Proceedings of
8th International Conference on Construction Applications of Virtual Reality
CONVR 2008

Seri Pacific Hotel
Kuala Lumpur
20th - 21st October 2008

JOINT EDITORS:

Nashwan Dawood
Maisarah Ali
Puteri Shireen Jahn Kassim

Organised by: Co-Organisers:

MSC MALAYSIA Spearheading Transformation

CIDB MALAYSIA

UNIVERSITY OF TEESSIDE

Proceedings of 8th Annual Conference On Construction Application of Virtual Reality

Seri Pacific Hotel Kuala Lumpur, University Malaysia

20 – 21st October 2008

EDITORS: NASHWAN DAWOOD
MAISARAH ALI
PUTERI SHIREEN JAHN KASSIM

KULLIYYAH OF ARCHITECTURE & ENVIRONMENTAL DESIGN
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA
P.O BOX 10, 50728 KUALA LUMPUR

International Islamic University Malaysia | University of Teesside | CIDB Malaysia | Multimedia Development Corporation

Published by
Kulliyah of Architecture & Environmental Design
International Islamic University Malaysia
P.O. Box 10, 50728 Kuala Lumpur, Malaysia
Tel: 603-61965271/5241/5221 Fax: 603-61964864

Printed in Malaysia

First Print 2008

ISBN: 978 – 983 – 3142 – 09 - 5

Proceedings of 8th Annual Conference On Construction Application of Virtual Reality

Nashwan Dawood, Maisarah Ali and Puteri Shireen Jahn Kassim

8th International Conference on Construction Applications of Virtual Reality (CONVR 2008)
October 20-21, 2008
ISBN 978 – 983 – 3142 – 09 -5

DEVELOPING A VIRTUAL ENVIRONMENT FOR VIEWING URBAN SPATIAL PLANNING AND CONSTRUCTIONAL FEATURES OF AN URBAN HERITAGE SITE - THE CASE OF FATEHPUR SIKRI, INDIA

Dr. Puteri Shireen Jahnkassim
Assistant Professor, Department of Building Technology and Engineering
Kulliyyah of Architecture and Environmental Design,
International Islamic University Malaysia

Dr. Mansor Ibrahim
ProfessorDepartment of Urban Regional Planning,
Kulliyyah of Architecture and Environmental Design,
International Islamic University Malaysia

Dr. Zuraini Denan,
Assistant Professor, Department of Architecture,
Kulliyyah of Architecture and Environmental Design
International Islamic University Malaysia

Dr. Muhammad Abu Eusuf
Associate Professor, Department of Building Technology and Engineering
Kulliyyah of Architecture and Environmental Design
International Islamic University Malaysia

Dr. Murni Mahmud, Assistant Professor
Department of Information Systems
Kulliyyah of Information and Communication Technology, International Islamic University Malaysia

Juliana Aida Abu Bakar, PhD Candidate
Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia

ABSTRACT

The paper discusses the processes of implementing virtual reality to highlight salient aspects of traditional urban planning and constructional aspects of a heritage complex; and the development of three dimensional (3D) user interfaces to view and navigate through the model. The interface allows flexible navigation to explore the space and construction of Fatehpur Sikri; however, in some cases navigation is restricted by a guided sequence in order to enhance learning and understanding of the elements of architectural heritage. The complex of Fatehpur Sikri itself consists of a series of large buildings, surrounding large centre courts. Two dimensional (2D) measured drawings are developed into 3D models and integrated into interfaces which sequentially highlight the macro (urban planning) aspects to the more detailed structural aspects. One of the focuses is to deliver how the spatial effects of the complex may be affected by the organization and construction of built forms around open spaces, and the way they shift in major axes occur as a viewer moves along the city. Virtual reality is used to highlight the essential qualities of site such as terrain of a rocky sandstone ridge rising some 30 m to 45 m, the main buildings i.e. Royal residences, pavilions, halls and meeting areas where the topography necessitated in creating levels within the Royal complex with the result that the courts are staggered one behind the other. The main structures and the city form are highlighted; a city within a city, zooming in on selected elements such as the renowned raised square platform in the center of the pool approached by the four narrow gangways. Visualization is used to show how the sun moves into a particular position over the axis of the mosque and how the modular grid, developed from an axis and the square, became a systematic design instrument. The structural visualization software is used to visualize structural forces within Central pillar of Diwan-i Khas – in order to understand various elements of construction. This paper describes few challenges encountered throughout a) to identify the best possible way of translating historic information and representing architectural information to user, and b) to further leverage the level of realism and real time rendering performance. Future work includes evaluating the interface and interaction issues and to what extend user absorbs information in the virtual environment.

KEYWORDS

Virtual Reality, Cultural Heritage, Fatehpur Sikri

1. INTRODUCTION

The term "virtual heritage" refers to the use of virtual reality (VR) systems to generate, navigate and explore reconstructed environments that are of cultural heritage interest. This emerges from the term digital heritage which uses digital technology especially computer systems to preserve and communicate cultural heritage. The purpose for virtual heritage may include the following reasons; (a) to accurately represents an old historic city of a last decade (Cabral et *al.*, 2007), (b) to restore the ancient appearance of historic buildings that have been severely damaged (Ikeuchi et *al.*, 2003) and (c) to preserve the cultural documents accurately. The outcomes may be represented by means of video output files, rich in sound and animation scenes, to reach wider audience.

In last decade, many cultural heritage projects concentrated on how data acquisition technology uses three-dimensional (3D) scanning facility for large objects, and how this 3D data can be viewed and accessed by thousands of people. Digital Michaelangelo Project involves 3D scanning of large fragile objects. This multi-year project combines the use of laser rangefinder technology and complex algorithms to produce large dataset 3D artefacts of ten five-feet statues (Koller and Levoy, 2006). As the dataset is very large, it is almost impossible to share these masterpieces with public via the Web. This has led to a development of dedicated viewer, ScanView by the team. This viewer allows user to rotate and translate the 3D shaded rendering of the models while protecting the contents from unauthorized extraction.

Apart from 3D scanning which eventually involves large amount of data, a 3D morphing algorithm is used for restoring the original shape from the digital model obtained. This technique is designed to reconstruct the ancient Nara Buddha statute in Japan. Being severely damaged by fire, it was reconstructed using information available in inherited literature. The restoration of the surrounding temple was done by digitizing the miniature model of the temple and then scaling the digitized model up to its original size (Ikeuchi et *al.*, 2003). The result of the project is made public by producing a video and image screen shots hence limiting user interaction with that model.

Virtual gallery developed in Hendricks et *al.* (2003) is an exhibition of various artworks on the Web combining the use of HyperText Markup

Language (HTML), Java3D, and Virtual Reality Modelling Language (VRML). It uses the 3D metaphor for the navigation interface where user may walkthrough in the virtual environment and selects the artwork of interest along the way. The artwork is then displayed in 2D image with some text information available to explain further details about that particular artwork.

Other associated term, "virtual museum" is an organized collection of electronic artifacts and information resources include paintings, drawings, photographs, recordings, video segments, and all possible digitized items. Virtual museum is likely to take place as online resources making valuable historical artefacts and information more accessible to larger pool of audience. Virtual museum may also allow user to walkthrough a virtual environment of the real museum (Norazimah, 2008). The historical resources are displayed in 2D or in a video as user moves along. Another work has developed 3D models of historic complex and using digital rendering and animation to produce a video output for public viewing (Pirbabaei et *al.*, 2007).

There is effort to digitizing historical items and transfer them into a game-like environment in order to engage the user to immerse in the virtual environment. Game engine such as Quake is used together with ray tracing methods to develop a real-time simulation of virtual temple (Calef et *al.*, 2002). Such application provides user with the ability to select view in greater detail as they travel along. The interaction of participants inside such game-like environment contributes significantly in providing enjoyable experience while visiting an archeological site for public especially teenager (Andreoli et *al.*, 2005).

Previous virtual heritage projects concentrates on preserving artefacts and monuments and disseminating them through video output to public viewing. Besides having these historical items with accurate measurements and details in the database, recent work in the area has proceed to make this information accessible to the public audience. Currently, there are efforts to use VR for demonstrating a ruined Citadel of Bam, Iran (Ono et al., 2008). In our study, we developed a virtual environment to view urban planning and constructional aspects of the historical city of Fatehpur Sikri in Agra, India. The interface allows flexible navigation to explore the space and construction of Fatehpur Sikri;

however, in some cases navigation is restricted by a guided sequence in order to enhance learning and understanding of the elements of architectural heritage. Focusing on Fatehpur Sikri, we extended the existing method of heritage studies to include the use of state-of-the-art technology. It is contended that VR will make architectural heritage education and exhibition exciting and increase user appreciation to the distinctive beauty of historical monuments.

1.1 Initial phase of research and development project

The initial phase of this research and development project concentrates on urban planning and constructional features based on selected monuments in Fatehpur Sikri. It is decided that the final output of this project would deliver how the spatial effects of the complex is affected by the organization and construction of built forms around open spaces and the way shifts in major axes occur as a viewer moves along the city. Virtual reality is used to highlight the essential qualities of site such as terrain of a rocky sandstone ridge rising some 30 m to 45 m, the main buildings i.e. Royal residences, pavilions, halls and meeting areas where the topography necessitated in creating levels within the Royal complex with the result that the courts are staggered one behind the other. The main structures and the city form are highlighted; a city within a city, zooming in on selected elements such as the renowned raised square platform in the center of the pool approached by the four narrow gangways. Visualization technology is used to show how the sun moves into a particular position over the axis of the mosque and how the modular grid, developed from an axis and the square, became a systematic design instrument.

The monuments were selected based upon the complexity of architectural forms and the building services. Diwan-i Khas or Hall of Private Assembly, for example, contains an elaborately carved large pillar, almost one meter in diameter, which mushrooms into a gigantic capital, which stands in the centre to support a circular stone tray linked to galleries around the walls by four radiating gangways. The real function on this building is still in dispute, due to many arguments, it is believed that the Diwan-i Khas has been used for at least one of the following functions; (a) as Hall of Private Assembly where the Emperor Akbar is said to discuss the affairs of the state with his Ministers who sat around the gallery, (b) as the Jewel House where the gems and jewels were kept, and (c) as Ibadah Khana that constituents scholars from various religions in the country (IIUM Heritage Studies, 2005).

The aesthetic vision in Fatehpur Sikri is enriched by the inner details and builds up of visual forces in the architectural detailing. A general overall unity is achieved in the structural system by surface decoration and, at places, with stylized Arabic calligraphy. An order and rhythm in the individual facade of buildings further result from repetition of identical architectural features such as ornately carved stone brackets, projections and balconies besides extensive use of red sandstone not only in buildings, but also as floor paving in the open spaces. In addition, it repetitively uses intricate carved stonework using geometric and floral patterns, besides stone-inlay work which is typical of Islamic architecture.

1.2 Summary of research process

This study is a combination of two disciplines: cultural heritage and virtual reality, in which the combination between this two has emerged into a term virtual heritage (Addison, 2000). The traditional method of field study has been extended to make full use of state-of-the-art technology of virtual reality and multimedia as shown in Figure 1 as an alternative means to better comprehend and disseminating architectural heritage knowledge.

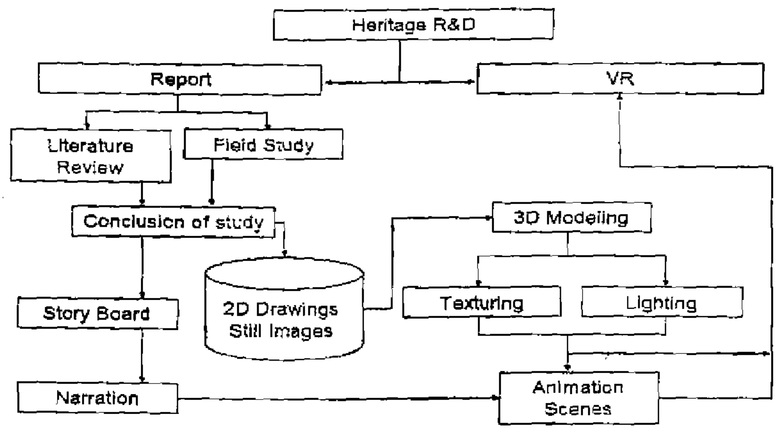


Figure 1: The R&D activities of our cultural heritage project

Heritage research and development (R&D) can be approached by extensive reporting which adopt the established research framework. The framework may include literature review and field study then conclusion can be produced. Storyboard and narration may be derived from the conclusion which subsequently provides the requirement for animation scenes. By manipulating and/or converting the 2D drawings and series of still images into 3D modelling processes, animation scenes can be generated with added extensive texturing and lighting. Results of 3D modelling, animation scene and overall outcomes of the Heritage studies are critical input into the VR output. The details of Heritage R&D will be described in the subsequent sections.

2. URBAN PLANNING AND CONSTRUCTIONAL FEATURES

Fatehpur Sikri, built by Akbar, a great builder of Mughal Empire (1556-1607) is located 38 km from Agra, India. It is famous for its construction record time and indigenous craftsmanship from various regions (Petruccioli, 2007) . Its site was a point of convergence on a point which combines 'Sikri' literally means 'Shukran' (the Arabic term for thanks or to express gratitude) and 'Fateh' means victory. Its architecture and planning was born from the aim of creating a bold new imperial style. The heritage of Arabic traditions and Central Asia merged with Indo-Islamic traditional forms to produce a masterpiece of Mughal architecture.

The urban planning of Fatehpur Sikri is a mixture of religious, secular and defence architecture. The following are main constructional features of Fatehpur Sikri extracted from various literatures:

- The city was built on a flat terrain of a rocky sandstone ridge rising some 30 m to 45 m above a ridge oriented northeast-southwest, and was bounded on the north by an artificial lake which is now drained, and enclosed by the city walls (Jaswant, 1993).
- The palace complex consists mainly of the royal residences, pavilions, halls and meeting areas. The topography necessitated in creating levels within the Royal complex with the result that the courts are staggered one behind the other (Nath, 1982).
- The Jami' Mosque, located on the very summit of the ridge, faces westwards towards Makkah, the holy Islamic city.

- The axes generated a comprehensive relationship of the three structures with one another. The distance of the inn from the Centric Mosque measured in units of Akbar's time, is 300 'ilahi gaz'. One 'ilahi gaz' equals one royal yard, equivalent to 30.75 inches or 78 cm. This measurement determined the location of important structures and the main elements of the city (Petruccioli, 1984).
- The territory was divided into eight super squares, each of which was then divided into nine smaller squares of sides measuring 300 of the above units. Each of the nine modular squares was further divided into sub-modules. A grid of nine squares applied both horizontally and vertically, together with a network of super squares was instrumental in establishing the form of the city (Jaswant, 1993).

3. THE PROCESS OF MODELING AND ITS MANAGEMENT

As part of our architectural curriculum, students are required to undergo heritage studies in order to expose them to heritage architecture around the world. Students were sent off to various countries throughout the world to do site survey where findings and measurements were documented. The final output includes digital pictures, digital videos, manually and computerized measured drawings, multimedia and poster presentation, and final report. We decided to use two-dimensional (2D) computer aided design (CAD) drawings as primary resources to the 3D modelling process. Nonetheless, other output files and documents, together with scholar books and articles, are complementary resources and served as cross references to this research and development projects. The process of digital reconstruction is depicted in Figure 2.

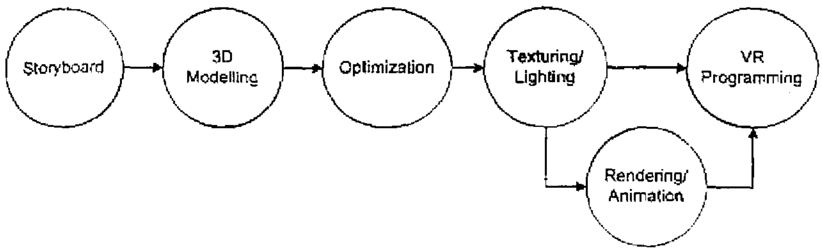


Figure 2: The development process of the virtual environment

3.1 Heterogeneous Data Resources

The output and findings obtained from field study were properly documented in terms of final report, leader's diary, manual and computerized drawings, and exhibition poster. Thus, data resources comprise of different types of file formats. The following are available data resources and their file formats: final report in doc file format; 2D CAD drawings in dwg file format; still images in jpg and gif format; and video and movie files in avi and mpg format.

The identification of file formats in database is important especially the primary data resources for the digital reconstruction process in order to make possible arrangement for later use in the participating software. In any case the primary data resources are not available, complementary data resources such as still images and movie files were used instead.

3.2 Management of 3D Models

Our development team comprises of nine people from various education background i.e. history, architecture, multimedia and computer science. As the team members background diversifies, fortnight meetings were held to uniform ideas and disseminate relevant knowledge as well as to resolve both technical and administrative issues. The storyboard of the project was outlined at the earlier stage of this project to ensure all parties obtained a clear overview of the project. It was also used as a foundation for animation scenes and served as basic requirements for user navigation in the virtual environment. Screenshots of storyboard sketches deliberating on Diwan-i Khas animation scenes are illustrated in Figure 3.

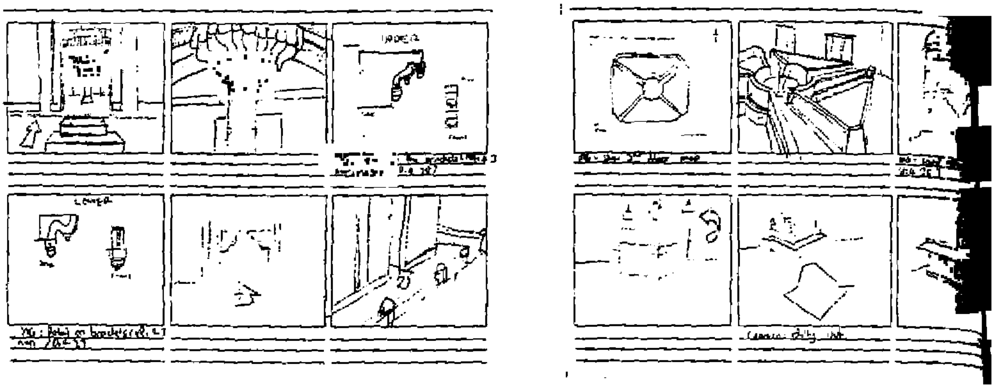
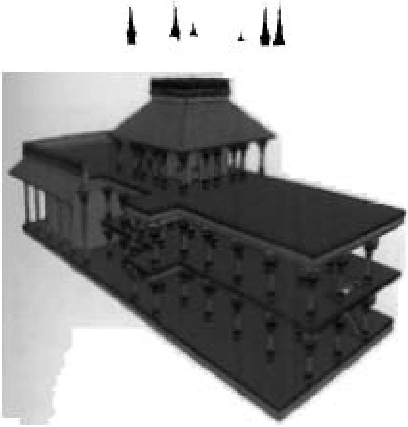


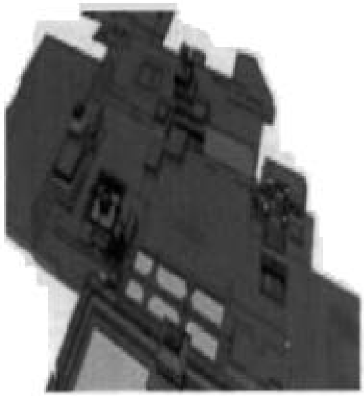
Figure 3: Storyboard sketches

Tasks such as terrain modelling, 3D modelling and interface design were then delegated among team members to meet dedicated deadlines. At this stage, 3D modelling guidelines were developed in order to provide reliable output and minimize error in the final model.

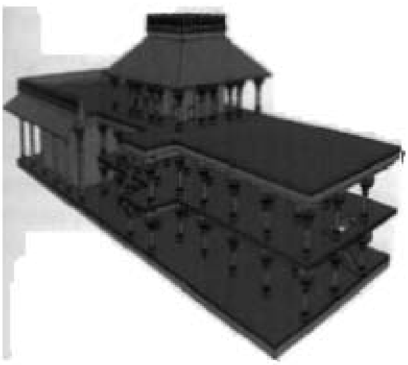
4. 3D MODELING

The software *SketchUp* was used to perform 3D modelling. The process of modelling began with extruding in z-axis all entities provided by 2D CAD drawings. These 2D measured drawings were imported from *AutoCAD* software. Buildings in Fatehpur Sikri were modelled separately and stored in different files. Even it is in an individual file, the file size is extremely huge and we have to increase our high performance computer memory to compile them. Basic models of Buland Durwaza and Panch Mahall in Fatehpur Sikri and the combination of these monuments are illustrated in Figure 4.





c)



b)

Figure 4: Basic models of (a) Buland Durwaza, (b) Daftar Khana, and (c) the combination of several monuments

The 3D modelling in *SketchUp* is relatively easier and faster for architectural applications. However, the resulted models when exported to

3ds Max possess huge numbers of polygon count, approaching nearly five million. Hence, these models were optimized by means of several methods as discussed in Section 5.

4.1 Terrain Modelling

"From a morphological standpoint, we can identify the structurizing aspects of the city on the ridge about 40 m in height..." (Petruccioli, 1984). Literature states that Fatehpur Sikri is built upon a different terrain levels. With the aid of a diagram given in Petruccioli (1984), a basic model of the terrain was developed using *SketchUp*. Figure 5 depicts the modelling output of the terrain.

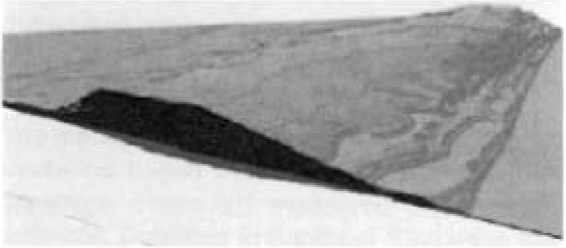


Figure 5: Basic terrain model

4.2 Modelling From Still Image

Still images were used as basis to provide clear reference on the 3D outlook of the extruded models. Cross referenced method is a common procedure to describe missing or ambiguous data in 2D CAD drawings. The process of modelling Anup Talao, a raised square platform in the center of the pool approached by the four narrow gangways, used human scale to model the narrow gangways as illustrated in Figure 6.

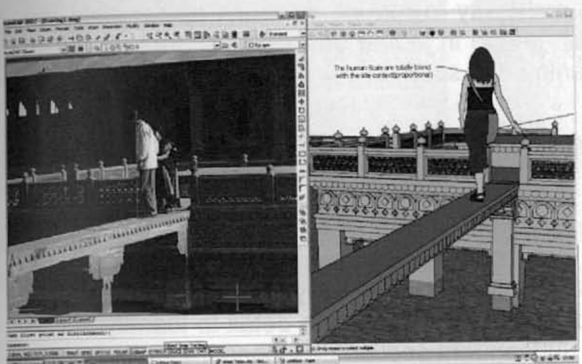
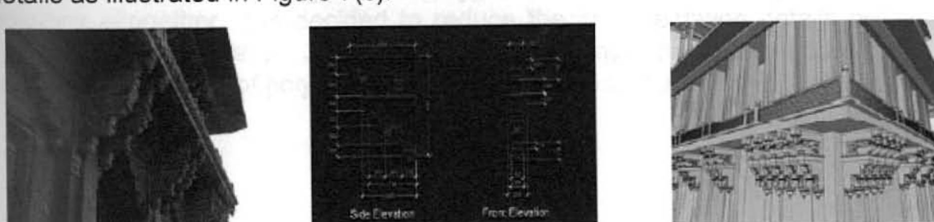


Figure 6: The reconstruction of Abdar Khana missing data based on a still image

Fatehpur Sikri buildings are famous of their indigenous craftsmanship from regions like Gujarati and Bengali. This captivating craftsmanship is manifested, for example, in brackets as in Figure 7(a). As available information is only in 2D CAD drawings without ornamentation details as depicted in Figure 7(b), modelling brackets for 3D requires extensive effort, searching from one still image to another, to determine the possible measurements. The output of bracket model was relatively high in level of details as illustrated in Figure 7(c).



(a) (b) (c)

Figure 7: Bracket modeling in Diwani Khas based on (a) still image and (b) 2D CAD drawings, producing (c) high level of details output

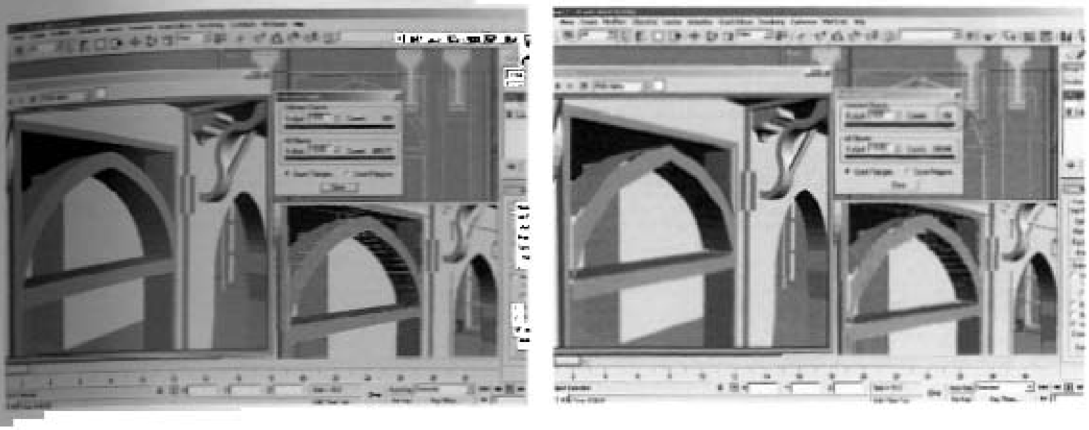
It is a lesson to learn that eventhough the modelling guidelines have been set in the early stage of this project; the resulting models have to be retouched because each participating modeller had their own style of modelling. Each model possessed a relatively large number of polygon counts and optimization process was done afterwards to reduce the polygon count. While it is a necessity to reduce as much as possible the polygon count for ease of navigation in virtual environment, these models are left in high polygons for animation scenes to preserve the realism.

5. OPTIMIZATION OF MODELS

The optimization process was completed in *3ds Max* by using available features such as the existing modifiers, redrawing *spline* entities, and replacing less important objects that carry high polygon count with texture image. Polygon count of each model was studied in detail to identify which entities would be optimized. Subsequent section describes the optimization process with examples.

5.1 Use of Existing Modifiers

The *Optimize* modifier in *3ds Max* allows reducing number of faces and vertices in an object while *MultiRes* allows reducing number of vertices and polygons. These modifiers when applied might reduce the number of polygon count to almost half in which the appearance of the respective entity was relatively sacrificed as depicted in Figure 8.

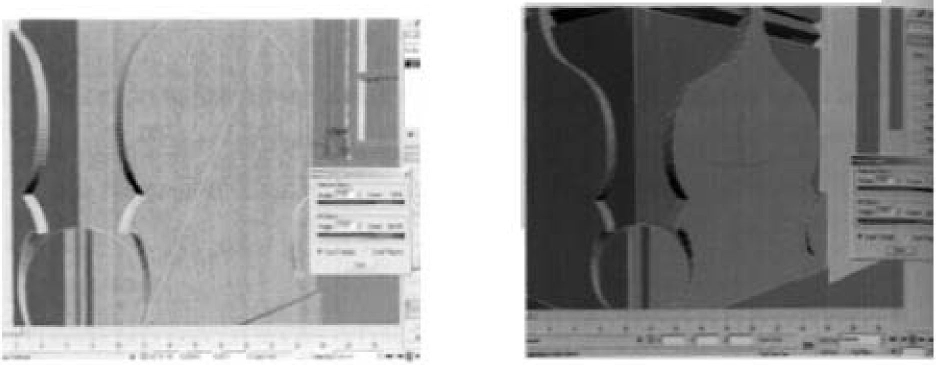


a b

Figure 8: The appearance of arch (a) before and (b) after applying the modifiers

5.2 *Spline* Redraw

Fatehpur Sikri has a great number of decorative features in almost all columns and shafts. This ornamentation is full of floral motifs which needed to be sacrificed in the virtual environment. In some cases, however, this ornamentation is preserved. One column in Salim Chisti Tomb building, for example, has approximately 13,000 polygon count. As this building has 22 columns altogether, it is decided to reduce the ornamentation details by redrawing the spline in *3ds Max*. This technique has tremendously reduced the number of polygon count of the column as shown in Figure 9.



(a) (b)

Figure 9: The ornamentation (a) before and (b) after redrawing spline

5.3 Texture Replacement

Anup Talao is a lake consists of a squared platform in the middle which interconnected with four narrow gangways. On this platform, the literature stated that the musician, Tansen played his music to the pleasure of Akbar, the Emperor. The carving fence surrounding the squared platform in Anup Talao was modelled in a great detail hence amounting to 35,000 polygon counts as depicted in Figure 10.

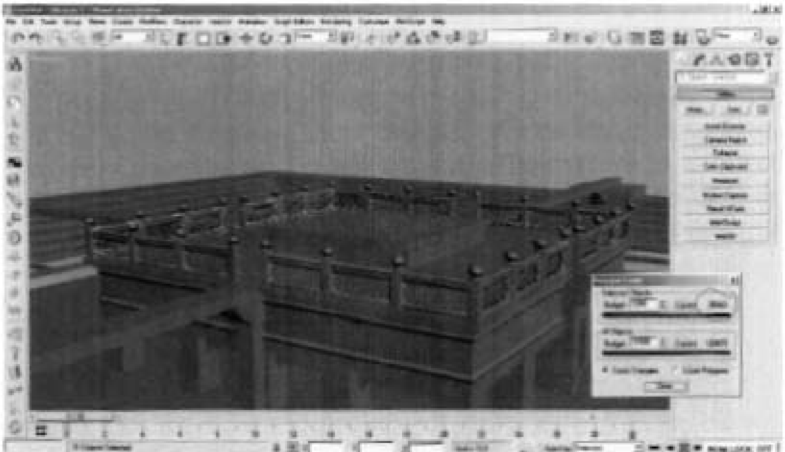


Figure 10: A screenshot showing polygon count of the 3D fence surrounding the square platform of Anup Talao

The fence model was captured and edited in *Adobe Photoshop*, adopting opacity texture in the image. This image was exported to *3ds Max* and mapped back to replace the 3D model of the fence. It is observed that the use of this technique has tremendously dropped the polygon count as shown in Figure 11.

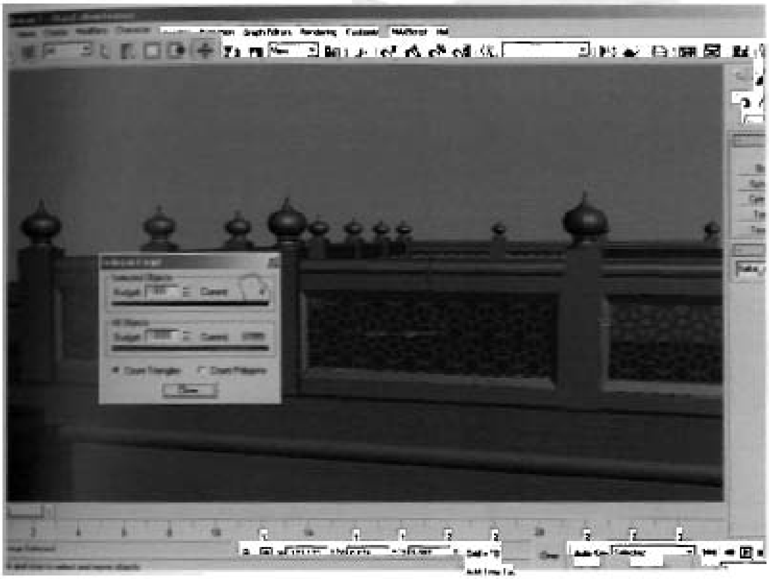
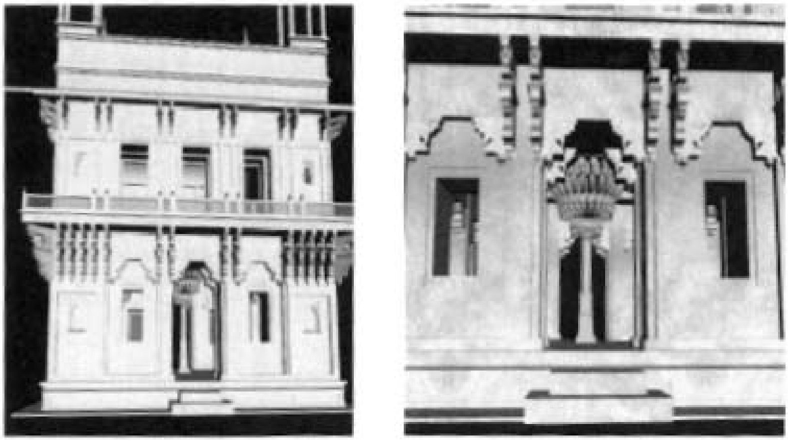


Figure 11: Polygon count after replacing the 3D fence with image texture

The optimization process, in our case, consumes a lot of time and effort. However, this process is crucial in order to obtain relatively smooth navigation experience in the virtual environment. The following section continues to describe the process of texturing and lighting the virtual environment.

6. TEXTURE AND LIGHTING

Texture and lighting are necessary to provide a certain degree of realism to the virtual environment. In our case, we did texture baking to the 3D model in order to have realistic shadow, light effects, and reflection in a single texture, with relatively small increment in the file size. The texture baking process was done in *3ds Max* with the use of lighting source and 'render to texture' feature. The baked texture was then mapped to respective objects in which a screenshot of the output Diwan-i Khas is depicted in Figure 12.



(a) *(b)*

Figure 12: Diwan-i Khas building (a) before and (b) after baked texture mapping

Models with baked texture are supported in *Virtools*, the software we used to create the virtual environment. At this point, the visualization and animation scenes were prepared as they would serve as information materials to the virtual environment.

7. VISUALIZATION AND ANIMATION SCENES

Visualization and animation scenes are used to provide extended information to better comprehend the text in the literature and to appreciate the uniqueness of structural forms in Fatehpur Sikri. The basis of visualization and animation works includes the following remarks and highlights:

- "In this attempt to control the unitary form of the city, for the first time the modular grid, of casual help to the designer, becomes a systematic design instruments at all scales." (Petruccioli, 1984);
- The movement of sun into a particular position over the axis of the Jami' Mosque;
- The structural forces of the central pillar of Diwan-i Khas;
- Exploded axonometric of several buildings; and
- The rainwater harvesting system at Fatehpur Sikri is the oldest documented system in India (IIUM Heritage Studies, 2005).

The visualization and animation works were prepared using variety of software that suits the above purposes. The output is rendered to either video or image file format. For instance, the movement of sun into a particular position over the axis of the Jami' Mosque is visualized using *Ecotect* software as illustrated in Figure 13.

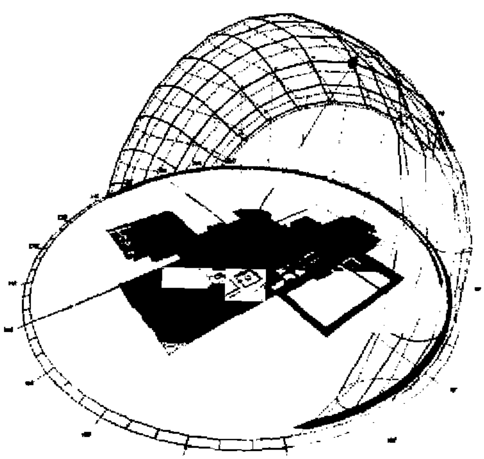


Figure 13: The sun path visualization

The process of developing these materials is unique and subjected to individual software and is being describes elsewhere. In the virtual environment, these materials are loaded upon user presence in the vicinity of the respective area. Subsequent section describes the implementation of navigation and interaction in the VR software.

8. NAVIGATION AND INTERACTION IN THE VIRTUAL ENVIRONMENT

The finalized 3D model from *3ds Max* was exported to *Virtools* in cmo file format to generate the VR environment. Interactivity elements were added into the environment by available features and scripting. For example, proximity sensor was added to sense a presence of user nearby a specific area. In this VR environment, the users may navigate freely; an icon that indicates information is available when a user is in a range of proximity to a particular attraction or monument. By triggering the icon (i.e. user collides with the icon), the user may view extended information regarding the attraction or monument. The information can be shown to the use in the following formats: text, still images or movie files, as shown in Figure 14.

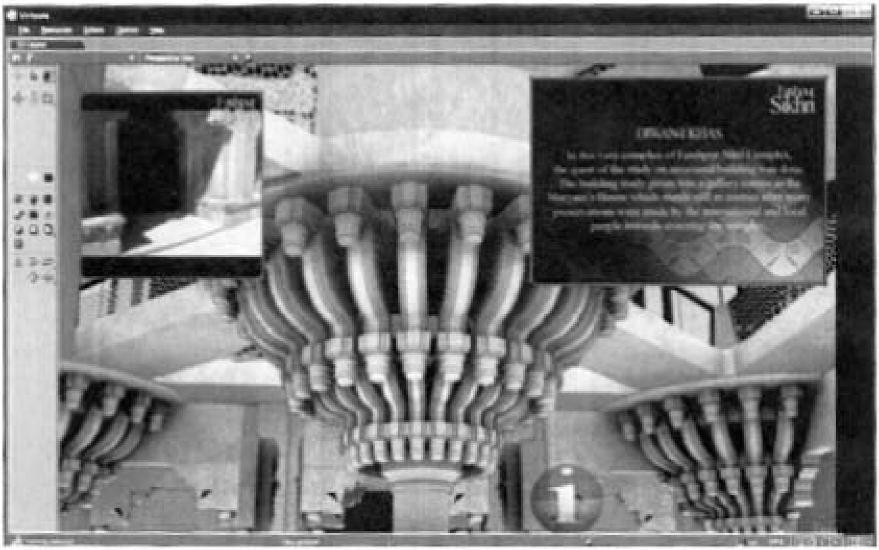


Figure 14: Screenshot of the VR showing information regarding central pillar in the Diwan-i Khas

An avatar which represents a virtual character of people was created to simulate the user navigation and movement in the environment. Avatar, in our case, is created for the purpose to provide human scale in relative to the spaciousness of buildings and open courts in Fatehpur Sikri. As this virtual environment is intended to emphasize on the urban spatial planning and constructional features of Fatehpur Sikri, this avatar was created simple and transparent.

In this VR environment, users' navigation in the 2D graphical user interface (GUI) was facilitated by sidebars and drop down menu. These navigation features were incorporated in the VR interface. These interface design features have been included in the VR to find out if 2D GUI will provide a better support for the user navigation in the VR environment. It is speculated that 2D GUI may yield a more efficient navigation due to familiarity and simplicity. The navigation features are available upon demand (i.e. by clicking the sidebars and/or pressing keyboard buttons); such design decision is to avoid cluttering in the virtual environment with irrelevant substances and features which may lead to user confusion and loss in the environment. Figure 15 depicts the interface with the 2D GUI navigation features (e.g. sidebars) which facilitate the user navigation in the Fatehpur Sikri virtual environment.

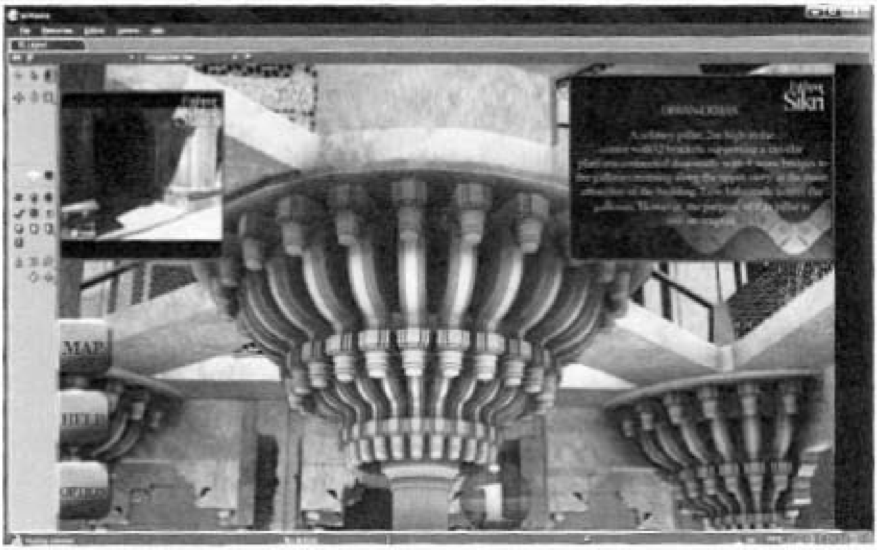


Figure 15: The navigational aid is given by 2D GUI sidebars (bottom left)

The final output of the virtual environment was exported to Web player in vmo format. At this point, it is decided to leave the virtual environment in stand alone mode rather than to upload in any server. The high end graphical processing unit was used as a platform of the virtual environment.

9. CONCLUSION AND FUTURE WORK

This paper has described the initial phase of the research and development project in using VR to view urban planning and constructional features of a heritage site, Fatehpur Sikri. It discusses the development process of the virtual environment using various visualization, 3D modelling, CAD, and VR software. The 2D GUI metaphor was integrated into the virtual environment to help user navigation and to link user with extended information of the objects (e.g. monuments) in the virtual environment. Visualization and animation scenes were added to educate users in a particular subject matter in the virtual environment. This virtual environment allows users to navigate the virtual historical city of Fatehpur Sikri. The navigation is guided by 2D GUI metaphor and the interaction between user and the virtual environment allows more access to information via visualization and animated scenes.

At this point, the research has explored the process of developing virtual environment for viewing and navigating a large heritage site; subsequently, this study plans to expand user interaction activities in other virtual historical cities. The use of semi curve screen display and head mounted display will be investigated to understand if such devices will create an immersive experience for the users in the virtual environment. To support heritage education, we intend to add more information that can be accessed by the users when navigating the virtual historical cities. This allows user to view other types of data such as text that contains more information of specific monuments, movie files with narration of particular events,

and realistic still images of ornamentation and carvings. These will eventually lead to user appreciation of historical monuments and distinctive beauty of past architecture. Future research and development includes evaluation of interaction between the users with the virtual environment interface. The evaluation may surface the interaction issues and to what extend the users are able to absorb information in virtual environment.

10. ACKNOWLEDGEMENT

We would like to extend our warmest gratitude to Multimedia Development Corporation, Malaysia for granted us financial assistance and VR Centre for granted us access to its VR facility. We appreciate the contribution of IIUM Heritage Studies for supplying our development team with lots of materials towards the completion of this project. We also would like to thank Husam Abdulfatah Haron, Syed Huzaifah Syed Omar, Edry Faizal Eddy Yusof, Irfan Hassan, Mohd Fadhli Ilias, Muhammad Afiq Ibrahim Shukri, Mohammad Nazirulhaq Abdul Wahab, and Abdul Fattah Abd Ghani for their endless effort to help making this project successful.

REFERENCES

Addison, A. C. (2000). "Emerging Trends in Virtual Heritage", *IEEE MultiMedia, IEEE Computer Society, 07*, pp.22-25.

Andreoli, R., Chiera, R.D., Erra, U., and Scarano, V. (2005). "Interactive 3D environments by using videogame engines," *Proc. of International Conference on Information Visualization (IV2005)*, pp. 515-520, July 6-8.

Cabral, M., Zuffo, M., Ghirotti, S., Belloc, O., Nomura, L., Nagamura, M., Andrade, F., Faria, R., and Ferraz, L. (2007). "An experience using X3D for Virtual Cultural Heritage", in *Proceedings of ACM Web3D 2007*, Italy, April 15-18.

Calef, C., Vilbrandt, T., Vilbrandt, C., Goodwin, J., and Goodwin, J. (2002). "Making It Realtime: Exploring the Use of Optimized Realtime Environments for Historical Simulation and Education," *Museums and the Web 2002*, Retrieved October 5, 2007 from *http://www.archimuse.com/mw2002/papers/calef/calef.html*.

IIUM Heritage Studies, (2005). *Diwan-i Khas*, Unpublished report, Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia.

Ikeuchi, K., Nakazawa, A., Hasegawa, K., and Oishi, T. (2003). "The Great Buddha Project: Modeling Cultural Heritage for VR Systems through Observation," *Proc. Of Second IEEE/ACM International Symposium on Mixed and Augmented Reality (ISMAR03)*, Tokyo, Japan.

Jaswant Rai. (1993). "Mathematics and Aesthetics in Islamic Architecture: Reference to Fatehpur Sikri", *Architecture and Planning*, Vol. 5, pp. 19-48.

Koller, D., and Levoy, M. (2005). "Protecting 3D Graphics Content", *Communications of the ACM*, Vol. 48 No. 6, pp. 74-80.

Nath, R. (1982). *History of Mughal Architecture*, New Delhi.

Norazimah Awang. (2008). *Virtual Museum Development: User Acceptance of the New Technology*. Sintok, Malaysia: Faculty of Technology Management, Universiti Utara Malaysia.

Ono, K., Elham Andaroodi, Alireza Einifar, Abe, N., Mohammad Reza Matini, Bouet, O., Chopin, F., Kawai, T., Kitamoto, A., Ito, A., Eskandar Mokhtari, Saeed Einifar, Seyyed Mohammad Beheshti, and Adle, C. (2008). 3DCG reconstruction and virtual reality of UNESCO world heritage in danger: the Citadel of Bam, *Progress in Informatics,* No. 5, pp.99-136.

Petruccioli, Attilio. (1984). "The Process Evolved by Control Systems of Urban Design in the Mogul Epoch in India: The Case of Fatehpur Sikri". Environmental Design: Journal of the Islamic Environmental Design Research Centre 0,18-27.

Petruccioli, Attilio. (2007). *Fatehpur Sikri,* Italy: Electa.

Pirbabaei, M.T., Rahimian, F.P., and Ibrahim, R. (2007). "The Development of Virtual Museums in Iran Presenting Historic Buildings of Azerbaijan Province, Iran in 8 Historic Complexes, Combination of Different Models and Materials", in *XXI International CIPA Symposium*, Athens, Greece, October 1-6.