USING DIGITAL TERRESTRIAL PHOTOGRAMMETRY IN CULTURAL HERITAGE CASE STUDY: THE GREAT WALL OF GORGAN IN IRAN

Seyed Yousef Sadjadi

Geomatics Department, School of Civil Engineering, University of Tafresh, I.R. Iran

sajjadi@tafreshu.ac.ir

KEY WORDS: Terrestrial, Digital Photogrammetry, modification, Extraction, A/AIS, Cultural Heritage.

ABSTRACT:

An assessment of the influence of using digital terrestrial photogrammetry for surveying and documentation of cultural objects is presented in this paper. The approaches including digital image enhancement, digital rectification and restitution, feature extraction for the creation of a three-dimension geographical information system model from the photogrammetric record and the computer visualisation of cultural monuments. Manual three-dimension processing of terrestrial images using analogue photogrammetric procedures is slow, can register little information and has limited application and cannot be re-examined if the information desired is not directly presented. In addition, it is a very time-consuming task and requires the skill of qualified personnel. It seems there is a need for an environment-based information system with the ability to display precise and measurable imagery for use of the architectural and archaeological information system by integrating digital photogrammetry and AutoCAD facilities as applicable to support the reconstruction of many cultural heritage places. Architectural structuring and guidelines can be used to develop invaluable historical monuments in Iran such as the Great Wall of Gorgan. While the research is in completion, the output of the Great Wall of Gorgan can be documented and recorded in the world.

1. INTRODUCTION

Knowing that the use of analogue photogrammetric three-dimension (3-D) measures for processing terrestrial images is slow, unable to record large information, poor for re-examining indirect available data, limited application and time-consuming. This paper highlights the development and implementation of an Architectural and Archeological Information System (A/AIS) by integrating digital closed-range photogrammetry facilities as applicable to support the reconstruction of many cultural heritage places in the world such as Iran (Dallas, 1996). The analysis of an A/AIS has been newly endorsed using the Great Wall of Gorgan (GWG).

The GWG is situated in the North East of Iran (from Kalaleh city to Gorgan city) known as the Red Snake due to its red coloured bricks. GWG is a very well-known historic wall along the Caspian Sea. GWG is the largest defensive wall in the world after the Great Wall of China, which is about 200 kilometres in length and 30 meters in width (Ghasemian, 2007). Unfortunately, most of the over ground wall has been ruined. Another aim of this study is to discover a base remaining under-ground of GWG with an examination of archaeologists' groups.

The Iranian archaeologists and a group of archaeologists from Edinburgh and Durham Universities in the UK, found that the construction of the massive walls of brick modelling to tens of millions disappeared completely (Rekavandi, et al., 2008). The belief is that if the wall was documented, it would have been reconstructed easily. Documenting, preserving and maintaining this very important cultural heritage could have been supported through the International Committee for Documentation of Cultural Heritage (CIPA). However, an attempt has been started, for modelling and documenting the wall to prevent more destruction.

Figure 1. Prospect of the Great Wall of Gorgan

Figures 2(a) and 2(b): Close-up Pictures from the Great Wall of Gorgan

2. DESCRIPTION

A geospatial information system specifically for use of A/AIS can be an expensive suggestion, but in this review the system can be relatively inexpensive (Chen, et al., 2015) (Nikam, 2015). Figure 3 shows a flowchart of this proposed system. A/AIS is based on the combination of digital photogrammetry and 3-D GIS (Sadjadi, 2008). Such a system can be included following steps;

a) create a digital model of cultural heritage that can support the analysis in the selected environment,
b) the content of digital information can be determined by the images required for this model.

The main purpose of this paper is to use a short-range digital photogrammetry in ancient buildings and cultural heritage conservation (Lo Brutto, et al., 2014) (Mozas-Calvache, et al., 2012).

The comprehensive documentation of a cultural object requires that reconstructing the whole object both geometrically and pictorially is achievable. Combining Digital close-range photogrammetry technique and digital facet modelling, use for constructing the pictorial characteristics of a building. Additional information is accessible through the "hotlinking" or an equivalent facility.

The elements of the database can be integrated with graphical entities like raster images and textual information for visualisation. The output of digitised points can be fed directly a 'hub' package such as AutoCAD. Although the acquisition of some measurements was a component of this task to make a scaled model, the accuracy obtained from the photogrammetric procedures was considerably in excess of requirements (RMSE 10 mm).

3. METHODOLOGY

Based on international rules and regulations, the real form of the buildings and the damages that have entered into them (including desires or unsolicited) should be recorded. Surveying and photogrammetry are the most effective method for providing the information and maps of 3-D and digital models. Any action to be taken on the recovery, restoration and analysis of historical monuments must be done by precise measurement and complete documentation. With this information, the historical monuments and cultural heritage can be preserved smartly. Creating a trustworthy archive of these monuments, the key information, such as feature sizes, general measurements, facet details and other information can be extracted to aid in the reconstruction process via 3-D surface modelling and to facilitate further studies, especially if the monuments have been completely ruined (Baillard, et al., 1999).

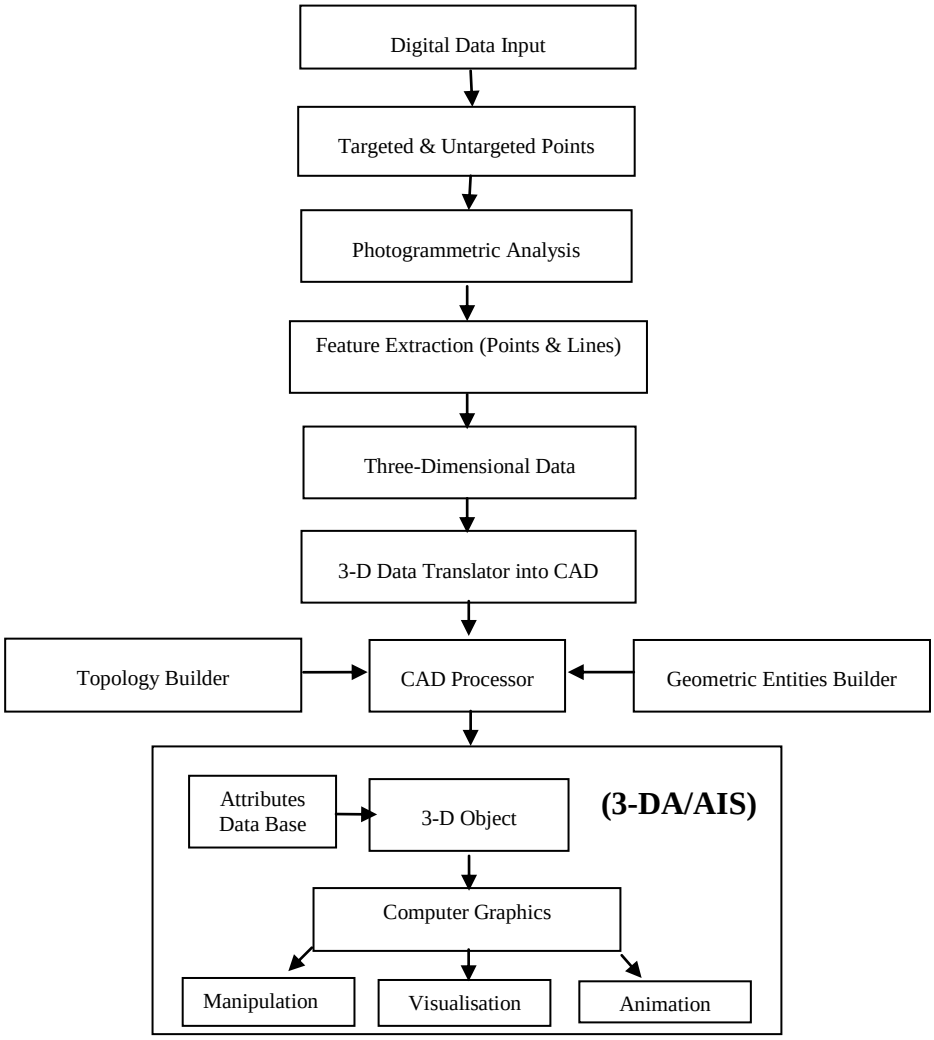

Figure 3: Overview of Architectural and Archaeological Information System

In this project, the comprehensive and documentary removal of the defensive wall of Gorgan in the form of three-dimensional model and using digital close-range photogrammetry, which is the science and technique of surveying engineering, will be conducted as a documentary and according to the International Committee for Documentation of Cultural Heritage and Photogrammetry, Architectural (CIPA), which it will have a global registration capability. The implementation results of this mega-plan are used in the following cases:

- historical study for architecture and archaeology buildings,
- recognise the historical effect at the national and international level,
- implementation for the principles of preservation, repair and rehabilitation programs, and,
- complete the log file of the UN World Heritage List.

The comprehensive documentation of cultural heritage needs to be achievable with geometric regeneration (Anuar Ahmad, 2011). The composition and integration of geometric and visual characteristics of the monuments, the application of digital close-range photogrammetry method, the ability of digital modelling and finally information available from the computer (hotlinking) or the equivalent can do so. Database elements can aid the result to seamlessly integrate the graphical organizations such as images and text information for the visualization and visibility of the object.

The points of digital outputs can be used to power software (code system) such as AutoCAD.

4. DATA ACQUISITION

Digital close-range photogrammetry for the conservation of the desired object surfaces has enough required information about the number of bricks used in the construction of the defence wall and now it is not available. To do this, the digital images are with a scale of 1:20, and then the necessary information is provided to the appropriate software such as Agisoft Photo Scan Professional (APP), creating and reviving the precise parts of the building or the entire cultural heritage working with AutoCAD tools will be accurate in the 3-D space that is suitable for reconstruction (Doug, et al., 2016). However, preliminary research has been conducted to extract data through APP. APP is used to build 3-D surface model, and the outputs of this software is used in the AutoCAD space to be transferred to A/AIS and after manipulating and performing appropriate interaction in this space, to form the desired digital model of the wall based on geometry and measurements (Arefi, et al., 2008).

5. PROCESSING

Processing the photographs is achieved with APP. In APP, the procedure of creating 3-D surface models starts with the connection of 3-D points, edges, curves, etc.

- Create a camera calibration report,
- plan the measurement of the object,
- capture photographs of the object,
- import the captured photographs,
- "Mark" the features on one photograph, that will be 3-D vertices (either control points, feature points or tie points),
- identify the same 3-D vertices on the other photographs,
- process data, and,
- export the results in the form of 3-D coordinate data for the vertices or orthophotos for example to AutoCAD or ArcGIS.

Once the processing was completed and the photographs were oriented, the orthophotos will be generated. Text and DXF files can be used while linking different programs, for example Object Linking and Embedding (OLE) can be used. DXF and Text file formats support Running External Programs (REP) for an embedded link between different programs. An object which created by AutoCAD can be used as an OLE object. A destination application creates the compound document that accepts OLE objects created with the program. The OLE links to one or more compound documents and exports the information to other applications.

Many CAD and rendering packages, and others, such as AutoCAD and ArcGIS can import text, diagrams, digital photos and DXF data files for more detailed measurements in A/AIS applications. This means that more interpretation of the object components should be added to the previous information, which is called topological information. It would be mentioned that a Triangulated Irregular Network (TIN) modelling the project surface is created from registered data points and fits the original data exactly. A list of 3-D points will be created through the processing. In Table 1 shows processing parameters.

Processing Parameters

General	
Cameras	13
Aligned cameras	13
Markers	3
Shapes	
Polygons	1
Coordinate system	**WGS 84 (EPSG::4326)**
Rotation angles	**Yaw, Pitch, Roll**
Point Cloud	
Points	4,779 of 7,343
RMS reprojection error	0.222997 (1.44011 pix)
Max reprojection error	0.705876 (14.975 pix)
Mean key point size	7.43549 pix
Effective overlap	2.80321
Alignment parameters	
Accuracy	Medium
Generic preselection	Yes
Reference preselection	Yes
Key point limit	40,000
Tie point limit	4,000
Adaptive camera model fitting	Yes
Matching time	11 seconds
Alignment time	9 seconds
Optimization parameters	
Parameters	f
Fit rolling shutter	No
Optimization time	0 seconds
Dense Point Cloud	
Points	303,648
Reconstruction parameters	
Quality	Medium
Depth filtering	Aggressive
Depth maps generation time	27 seconds
Dense cloud generation time	2 seconds
Model	
Faces	59,999
Vertices	31,731
Texture	4,096 x 4,096, uint8
Reconstruction parameters	
Surface type	Arbitrary
Source data	Dense
Interpolation	Enabled
Quality	Medium
Depth filtering	Aggressive
Face count	60,000
Processing time	31 seconds
Texturing parameters	
Mapping mode	Orthophoto
Blending mode	Mosaic
Texture size	4,096 x 4,096
Enable hole filling	Yes
UV mapping time	0 seconds
Blending time	14 seconds
Tiled Model	
Reconstruction parameters	
Source data	Dense cloud

Table 1 Shows Descriptions and Specifications of the 3-D Model Obtained from APP

6. SURFACE MODELLING

AutoCAD reads all coordinates of vertices, which have been stored already in a text file as 3dpoly. The script file

(3dpoly.scr), contains a list of all the planes of the object. All the vertices are stored as 3-D coordinates, with each set of these vertices representing a plane of the object. The resulting 3-D surface model could then be rendered and enhanced. The 3-D points of the vertices of the GWG would be created. The AutoCAD environment provides the surface modelling (Skarlatos & Kiparissi, 2012).

There has been considerable recent work in developing efficient 'reverse engineering' tools which can take a point cloud and produce a surface (facet) model, but AutoCAD has been used in this study, which generates similar outcomes. For example, one of these uses the drawing tools of either AutoCAD or Micro-Station to snap to the scanned (i.e. point cloud) points, thus making tracing accurate and works with the CAD dimension tools, to get exact measurements in 3-D space, which is appropriate for remediation.

7. EXTRACTION DATA AND OUTPUT

AutoCAD can supply the data for different layers to illustrate the archaeological and architectural elements, damaged surfaces, etc. of a cultural object. The content of layers and their representation (e.g. colours, line types, etc.), and the operations between layers depend on the proposed applications. The different facets of GWG are archived for further development of the A/AIS. Data extracted from the APP is a type of data (pixels), vector, or text. The extract is provided using non-compact (TIFF) formats. Vector Data Extraction (DXF) in A/AIS gives many outputs with our available vector files. As a result, a text file of 3-D coordinates of the wall will be formed during the process. Preparing a script file from the stored 3-D which is imported into AutoCAD, generates a measurable wall-size visualization. Extracting data as the output of the project shows that every 13 digital packages (digital images) obtained from the camera, which are also aligned, have been used in the production of cloud points and 3-D surface models. Some of this data can be seen below:

- 3-D Vertices
- Node/Tie Points
- 3-D and flat surfaces (Facets)
- Cloud points
- Text files and DXF
- Generate Cloud Density Points
- Production of Mesh Surfaces (Mesh Faces)
- Composition of Tissue
- Tiles Ortho
- Model of String Frame (Wire-frame Model)
- Formation of Irregular Triangular Networks (TIN) from Surfaces
- Model Rendering
- 3-D model
- Digital Elevation Model (DEM)

Various details and results of 3-D model can be publicised in Table 2 and Figures 3, 4, 5 and 6.

Table 2 Shows Details of 3-D Model Attained

Tie Points: 4779 Points
Dense Cloud: 303684 Points
Number of 3-D Model: 59,999 Faces
Levels of Tiled Model: 8 Levels (1.59 cm/pix)
Number of DEM: 4726 x 8427 (6.35 cm/pix)
Levels of 3-D Model: 8 Levels (1.59 cm/pix)
Orthomosaic: 7954 x 14353 (1.59 cm/pix)

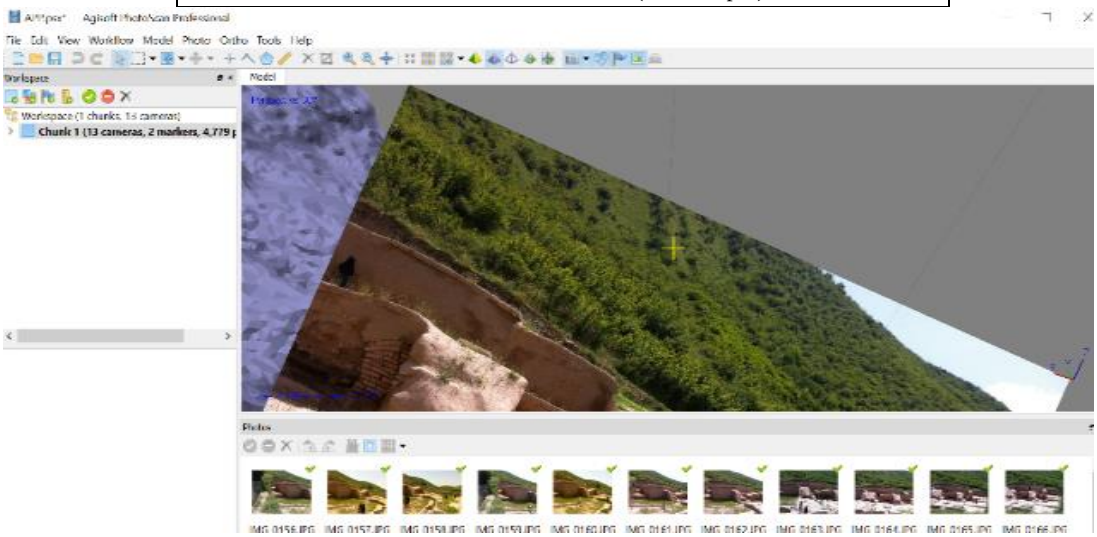

Figure 4 Shows TIN Facets a part of GWG

Figure 5 Shows Production of Mesh Surfaces

Figure 6 Shows Production of 3-D Surface Model and Digital Elevation Model (DEM)

8. DISCUSSION AND CONCLUSION

In the very recent past, manual measurements and direct copying of photographs of freezes onto transparent foil have served well in documenting cultural heritage. Manual 3-D processing of terrestrial images using analogue photogrammetric procedures is slow and may result in little information. In addition, it is a very time-consuming task and requires the expertise of qualified personal.

Ancient objects need to be documented without physical contact, either because of inaccessibility or it's fragile nature. The photographic method of data acquisition takes only a few minutes per photo and therefore it is possible to gather the data in a day. Digital close-range digital photogrammetry permits rapid data recording at low-cost relative to other techniques, and it offers flexibility, such as if the bundle adjustment method is selected and high measurement accuracies. For example, capturing digital data, data processing, recording and documenting of the cultural object can be done within a day. It is important to identify records that are primary in the sense that they contain the maximum quantitative and qualitative information about the monument sites. Some photos will be used to produce a small-scale model of the object, to which a variety of documents and scripts can be linked. Other larger scale photos could be producing precise coordinates of fine detail.

Thus, 3-D geometric data for the generation of geometric representations in an information system can be acquired by digital close-range photogrammetry. The software interface between digital photogrammetric processing and CAD or GIS systems make it possible to transfer the acquired 3-D digital data, captured using digital photogrammetric software by measuring either the original imagery or the orthophoto, to the CAD system and use it to create 3-D wireframe models forming the basis of the solid models used to produce the 3-D visualisation of the cultural objects.

REFERENCES

Anuar Ahmad, L. R., 2011. Generation of Three-dimensional Model of Building using Photogrammetric Technique. *IEEE, 7th International Colloquium on Signal Processing and its Applications.*

Arefi, H., Engels, J., Hahn, M. & Mayer, H., 2008. Levels of Detail in 3-D Building Reconstruction from Lidar Data. *The International Archives of the Photogrammetry, Remote*

Sensing and Spatial Information Science, Volume XXXVII, pp. 485-490.

Baillard, C., Schmid, C., Zisserman, A. & Fitzgibbon, A., 1999. Automatic Line Matching and 3-D Reconstruction of Buildings from Multiple Views. *IAPRS, Muenchen*, 32(1), pp. 69-80.

Chen, Y., Zhao, X. & Jia, X., 2015. Spectral Spatial Classification of Hyperspectral Data Based on Deep Belief Network. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing,*, 8(6), pp. 2381-2392.

Dallas, R. W. A., 1996. Architectural and Archaeological Photogrammetry. *Close Range Photogrammetry and Machine Vision*, pp. 282-302.

Doug, C., Loy, C. C., He, K. & Tang, X., 2016. Image Super Resolution using Deep Convolutional Networks. *IEEE transactions on pattern analysis and machine intelligence*, 38(2), pp. 295-307.

Ghasemian, M., 2007. *Gorgan Wall: Great Wall of the Third World.* Tehran: Etemad Sunday News Iranian Paper, No. 1508.

Hidayat, H. & Cahyono, A. B., 2015. Reconstruction of Singosari Temple Using Terrestrial Images and Structure from Motion Algorithm. *Proc. of Int. Conf. of Indonesian Society for Remote Sensing (ICOIRS).*

Iran Review, 2016. *Red Snake of Iran: The Great Wall of Gorgan.* [Online] Available at: http://www.iranreview.org/content/Documents/The_Red_Snake_The_Great_Wall_of_Gorgan.htm
[Accessed 10 January 2019].

Lo Brutto, M., Garraffa, A. & Meli, P., 2014. UAV platforms for cultural heritage: first results ISPRS. *Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences.*

Mozas-Calvache, T. et al., 2012. Method for photogrammetric surveying of archaeological sites with light aerial platforms. *Journal of Archaeological Science.*

Nikam, S. S., 2015. A Comparative Study of Classification Techniques in Data Mining Algorithms. *Techno Research Publishers*, 8(1), pp. 13-19.

Rekavandi, H., Sauer, E., Wilkinson, T. & Nokandeh, J., 2008. The Enigma of the Red Snake. *Current World Archaeology.*

Sadjadi, S. Y., 2008. An Investigation of Architectural and Archaeological Tasks Involving Digital Terrestrial Photogrammetry. *WSEAS TRANSACTIONS on ENVIRONMENT and DEVELOPMENT*, 8(4).

Skarlatos, D. & Kiparissi, S., 2012. Comparison Laser Scanning, Photogrammetry and SfM-MVS Pipeline Applied in Structures and Artificial Surfaces. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume XXII.

Surendra Pal Singh, K. J. V. M., 2013. Virtual 3-D Campus Modeling by Using Close Range Photogrammetry. *American Journal of Civil Engineering and Architecture.*

Revised August 2019