Documentation of the Nasif Historical House using the Terrestrial laser scanning and Image Survey Methods in Historical Jeddah - Saudi Arabia

A.Baik [a,] , J. boehm [b], S. Robson [c]

[a] Dept. of Geomatic Engineering, University College London, Gower Street, London, WC1E 6BT UK – Ahmad.Baik.12@ucl.ac.uk
[b] Dept. of Geomatic Engineering, University College London, Gower Street, London, WC1E 6BT UK – j.boehm@ucl.ac.uk
[c] Dept. of Geomatic Engineering, University College London, Gower Street, London, WC1E 6BT UK – s.robson@ucl.ac.uk

KEY WORDS: Heritage Recording, Terrestrial Laser Scanning, Historical Jeddah

ABSTRACT:

Historical Jeddah, one of the most important historical sites in Kingdom of Saudi Arabia, has had a long history since it became the main gateway for the hajjis. The city contains many historical monuments founded more than 100 years ago, such as the Nasif House, which was built in 1881. However, the historical monuments in Jeddah face serious issues of different natures, such as problems of documentation and conservation. In the last decade, several manual measurement techniques were used to document these buildings; however, these techniques take a long time, often lack completeness, and may sometimes give unreliable information. In contrast, Terrestrial laser scanning "TLS" surveys and image surveys have already been undertaken in several heritage sites in the United Kingdom and other countries of Europe as a new method of documenting heritage sites. This paper focuses on using the Terrestrial laser scanning and image survey methods to document Nasif House, as an example of historical architectural documentation.

1. INTRODUCTION

1.1 Historical Jeddah and the Nasif Historical House: Background

A coastal city located on the western side of the Hijaz region, Jeddah is one of the most important cities of the Kingdom of Saudi Arabia. According to Telmesani et al., (2009), "its geographical features contain a natural harbour in the shape of a crescent, and the city is surrounded by a series of mountains and hills'. Further, 'this coastal area is hard to navigate for ships because of the coral reef surrounding the harbour, which was formed to defend the city from invasion and attacks in older periods". The city of Jeddah contains a number of historical buildings, such as the Nasif Historical House or 'Bayt Nasif'. Sheikh Omar Afandi Nasif constructed the Nasif Historical House during the latter part of the 19th century. The work commenced in 1872 and the building was completed in 1881 (Saban, n.d.). It consists of four storeys with an architectural design of identical dimensions, giving it a very neat and aesthetic look. It is situated right in the middle of Historical Jeddah, at 'Al-Balad'. The exterior face of the building is finely constructed with aesthetically created corners. However, the main attraction of the whole building is the attractive woodwork on the main door, Roshan, and other wooden pieces (Fig. A). According to Nawwar (2013), "this carving has been done on impeccable quality wood that has been brought into the city from eastern countries". Figure B below shows the floor plan of the Nasif House. As can be seen, the inside of the building has also been carefully thought out and developed, with big rooms at the centre, flanked by smaller living rooms on the sides. The large twin flights of stairs are situated in the middle of the rear of the building. The rooms for aides and servants are also situated at the back. The interior of the building is as distinctive as the exterior, in the sense that every storey presents a unique architectural construction. For example, the first storey houses a unique angular arch along with dawn (Fig. C). The second storey has a very beautifully designed area in the lobby (Fig. D), while the third storey boasts a bathroom with a little dome in the ceiling, known as the Turkish bath (Fig. E). The fourth storey offers a huge terrace that extends to the front part of the central room, along with a majestic kitchen situated at the back. Finally, the penthouse is

Figure A, Main door and the Mashrabiyah of Nasif House.

constructed with fine woodcarvings that share their designs with the carvings on the floor just below it (Fig. G). Moreover, as Nawwar (2013) says, "coral rocks extracted from the bed of the Red Sea have been carved in shapes with equal length and breadth before being used to construct the walls of the building" (figure F shows an example of a coral-stone block). The penthouse of the Nasif House is situated at the very middle of the roof and is adorned with beautiful carvings that share designs with the carvings on the faces of the corner rooms on the fourth storey (Fig. G).

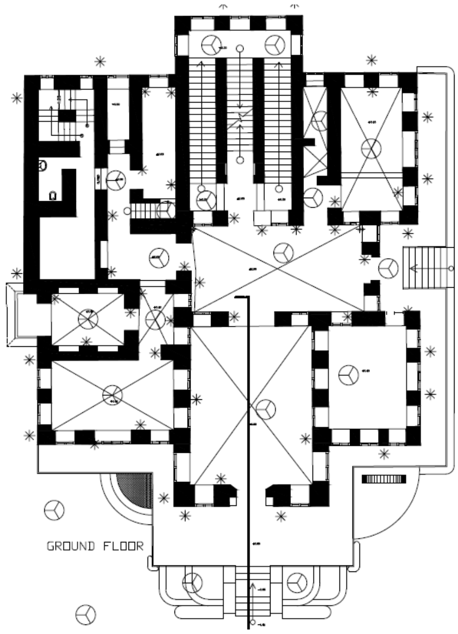

Figure B, Nasif House site plan.

Another feature of the building is the large kitchen situated on the fourth floor. This is simply gigantic with three different cooking places and a passage to the roof, leading to a large oven.


Figure C , Arch in the ground level.


Figure D, the place in the second level.


Figure E, Turkish bath at Nasif House

Figure F, Coral block "Mangabi"

Figure G, The penthouse.

1.2 The Nasif Historical House: Issues

The main question that faces the Nasif Historical House these days is how the municipality of Historical Jeddah can document, reconstruct and save the building in the view of a possible collapse or erosion due to environmental or human reasons and disasters as such fires (Baik et al., 2013). Presently, the Historical Jeddah Municipality is planning to reconstruct the building to be used as a historical museum of Jeddah (Nawwar, 2013).

1.3 Aims

In this project, we aimed at creating full historical architectural documentation data of the Nasif Historical House by importing laser scanning survey data and image survey data. The outcome data could then be used as the base data for several applications for structural, architectural, constructional and other purposes (Baik et al., 2013).

2. LITERATURE REVIEW

2.1 Terrestrial Laser Scanning "TLS"

Terrestrial laser scanning is an automatic measure method that measures the 3D co-ordinates of the surface of the selected object. The output data from the laser scanning are represented in point cloud form. Each of these points has x, y and z coordinates of the scanned surface. Moreover, according to Murphy (2013), “the laser ranger is directed towards an object by reflective surfaces that are encoded so that their angular orientation can be determined for each range measurement”. There are several laser scanning systems available in the engineering market these days. However, according to Murphy (2013), “there are three types of scanners suitable for metric surveys for cultural heritage” which are “time of flight scanners, triangulation and phase comparison”. The difference between these systems concerns the way the scanner calculates the 3D co-ordinate measurements. For example, in the case of the triangulation type, the scanner uses the spot of the laser ray on the surface of the object captured by one or more cameras (Murphy, 2013). On the other hand, according to Boehler et al., (2003), “time of flight scanners calculate the range, or distance, from the time taken for a laser pulse to travel from its source to an object and be reflected back to a receiving detector”.

Figure H, Leica C10

2.2 Terrestrial Laser Scanning Data Processing

Laser scanning collects a huge range of data representing 3D co-ordinates, described as ‘point cloud data’. A professional program is necessary to deal with the huge amount of 3D point cloud data. According to Baik et al., (2014), “while laser scanners could take a few minutes to scan millions of accurate 3D points, there is enormous work in transporting this data into a 3D model containing useable information”. According to Remondino (2003), “dedicated software programs such as Leica cloud-works, Polyworks, AutoCAD, and RiScanpro have highly improved the processing, manipulation and analysis of vector and image data from the point cloud’ and ‘all of these software platforms have combined algorithms for triangulation and surfacing of the point cloud”.

Once the scanner’s point cloud is transferred, there are several suitable software programs that can be used to fix and clean up the point cloud noises or distortions in the scanner data. Furthermore, each system of these laser scanners has its own software. For instance, Leica Cyclone® deals with the Leica laser scanning systems. Overall, the modelling method in Leica Cyclone® involves generating the best-fit geometric objects from the point cloud. Moreover, Leica Cyclone® has a number of object-suitable utilities for the user to select from, depending on the topology of the scanned point cloud. Conversely, as Ikeuchi (2001) points out, “other applications are used instead of polygonal 3D models; NURBS surface models, or editable feature-based CAD models”.

2.3 Combining Laser Scanning and Digital Images

Most of the modern laser scanning systems have built-in cameras for the image data. Moreover, the 3D point cloud can be coloured by applying the multi-image batch to the point cloud data. According to Abmayr et al., (2005), “the RGB colour data from the images can be mapped onto range data by taking account of point translation, instrument rotation and perspective projection”. For this, both the laser and the camera, as pointed out by Murphy (2013), “must be correctly geometrically calibrated” and “the correction of the camera is presented to correct the distortion of camera lenses, and by mapping onto the point cloud any perspective contained in the images is removed”. Moreover, the High Dynamic Range “HDR” colour images, according to Beraldin (2004), “can be precisely mapped onto a geometric model represented by a point cloud, provided that the camera position and orientation are known in the coordinate system of the geometric model”.

3. MATERIAL AND METHOD

3.1 Technology, Programs and Equipment used

Leica Scan Station C10 is used for the 3D laser scanning (Fig.H). According to ‘Leica ScanStation C10,’ (n.d.), “the scanner features a field of view of 360º in the horizontal direction and 270º in the vertical direction, allowing the collection of full panoramic views”. The distance dimension is recognised by the time of flight dimension principle, which is based on a green laser at 532 nm. Moreover, the range of C10 scanner technique allows distance capacities between “2 and up to 300 m”. As the spot size of the scanner is 4.5 mm from a distance of 0-50 m, the regular deviation of the distance measurement is 7 mm for a single shot. Furthermore, according to ‘Leica ScanStation C10,’ (n.d.), “the laser scanning system is able to measure 50,000 points per second”. We used Leica Cyclone® software version8.1.1 for registration and cleaning-up the noise from the point cloud data. Moreover, to take free images of the Nasif Historical House, we used a professional Nikon D5100 - 18 mega pixels camera.

3.2 Images Survey

The fieldwork began with the image survey to document the architectural characteristics of the Nasif Historical House. This stage took from a week to two weeks. The Nasif Historical House has architectural characteristics of different Islamic cultures and ages; for example, the Roshans and Mashrabiyahs were borrowed from the Ottoman culture. By using professional software, such as PhotoModeler and Autodesk Recap, we were able to use these images to build the 3D modelling ‘architectural photogrammetry’.

3.3 Laser Survey

Before using the Leica C10 scanner to scan the Nasif Historical House, we had prepared the location for this step by determining the scan stations. We chose the HDS White and Black ‘W/B’ targets method for the purpose. This step took around a week to be completed. At the preparation stage, we picked the most suitable locations for the scanner HDS ‘White/Black’ targets and for the scanning station. Moreover, the station positions were picked in the positions where they would cover the site to be scanned, in order to have the best visibility for the laser scanning survey. To get a good overlap of the ‘ScanWorlds’ and for more accuracy, at least three targets must be picked that are common to these ScanWorlds. To carry out a successful survey, it is very important to select the most suitable viewpoint positions, especially for heritage sites, since the number of possible scanning stations is usually restricted by the complexity of the site and structure. In the next step, we scanned the building from inside to outside. The laser scanning took more than four weeks to scan the entire house. The laser scanning data, which were produced from scanning the Nasif Historical House, amounted to more than 70 GB. The laser scanning resolution for scanning the inside of the house was 7 cm with 10 m distance, and up to 70 m for outdoors. We spent, on an average, 30 minutes for each scan setting and target registering. The exact time depended on the target number. Moreover, we spent, on an average, 15 minutes to scan each station but more than 20 minutes for the image scanning. To be specific, the numbers of the 'White/Black' HDS targets and scan stations were:

A. Around 400 'White/Black' HDS targets, each target taking around 3 min to be restarted (total around 20 hours)
B. Around 150 scan stations, each scan taking around 30 to 45 min (total around 112 hours)

3.4 Laser Scanning Data Processing

The required 3D point cloud models can be generated in different processing steps by using a number of software programs, such as Autodesk Recap®, and Leica Cyclone®. In our case study, we first used Leica Cyclone® to remove noise. In this step, we spent around two to three weeks to complete the data processing. Afterwards, several ScanWorlds corresponding points in overlapping sections were linked for the registration purpose. Our survey team registered these point sets in accordance with the coordinate system and elevation above the sea level. According to Attar et al. (2010), "this allowed for geo-referencing of the entire dataset by knowing the precise position of each point in terms of real-world coordinates". Figure I shows more than three ScanWorlds registrations, collected for the Nasif Historical House.

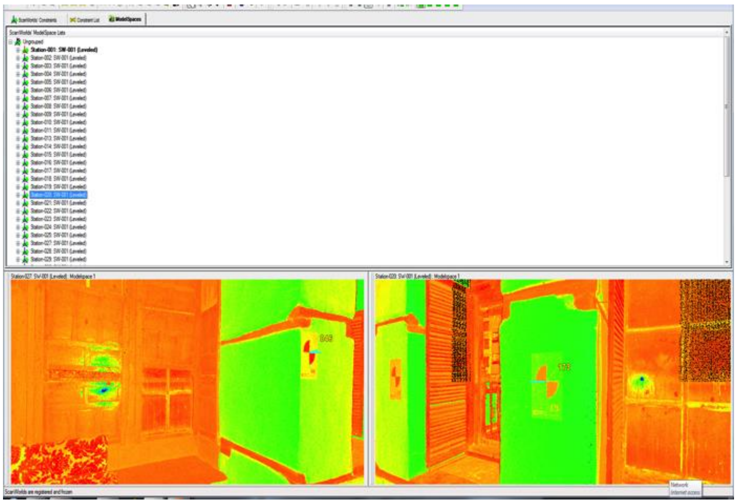

Figure I, ScanWorlds registration

After the registration step, we used Leica Cyclone® to create a non-redundant surface representation. At this stage, each single part of the object measured is found only once. Figures (J-O) show the resulting combinations of scans for 3D point cloud model. The average resolution of 3D point cloud model of Nasif Historical House was 7 cm on the object surface. Afterwards, we created an ortho-image from the point cloud data, which allowed us to represent all the geometric and image data. According to Murphy (2013), the ortho-image can "be exported for visualisation or further processing in CAD, VRML or other modelling platforms". These ortho-images can be described as realistic image models, with width, height and breadth of the scanned object.

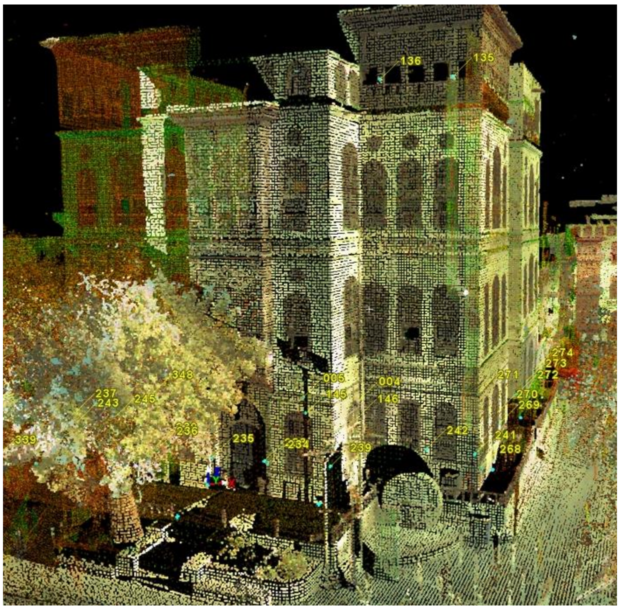

Figure J, 3D points cloud model with image batch

Figure K, North Elevation

Figure L, East Elevation.

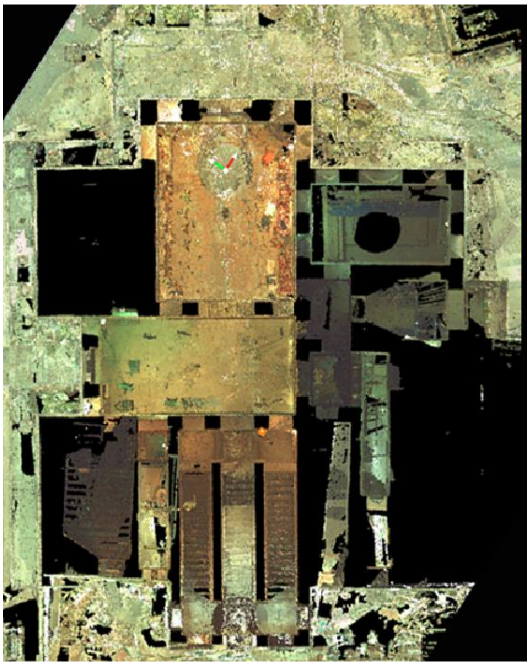

Figure M, Ground floor

Figure N, 1st floor.

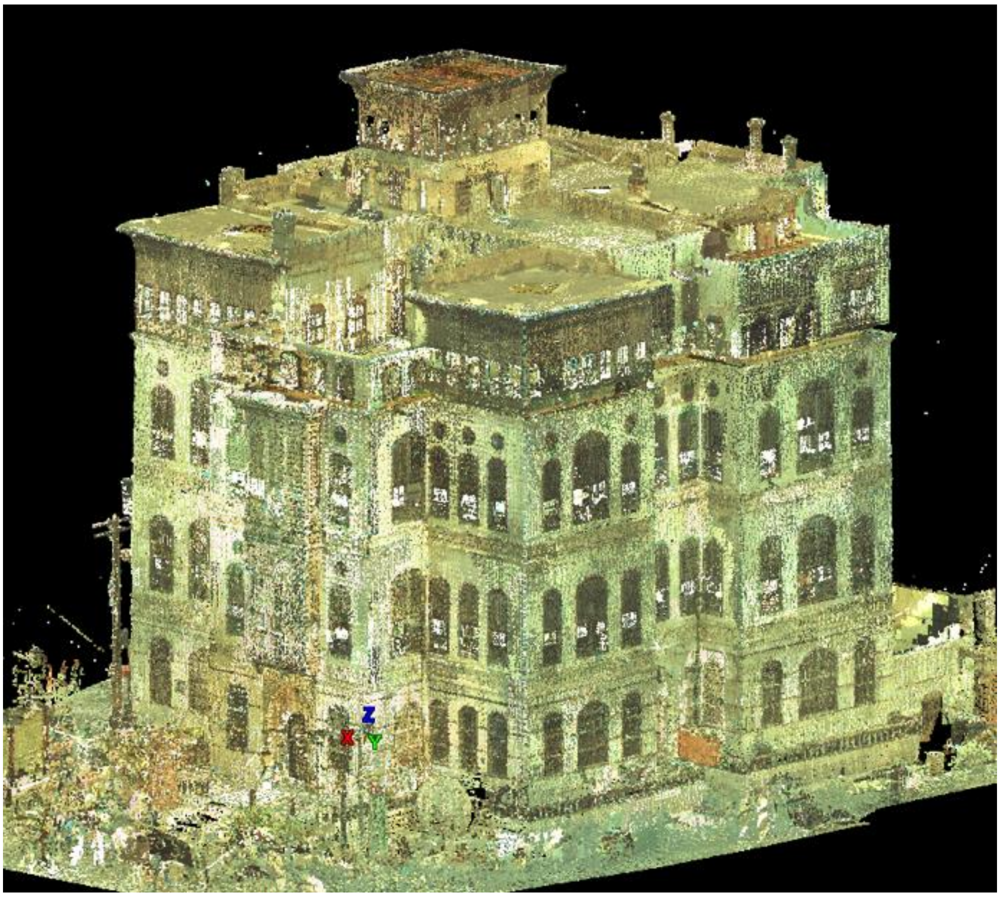

Figure O, 3D points cloud model

4. CONCLUION AND FUTURE WORK

This paper presented a framework for remote data capture using terrestrial laser scanning (TLS) and image survey. This framework demonstrated the initial elements for the next step, which would be Jeddah Historical Building Information Modelling (JHBIM). According to Baik et al. (2013), "all extracted information from the constructed 3D models, such as maintenance activities, house structural condition, could be stored in the JHBIM database for spatial modelling and follow-up purposes". Additionally, through the outcome data from the JHBIM, we can decide which buildings need to be preserved, which cannot, and which must be destroyed. Finally, the 3D JHBIM models can be remotely reviewed in both their 'interior and exterior' with better understanding than that presented in 2D drawings.

4.1 ACKNOWLEDGEMENT

I would like to thank Eng. Sami Nawwar The director of Jeddah Historic Preservation Department, Jeddah Municipality for his corporation to work in Nasif Historical House and the useful information about Old Jeddah in different areas. I would like to thank Arch. Abdulrahman Al-Orabi from Taibah University for his corporation and supporting during the Nasif house project. Finally, I am really thankful for Doctor Reda Yaagoubi, head of Geomatics department, King Abdul-Aziz University for his supporting and allowed me to use the department Facilities.

5. REFERENCES

Abmayr, T., Härtl, F., Reinköster, M., Fröhlich, C., 2005. Terrestrial laser scanning–applications in cultural heritage conservation and civil engineering, in: Proceedings of the ISPRS Working Group V/4 Workshop 3D-ARCH 2005, Virtual Reconstruction and Visualization of Complex Architectures, International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Mestre-Venice.

Attar, R., Prabhu, V., Glueck, M., Khan, A., 2010. 210 King Street: a dataset for integrated performance assessment, in: Proceedings of the 2010 Spring Simulation Multiconference. Society for Computer Simulation International, p. 177.

Baik, A., Alitany, A., Boehm, J., Robson, S., 2014. Jeddah Historical Building Information Modelling“ JHBIM”–Object Library. ISPRS.

Baik, A., Boehm, J., Robson, S., 2013. Jeddah Historical Building Information Modelling “JHBIM” Old Jeddah –Saudi Arabia.

Beraldin, J.-A., 2004. Integration of laser scanning and close-range photogrammetry-the last decade and beyond, in: International Society for Photogrammetry and Remote Sensing.

Boehler, W., Vicent, M.B., Marbs, A., 2003. INVESTIGATING LASER SCANNER ACCURACY. Presented at the XIXth CIPA SYMPOSIUM.

Ikeuchi, K., 2001. Modeling from reality, in: 3-D Digital Imaging and Modeling, 2001. Proceedings. Third International Conference on. IEEE, pp. 117–124.

Leica ScanStation C10 [WWW Document], n.d. URL http://hds.leica-geosystems.com/en/Leica-ScanStation-C10_79411.htm (accessed 10.24.13).

Murphy, M., 2013. Historic Building Information Modelling â☐“ Adding intelligence to laser and image based surveys of European classical architecture. ISPRS J. Photogramm. Remote Sens. 76, 89–102.

Nawwar, S., 2013. Jeddah Historic Preservation Department, Jeddah Municipality.

Remondino, F., 2003. From point cloud to surface: the modeling and visualization problem, in: International Workshop on Visualization and Animation of Reality-Based 3D Models. p. 5.

Saban, A., n.d. The Nasif House Jeddah, 1st ed. ed. Printing CO. LTD, Jeddah, Saudi Arabia.

Telmesani, A., Sarouji, F., Adas, A., 2009. Old Jeddah A Traditional Arab Muslim City In Saudi Arabia, 1st ed. ed. King Fahad national library, Jeddah.