

The State-Of-The-Art Integration of Laser scanning and Close range Photogrammetry

Laser-Photogrammetric mapping of Bam Citadel (Arg-E-Bam)

After a devastating earth quake (26.12.2003, 6.3 Richter Scale) in Bam city/ Iran, Riegl LMS GmbH /Austria (www.riegl.com) and the Iranian agent, NPR Co. (www.nprco.com) have formed a mission to perform a 3D mapping project of the greatest mud brick and adobe complex of the World, The historical ancient Citadel of the Bam (Arg-E-Bam), with a history of more than 2500 years (Achaemenian period) using a unique integration of the close range photogrammetry and laser scanning technologies. The author describe the implementation of 3D documentation using this state-of-the-art technique and try to prove that this bi-technique integration is a must and golden key to have a true color-texture 3D as-built models of such a huge cultural heritage sites.

By Mehdi Boroumand / Managing Director of NPR Co./Iran , The Iranian agent of Riegl LMS GmbH/Austria

Since the last similar article of the Persepolis/Iran in June 2002, about the 3D laser scanning of the Persepolis, The author (From NPR Co. [www.nprco.com] and RIEGL LMS GmbH [www.riegl.com]) have realized some vital key factors to achieve the best results and continued their practical co-operations and experiences with The Iranian Cultural Heritage Organization (ICHO)[www.iranmiras.org], for the 3D documentation of the historical sites in Iran. They perfectly knew that the point clouds could not completely respond the demands for fine feature extractions from the historical walls or the exact modeling of the roughness and textures as well as the material studies by true color information needed by the archaeologists, etc. And such experiences from all over the World led RIEGL LMS GmbH to a clever idea of new generation of fully integrated laser scanning and close range

photogrammetry solution. ICHO is the Iranian state entity, in charge of restoration, preservation, historical and archaeological research as well as surveying and documentation of the sites to register them in World heritage list or its sublist as World heritage in danger list to draw the international support and care, as they are the belongings of the all nations. In last days of 2003 a terrible earth quake shook the Bam city with more than 50,000 casualties left, Bam is located 1000 Kilometers south of Tehran, north of Persian Gulf which has guarded the silk road for over 2000 years. Its history dates back to 2500 years ago (Achaemenian period) made entirely of mud bricks, clay, straw and the trunk of date palms,

Intensive restoration works began since 1953 till earth quake. More than %70 of the Bam citadel (Arg-E-Bam) was ruined (See figure 1.) and of course after the humanitarian urgent helps for the people and children, it was considered by the Iranian authorities and UNESCO as the valuable cultural heritage in danger and crisis. Intensive regular meetings started since the first moments and a mission headed by the UNESCO World HeritageCentre[whc.unesco.org] and accompanied by ICOMOS [www.icomos.org], its ICOMOS/ISPRS specialized documentation Committee, CIPA [cipa.icomos.org] and ICCROM [www.iccom.org] joined to assess the state of damage and an action plan for rehabilitation, consolidation and reconstruction.

Current Laser scanners need to be integrated with close range Photogrammetry to reach to the high detailed 3D models.

Utilized Solution

It was clearly agreed that the initial step for any plan for operations was a basic map to plan for consolidation of unstable structures as well as removing the debris and ruins (Figure 2.) and after cleaning the site, again a



Figure 1. Bam Citadel Before & After earthquake

precise as-built map but not a simple line maps like topography or wall by wall cross sections or orthoimages were needed.



Figure 2. Z420i in Bam Citadel

A mission has been formed by NPR and RIEGL to achieve this goal. They benefited the latest technology. This time RIEGL did not suggest the laser scanning only, but also the photogrammetry in conjunction as both subjects could fill each other's technical gaps. As a matter of fact, it was planned to have the huge geometric information as well as millions of GCPs by LMS-Z420i Riegl scanner (Figure 3.) UTM georeferenced by GPS and the work base to extract and vectorize features, edges, bricks, etc by high resolution images taken by 6 million pixels digital camera. The mathematical relation between these two had been defined by a perfect hardware calibration at factory. Thus the system perfectly knew which point in point cloud in scanner relative co-ordinate system refers to which pixel in camera photo co-ordinate systems. After transportation or dismounting the camera, it was needed to check the camera calibration as well as the mounting calibration to have a perfect adjusted and calibrated system which can be done through a simple procedures on site. If the Geomatic scientists don't mind, This method can be called as Laser-Photogrammetry and the instrument can be called as Photo-Laser scanner and can be added in Geomatics terminology.

Suggested new terms:
Laser-Photo grammetry and Laser-Photo scanners



Figure 3. LMS-Z420i

Project Definition

The required basic expectations from ICHO experts plus unbelievable outputs recommended by Riegl/NPR team were as follows:

- * Old fashion Topographic map in requested scale.
- * Cross sections of specific 3D features based on points of interest.
- * Volume calculations of ruins considering the base surface extracted from the old aerial photos.
- * Specific feature based Orthophoto-Vector maps including bricks, cracks, textures, roughness and other historical signs in UTM 3D co-ordinates.
- * General 3D reconstruction of geometric models of existing situation of structures to enable experts to do a deep study how to reconstruct the structures.
- * Providing the General tools to measure any distance or 3D co-ordinates to extract as well as sections, calculate any volumes in any direction for various studies.
- * 3D visualization of the whole site (Area: around 20,000 Sq. meters) as well as fly through

animations for the management analysis.

* To meet the documentation standards needed to be registered in World heritage in danger list.

Implementation

As the first priority, the demand was for the governing place which was located highly on a huge rock foundation.

Obviously it was a must to have many different scanning positions to cover the shadows and blind spots. In the order list, it was also mentioned to have every points or final products in Global (UTM) co-ordinate system (Figure 4.). Firstly it had to be planned to place 360 degrees reflectors, as many as possible in different positions in the area in a way that at least 4 or 5 of them could be seen commonly between adjacent positions and measuring their UTM co-ordinates by dual frequency GPS receivers disclosed to the nearest known country GPS points. It was good to have the global co-ordinates of

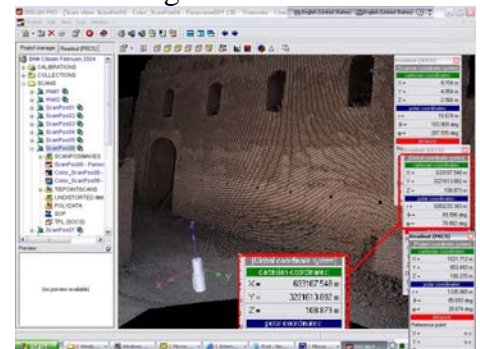


Figure 4. Global Co-ordinates

each reflectors which were supposed to play the role of the tie points in merging the separate scans because it would be possible to remove the obligation of having the common reflectors and the possibility of direct georeferencing the scan point clouds but it would be a time

consuming job to measure around 80 reflectors which were distributed in the site so the team was combined two methods to optimize the job by having the minimum known coordinates and common reflectors to have the maximum degree of freedom in final least squares error minimization process, More common reflectors, higher accuracy and certainty in final merging and less residuals. Therefore, after a quick survey the best positions were chosen to put the reflectors to cover the Ruler's place then an on-site calibration was done to make sure that the best results would be achieved.

Post-Processing

After data collection and having all the scans merged in millimeter accuracy in RiScanPro software from Riegl Co., which was obtained by combining the GPS global coordinates of some reflectors and enough number of common reflectors between each adjacent scan positions, a unified data base including true color point clouds plus linked and oriented images, was ready in Riegl software named RiSCAN PRO to be post-processed to generate the final requested products.

Among the specialized softwares, the choice was Phidias from Phocad/Germany [www.phocad.de]

As it had the best environment and tool to import this type of combined database full of different scans and images. The beauty was , at the first moment of importing, huge number of images were perfectly oriented in global co-ordinate systems. Phidias is an add-on module which uses Bentley's Microstation as a CAD environment so one can benefit a perfect set of CAD tools plus the specialized facilities to define the working plane or patches, linear or non-linear co-ordinate systems

To have the 2D working space to project and extract features for 2D maps or 3D vectorization directly in 3D space. (Figure 5.)

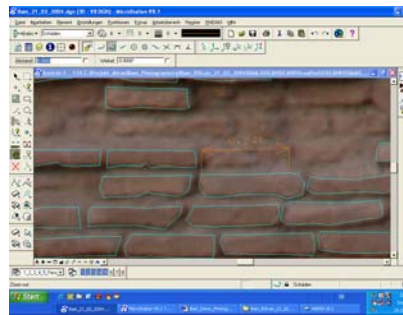


Figure 5. Feature Vectorization

Concluding Remarks

Despite this fact that the latest and best laser scanner of its kind has been used with narrow beam divergence (0.2 mrad) and an extreme compromise between two old enemies (Range and accuracy) exist in used LMS-Z420i with range up to 800m and accuracy of 12 mm for single measurement and improvable up to 5mm by iterations but in some applications where one needs high detailed sub-millimeter features or requires to recognize and vectorize edges as feature or break lines for improving the DEM in huge sites, Close Range Photogrammetry can play a vital roll to fill this gap and these two are ideally complementary solutions.

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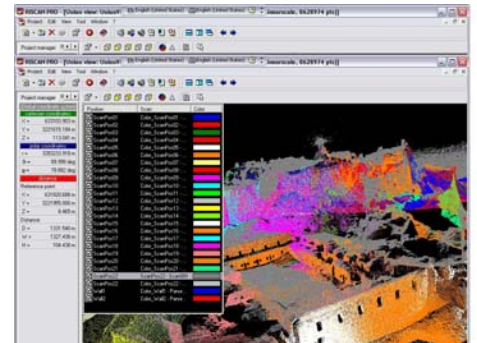


Figure 6. Different scans, different colors in RiSCAN PRO

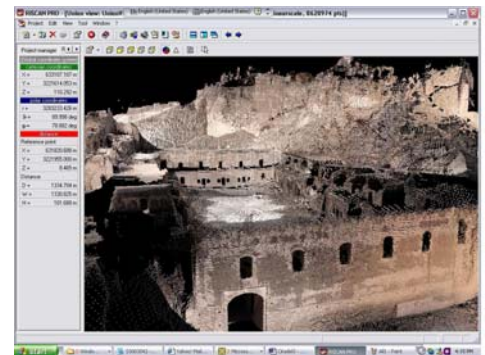



Figure 7. 3D merged true color point clouds in global coordinate system in RiSCAN PRO

Biography of Author



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