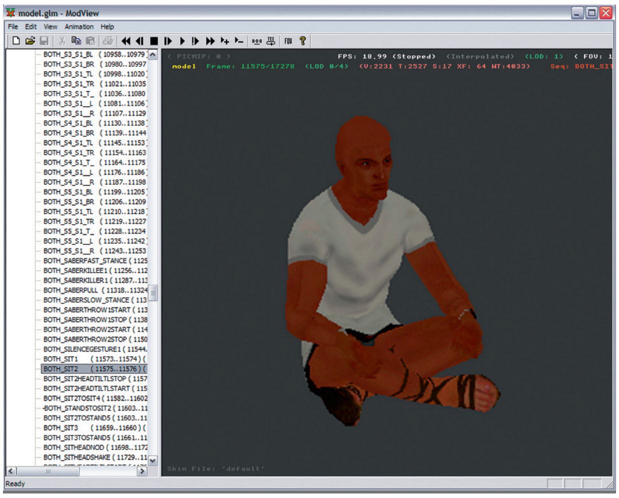

Fig. 4. Scripting inhabitant behaviour.

ing subroutines combined with an innate artificial intelligence. While it takes some patience with the code, in the end, individual characters can be given tasks and a set of conversational and behavioural responses which reproduce the behaviours of real people.

Almost every component of the game system may be controlled with these scripts, including extended "cut scenes" for conversation and character interaction. For game designers, these are used to provide interaction, character development and storyline, but they also imply a number of potential academic and didactic uses. It is easy to imagine a virtual reality based Latin exam or lesson which mimics ancient daily life. Furthermore, as AI controlled models interact with the environment, they may bump into each other, converse, or argue as real people might in a real environment. This suggests that in essence the reconstruction might act as type of a test environment for theories regarding the ancient use of space.

Results

Figures 1 to 4 present the current state of the case study. The rendering quality of the house and its lighting conditions, whilst not quite as refined as would be the case in a true ray-traced 3D render of a highly detailed model, accurately reflects architectural reality including shadows, reflected and ambient light, environmental conditions and colour. Furthermore, the house is inhabited by two different computer controlled slaves who perform a variety of different tasks and are capable of interacting with the viewer or each other should the need arise. They are scripted to walk between different locations, work in areas for a specified period of time and then move on. While these only represent one kind of inhabitant in the Pompeian house, nevertheless they suggest the possibilities for future work. In addition, the model has been enhanced via the addition of sounds such as the splashing fountain, the occasional chirping of a bird, work being done in the kitchen, the footfalls of the inhabitants and visitor, and general noise from the street. These sounds are modelled effectively and they attenuate naturally from their sources providing stereo aural information for the viewer experiencing the reconstruction. Overall, the immersive effect of the model is significantly higher than many virtual reality reconstructions and highlights the importance of these features in academic reconstruction efforts, whether achieved via computer game technology of via some other means.

Future Directions and Challenges

This paper has presented a single stage in a project of research which is ongoing. The next stage will be to move to newer game engines with more sophisticated light rending engines, detailed game physics, AI and scripting abilities, including open-source game engine platforms such as that contained within Blender. It will also be necessary to address issues of data integrity, longevity and reusability.

It is clear that computer game based reconstructions could and should never replace the sorts of detailed and extremely accurate work of projects such as Packer's work in Trajan's Forum (Packer 2004), the Rome Reborn Project, the UCLA CVRL, the TroiaVR Project[3] and others. Nevertheless, when used properly and carefully they can be used to produce academically valid reconstructions, presenting a useful and accessible alternative to more expensive software. Furthermore, because computer games are today a multimillion dollar industry with an undying need for ever greater realism to satisfy the expectations of game players, the state of the art is constantly being pushed forward as

[3] http://www.uni-tuebingen.de/troia/vr0101_en.thml

new and more realistic game engines are developed, at no cost to academia. While this pace of development does require dedication on the part of the researcher, nevertheless it means that with each generation of game engine technology, reconstructions based on this software move ever closer to the results produced by professional rendering packages.

Furthermore, the constantly evolving and competitive nature of the computer game industry can also present difficulties regarding the migration of data from one engine to another, issues of data longevity and concerns over the accessibility of proprietary data formats. The challenges that will be faced in moving the present case study research to any of the more recent game engines will undoubtedly reveal the potential obstacles for long-term academic use. While migration of data to new standards or new platforms is equally problematic for those who use professional rendering packages, the blazing pace of innovation, the impossibility of an industry standard, and the concern of proprietary formats make this a more pressing issue for the game industry than elsewhere.

Finally, it should be pointed out that game engine based virtual reconstruction could benefit greatly from organised collaboration and the sharing of knowledge and resources. Community and volunteer based projects of this type have already been proven to be successful such as in the case of "Rome: Total Realism",[4] a modification of the Rome: Total War series that aimed at greater historically accuracy. Nor are the didactic and outreach potentials of game engine and game technologies exhausted by 3D reconstruction alone. So-called massively-multiplayer worlds,[5] where Classics, archaeology or history formed the basis of a collaborative learning experience might also be a possibility. It is time to begin to make full use of the potential of game engine technologies and to form an official academic organisation coordinating cooperation, communication and documentation. It will be the goal of the future to make these possibilities a reality.

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4 cf. http://www.rometotalrealism.com/

5 Such as are represented by World of Warcraft, Sedond Live, etc.

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Michael Anderson

San Francisco State University
Department of Classics and Classical Archaeology
1600 Holloway Avenue
San Francisco
CA 94132
USA
maa35@sfsu.edu