

Living History with Open Virtual Worlds

Reconstructing St Andrews Cathedral as a Stage for Historic Narrative

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Abstract. St Andrews Cathedral is located on the East Coast of Scotland, construction started in 1160 and spanned Romanesque and Gothic architectural styles. It was consecrated in 1318, four years after the battle of Bannockburn in the presence of King Robert the Bruce. For several hundred years, the Cathedral was one of the most important religious buildings in Europe and the centre of religious life in Scotland. During the Scottish Reformation, John Knox lead reformers in divesting the Cathedral of much of its finery. Thereafter it fell into disuse and decline. Today the impressive remains only hint at the former glory of this important building.

Cultural Heritage encompasses physical aspects such as architecture and artifacts along with less tangible culture such as music, songs and stories. Open virtual worlds offer an extensible collaborative environment for developing historic scenes against the background of which material and ephemeral aspects of cultural heritage associated with a site may be explored through engagement with historic narratives. They offer the potential to reconstruct within a 3D computer environment both the physical structures of the past and important aspects of the light, music and life that once filled those structures. Virtual reconstructions enable scenarios to be created where individual pieces of art can be located and appreciated within the audio, visual and spacial contexts for which they were originally created. Bringing together architecture, sculpture, illumination, stained-glass, music, procession and lighting into a scene which can be explored from multiple spatial perspectives enables holistic experience and appreciation. Historic reconstructions may be created upon virtual stages allowing new and engaging Cultural Heritage perspectives to be accessible to diverse audiences.

Through the example of St Andrews Cathedral reconstruction this paper presents an example of Open Virtual Worlds as a technology for supporting the creation and use of virtual reconstructions as a platform that promotes understanding of and engagement with Cultural Heritage. The use contexts discussed range from research based exploration of 3D spaces, to primary schools students using the reconstructions as a backdrop for tag. The digital literacies of the audience and goals of the use case impact on the appropriateness of the user interface. A range of interfaces are explored including games controllers, touch screens, tablets that provide location aware views into the model and hands free gesture control systems.

Keywords. virtual worlds, Cultural Heritage, Virtual Reconstruction, Narrative

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This paper discusses reconstructing St Andrews Cathedral and bringing it back to life. The motivation was to deepen understanding of the monument in its prime, to explore and extend the capabilities of virtual world technology and to provide new accessible perspectives on the past. The reconstruction encompasses, the surrounding landscape, physical structure and architecture, fittings and furnishings, lighting, the soundscape as well as the inhabitants and their activities. The reconstruction provides a platform for interactive historical narratives, a stage for visitors to play upon and engage in both serious, and not so serious games and serves as a focal point for educational investigations into local history and culture [12].

Cultural Heritage can be defined as:

the legacy of physical artifacts (cultural property) and intangible attributes of a group or society that are inherited from past generations, maintained in the present and bestowed for the benefit of future generations. Cultural heritage includes tangible culture (such as buildings, monuments, landscapes, books, works of art, and artifacts), intangible culture (such as folklore, traditions, language, and knowledge), and natural heritage (including culturally-significant landscapes, and biodiversity)².

Virtual worlds are similar to many popular computer games. They typically provide a 3D environment, where the user is represented in world by an avatar much as a user would be in a First Person Shooter (FPS) [18,4] or a Massively Multi Player Online Role Playing Game (MMORPG) [3,2]. There are however, important differences. In a game setting users are presented with a well defined set of goals, in a virtual world there are no predefined goals, rather users are free to think up their own. This means that virtual worlds can support a diverse set of applications, including serious games about cultural heritage³. Virtual worlds provide a framework, which may be used to develop serious games for cultural heritage [11,12,10].

Open Virtual Worlds allow an organisation to run their own service much as they might run a web service. Open Virtual Worlds can make an important contribution to Cultural Heritage [13], because they offer the potential of mass participation in the creation and propagation of cultural heritage. Further, through leveraging current digital literacies they offer the possibility of making cultural heritage more accessible and engaging than it might otherwise be. By recreating past buildings, characters and events and through the proxy of an avatar situating people in the middle of these, they support narrative based engagement with the past. Consequently, they offer the potential to bring history alive.

The remainder of this paper is organised into the following four sections:

Reconstruction Sites: The history of St Andrews Cathedral is introduced and the current condition of the site described.

Open Virtual World technology: Functionality is defined, architecture analysed and a range of user interfaces discussed.

Reconstruction process: Stages in the process of OVW historic reconstructions are identified and described.

Deployment scenarios: Real world scenarios where reconstructions have been deployed and used are described. Technical challenges for each scenario are identified and evaluation of value and impact for each case presented.

²8/4/2012 http://en.wikipedia.org/wiki/Cultural_heritage

³10/07/12 <http://heritage-key.com/>



Figure 1. Aerial View of Cathedral



Figure 2. View from Knave to Choir

1. St Andrews Cathedral Site: Narratives from Independence to the Reformation

St Andrews Cathedral occupies a site used for worship since the 8th Century AD. It was the center of the Scottish medieval church through to 1559. Work on the Cathedral began around 1160 and was completed 150 years later (the west facade and parts of the nave collapsed in a storm around 1270). It was finally consecrated in 1318 four years after the battle of Bannockburn and in the presence of Robert the Bruce. St Andrews Cathedral was in its prime, Scotlands largest and most magnificent church and its presence was the catalyst for the foundation of a university at St Andrews in the early fifteenth century [6]. In 1561 following the Scottish reformation it was abandoned and replaced by the parish church as the chief place of worship. The former headquarters of the Scottish Church was left to fall into ruin, and much of its stone used in the construction of town dwellings.

During its time the Cathedral was central to Scottish personalities and history. St Andrews was the highest ranking Scottish see. The establishment of Augustinian Canons followed by the initiation of building work by Bishop Ernald reflected integration with the European church, economic dynamism and decline of the Celtic Church. The diocese funded Robert the Bruce during the Wars of Independence. Its Bishop William de Lamberton contributed to the formulation of the Declaration of Arbroath a central document in the formation of Scottish Nationhood. Isabella, sister of Donnchadh IV, last pictish Earl of Fife, crowned Bruce King. John Knox lead his congregation against the Cathedral's finery and following the murder of Cardinal Beaton the first Scottish protestant congregation was established in the Bishop's palace.

Important fragments of the Cathedral remain. The east gable of the presbytery, where the relics of St Andrew were kept, along with the south wall of the nave, and the majestic west front all point to the cathedral's former majesty. The cloister retains its ruined chapter house and stone-vaulted undercrofts. Consequently, much evidence of the Cathedrals form exists, although without substantial scholarship it is difficult for the visitor to reconstruct the cathedral in their imagination. The current monument is shown in figure 1 and figure 2.

Developing the reconstruction of St Andrews Cathedral involved collaboration between computer scientists, archeologists and art historians. It drew upon existing resources relating to the cathedral: for example, surviving architecture on site, architectural fragments both in the museum and reused throughout the town, and the existing work of medieval architectural historians [8,6,9], which incorporates architectural drawings and artistic impressions of the Cathedral's original appearance.

2. Open virtual world Technology as a Platform for Virtual Reconstructions

The potential of Open Simulator as an environment for developing [17] and delivering historical reconstructions and serious games is explored in this section. OpenSim project is an application server which integrates with the World Wide Web. At the heart of an OpenSim application is an extensible, mutable, 3D environment users inhabit through the proxy of an avatar. Other users are able to see the avatar's actions and engage in synchronous communication through movement, gestures, text chat, and voice. This projection of presence enables both collaborative and competitive exploration.

An OpenSim virtual world is made up of three discrete components: the client, the simulations and services.

A *client* allows the user to connect to a server and provides an interface for viewing and interacting with the content the server provides. It provides control over lighting, view distance and fidelity of the data. There are several clients including: SecondLife, Firestorm, Imprudence and Hippo.

Each *simulation* is responsible for tracking all the objects and avatars contained within a virtual space. It receives updates from and distributes updates to clients that are connected to it. Each simulation makes use of services, to retrieve information about avatars buildings and landscapes.

The *services* provide the information required by a simulation to both run the simulation and to control access. These may be located on the same machine as the simulation, on a single machine or distributed across multiple servers. Services include user authentication, and provide content.

Each simulation is made up of components which provide distinct functionality. These include controlling the weather, the physical structure of the space, the actions of avatars and interactions with other Internet resources.

Regions: A simulation may contain one or more regions. Each region represents a discrete piece of rectangular land, each side is a multiple of 256m. Regions may be placed contiguously, whether they are in the same simulation or not, in which case a user will be able to walk between them and may simultaneously view the contents of multiple regions. **Environment:** The amount, colour and movement of clouds, the colour opacity and reflectivity of water, visibility and mist, lighting and the presence of shadows as well as the time of day are all configurable by the server and may be overridden by the client. **Landscape:** The surface of the region may be adjusted to give the impression of grassy plains, rocky hills, deserts or forests. There are three components, sea, land height and textures. There are four slots for textures, which are combined to colour the landscape. The heights at which the textures are used may be adjusted.

Prims and Meshes: The structure of the architecture, fittings and furnishings of buildings may be constructed in OpenSim out of primitives (prims) or imported as meshes. Primitives may be linked together to form structures. Meshes may be created in 3D modeling programs or from real world data such as a points cloud. **Textures:** Textures are images that are applied to the surface of primitives and meshes.

Avatar: The movement and appearance of avatars is customizable. Inworld tools provide control over body shape, size and colouring as well as the garments that are worn. More control can be achieved by using external modelling programs to design clothing, body shapes and animations. Libraries of clothes, body shapes and animations may be freely imported. Avatars may also represent in world Non Player Characters, that



Figure 3. Microsoft Kinect.

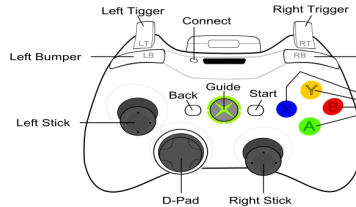


Figure 4. X Box Controller and Virtual Time Window

have preprogrammed responses to events. The *libopenmetaverse* [1,14] library provides support for creating avatar bots controlled remotely by a programmable client.

Sounds: Short clips of sound may be embedded in objects and played in response to events. Voice over IP may be used for peer to peer communication between clients and sound may be streamed to particular locations. **Media and Web Interaction:** Media textures may be attached to prims allowing media to be streamed and displayed on the Prim surface. A web page may be embedded on a surface and set to point at a web address. Web pages can also be loaded into a browser by scripts embedded in objects.

Scripting: OpenSim is written in C# and runs over the .net framework or mono. In world scripting is supported in LSL and C#, this allows Avatars or other objects to respond to events, such as being touched or receiving messages on a chat channel. Mini regions modules, regions modules allow for powerful virtual world applications to be created [15].

OpenSimulator may be configured to support a range of delivery scenarios. In *Sandbox* mode the client and server are both run on the same computer. This allows private copies of OpenSim to be run. It is particularly useful for development and presentations. In *Stand Alone* mode a simulation is run on a single server. It may be accessed by multiple concurrent remote clients. In *Grid mode* multiple servers run separate simulations. The regions of the different simulations are on a single grid. In *hyper-grid* mode organisations may run separate Grids, for example maintaining their own log on services, but these GRIDS may be connected together so that Avatars may move between them. Finally, a simulations scene graph may be distributed across multiple servers.

2.1. Exploring the past with Mice, Games Controllers, Mixed Reality and Gestures

As part of this work interaction using keyboard and mouse, touch screens, games controllers, Virtual Time Windows and Kinect devices have been explored.

The standard mode of interaction is with a *keyboard and mouse*, which offers good all round control. Virtual worlds may be controlled through a *touch screen* interface. This has the advantage that no external devices are required and is appropriate for exhibition spaces. The client may be configured to support a *games controller*. (Fig 4). On an XBox controller there are 3 2D joysticks. These are mapped to Move (forward, backward, turn left, turn right), Mouselook and Mouse. There is a 1D axis (large triggers fly up and down). Shoulder buttons are mapped to right and left mouse click. A headset may be added to the controller providing voice communication. Textual chat communication is facilitated through a plug in keyboard similar in size to a larger mobile phone.

The Second Life client has been extended in the Virtual Time Windows and TARDIS projects. A Virtual Time Window (VTW), utilises a tablet computer to provide visitors

with a 'window' into the past [5]. Visitors view the site in its current state around them and a 3D reconstruction through the window; thus supporting simultaneous exploration of real and virtual environments. Figure 4 illustrates this concept. To maintain a natural and unhindered sense of exploration, changes in a tablet's position are automatically reflected by a corresponding movement within the virtual environment, making use of a combination of location tracking technologies. The direction that a visitor faces is monitored by a magnetometer ('digital compass') and the angle that their tablet is held at by an accelerometer; this information is reflected by the direction and pitch of the camera within the virtual environment. The resulting style of interaction is similar to using a digital camera to take a photo: the screen on the back of the camera shows what the image will look like when the shutter is released, whilst with VTW the screen on the tablet shows what the site looked like in the past.

The release of Microsoft's Kinect in November 2010 opened up new and exciting possibilities in terms of creating affordable immersive interactive experiences. The TARDIS project extends existing virtual world capabilities to allow them to support Immersive Environment applications by extending the functionality of virtual world clients [16]. The modifications are two fold. For output the viewer is extended so that one single avatar (as the server perceives it) powers several displays. These multiple displays can then be arrayed around the user to give 180°, or 360°, views of the virtual world. For input the Kinect is used so that the user can interact with the world without ever using a peripheral. Gestures are used to control orientation movement, view and interaction with in-world elements.

2.2. Holistic modelling, flexible deployment and intuitive interfaces

Support for modelling not only terrain architecture, sculptures and furnishings, but also intangible elements of cultural heritage such as music and the interactions between people make virtual worlds an attractive platform for developing multi faceted reconstructions that allow individual pieces of culture to be placed within context and understood holistically. The OpenSim platform provides distributed users with shared access to an integrated 3D environment. This opens up the possibility of exploring historical reconstructions which provide a stage for collaborative investigations. The server architecture supports multiple deployment scenarios including: standalone, institutional services and inter institutional networks. The systems are open source and supports the sharing of libraries resources. The user may interact with the environment through keyboard and mouse, gestures, games controllers, and touch screens. The flexible architecture and multiple control modes mean that multiple use cases can be supported.

3. Reaching into the past to recreate the Cathedral's architecture and majesty.

At the heart of the reconstruction process lies collaboration between experts in the archaeology and history of the monuments, graphical designers capable of developing 3D models which match the vision of the historians and computer scientists who develop, configure and administer the computer systems. The virtual world provides an environment which facilitates such collaboration. Iterations of the model can be viewed and evaluated by domain experts who in turn give direction to developers.

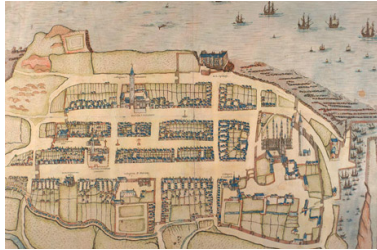


Figure 5. The Geddy view of St Andrews

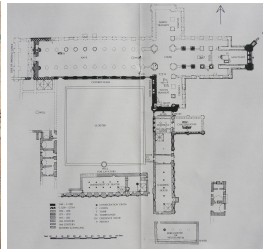


Figure 6. Scale Floor Plan

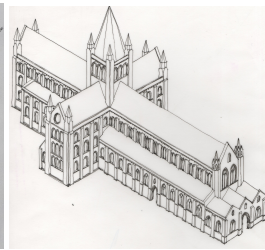


Figure 7. 2D Sketch



Figure 8. The East End

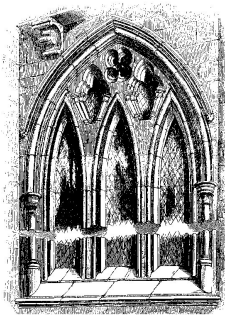


Figure 9. Gothic Window

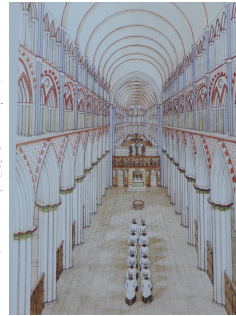


Figure 10. Procession



Figure 11. Ripon

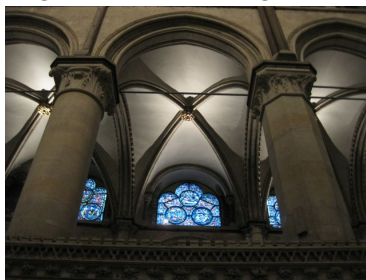


Figure 12. Nave Vaulting Canterbury



Figure 13. Cloister in Durham



Figure 14. Choir

A number of discrete but interconnected steps make up the process of reconstruction: research, setting the scene, landscaping, architecture, furnishings and fittings, soundscape, character development, linkages to web and social media as well as the development scenarios.

Research: The reconstruction draws upon existing scholarship in medieval religious buildings, medieval books and medieval music. Contextualisation of surviving architecture on the site and reference to surviving features on other sites inform the reconstruction. Research into personalities contemporaneous with the Cathedral and modes of dress inform the creation of in world characters.

Landscape: Real world ordnance survey point heights provided the framework for the terrain. The OS coordinates for the monument were identified. The point heights were then scaled to minimize quantization error and loaded into a bit map image file. The map is then transformed using cubic interpolation from one point per 10 meter to one point per meter. The image map was then loaded into the OpenSim region. The in world height and the scale of the land were then adjusted to agree with the real world heights.

Architecture: The process for reconstructing the architecture was divided into three substages: establishing scale, layout and orientation; developing external form; and establishing the internal form and features. Each substage was iterative. Initial discussions identified evidence to work from and a plan for development, regular meetings between developers and historians were held. During the meetings virtual tours of the virtual building site were conducted and discussions held as to the correctness and appropriateness of the current content.

The first stage is to create or locate scale architectural drawings of floor plans, elevations and details. The floor plan can then be imported into the virtual world as an image, laid on the ground and scaled to provide a blue print for the location of walls, doors and other features. With this in place the shell of the building can be created relatively quickly. Primitives are created and shaped to the appropriate size for walls and floors, with spaces being left for windows, doors and other features. Appropriate textures are applied to the primitives to give an authentic look.

The Geddy view, although drawn in 1540 (figure 5) provides context. The church was laid out in a cross with the length running from the more sacred areas in the East to the nave in the West. A scale ground plan of the Cathedral (figure 6), a ground plan of the site, reconstruction sketches (figure 7), photographs of the site (figure 1) and physical site observations (figure 15) provided evidence for the reconstruction.

External Form: Issues addressed in establishing the external form of the building include the structure of the East and West ends, the form of the windows along the length of the choir and nave and the structure of the cloister area. Reconstruction work was based on existing drawings, themselves based on the evaluation of on site physical evidence and reference to surviving features in churches developed in the same architectural style. A series of two dimensional elevations guided proportions. Reference was made to sketches of Gothic window tracery (figure 9), buttresses and to surviving features in Jedburgh, Elgin and Glasgow Cathedrals.

A photograph of the remaining East End is shown in figure 16. This shows a lower tier of three windows with a large upper window. This configuration was established after the fire of 1378. Previously there were three tiers as shown in figure 19. During the construction of the Cathedral architectural tastes changed from romanescque to gothic. This is reflected in changes in the form of the nave windows. Towards the west these have simple rounded arches, towards the east the arch is pointed and the windows contain a delicate Y shaped tracery as shown in figure 18.

The West front was the ceremonial entrance to the Cathedral used only on special occasions. It consists of a *'magnificent doorway framed by five receding orders of arches, is flanked by tall polygonal turrets.... A stone-vaulted porch in front of the doorway (now gone) stretched across the west front'* [7]. Placement and size of the windows in the Cathedral in the West entrance went through several iterations before arriving at a reconstruction which reconciled surviving architecture, correct styling and placement in relation to the west port vestibule. An external view from the West is shown in figure 17.

The outline of the cloister is clearly discernible from above in figure 1. The surviving cloister at Durham (figure 13) provided a model to work from. The known position of the Cathedral windows provided a guide for the height of the cloister. Located in the cloister is a well. The friars eating (figure 26) and sleeping quarters (figure 24), the kitchens (figure 23) and the Chapter house (figure 25) can all be accessed from the cloisters. A view of the Cathedral from the cloister garden is shown in figure 18.

Internal Form and Features: The internal architectural features were developed from evaluating existing 2D reconstruction drawings for example figure 20, surveying surviving features at the site and with reference to architecture at Canterbury (figure 12), Jedburgh, Rippon Minster (figure 11) and Durham Cathedral's Cloisters (figure 13). Important features included:

Only the bases of the transept *Pillars* survive at St Andrews. However, pillars at the Cathedral in Rippon (figure 11) provide a good model for how St Andrews pillars would have looked. There are surviving pieces of pillars and bases in the Cathedral museum. The pillars in the transept, choir and knave differ in style and detail. The Choir pillars are more decorative than the nave reflecting the higher prestige associated with access to these parts of the Cathedral. In recreating the pillars, the base, the columns and how the finial connects the column to vaulting were all considered.

The *vaulting* was in the Gothic style, similar to that in the Naive at Canterbury Cathedral (figure 12). Technically it was difficult to model this as the shapes are difficult to arrive at from OpenSim primitives. Consequently, they were created in a 3D modeling program (Blender) and imported.

The *choir section* contains a tri-foil of surrounding arches as does the choir at Ripon figure 13. The choir screens played both a decorative and functional role. The relics of St Andrews were purported to be located within the reliquary to the east of the choir. Heights of windows, positioning of the screen and the magnificent vaulted ceiling are all features of this part of the building, captured in the reconstruction figure 19.

The location of the *stairs to the refectory* was investigated as the exact position was not clear from surviving architecture. Their position adopted makes the most sense in providing access to the well, cloister, kitchen and refectory. The view from the night stair into the transept is shown in figure 21.

Putting Books back in the Cathedral: Books and manuscripts would have been central to the life of the monasteries. The book presses are located at the junction between the Cathedral and cloisters. By 1400 the cathedral had a library of some 100 books. This project has created a model of a Scriptorium, an in-world exhibition of books in the Cathedral and has placed models of appropriate books in the Scriptorium, book presses and lecturns in the Choir, dining areas and Chapter house. In the exhibition visitors can learn about how books were created in the middle ages, gain access to rare and valuable books and charters and interact with models of books that were held in the Cathedral's library. They are able to view a video about book binding and to read digitisations of three of the Cathedral's books.

Historical Characters: Non Player Characters (NPCs) appear as avatars and may be programmed to follow scripted behaviour and to respond to questions. Simple scripts can be placed within the characters, which enable them to react to events. For example upon being approached by an avatar they may greet them by name, they may respond to simple questions, or follow routine tasks. For St Andrews Cathedral models of Robert the Bruce, Bishop Robert de Langford, Augustinian Canons, Peasants and a Ghost have been developed. For each character, appropriate physical models, clothes and accessories have been researched, designed and created. The characters each have a story to tell about their lives.

Soundscape: Streaming media can be associated with locations, so that as an avatar enters a room they will hear appropriate background elements of the sound scape. This is appropriate for providing ambient background noise. Voice communication between



Figure 15. Tour of the grounds



Figure 16. The East End

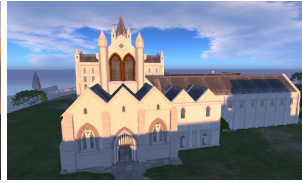


Figure 17. The West Entrance



Figure 18. Cathedral Cloisters

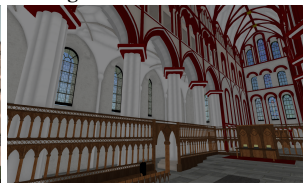


Figure 19. Internal view to East

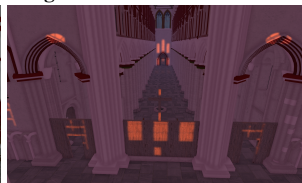


Figure 20. Sunrise view of Nave

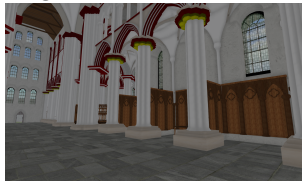


Figure 21. Transept from night stair



Figure 22. The Chapter House



Figure 23. Cathedral Kitchens

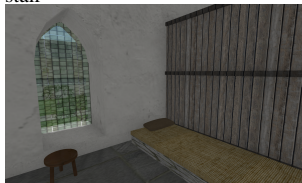


Figure 24. Sleeping quarters



Figure 25. Warming house



Figure 26. Cloister dining area

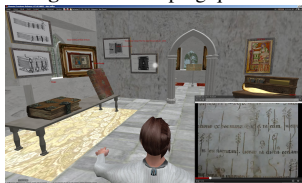


Figure 27. Book Exhibition



Figure 28. Book binding video

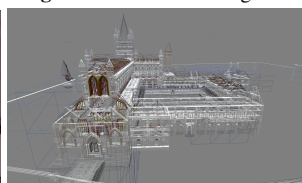


Figure 29. Wire frame model

avatars is supported through a Voice Over IP open source telephony system. With a microphone and headphones visitors may communicate with each other through voice chat even when in different physical locations. Specific sound clips are embedded in the environment to be triggered by appropriate actions. For example a door creaks when opened, a NPC answers a question and the fountain bubbles. Music, commentaries and explanations are embedded in a location aware heads up display. Music, commentaries and explanations may be accessed through an embedded web interface. Visitors to the Cathedral are able to hear a soundtrack of music appropriate to the time and place.

Historic Scenarios: The resource acts as a platform for playing games and engaging

with historical narratives. These may be as simple as hide and seek or more explicit educational activities such as quests. These are tailored to suit various educational contexts. From simple tasks such as find the kitchen scullion and ask them what they are doing today, to more complex quests such as a treasure trail which involves finding several objects and people, as well as solving a series of historical riddles which allow a final goal to be achieved.

3.1. Reflections of the Process of Virtual Reconstruction

The ability to walk around the building whilst under construction and to view the model from a multitude of viewpoints allows the placement of features that are missing from the archaeological record to be explored and tested from the perspective of spatial dynamics. This is particularly relevant to the placement of doors, the direction of stairways and establishing the function of rooms. These aspects can be considered in an holistic way adding insights gleaned from the reconstruction to the existing knowledge base.

From the historians perspective the reconstruction of the Cathedral involves both the mental reconstruction of modified and lost features, and the establishment of the range of ways in which buildings that represent a spirituality alien to modern times were intended to function. As such it offers an invaluable academic discipline for those involved in the reconstruction, providing eminently practical ways of testing theories and assumptions. It is then of the greatest value for conveying more widely the understanding that has been gained.

4. Use Contexts

The reconstruction of St Andrews Cathedral was part of the Sensation exhibition at Dundee Science Centre over the weekend of 16th, 17th and 18th of March 2012. Other contexts are also supported: for example using the reconstructions in sandbox or stand alone mode. However, recounting this example illustrates the impact achieved. The exhibition was well attended by both local schools and the general public. On Friday several groups of students from local primary schools visited and during Saturday and Sunday there were over 800 visitors.

There were four public facing terminals connected to a mobile server via a switch. The public facing terminals included two 24 inch monitors and a 150 inch projection. The user interface utilized X Box controllers. Each X box controller had a headphone and microphone attached. Voice communication was enabled in world using the FreeSwitch VOIP exchange.

A terminal was used for monitoring performance and controlling the server. During the session network traffic traces were captured, along with application load inferred from server frame times and frames per second, traces of memory usage. Connection to the server via WiFi was supported.

Several laptops were used to run historic characters that would interact with visitors' avatars along with a tablet demoing a touch screen interface.

A range of activities were prepared including the following: simply leaving the visitor to explore the site; a guided tour provided by an in world character; a guided tour provided by an out of world character; a treasure trail/ task oriented quest; and finally

playing games of tag or hide and seek against the backdrop of the Cathedral. The experience was evaluated in three ways: users of the system were observed, a visitors book was provided where free form feedback could be provided and some questionnaires were distributed. The feedback received was strongly positive. Some forty comments were left in the visitors book with none of them negative. It was clear throughout that people were attracted to the exhibit and found it easy to use, engaging and educational. All ages were able to quickly master the user interface and navigate the environment with a few seconds instruction. School children were particularly adept at using the game controllers.

male primary school student: *the best place I have ever been love everything inside and will be looking forward to coming back*³ female primary school students: *very detailed and interesting. good game. we like Robert the Bruce :) parent: kids were very interested and enjoyed being able to interact with the cathedral, the controllers were a medium that made it easy for them to do this family group: Fantastic work. Can't wait to visit St Andrews again to look at the cathedral ruins STEM ambassador: Very interesting would be great to be shown in schools*

Over the three days hundreds of people interacted with the model of the Cathedral. They all took something positive from the experience, whether they were a university lecturer or a primary school student. Embedding the reconstruction of the Cathedral within a virtual world created a new perspective on Scottish history and made it accessible across the generations. Many expressed a desire to follow up the experience through visiting the cathedral ruins or by connecting to the Cathedral model from home and exploring it in more detail.

5. Conclusion

Open Virtual Worlds provide a flexible platform offering holistic support to the development and deployment of distributed interactive 3D applications. These are particularly appropriate for developing historic reconstructions related to the promotion of cultural heritage as they facilitate cooperation and collaboration during the development process and provide an immersive environment upon deployment. This allows technical experts and domain scholars to collaborate in the creation of historically accurate environments and allows both physical and intangible aspects of the past to be modelled.

Virtual worlds provide an interactive 3D environment users can explore and shape through the proxy of an avatar. They provide a framework which may be used to develop 3D applications. As such they meet many of the requirements for facilitating the development of serious games which promote cultural heritage. The framework enables distributed access through virtual world clients and collaborative working enriched through the sense of presence achieved with avatars. Whilst the cost of the service provided by Second Life, the most populace virtual world, limits the scale of reconstructions, the OpenSim server enables individuals and organisations to provide their own service and even to create an interconnected web of reconstructions through a hyper grid. Here it is possible to teleport avatars from place to place much as it is possible to jump around the web using hyper links.

In the 3D space the speed of technological change has led to inverted digital literacies. Children are able to explore 3D spaces using games controllers sometimes before

they are able to spell their own name. The ability to configure open virtual worlds in a spectrum of configurations ranging from client server web applications to personalized sandboxes combined with their flexibility in supporting multiple user interfaces including traditional key board and mouse, games controllers and touch free gesture control combine to allow a reconstruction to be deployed in a range of contexts.

In summary our usage of open virtual worlds as a platform for supporting the exploration of cultural heritage, has been extensive. The wealth of experiences put together reveals as many challenges as have been solved. However, the experience has been overwhelmingly positive and demonstrates that with the right investment history can truly be brought alive and made accessible to new generations.

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