New software and technologies applied to documentation and communication of Cultural Heritage

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Abstract: In the last seven years researchers have been using the stereo-photogrammetry technique to achieve more data in comparison to the monoscopic photogrammetry. The stereoscopic vision is achieved by two or more pictures taken from different positions (with at least the 60% of overlapping between the two shots), unified in a second step with common spots. Using this method it is possible to detect more levels of the object's history and conduct through measurements in real time. Many professional and semiprofessional photogrammetical software based on the image processing have therefore been recently developed, for archaeology, architecture, and more in general the restoration and preservation sector: ZScan (Menci Software), Z-Map (Menci Software), UMap (Menci Software), Photomodeler Scanner (EOS System), Orthoware (Metria Digital S.L.), Image Master (Topcon), Photoscan Pro (Agisoft), Image Modeler (Autodesk). This software allow to produce several analyses from the photos: orthophotos, D.E.M., geometrically correct 3D reconstructions, coordinate system creations, metrical inquiries, 2D and 3D drawing on models. Every software, even if usable in several disciplines, has its peculiarity and specific function, so that the ideal study of a site, building or object can be achieved combining more techniques and software, trying to use the bright sides of each one. The rapid development is making it also possible to do photogrammetical 3D reconstruction with any mobile device (smartphone or tablet), getting closer to a far more numerous public than before. The aim of my research was to compare and study the various software in their application to Building Archaeology, in order to suggest which software fits best for which project, and to suggest how to combine them.

Keywords: Photogrammetry, 3D reconstructions, Software, Cultural Heritage, Buildings Archaeology.

The importance of photogrammetric survey

In the field of Cultural Heritage, like in archaeology and architecture, a tridimensional survey is essential because it allows us to reconstruct accurately the geometry of object or buildings, to study it, for example, gradually in a laboratory. In case of walls or buildings damaged, for example damaged due to an earthquake, the 3D survey allows us to have all geometric and volumetric data for a possible restoration and real reconstruction, allowing in addition to map all stratifications and decay's layers.

The survey's quality depends, mainly, on the quality of images (in terms of resolution); in this case the quality is influenced by many factors (subjective and objective), like the technical ability of operator, environmental shadows, reflections, glare and others. The quality of images, in addition, depends on the kind of camera or video camera; obviously a better camera will produce better images and these will produce better results and reconstructions.

In terms of image quality, the selection of professional (for example Nikon FX) and semiprofessional (for example Nikon DX) cameras also requires the important selection and management of every technical setting (for example the RGB profile, the ISO values, the time exposure and the aperture of lens). The best image format we can use is the RAW format for every professional camera: for example the CR2 format for Canon and NEF format for Nikon. RAW format is better than others formats because it maintains the original quality of the image without any compression and automatic revisions. In addition to RAW formats we can use, for our survey, TIF or TIFF format; it is universal and a common camera format that allows to maintain the original quality of images (like RAW format), resulting heavier format than the RAW format and JPG or JPEG common format.

After we've chosen the better camera and the better image format, we have to choose the better shoot technique for our archaeological or architectural survey. There are many techniques to accomplish a survey, the most used being: the parallel convergent shoot technique and the convergent shoot technique. The first one, where you have to move in parallel at regular gaps, is used mainly to reconstruct objects with low depth, like walls and masonry, the second one is used for objects with high depth and you have to turn around the objects converging in one single point. Both techniques work with at least 60-70% of image overlapping.

Before we start a new photogrammetric project, we have to calibrate the camera lens: with this step we can remove the original lens distortion, and it allows us to create geometrically correct 3D models. Therefore, the calibration step allows us to identify all distortion parameters, such as the K1-K2-K3 parameters (radial distortion) and P1-P2 parameters (tangential distortion). If we want to start a new photogrammetric project without the calibration step, then using only an EXIF file (with image metadata), will not have enough results, because the EXIF does not contain distortion parameters but only others information such as the ISO values, the time exposure and the aperture of lens, details that are not enough to adjust the original lens distortion.

The computer (hardware and software) and photographic (cameras and lens) innovation has aided the development of new technologies based on photogrammetry permitting the creation of new photogrammetric surveys made with mobile devices (smartphones and tablets). For this reason, today it's possible to do a photogrammetric survey using smartphones or tablets of the latest generation; these devices have good cameras and lens (with resolution between 5 megapixels and 10-20 megapixels) and it is also it's possible to install on it additional semi-professional lenses.

Experimentations

For the experimentation we have tested EVO Suite, Orthoware, Photoscan Pro and Photomodeler Scanner.

EVO Suite (UMap)

UMap, the advanced version of Menci software ZScan, was tested doing a photogrammetric survey in the Camaldoli Monastery, in particular the *Maldolo's courtyard*; it was surveyed using this equipment: Nikon D700 digital reflex; Nikkor lens 28mm f/2.8D AF; Slider (90cm) with sliding head; Manfrotto professional tripod. The shoot technique chosen was the parallel convergent shoot technique.

Photos were shot in TIF format (.tif), with three shoots (with at least 60% of overlap) sliding the camera on the slider (Menci Software's technique). The translation distance of the camera on the slider depends on distance between the camera and the object: the greater distance the wider translation.

PHOTOS	DIMENSION	SURVEY'S TIME
322 in TIF format	11 GB	3 h

Tab.1 – Survey report

At the end of the survey, we have collected 322 photos in total; all these photos were used in UMap software setting up the maximum quality of creation, that is to say reconstruction step 5 and accuracy level 1. Photos were collected in different groups of 12-18 photos, using 20-25 minutes for the creation step of each group (in totally 12h). Whereas UMap creates only RGB 3D point clouds, we have created the wireframe and mesh (surfaces) with Geomagic Studio software, setting up the triangle creation on 55% of 3D point cloud. All 3D models created with each groups of photos were connected and managed with Meshlab and CloudCompare free software.

PHOTOS	3D MODEL DIMENSION	POINT CLOUD	SURFECES	CREATION TIME
322	605 MB	11.975.028	22.925.761	12 h

Tab.2 – Final report of 3D reconstruction of Maldolo's courtyard


Fig.1-2 – Maldolo's courtyard and 3D reconstruction of it.

Orthoware

Orthoware permits to create high resolution orthophotos and 3D models including wireframe and texture. It was tested using only two photos of an architectural element of the Orsanmichele church in Florence. The equipment used for this survey was: Nikon D3100 digital reflex; Nikkor AF-S DX 35mm f/1.8; Manfrotto tripod and photos were shot in JPG format; in addition these photos were shot using the convergent shoot technique (distance from object 8m).

PHOTOS	DIMENSION	SURVEY'S TIME
2 in JPG format	15 MB	3 min

Tab.3 – Survey report

Orthoware was set up with a high quality of creation, that is to say point density 3. For the 3D model creation we have used about 25 minutes and at the end we have cleaned and managed the original model (OBJ) in Meshlab software converting them to PLY format. This is the final report of creation (Tab.4):

PHOTOS	3D MODEL DIMENSION	POINT CLOUD	SURFECES	CREATION TIME
2	135 MB	1.251.738	2.497.850	40 min

Tab.4 – Final report of 3D reconstruction

Fig.3-4 – Orsanmichele architectural element and 3D reconstruction of it (point cloud particular).

Photoscan Pro

Photoscan Pro allows us to obtain a 3D high texured model and also 3D dense point clouds. This software was tested using 6 photos on a bas-relief still near Orsanmichele church in Florence. These photos were shot again with Nikon D3100 digital reflex, Nikkor AF-S DX 35mm f/1.8 lens, Manfrotto tripod and were shot in JPG format using the convergent shoot technique (distance camera-object 2m)

PHOTOS	DIMENSION	SURVEY'S TIME
6 in JPG format	37,5 MB	6 min

Tab.5 - Survey report:

For this test we have chosen to obtain only a 3D dense point cloud, setting up Photoscan to high quality both for photo alignment and for 3D dense point cloud creation. Although it allows to create a full 3D model with mesh and texture, we've decided to export only the 3D dense point cloud, building manually the mesh with Geomagic Studio software, setting up the triangle creation on 56% of the 3D point cloud.

PHOTOS	3D MODEL DIMENSION	POINT CLOUD	SURFECES	CREATION TIME
6	58,8 MB	3.673.855	6.529.913	30 min

Tab.6 – Final report of 3D reconstruction

Fig.5-6 – Low relief's photoset and 3D dense point cloud of it.

Photomodeler Scanner

Photomodeler Scanner was tested in two different projects. The first object surveyed was an Etruscan inscription, on the Archaeological Museum in Fiesole (Florence). For the survey, the equipment used was: Nikon D700 digital reflex and Nikkor lens 28mm f/2.8D AF, and only 3 photos were shot in TIF format (camera distance from object: 50 cm).

The second project was made with a particular portable camera, iPhone 4 camera (5MPX and about 30mm focal length) and the object surveyed was a copy of a prehistoric fragment, using 6 photos shots in JPG format at 15cm distance from the object. The iPhone 4 camera calibration method was the same as for the others cameras calibration: 12 shots in different positions of Photomodeler's calibration grid.

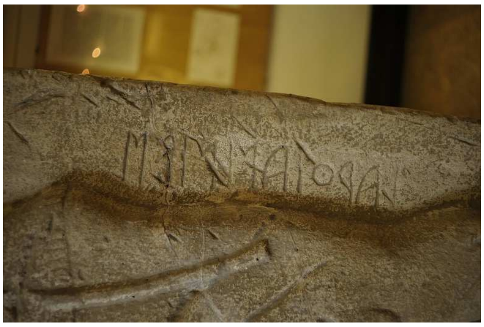
Project 1		
PHOTOS	DIMENSION	SURVEY'S TIME
3 in TIF format	88,5 MB	3 min
Project 2		
PHOTOS	DIMENSION	SURVEY'S TIME
6 in JPG format	12,5 MB	2 min

Tab.7 – Two projects survey report:

Photomodeler Scanner, for these projects, was set up with medium – high quality of creation, and it has worked about 40 minutes for both projects (alignment, point cloud and mesh creation).

Project 1				
PHOTOS	3D MODEL DIMENSION	POINT CLOUD	SURFECES	CREATION TIME
3	77,2 MB	772.552	1.543.669	22 min
Project 2				
PHOTOS	3D MODEL DIMENSION	POINT CLOUD	SURFECES	CREATION TIME
6	28,6 MB	287.003	572.506	20 min

Tab.8 – Final report of both projects about 3D reconstruction



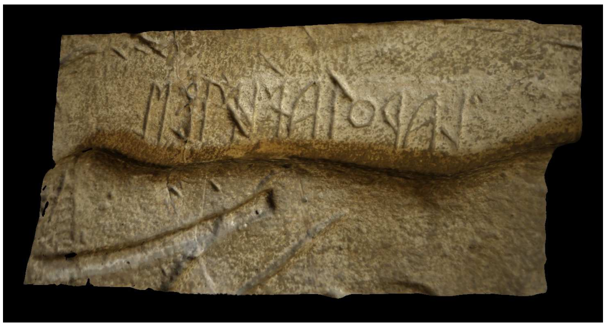


Fig.7-8 – Etruscan inscription, photo and 3D model (mesh and texture).

Fig.9-10 – Copy of a prehistoric fragment, photo and 3D model (particular of 3D wireframe RGB).

Hardware performance

The photogrammetric software we have seen before cannot be installed on every computer. This limitation depends on machine language of software compilation; every operating system (OS), such as Windows, Macintosh or others, has its own machine language. All the photogrammetric software is available with Windows operating system (most common), whereas we have very few photogrammetric software (in large parts open source) available with the other OS.

	PHOTOSCAN	PHOTOMODELER	ORTHOWARE	EVO SUITE
WINDOWS x86	✓	✓	✓	✓
WINDOWS x64	✓	✓	✓	✓
MAC OS X	✓			
LINUX	✓			

Tab.9 – Software Compatibility

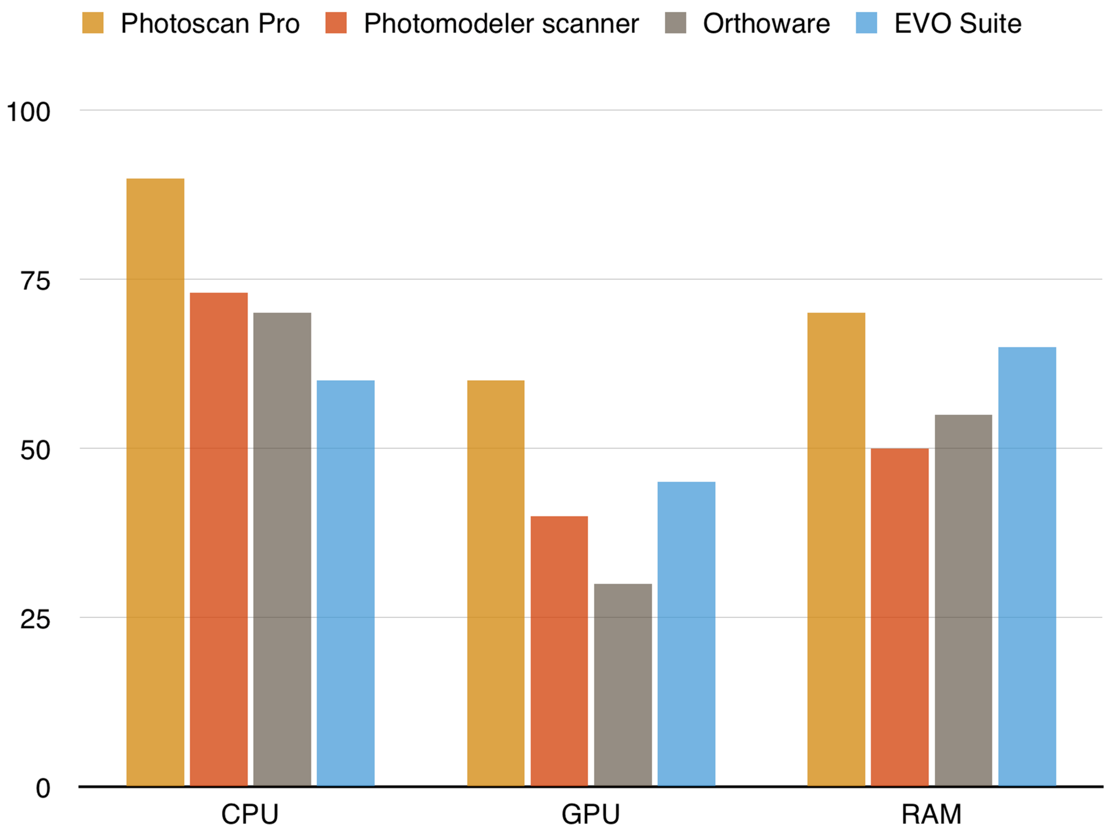
In order to install and work correctly on every computer, the minimum requirements every type of software must present, in addition to the compatible operating system. These refer to the most important parts of every computer: processor (CPU), memory (RAM) and graphic card (GPU); for these reason photogrammetric and three-dimensional software needs continually hardware update, especially for processor and graphic card.

All the photogrammetric experimentations have been made using a computer with these requirements:

- OS Windows 7 SP1 64bit
- Intel Quad Core i7 2,7 GHz processor
- 16 GB 1600 MHz DDR3 memory
- NVIDIA graphic card GT650M 1GB DDR3

The software used before for the experimentations had different a behaviour and has used the hardware in different ways. Here is the software behaviour for CPU, GPU and RAM during the point cloud creation time from only 3-6 photos (Tab.10).

As we can see, Photoscan Pro is able to use nearly 100% of the processor resources (Quad core CPU). In order to do the 3D point cloud creation there are many parameters that influence the hardware usage: the global quality, although we can choose from different parameters (lowest, low, medium, high, highest), of models depends on (mainly) the triangles number on the wireframe. The bundle adjustment step in every 3D models creation depends on the processor performance, while the texturing step depends only on graphic card performance. Setting up the 3D creation on medium-high quality, EVO Suite (UMap), Photomodeler Scanner and Orthoware are able to work without influencing particularly the hardware performance, permitting also multiple processes with the same software (it becomes very difficult with Photoscan Pro). The creation quality we can set up influences therefore the hardware performance, operating also on creation and exportation time; in fact Photoscan Pro can use easily 30-40 minutes to create 3D models starting from 5-7 photos.



Tab.10 – Software behavior

Conclusions

Three-dimensional survey in archaeology and in architecture is a fundamental moment because it allows us to reconstruct exactly (geometry) every object and building; in case of damaged buildings, for example caused by an earthquake, a photogrammetric survey allows us to obtain volumetric data for possible reconstruction or restoration.

The documentation and communication of Cultural Heritage are fundamental moments to transfer important data to public; the big amount of data we can derive from photogrammetric survey allows us to obtain different data to manage and communicate. The problem of final data communication is still open: a photogrammetric survey of a big building, like *Maldolo's courtyard* (more than 300-400 photos), generates too big files to manage and communicate with clarity and facility. For example, starting from EVO Suite final data it is possible to obtain a single file, containing all 3D point clouds of the courtyard, only if we reduce the final 3D point cloud and mesh (also 50%), and then reporting a false final result. In order to communicate clearly the final results, Photoscan Pro could be more dynamic, flexible and user friendly than other photogrammetric software. Finally, the massive diffusion of freeware and open source software, for example 3D viewer and other photogrammetric simple tools, and the technological changes (we can do a photogrammetric survey even with a smartphone) have aided the documentation and communication in Cultural Heritage (DIARA F. 2013).

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Imprint:

Proceedings of the 18th International Conference on Cultural Heritage and New Technologies 2013 (CHNT 18, 2013)

Vienna 2014

http://www.chnt.at/proceedings-chnt-18/

ISBN 978-3-200-03676-5

Editor/Publisher**:** Museen der Stadt Wien – Stadtarchäologie

Editorial Team: Wolfgang Börner, Susanne Uhlirz