Design and use of a virtual heritage model to enable a comparison of active navigation of buildings and spaces with passive observation

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Abstract

Wide ranging and significant research in recent years has highlighted the need for greater levels of engagement with end users in planning and design of the built environment. This has been against a background of far reaching advances in IT technologies, which have facilitated the widespread use of computer modelling to present design ideas in non-traditional and non-technical formats. In the context of urban redesign and public participation, the research reported in this paper emerged from an observation that pre-rendered walkthroughs of designs have become commonplace, and that the effect on cognition and preference might be significant. For the particular case study area, it was notable that the arrangement and proximity of buildings was such that the site could arguably be best understood through navigation at human scale, as opposed to through the use of traditional drawings or plans. The research proceeded to investigate whether the active navigation of a desktop virtual model of an urban environment leads to better understanding and perception than passive observation of a walkthrough, and the methodology employed commonly available and widely used modelling packages to present a small townscape, navigable using controls commonly found in modern computer 'games'. The technical and study based results from this research have implications for how design ideas can be best presented to clients and other end users in the future, to ensure that design processes can be more clearly informed, and to avoid problems related to the interaction and understanding of architectural information by non experts..

Keywords

Virtual; navigation; heritage; 3D; participation.

1. INTRODUCTION

The research described within this paper had two overall aims. Firstly, the research aimed to model a culturally significant area of the built heritage, constructed and maintained using vernacular construction methods. The case study used was that of the medieval village at Tinganes at Torshavn in the Faroe Islands. This aspect of the research aimed to present the results of that process through the use of high quality 3-dimensional computer models of the areas studied, and to ensure that the model provided users with the ability to interact with and navigate the spaces between buildings.

The second aim of the study was to investigate whether permitting people to actively navigate a modelled environment, as it is presented in a desktop situation, enhances understanding and perception of an environment when compared with passive observation of a walkthrough.

2. VIRTUAL HERITAGE

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Tinganes is designated as a conservation area, and provides an important insight into the manner in which vernacular building designers (including occupants) responded to their prevailing environment. An excellent commentary on the history of these buildings was provided in Hoydal [1], who makes an interesting case for the importance of recognising the oral tradition of northern European countries, in that the historical importance of Tinganes is arguably more important from the perspective of understanding Faroese social and cultural history, than for the architecture alone. A deeper anthropological analysis of this subject would be extremely worthwhile. The overall narrowness and undulating topography of the headland at Tinganes has dictated that the buildings take an almost organic approach to village 'layout'. The modern village buildings have developed a sense of increasing importance towards the outermost points, with an overall increase in building height, although use of materials is largely constant throughout. It was felt to be of cultural importance that an assessment and record of such buildings is realised to ensure the site is preserved for the future, and it was felt that the development of an interactive model would help to promote collaborative discussion, debate and greater levels of public participation in the future. For this site, in particular, it was also felt that the proximity of buildings, and the organic layout of the townscape, meant that appreciation of the sites topography, arrangement and design would be best appreciated and understood through navigation and viewing, rather than through the analysis of drawings, plans or photographic stills.

Fig. 1. Location photo from Tinganes (taken in February 2004)[1]

Previous studies have successfully presented virtual 'tourism' sites, through which users can access virtual models of towns and cities, or interrogate information regarding cultural heritage. These include web sites containing navigable VRML models, where an emphasis is placed on providing pertinent data as users move through a space (for example, [2, 3]). These studies were concurrent with research which concentrated on the development of the VRML technologies themselves, which allowed users to navigate interactive and photo-rendered spaces [4]. A key strength of such systems is that they are capable of containing and displaying a suitable range of text and image based data, potentially selected and presented in response to specific user characteristics (for example, [5]). Other recent work [6] has utilised panoramic views of cityscapes, again from the user's perspective, to allow participants to navigate public space, and subsequently make judgements regarding travel and navigation through urban areas.

The method used to model and represent the area within this research included aspects of site surveying, collection of texture and material samples, geometric modelling, and various visualisation techniques. An objective throughout was to ensure that as little site data as possible was lost during that process, and to ensure that the resulting model could be used as a reasonable surrogate for the actual space.

3. TECHNICAL PROCESS

The main aim of visualisation undertaken for this study was to provide a fully navigable model of the area. Rather than concentrating on providing a fully photo-realistic model (although this was achieved), the intention was rather to provide a virtual space within which users, occupants, planners and other interested parties might be able to discuss issues and debate proposals. Clearly, 'traditional' approaches to the presentation of design ideas within the built environment would be insufficient to meet this aim.

Recording the area included a measured survey of the site layout and buildings of significant heritage value. An extensive photographic record of key 'squares' was completed, and an on-site log of important built heritage information was compiled (including such items as building type, construction methods and building materials used).

Using the material collated, a three-dimensional computer model of the area was produced using a process involving CAD and 3D Studio, followed by further work using the Unreal Runtime engine. This extends processes extensively described elsewhere (and summarised, for example, in [7]), which aim towards the

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[1] It should be noted that heavy snowfall is relatively uncommon in Torshavn, and that the research team also visited the site during the summer of 2003.

creation of models which can provide walkthroughs or panoramic displays. A longer term aim of the visualisation work is to provide a practical base to further develop the manner in which conservation theory can be taught, leading in turn to the development of research centred on the interface between conservation studies and emerging (and increasingly pervasive) technologies.

This section sets out a technical process which can be followed when converting 3D models constructed within architectural modelling packages for use within immersive and interactive 'gaming' environments. It will be essential in most cases to ensure that the sizing and texturing of models is preserved within such environments, so that questions of perception, interaction and distance can be addressed in a realistic manner. It is also similarly important to ensure that significant amounts of work involved in the original modelling process do not require duplication simply because the package itself has changed.

3.1 Process

It is suggested that the process of modelling the built environment for use within architectural packages, and subsequently within interactive environments, should happen over a number of stages. The ordering of stages is vital, in that the collection and implementation of essential data sets will be more effective as a result.

- Information gathering. That is, the information required to enable modelling to progress.
- Calculating all dimensional measurements. The calculation process may vary between modelling packages, and this stage can ensure that dimensional accuracy is not compromised. When dealing with historic environments, there will be an added challenge to the modeller, in that data will often comprise a combination of site recorded data, digital maps, and historic map data.
- Modelling site buildings.
- Creating textures
- Optimising geometry
- Applying textures and UV mapping
- Importing objects into Unreal editor
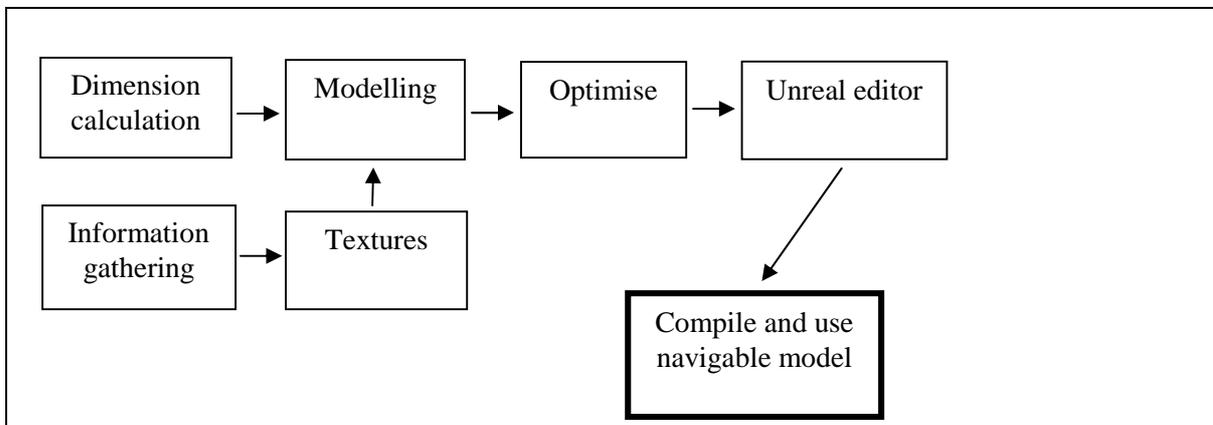- Compiling the real-time environment

Fig. 2. Flow diagram for modelling process

The authors recognise that aspects of this process concerned with the collection of geometrical data will most likely not be required in future studies, due to the availability of 3D laser scanning equipment. In fact, recent studies ([8], for example) have shown that most steps prior to the optimisation of geometry can now be automated, with extremely accurate results, and even across vast and complex natural landscapes ([9]). For the virtual representation of landscapes, as opposed to closely recorded detailing, methods using cross-correlation between photographs are also available (for example, [10]), and have begun to supersede approaches which begin by building models from first principles, of which [11]) was a seminal example. Whilst such equipment is also capable of collecting photographic material to record textures, for the purposes

of creating virtual environments, it may still be advisable to collect on-site and perspective corrected samples, which can be subsequently matched to the appropriate surfaces.

3.2 Information gathering

Before modelling of the site can begin it is important that specific information be gathered relating to the layout and aesthetics of the site. This information can take various forms but it is usual that a detailed scale site plan (at least 1:1250) is obtained as well as a detailed photographic study of the site. It is also useful if basic measurements are physically recorded when visiting the site so they can be referenced back to the site plan to ensure best accuracy.

When photographing the site it is important to keep in mind that the photographs will be used as reference material as well as being the basis for the majority textures used within the virtual environment. In the case where buildings are to be photographed it is preferred that each facade is captured looking straight on to ensure minimal distortion of the image. However when it is not possible due to immovable obstructions or limited space, Photoshop (or similar software) can be used to adjust the perspective of any photograph taken from an angle.

3.3 Calculating dimensional measurements

If a high quality site map is available, of at least 1:1250, then a decent proportion of the required measurements can be sourced from there. Before beginning the process of calculating all the length, width and height information required to model the site, it is important to consider the accuracy level required. In cases where large areas are to be modelled it may be impractical to carry out a detailed onsite measurement survey due to time and cost implications. Reference could, of course, be made to the potential for using 3D scanning equipment to meet this requirement.

Once the width and height of a building's façade was identified (as described above) the best photograph showing the whole façade was opened in Photoshop so the perspective could be adjusted. Using the transform perspective tool all edges of the façade image were made square. In cases where the photograph was taken from an angle additional transforms are required so that the features along the length of the façade are equally spaced. Photoshop is then used to first scale the image to equivalent pixels (i.e. if a façade is 8000mm by 2600mm then the image would be resized to 8000pixels by 2600pixels), and then resized (maintaining the aspect ratio) to make the resultant image more workable. Note: although the edited image is used to measure building features it is also used as a texture within the virtual environment.

The next stage involves importing the adjusted photograph into AutoCad so that dimensions can be taken off it. The photograph is imported as a raster image then scaled within the viewport using the reference function of the AutoCad scale command. This means, in effect, that once a known length of the image is scaled to 'real dimensions' all other features of the photograph are automatically scaled and thus can be measured using the distance command within AutoCad. During the process of measuring the photograph it is important that the dimensions are converted onto either digital elevation or sketched drawings of the subject building. Having a complete record of this information will help greatly when the process of modelling begins.

3.4 Modelling site buildings

Once a record of the buildings' dimensions has been recorded, either through scaled elevation drawings in a CAD package or on sketched drawings, modelling of the buildings in three-dimensions can begin. In the case study example all the initial geometry were created in AutoCAD using a combination of solid and surface modelling techniques. It was felt that the simpler shaped building elements would be best modelled using solid modelling and the more tricky elements, such as the roof coverings to the dormer windows, by surface modelling. In either case it is up to the person carrying out the modelling work which method they prefer to use.

As the textures were used to display all the intricate detail, the geometry is used to focus more on reproducing the overall form of the building. The layering system in AutoCAD was used to distinguish between the separate elements of each building or in other words the different materials or textures. For example, all the geometry that made up the granite walls of a specific building was placed on a layer called 'ExternalWalls', and all the roof geometry or objects that would receive slate tiles texture on the Roof layer. It is important to follow a similar workflow so when the model is exported for texturing and inclusion within the real-time environment it is in the correct format.

The process of modelling a building in three-dimensions usually starts from a 2D plan or elevation which is then extruded (given a third dimension) to the value of the building height in the case of a plan, or wall thickness when working with elevation information. In any case it is usually wise to model the larger elements, such as external walls, first as this creates a reference point from where other features can be attached. For example a building from the case study would be created as follows:

- Footprint plan of external walls extruded to height of eaves

- Gable end walls built up to ridge height

- Window and door openings cut out from external walls

- Windows and door drawn and inserted into openings

- Roof covering extruded from outline using profile of gable wall as guide

- Chimney stack extended from gable wall and chimney pots added

- Dormer windows created from measurements and located using pitch of roof covering object

Once the building envelope is complete (**Fig 3**) it is saved as a DWG file or equivalent ready to be imported into a texturing program.

Fig. 3. Building envelope within AutoCAD

In this case the model was imported into 3D Studio Max 6, a high-end modelling/texturing package. Max was used to edit the geometry into the correct format, add textures and apply the correct texture mapping. 3D Studio Max 6 is produced by Discreet, a division of AutoDesk, the makers of the AutoCad series, and is therefore jointly compatible with the DWG file format. This is very important as all the layering system set up in the AutoCad drawing will be maintained when imported into Studio Max 6 and saved as a MAX file.

3.4.1 Creating Textures

As textures are used to display a lot of the realism within the virtual environment it is important that they are prepared correctly and are of the best possible quality. In cases where the virtual environment is trying to reproduce existing real environments then digital photographs are used to represent the texture of any given object.

As explained, photographs that have had the perspective rectified can be used as textures. In cases where there have been objects in front of the building when the photograph was taken, Photoshop can be used to remove these. In many examples, there may be occasions when site vegetation or telephone lines obstructed the front of select buildings and thus were imprinted onto the photograph. The easiest way to remove these obstructions is to copy areas of the photo that are clear onto the areas that are not. This can be a time consuming process if the results are going to be effective but will add to the realism once used within the virtual environment.

Once the texture has been rectified and 'cleaned', the next stage is to prepare it in the format that the games engine can understand. In the research described here, a freeware version of the Unreal game engine called UnrealEngine2 Runtime$^{©}$ was used. Although fully compatible with models exported from 3D Studio Max, the Runtime software does require that all textures used be in the TGA or TARGA image file format. The software also requires that all textures be sized so that the vertical and horizontal numbers of pixels of the image are to the power of 2 (e.g. 16, 32, 64, 128, 256 pixels). This fact must be recognised at the outset of the texture creation process, to ensure that any subsequent scaling or tiling within the model preserves texture proportions.

Creating a 3D environment regardless of the size or complexity will result in the production of many individual textures. It is therefore necessary that each texture be given a unique name then stored in a location that will be easily available otherwise some files may be overwritten or substituted with the wrong file.

3.4.2 Optimise geometry

In virtual reality where the environments are displayed to the user in real-time rather than pre-rendered movies, frame rate becomes very important to ensure movement within the environment is as realistic as possible. To ensure a realistic frame rate (TV broadcast is usually 25fps), the model has to be optimised to display only the information that is needed. In other words, 3D Studio Max is useful as it enables the modeller to remove certain faces from the 3D objects that will not be visible within the virtual environment (i.e. faces created underneath the walls of the building). The editing or optimising of the geometry is only required on objects that have been created using solid modelling techniques as surface modelling only produces 3D faces that will be seen by the camera.

3.4.3 Apply textures and UV mapping

Once all the textures for a given model have been produced and saved in the correct format they can be applied to the corresponding faces of the geometry. In 3D studio Max textures are first imported into a Material Editor where they are given a unique name. Once all the relevant textures are imported they are applied by selecting all the faces of the geometry that have the same texture, (i.e. all surfaces of the roof), then dragging the corresponding texture from the editor onto the surface. Once applied the texture is aligned and scaled using mapping coordinates defined through the UVW Map Modifier within Max 6. UVW mapping corresponds with the X, Y and Z coordinates used in any virtual space/environment.

This process is repeated until all the faces of the model have been textured and mapping applied. Once complete the separate objects that make up the model are attached together to form one single entity. This is an important step as importing models from Max into the games engine only work if the file contains one complete object.

Fig. 4. Export from 3D Studio as a single entity and ASCII file

Fig. 5. Illustration showing the development of information from sketch representations to a fully modelled landscape.

3.4.4 Importing objects into the Unreal editor

UnrealEngine2 Runtime is freely available for non-commercial and educational purposes. It was selected over other available technology due to the fact it has been specifically produced to create interactive walkthroughs and simulations rather than focused solely on game environment creation. Another reason why Runtime was chosen was because it is able to import fully texture models from 3D Studio Max without the need for any editing once within the engine environment.

Once a model is completed in 3D Studio Max it is exported as an ASCII file. The ASCII file can then be imported within the Runtime editor as a static mesh. This is a relatively straightforward process, however to ensure that the model is fully textured within the editor, all the model's textures have to be imported first. The Runtime editor requires that all its content, in others words models and textures, are stored within packages. It is usual that all textures relating to one virtual environment are contained within one texture package and all the models are contained with one static mesh package. It is important that all the textures imported are those that were for these images once it has been imported.

Fig. 6. Model shown inside the Runtime editor

As each model is imported as a static mesh it can be viewed within the browser to check that all texturing is as it should be. There is one thing to note at this stage, all models that are created to 'real life' dimensions will become overly large once inserted into the game engine environment. The units of measurement within the Runtime editor are scaled to correspond with the size of the textures used (i.e. to the power of 2). Therefore models inserted into the environment have to be scaled by 0.11, if 1 is the equivalent to 100%. By scaling the imported models in this way they become equivalent to the height of the viewing camera (the view which the user sees).

3.4.5 Compiling the real-time environment

In 3D Studio Max, as well as AutoCAD and other similar CAD based systems, objects are introduced into a 3D space that has no mass or solid objects to start. In the Runtime editor the 3D space starts as a solid mass from which areas have to be subtracted in order that space for the models are created. In other words, it is as if you are starting in the middle of solid rock and first have to cut out a cave or vault before creating objects within. Therefore before any of the building model can be inserted, an area large enough to contain the entire site has to be cut out from the initial 3D mass.

The next stage is to create an atmosphere within the created volume to imitate the sky within a real outside scene. This is done by projecting animated sky textures onto the inside walls of the subtracted volume. By using this inbuilt feature of the Runtime editor an impression is given that the textured sky is an infinite distance away, similar to reality. Terrain maps or contour data can be used to model the topography of the land and then textured with aerial photographs to improve realism and help to position site objects.

Fig. 7. Still taken from the 'live' navigable model

4. ACTIVE NAVIGATION VS. PASSIVE OBSERVATION

A second stage of the research employed a between-groups design, where participants were divided into two main groups. The first group was comprised of participants who viewed pre-defined walkthroughs of two versions of the townscape model (passive observation), whilst a second group of participants navigated the two different versions of the model (active navigation). Subjects were required to view the virtual environment on a desktop monitor, and those subjects asked to navigate the model did so using keyboard and mouse navigation. Movement was confined to a 'walking' mode i.e. there was no option to 'fly' through the model, or to move at anything other than a walking speed.

The two versions of the model differed in terms of alternative street design/signage, building colours and textures etc. in three target areas and, following the viewing/navigation, subjects were asked to indicate which of the two models they preferred, and then answer a number of open and closed ended questions relating to their perceptions and understanding of the environment.

In order to maintain a level of similarity between the active and the passive conditions, active group subjects were given verbal directions to follow a certain route which ensured they ended up at the same target areas as the passive group participants. However, subjects in this condition were also free to navigate the model as they wished. The route they took, and directions in which they looked, were logged and video-recorded.

In each condition the study utilised a think aloud protocol, where subjects were asked to describe their thoughts, actions and impressions as they observed/navigated the model. Following the observation/navigation the study included clarifying questions based on subjects' comments/actions during the observation/navigation. This technique has been used successfully in previous investigations of people's navigation of virtual cities and spaces [12, 13].

Subjective commentaries recorded during the observation were transcribed and analysed in the context of the actions/part of walkthrough being undertaken at the time (which was video-recorded). This helped the research to draw conclusions about which aspects of the models are effective or confusing, or liked or disliked, particularly with regard to the active or passive experimental condition. Further details of the experimental design have been reported in by Galan-Diaz et al [14], with a particular focus on the effects of navigability on cognitive load. The experimental results will be reported in the near future.

5. DISCUSSION AND CONCLUSIONS

The question of how virtual and navigable environments can add to the study and understanding of heritage is central to the kind of research described herein. An obvious area for application would seem to concern the properly organised and ideally collaborative use of virtual sites, enabling interested parties to remotely access information, whilst having the opportunity to discuss their opinions and findings with others.

Previous work in the area of collaborative virtual environments would suggest that networked computers offer the possibility of mediation for human to human interaction, and the opportunity for users to make sense of the information contained within a virtual space (for example, [15]). The fact that there has been much research in recent years concerning the manipulation by users of virtual models in real time, for planning and design purposes [16],[17], suggests that a dynamic interaction with the processes of heritage assessment should be possible. That many previous studies (including those cited by Peng and [18], for example) have tended to focus on the use of such models at the macro scale is interesting, and perhaps suggests that the work reported here has a distinctive area of potential. Although it is certainly possible to 'zoom out' to allow users to observe layouts from above, the potential for detailed scrutiny of buildings and their layout from a user's perspective adds a dimension to existing planning tools and available processes. Previous research has demonstrated that the use of a range of media and representation methods can assist in the dialogue between expert and end user [19, 20], and that these might include photographs, GIS, online studies, architectural endoscopy (using models and analogue techniques, [21]) and qualitative interviews. The mechanism of using interactive 'games' technologies to allow navigation of virtual space adds an additional method through which end users and non experts can be drawn in to the processes of design, heritage appreciation or public participation in planning.

The interface itself perhaps also merits further research, given that navigation using a keyboard and mouse is not necessarily the most intuitive method for all, and given that planning participation often requires the input of significant numbers working together, rather than as individual actors. Song et al take a particularly novel approach, utilising calligraphic brush strokes to enable movement within an immersive VR environment [22], and Stock et al have undertaken many studies experimenting with the use of multi user voting and navigation of macro and micro scale virtual spaces [23].

A further aim of this research would be to further develop the manner in which conservation theory can be taught and understood using emerging computer based modelling packages. Established notions of heritage value [24], and methods to assess those values, will require to be incorporated in the models themselves, which highlights a wider need to develop models which allow for interrogation of any cultural data embedded within. Clearly, though, we must also recognise that significant aspects of heritage value assessment are concerned with the place of a building within a real context, as opposed to isolated or disaggregated aspects of a structure.

An obvious use for such virtual heritage would be to allow users to navigate space either without threat to the fabric, or even where the 'real' buildings do not exist [25]. A growing number of studies have been

completed in recent years which have attempted to define methods whereby such heritage value can be understood and assessed [26]. When considering the development of a navigable virtual environment, and particularly one which constitutes part of the built heritage, it is arguably essential that the range of data which might contribute towards heritage value be incorporated, or at least considered.

Research within the field of human computer interaction has shown that there may be differences between the manner in which real and virtual spaces are evaluated, and that these may additionally be influenced by the method of delivery and viewing [27]. However, the same studies also tend to note that virtual representations can also complement other communication media with regard to perception and interaction with space and architecture.

6. ACKNOWLEDGEMENTS

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