3D MODELLING AND VISUALISATION OF AL BASTAKIA IN DUBAI, UNITED ARAB EMIRATES

KARIM HADJRI

Department of Architectural Engineering, College of Engineering, United Arab Emirates University,
P.O. Box 17555 Al Ain, UAE – khadjri@uaeu.ac.ae

KEY WORDS: architecture, urban, digitisation, modelling, CAD, Heritage, Dubai, UAE.

ABSTRACT:

Owing to the increasing need to catalogue and protect important urban heritage around the world, several recording techniques including Photogrammetry and 3D Scanning are used to create accurate digital models of historic sites or objects. However, the accuracy of the product varies with the technology used and the budget available for the purpose since sophisticated equipments are still expensive. This project firstly involved the examination of various kinds of built architecture such as wind towers and public buildings in order to examine their role in creating a historical reference for the built environment of the United Arab Emirates. Then, an important historical site was selected for further analysis, with the aim to eventually recreate it digitally using existing data. In order to do this, a photographic survey of the site was produce, and a 3D model was generated using existing cartography combined with the results of on-site surveys. In addition, the paper discusses the use of 3D digitisation and the digital modelling process, and assesses the benefits and limitations of this technology particularly with respect to urban 3D modelling. A preliminary research into scanning and digitisation methods including Photogrammetry was carried out to assess their applicability to the project. The implementation of the project resorted to the use of low-cost recording techniques owing to the limited resources available to the study. The project revealed that several recording techniques and software are needed in order to achieve optimum results. Further analysis is required to assess the applicability of the method used and the usefulness and applications of the produced model. The aim here was to create a 3D model to which a number of attributes can be added in addition to visualisation and 3D animation to achieve effective examination and production of improvement or renovation proposals.

1. INTRODUCTION

There is an increasing need to record and catalogue urban environment by displaying their 3D qualities and characteristics. This has been illustrated by a shift from traditional 2D representations such as GIS applications to 3D urban areas and city models. The aims behind the development of 3D modelling techniques are concerned with documentation, Virtual Reality applications, feasibility studies of urban design and planning projects, tourism, and GIS applications for urban and environmental development, management and control. 3D data acquisition remains problematic and its accuracy is expensive. There are many methods currently used to acquire data from manual to semi-automatic and automatic methods. Any 3D city model development is faced by at least three hurdles, which are: drawing of 2D digital map; creation of an accurate 3D model; and achieving realistic textured models of individual buildings.

This paper will discusses the use of 3D digitisation and the digital modelling process, and assesses the benefits and limitations of this method with respect to 3D urban modelling. To effectively illustrate the arguments presented by this paper, a historic area in Dubai called Al Bastakia was selected as a case study to further demonstrate the need to accurately and easily create useful 3D urban models.

2. AL BASTAKIA, DUBAI

Dubai is a city that is constantly changing due to a very fast urban growth fuelled by its business and tourism-oriented development. Dubai started as a transit commercial port between the Gulf countries, Persia, the Indian sub-continent and East Africa. It was established near the coast for easy access to transportation by dhows and the search for food and pearls.

Early history of Dubai suggests that the city started as a small and insignificant fishing village during the eighteenth century. By 1900, it was estimated that about 10,000 local inhabitants and immigrants had settled in three different neighbourhoods in Dubai, largely due to a growth in pearling and trade. At this time, Dubai's population started to be more mixed than Sharjah or Abu Dhabi. During the 1920s, an increasing trade with Persia attracted merchants to Dubai, some of which decided to settle down after that Dubai ruler invited them to do so with their families.

These people originated from **Bastak** district in a sub-province of Lar in the Fars Province. Trade particularly the import of wood, took place between Dubai and the port of Khamir. Bastak people were allocated a land parcel east of Fahidi Port to build houses for their families. This was a great location given its access to the creek and near the *Suq* of Dubai. This district was called **Bastakia** (Figs.1 & 4). (Heard-Bey, F., 1996: 244-245)

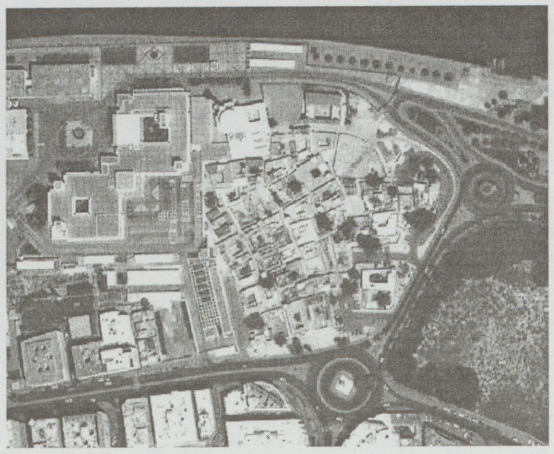

Fig. 1: A satellite image showing Al Bastakia area, 2002. Image courtesy of DigitalGlobe, www.digitalglobe.com

2.1 Historical Background

The Bastakia is the largest historic area in Dubai that exhibits vernacular architecture. The houses located in this area were built by master builders and masons who learned the skills from their fathers. Settlers from Persian introduced the wind towers to the coastal towns of the UAE. In fact, in the Bastakia, every house had at least one wind tower, while in other quarters of Dubai such as Deira and Shindagha, wind towers were introduced by those who could afford the building of more elaborate homes. (Heard-Bey, F, 1996:246)

Wind towers in Bastakia rise to about fifteen meters above ground level. "The upper part consists of four concave inner walls with pillars, arches and often intricate plasterwork to continue the square shape of the tower." The tower catches wind, which is channelled though a chimney down to a common room where the inhabitants appreciate the breeze. (Heard-Bey, F., 1996:246) Geographical and climatic considerations and cultural requirements, have contributed to the emerging of responsive vernacular architecture that can be found in the Bastakia.

2.2 Urban and Architectural Landmarks

Bastakia settlers after they chose a parcel, started by building a high fence to protect the family from views of intruders and passers-by as well as from robbers. The families initially lived in tents or shelters made of lightweight materials. Later a more durable shelter was built. As the family grew, more rooms were added to the compound, by locating them around a central courtyard. A first floor was added when there was no room on the ground floor. Wind towers and wind catchers were added to catch cool winds and thus improve the thermal comfort inside the house.

The Bastakia houses contain features of Arab-Islamic architecture, namely the use of a central courtyard, with many rooms organised around it and accessible from a gallery. The gallery is also present on the first floor. Roofs have high parapets to protect the female inhabitants from views of strangers.

Blind windows with modest decorations adorned outdoor facades, whereas indoor facades had many large openings (doors and windows) displaying rich decorations.

An urban analysis can reveal that Bastakia houses were laid out to enable direct access to the creek, by producing streets or axes perpendicular to the creek. Streets width varies between two and four meters. This was dictated by the neighbourhood's vocation at the time it was built. This being its dependence on trade coming from and leaving to the sea. Therefore axes of movement for transportation of goods had to link the creek to the inland. These axes were in fact the generators of the built form of Bastakia. It is claimed that the first houses were built on the edge of the creek and later more houses were added following the axes, as more land was made available for construction. Smaller and less important streets parallel to the creek link the main streets. The intersection of these streets sometimes results in the creation of small squares. These squares did not have an urban function but rather the result of unplanned growth, or to allow the continuity of a main street when its linearity is broken. (Fig. 3)

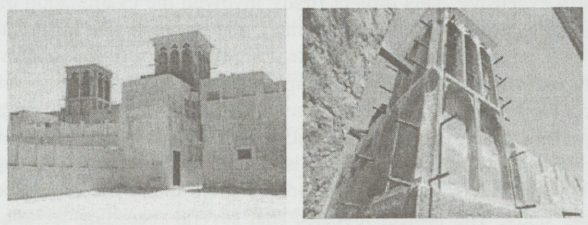

Fig. 2: Views of houses and wind towers in Al Bastakia area.

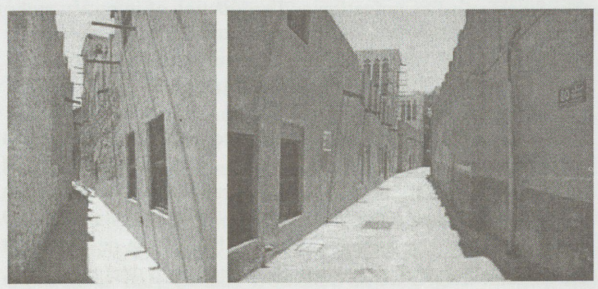

Fig. 3: Views of pathways in Al Bastakia area.

2.3 Aerial Surveys of Dubai

In 1996, Dubai Municipality contacted Hansa Luftbild – German Air Surveys – in order to carry out a comprehensive survey of Dubai using colour aerial photography. The objective of the contract was "to provide image data of high resolution and adequate accuracy that shall be suitable for the generation and updating of vector maps of a general Geographic Information System (GIS) for Dubai Municipality". (Mahlbreuer, A. et al., 1998:367)

As part of the product, the German firm also produced a Digital Terrain Model with regular 20m-grid spacing using MGE Terrain Modeller. Building heights were identified using stereo photogrammetric restitution. Digital ortho-rectification of scanned images was carried out using "Base Rectifier", a module of Intergraph's software. (Mahlbreuer, A. et al., 1998)

No further comprehensive surveys were carried out to date, however many aerial images of specific areas within Dubai are available.

3. 3D DIGITISATION

The study attempted to create a 3D model of Bastakia area in order to document an interesting spatial setting by testing affordable modelling methods and tools that should in principal allow the production of an acceptable 3D model. This product can be used by students in order to carry out urban analyses and develop and evaluate design proposals in this particular area. There was no budget available for the purpose of this exercise, apart from the interest of the author and students. Before embarking on the building of the 3D model there was a need to review and examine existing 3D digitisation methods and their suitability to the project.

There are many ways of digitising an object or a building, but these generally fall into seven categories: mechanical tracking technology, laser scanners, magnetic tracking, ultrasonic scanning, Photogrammetry, Interferometry technology, and optical 3D scanners.

3.1 Mechanical Tracking technology

This uses a mechanical arm that is compact and easy to use. This device digitises contours of physical models using software such as Inscribe 3.0 to process the data. The 3D computer model can then be transferred to a CAD application such as 3D Studio Max or AutoCAD for further modelling. This device has been used by students at the UAE University to scan physical models with relative success due to the fact that the captured 3D model needs considerable editing.

3.2 Laser Scanning

This is a very quick procedure that scans any physical object. A 3D dense mesh is produced as a result. This technology has some drawbacks since reflective or transparent surfaces are not digitised very efficiently. It is also expensive and the processing of the scanned data can be time consuming.

Laser scanning is being increasingly used to capture 3D models of real objects and buildings. This technology uses from airborne to handheld devices depending on the applications and the budget available.

3.3 Magnetic Tracking

This technology uses a magnetic field as the signal medium. However, this can be influenced by metal or magnetic fields that may be present near or in the digitised objects.

3.4 Ultrasonic Scanning

This technology uses sound waves to obtain coordinates in 3D space. Unfortunately, these scanners are not very accurate and can be influenced by atmospheric conditions and sound interference.

For example, the LSC Series incorporates a new ScanView scanning device. ScanView Plus combines motion and instrument control with data acquisition to provide unsurpassed ultrasonic imaging capabilities. Unique ScanView Plus features include: drag and drop gating, Scan Wizards for fast-guided setups, and configurable templates for organizing scan and analysis sequences. Analysis tools include automated clustering, point and area measurements, and a variety of image enhancement and signal processing utilities.

3.5 Photogrammetry

Photogrammetry means "the process by which accurate dimensions and 3D CAD-compatible models are extrapolated from stereoscopic photographs".

A number of photographs of physical models are digitised in three-dimensions to obtain a computer surface model that can be exported to any CAD application for further analysis. Its application is very attractive to architectural conservation, and recreation of built environments.

True Orthophotography is an efficient method to represent "photographic information in a 2D reference system", but its application in complex situation involving uneven objects such as buildings is problematic. The generation of accurate Digital Surface Model - DSM is complex and time consuming and requires sophisticated equipments such as laser scanners, in fact "the generation of a DSM cannot be automated". (Boccardo, P., 2002: 1) Several methods are used in conjunction to produce true orthophoto by means of using DSMs. (Amhar, F. et al, 1996). Simpler approaches have been developed using the latest technology in data capture, e.g. laser scanning, in addition to the development of software capable of accurately processing the data and generating true orthophoto. (Boccardo, P., 2002)

3.6 3D Camera series: Hi-speed/accuracy non-contact 3D measuring machine

The Handy Handheld Digitiser combines a sophisticated digital camera and the proprietary EOIS Moire Interferometry technology to create a totally wireless 3D digitiser. It is the only high-speed 3D digitiser that can capture data without being connected to a computer. The images are stored in a sophisticated digital camera, and later sent to a computer for final processing.

The primary EOIS product is the Mini-Moiré sensor. It is based on the original EOIS Moiré technology, for high-speed 3D XYZ measurement. This technology has a much higher data acquisition speed and point density than conventional touch probes or laser sensors.

3.7 DigiScan Optical 3D Digitizers

Being pushed by the availability of high speed and high precision image processing components, optical 3D scanners continue to find their places in an increasing number of demanding applications.

The measurement principle is based on a modification of the well-known structured light method. In many application fields there is a growing need for 3D replica of physical objects that cannot be created in traditional CAD. Numerous examples can be found in product design and presentation, manufacturing automation, and quality control.

New and attractive applications coming up are in medical and anthropometric measurement (scanning human body parts or

the entire body), requiring non-contact and reliable surface measurement in near real time, and in ergonomic design.

Having reviewed the main 3D digitisation methods, it can be said that the extent to which these are successfully used depends on the nature and size of the object and its applications, the intended output format, the amount of automation possible, and the budget available to the project. The selection of a suitable method is crucial given that a lot of methods lack automation and require considerable 3D modelling, therefore becoming costly and difficult to manage.

In the case of 3D urban modelling, the generation of a Digital Urban Model (DUM), which is composed of Digital Building Models (DBM) and sometimes, a Digital Terrain Model (DTM), combined with Photogrammetric data should lead to the creation of realistic 3D city models. Nonetheless, the way by which this is achieved varies a lot and is highly influenced by the resources available to the project. Software developers have been trying to create tools that enable the automatic generation of 3D city models. In any case, a number of methods and different data are used in order to achieve optimum results. In the case of the CAD Center Corporation in Tokyo, a combination of 2D digital map, aerial images, and laser profiler data were used in order to generate an impressive and expensive 3D city model of Tokyo. Software called MapCube was used to create the 3D model. (Takase, Y., 2003)

4. THE CHALLENGE

The development of 2D GIS technology and its successful application in many fields primarily for 2D analyses, has not given the same relevance to 3D urban information. Only recently, with the development of many packages that deal with 3D city modelling and Virtual Reality applications, GIS platforms started considering 3D builders and analysts as part of the package. However, these packages with all their added extensions are still expensive for low budget educational projects.

Digital cities can be very useful in determining future development and in assessing their overall effect on the city's skyline and urban patterns. Simulations can be carried out through Electronic Sketching, Spatial Interaction, and Virtual Reality. (Dokonal, W. & Martens, B., 2001:419)

As pointed out earlier, Al Bastakia is the only significant historic area in Dubai, which reflects the region's architectural heritage and local culture. This valuable heritage displays rich architectural and urban qualities, which reflect the users' search for comfort in response to a harsh climate, and to the need to preserve privacy by respecting local traditions. This meant that streets are very narrow and leading to dead-end routes as it is customary in many Arab-Islamic *Medinas*. The urban and architectural richness of this area encouraged the creation of a 3D digital model that can be used for educational purposes at the department of Architectural Engineering of the UAE University.

4.1 The Method

3D model was created based on 2D mapping information provided by Dubai Municipality, in addition to scanned plans from various documents. The area was also recorded on video in order to obtain information regarding heights of buildings and other important details. Digital photos were also available to complement information emerging from the video recording.

A high-resolution satellite image of the area acquired in 2002 was used in order update the site plan and record any missing information. (Fig. 1 above)

The texture application was difficult due to two reasons: a) the fact that buildings are very close to each other, and b) most buildings are undergoing restoration, and as a result there are a lots of scaffoldings erected. These factors complicated the recording of orthophotos for photogrammetric analysis and production of building textures.

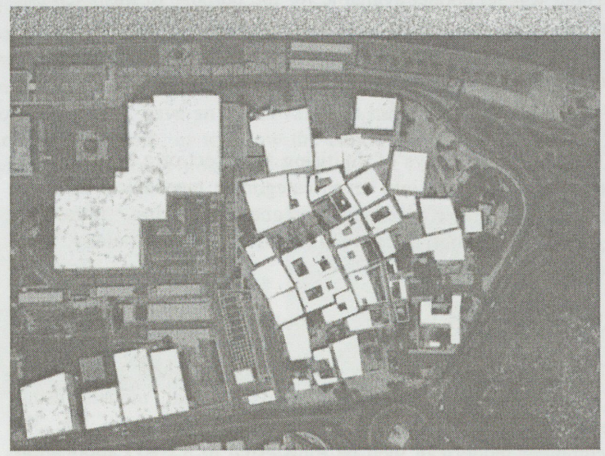

Fig. 4: A Plan view of Al Bastakia 3D Model.

4.2 The Result

The model was created in AutoCAD using 2D digital plan of the area, and plans of selected houses. Further information was available as hard copies such as sections and elevations. The area that was emphasised is the one becoming the main market zone, which is in the very centre of the neighbourhood. Dubai Municipality provided digital drawings of the renovated houses located in this area.

Once completed, the model was exported to 3D Studio Max for rendering and animation, and texture application. Obviously, more details can be added to the model, such as decorations, balconies, carvings and so on. But unfortunately, the lack of resources and time did not allow the team to move to that level of detail. The purpose of the project was to examine what technology is available in order to easily and cheaply reproduce a sample of a historic urban environment.

Clearly this is feasible since the area is relatively small, however in order to create a 3D model of the whole city an efficient recording method involving for example airborne laser scanning will be necessary. This method was successfully applied in the case of Tokyo by CAD Center. (Takase, Y., 2003)

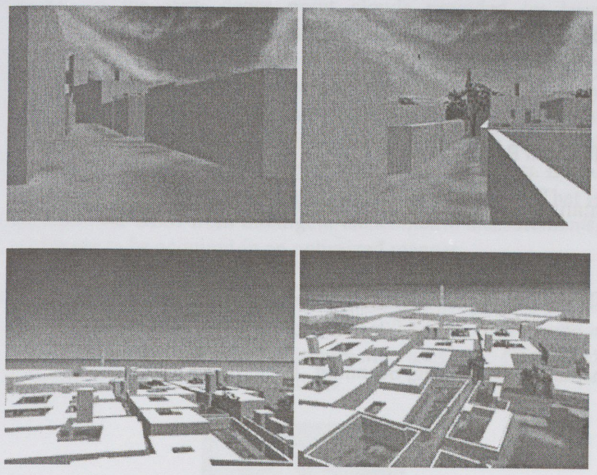

Fig. 5: Views of Al Bastakia 3D Model.

5. CONCLUSIONS

It can be said from this experience that as far as architects and urban designers are concerned, the creation of digital 3D models of existing urban environments continues to be done the conventional way. This is primarily due to the fact that scanning devices and associated software are still expensive and complex. In addition, the scanned product needs in many cases considerable editing, which requires expert CAD knowledge. Students attending architectural programs are not skilled enough to handle complex equipment and advanced 3D modelling. This is why faculty are always trying to bridge the gap between the advances in 3D scanning and city modelling technology and available resources.

A combination of 2D digital plans, satellite imagery, digital images and video captures were used in order to create the 3D model of Al Bastakia historic area in Dubai. At the moment of the production of the model, there was no sophisticated equipment available. But, it is planned that Dubai Municipality and the UAE University will carry out a joint project that will involve the use of advanced Laser scanning devices coupled with powerful software such as MapCube.

The relatively small study area allowed for the conventional 3D modelling method to be effective, however in order to create a 3D model of the whole of Dubai, there is a need for a more efficient 3D recording method involving technology such as airborne laser scanning, which is very accurate yet extremely expensive. Obviously, the purpose of the project and the expected use will justify the investment in something that is and will be greatly appreciated by generations to come.

Further research and development are needed in order to establish a powerful platform for 3D city modelling that should enable the data to be easily processed, visualised and updated.

Having said that, digital products can become easily obsolete if they are not updated on a regular basis. This has been the case with GIS platforms of many cities that could not afford to update their databases due to budget limitations. Nowadays 3D City models that are appearing rapidly and will soon reveal whether or not they are an important part in cities urban and economic planning and development.

REFERENCES

Amhar, F. & Ecker, R. (1996) An Integrated Solution for Problems of 3D Man-made Objects in Digital Orthophotos. In: International Archives of Photogrammetry and Remote Sensing, Vol. XXXI, Part B4.

Boccardo, P. et al. 2002. True Digital Orthophoto for Architectural and Archaeological Applications. http://www.arkeologi.net/articles (accessed 24 June 2003)

Dokonal, W. & Martens, B., 2001. A Working Session on 3-D City Modeling. Architectural Information Management [19th eCAADe Conference Proceedings/ISBN 0-9523687-8-1], Helsinki (Finland), 29-31 August, pp. 417-422.

Heard-Bey, F. (1996) "From Trucial States tom United Arab Emirates, A Society in Transition". Longman, London.

Mahlbreuer, A. et al. 1998. Digital Colour Orthophotos for Boomtown Dubai. IAPRS, Vol. 32, Part 4 "GIS-Between Visions and Applications", Stuttgart.

Takase, Y. et al. 2003. Automatic Generation of 3D City Models and Related Applications. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXIV-5/W10.

ACKNOWLEDGEMENTS

The author wishes to thank Arch. Rashad Bukhash of Dubai Municipality for providing digital plans of Al Bastakia houses. Special thanks also go to Arch. Djamel Boussaa for offering a valuable amount of information on Al Bastakia.