Using a 3D Laser Scanner for Mapping Persepolis, Iran

Scanning the History in 3D

There are few historical sites in the world that can claim to be as old as history. Persepolis can do it for sure. It was standing with pride from 520 BC, before it was sent down to ashes, when Alexander the Great, as many believe, surrendered to a favour from his mistress. It was once surveyed, by a group of German surveyors from Chicago in 1958. But it was not until late February 2002, that a group of surveyors, utilised RIEGL 3D-Scanner to scan the area and to capture it as Digital 3D model. The group was consisting of specialists from Cultural Heritage Organisation of Iran (CHOI), TEKNO Co. of Iran and an assisting engineer from Austrian RIEGL GmbH.

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Persepolis (φ= N29 56 46 λ=E52 55 26) is located 55 kilometres toward the north of Shiraz, in the southwestern part of Iran. At its time, it was located in the middle of vast Persian Empire extending from west to existing Turkey (then Ludia) and to north of India in the east! Now it is mostly believed the site was chosen by King Darius (Achemid dynasty) to act as a hideout place of Iranian Kings and a reception place for the kings ruling under the King of Kings.

It is a model of Persian architecture – neither Greek, nor Egyptian, nor Assyrian, nor Median, but containing elements of all.

Mission Persepolis

Cultural Heritage Organisation of Iran (CHOI) is the main government body in Iran to organise all the activities regarding the preservation, researching, investigating and surveying of the historical sites. It is apparently a demanding job when you are dealing with a country of over 3000 years of written history and much more in unwritten form. To comply with the UNESCO agreements, official documentation of all these sites should be prepared.

After detailed study of the requirements set by CHOI, TEKNO, started to match these requirements to the products available in the market. Considering availability, capabilities, specification details and of course total costs; the famous *RIEGL* products were found suitable for the task.. To meet the CHOI requirements, a demonstration-trip was organised by Mr. Boroumand, the founder of TEKNO and the most difficult mission with one of the highest priorities was selected: Mission Persepolis.

Workflow

The list of requirements set forward by the CHOI could be summarised into following categories:

- Site plans of different scales
- 3D visualisation of the sites
- Infrastructure to develop a Virtual Museum
- Digital CAD maps of different types e.g. Topography maps
- Off-line measurements of co-ordinates and lengths in computer
- Detailed maps of carvings and cracks on the walls and facades

From all of the over-mentioned requirements, preparation of the orthogonal maps of the facade details fell beyond the laser scanners' capabilities, thus for better results a combination of close range photogrammetry and 3D laser scanning was recommended.

Implementation

After evaluation of specification of several equipment, we chose the newly developed *RIEGL* LMS Z360. Its capabilities were much improved in respect to its popular sister LMS – Z210 that is well known for its reliability, mechanical stability, and rugged design. There were two more key improvements: firstly it's 12-millimetre accuracy of single laser shot and secondly the 360 x 95-degree scanning coverage that made it really unique.

We arrived at Persepolis on a

Hall of 100 Columns, Persepolis, *RIEGL* 3D Imaging Sensor LMS-Z360

3D Model of one of the 10 meters high gates in the Hall of 100 Columns, rebuilt by CHOI

cloudy day that is charactisic of end of February climate in the region. After a short introduction to CHOI authorities on the site, we started to design our net of reflectors. Contrary to single scanning of an object, merging the scans is more difficult. However this part is also very simple by the automatic recognition and merging technique that the *RIEGL* RiScan software incorporate. The only requirement for a smooth merging is that not less than 4 common reflectors can be scanned in both scans.
Apparently the more reflectors the better, because of the least square adjustment calculations, accuracy is boosted amazingly with more reflectors.
The correlation is found by comparing their geometry of arrangement and in this way one scan is online added to another while normal scanning is under way.

RIEGL LMS-360 proved to be very handy during our scans. A single car battery was adequate for our dawn to dust scanning of over 12 hours. Workload was very low and starting the scan was only a click away. The below-mentioned procedure was followed:

- 4 minutes for a 360 x 95 degree scan with an angular resolution of 0.12 degrees (7') (medium res scan for overall data acquisition and merging calculations).
- 3 –5 minutes for a selected part scan with an angular resolution of up to 0.01 degrees (36") (high resolution scan, when needed)
- In some cases we used the "Log To File" feature of RiScan to scan repeatedly up to 10 times, where we could increase the accuracy up to 5 millimetres. We applied this technique to several objects that were of higher interest.
- 2-4 minutes was taken for moving to next scan-spot. Thanks to its comparatively lightweight, an operator and an assistant were enough for this job.

We followed a star-merging procedure rather than a chain- merging. We picked a central scan that is usually the one that is located in the middle of the site. The other scans are added as the hubs are connected to a spoke in a bicycle wheel. In this way the overall accuracy will be much better than chaining the scan one after another.

Before leaving Persepolis, we were able to check for any gaps left among the scans.

Post Processing

After merging the scans, we are led to post processing. There are several post-processing tasks that can be done before we can face the finished product.

- Data filtering
- Creating the 3D presentation file
- Re-sampling
- Exporting as DXF / ASCII
- Exporting as other 3rd party software formats

It is obvious that data acquisition at a high rate of 10.000 points per second produces a huge amount of data. With existing computer performances, it is both difficult and unnecessary to deal with all data in one big set. Thus

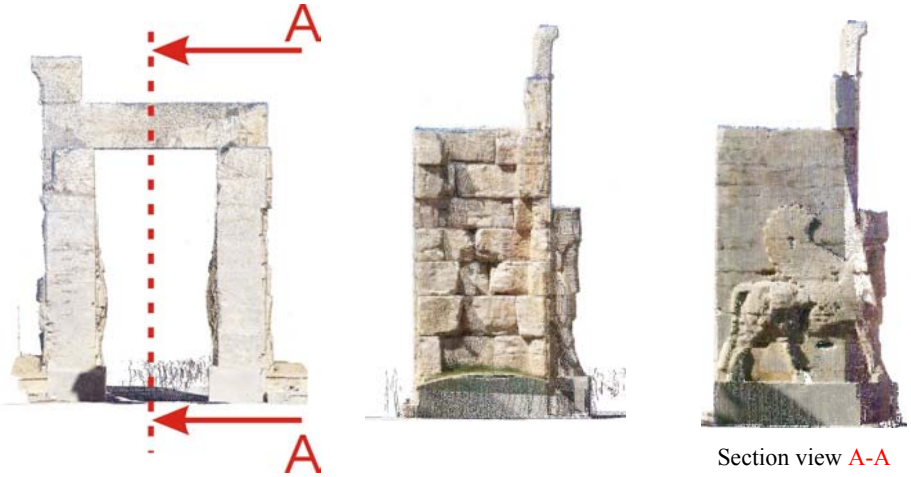
Site	No. of scans	Scanned area	File size
Hall of 100 Columns	57 + 17*	100 m x 100 m	2.3 Gbyte
Nation's Gate	12 + 12*	30 m x 30 m	560 MByte
Ardeshir Grave Site	1 + 2*	20 m x 10 m	50 MByte
Duration of scanning:	16 h + 5h + 0.5 h = 21.5 h		
Equipment:	RIEGL LMS Z360 + Notebook 800Mhz / 18 GB		
Date:	Feb 27th to March 1st 2002		

* Very high resolution scans

Project details in a glance

Hall of 100 Columns, 3D Point cloud of 57 merged true colour scans, re-sampled 0.3 m cube, created semi-automated while scanning, the grey areas were scanned during cloudy periods

Photograph



Section view A-A

Orthogonal views of the Nation's Gate – 3D model (outer and inner side)

filtering the data becomes very important. There are many handy filtration techniques available in RiScan such as plane, cubic, range, fence and selection filtering which we found very productive.

The filtered data can be exported directly into the 3D-presentation file format for *RIEGL's* RiView software. The example of the Nation's Gate can be seen above. For visualisation of the orthogonal projection of the inner side of the gate, half of the model was cut by a vertical plane shown as a dashed red line.

Re-Sampling is usually needed before the exportation of the data. As with all scanners, the data acquisition is in an equi-angle manner rather than uniform point distribution, which surveyors prefer more. Thus when it comes to exporting the data, for example to a CAD surveying software to create topography map it will be much easier and faster to have an uniform point distribution.

At the time of writing of this article an Auto-CAD map of the Hall of 100 columns was under process, based on point cloud DXF export of RiScan.

Conclusion

When we were thoughtful of the all the beautiful symmetry of the palaces and were dreaming of how this place looked like, in this glorious days, a cell phone ringed to remind that we should go back to reality and say goodbye to Persepolis. We left Persepolis with some sort of comfort. "Do not worry any more", we say to Persepolis ruins. "we have captured you in our Laptop and CDs. Let another Alexander put you on fire. We have enough scans to let anybody come and walk through you and be amazed of the culture of Iranians living centuries before many current countries start to exist."

However one should not make any mistake, despite all the lashes Persepolis has felt on his body through the ages, not much is reduced from its initial greatness and pride. After your visit to this cradle of civilisation, you are convinced to accept the high attitude of people masterminding the construction of such a wise site.

It is true that the *RIEGL* LMS-Z360 performed great, but one should not forget the helps and collaboration of all people who helped this to happen. We would like to express our acknowledgement to Persepolis's hard working staff and top management Cultural Heritage Organisation officials. Last but not least our thanks also goes to Tekno Technical managerMr M. Noormohammdi for his assistance during the mission.

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True colour channel - raw data of 95° x 360° scan / 791 x 3001 measurements