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HIGH RESOLUTION 3D SURVEY OF THE INSCRIPTIONS

1. Introduction

The aim of this experience is to provide a 3D realistic model of the three inscriptions of the Latin and Greek versions upon the Augustus’ temple.

In the past a full photogrammetric survey has been provided by the Ancyra project; the aim of this survey was to define, from a geometrical point of view, all the interesting objects of the site as a basis for a correct documentation of the “state of art”.

Considering the location of the site and the natural degradation which affects especially the inscriptions, a new survey project has been planned in order to set up a monitoring system able to follow the degradation of the inscriptions during the time due to natural phenomenon.

The amount of possible degradations can be considered of an amount of less than 1 mm so, high accuracy methods and instruments able to acquire a huge amount of points have to be used in order to check, in a proper and affordable way, the geometric disease of the inscriptions. This kind of instruments are generally known as Scanning Systems.

Scanning Systems are based on different physical principles (e.g. LIDAR, structured light, holography, photogrammetry, etc.) but they are usually equipped in order to be used inside controlled laboratories and not on the field as this application requires.

Only photogrammetry based scanning systems can offer a good solution: the reference system is fixed on the object and not inside the acquisition unit, the geometric survey can be directly connected to the radiometric information emitted or reflected by the object itself and a lot of automatic procedures can be used in order to speed up the acquisition phase and the generation of dense clouds of points.

The instrument used during our experience is an innovative photogrammetric based system which allows high accuracies and high performances in terms of practical solutions both during the acquisition phase and data treatment avoiding some of the troubles that the traditional photogrammetric systems always have (e.g. control point survey, orientation of stereoscopic images, autocorrelation, etc.).

2. The HANDYSCAN 3D by CREAFORM

Produced by CREAFORM, a Canadian Technological centre for reverse engineering and 3D digital solutions, HANDYS-CAN 3D has been classified as the third generation instrument of high resolution 3D scanners. It has been presented as the first self-positioned hand held scanner in the world.

The basic idea of this instruments is very simple (it is a digital photogrammetric system) but the adopted solutions represent a true novelty from different points of view in the Cultural Heritage surveying field.

The first interesting aspect is the dimension and the weight of the acquisition unit which can be handled for long periods without stress for the operator and it allows the possibility of obtaining all the details even in the case of very complex objects. The second attractive aspect is the possibility of acquiring objects of different
dimensions: from small objects (e.g. rings, fragments, etc.) to very large objects (e.g. statues, large inscriptions, etc.). Finally, the third attraction is the price, which is lower than the current quotations of the less accurate terrestrial laser scanners, even considering the laptop for the storage and the visualisation of the acquired data.

2.1 The acquisition phase

The acquisition unit contains two digital cameras mounted onto a rigid body. Four laser spots are placed around each lens and, at the bottom of the handle, there is a special laser tracker which is useful during the acquisition process to mark the surveyed points.

Before starting the survey, the instruments have to be calibrated both as far as geometry and radiometry are concerned.

The geometric calibration is performed by using a special control plate which is provided with the instruments (Fig. 2). The scope of this phase is to refine the relative orientation of the two digital cameras in order to avoid small movements of the mechanical components that occur during the transportation or due to the change in environmental conditions and so on. The geometric calibration fixed the base of the photogrammetric system and so the scale of the survey.

The radiometric calibration aims at setting the photographic parameters for the two camera lenses and the intensity of the laser tracker in order to speed-up the measurement process. The radiometric calibration is performed by acquiring some parts of the object with a common texture. If the object has different colours and/or illumination conditions this procedure has to be repeated before starting the acquisition on the portion of interest.

Before starting the 3D survey, the reference system has to be fixed. Several reflective targets (small 6 mm diameter circles) are fixed to the object using an irregular mesh with sides that can reach up to 10 cm.

Using the two stereoscopic cameras and

Fig. 1 – Handyscan 3D: the acquisition unit (980 g, 160 x 260 x 210 mm, ISO accuracy: 20 m + 0.2L/1000).

Fig. 2a-b – The geometric and radiometric calibrations of the Handiscan.
the eight spots around them, the reflective targets are surveyed and placed in a unique reference system which is now fixed on the object. If the object cannot be marked directly, it is possible to build-up a control network using other solutions.

In addition the operator defines the volume in which the object (or a portion of it) is contained. This volume is subdivided into voxels. It is possible to choose among three different resolution levels: low, medium or high. For the low resolution, the surveyed box is divided into 2.1 Mega voxels; the medium into 16.8 Mega voxels and the high into 134 Mega voxels. There is therefore a ratio of 1 to 8 between the medium and low resolution voxel numbers and the same between the high and medium resolution voxel numbers. The dimension of the voxels (the resolution of the survey) depends on the dimension of the acquisition volume. If high resolution is required, the object has to be split into different scans which are oriented in the reference system of the acquisition thanks to the previously acquired reflective targets. The accuracy is always the highest accuracy of the instruments (Fig. 6 comments).

Finally, the acquisition can be started: the operator has to check the distance between the acquisition unit and the object (red and green leds on the top make this possible in a practical way) and, by looking at the laptop, control the completeness of the acquisition that is displayed in real time as an STL format model.

During the survey, the stereoscopic cameras perform the absolute orientation using the previously acquired reflective targets. At the end of the acquisition, the recorded data are: the target positions, directly acquired points, STL format 3D model.

2.2 Data processing

The handling of the data can be performed using one of the well known software packages (e.g. RapidForm, 3Dmax., etc.). CREAFORM has a special link with Geomagic Studio which can directly manages the data from the HANDYSCAN3D system. The accuracy of the acquired data, their flexible resolution and the real time check of the completeness of the acquisition phase are the best requirements for a quick and correct model approach.

Fig. 3-4 – Placing the reflective targets on the object.
3. The survey of the Rex Divi Augustae inscriptions

3.1 Reference system set-up

Many practical problems have been approached during the survey. First of all, the use of Handy Scan requires to access the object from a distance not higher than 1 m, so a scaffold has been adopted in order to allow the specialists to be as close as possible to the inscriptions.

By using the scaffold all the required targets have been placed (Fig. 4). Considering the dimensions of the inscriptions, each of them has been subdivided into small portion of about 1 m². Each portion overlaps the adjacent ones by a percentage of about 10% in all directions in order to allow the control of the accuracy and a correct mosaic of the single acquisitions.

Each portion is referred to a unique reference system defined by means of a control network (Fig. 5). The network has been surveyed by means of traditional topographic survey (total station) and by using the rigorous approach of redundant observations.
1645 measurements have been acquired: all the measurements have been adjusted by using the least square method. The following table summarizes the statistical results of the network.

<table>
<thead>
<tr>
<th>Measured angles</th>
<th>1302</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured distances</td>
<td>342</td>
</tr>
<tr>
<td>N. of vertices</td>
<td>446</td>
</tr>
<tr>
<td>m.s.e. in X and Y directions</td>
<td>0.002 m</td>
</tr>
<tr>
<td>m.s.e. in Z direction</td>
<td>0.001 m</td>
</tr>
</tbody>
</table>

After the adjustment the network has been connected to the previous reference system used in 1997 for the photogrammetric surveys (prof. Fangi) in order to refer all the measurements to a common frame.

The use of the same reference system allows a correct comparison of the surveys performed in different epochs and makes it possible to detect the modifications of the objects along a period and to complete old survey campaigns.

The use of a unique reference system is today a common rule in metric survey but not always realized or maintained during the time. The lost of the reference system enables the possibility of integrate previous surveys and also the control of them especially when new techniques are employed.

3.1 Data acquisition

The dimensions of the inscriptions required an accurate project considering the potentiality of the used instrument.

First of all it was necessary to make a scaffold in order to place the marker onto the surface (Fig. 6-7). The acquisition of the high resolution digital images was made by Kodak DCS Pro 14N 14 Mpixel digital camera (Fig. 8-10).
The acquired points have been processed by using a commercial software (Geomagic) and a scientific software developed by Politecnico di Torino (LSR2004) in order to build up a 3D model of the three inscriptions (Fig. 11).

All the gross errors and outliers have been eliminated and a correct registration of the single acquisitions has been performed by using an original approach developed by our Research Group. The overlap between each part of the acquired surfaces is of about 10%; Each portion contains some known points (approximately 20 points for each portion).

By using the ICP approach (a well known method used in many commercial software to register point sets) a first registration of the portions has been performed. Considering the small overlap many systematic errors arise so a least square compensation of all the portions of a single objects has been computed using all the information coming from existing known points on the surface.

Finally all the digital images have been oriented in the same reference system of the 3D model by using the same known points of the control network described in the previous paragraphs.

3.3 Final products

The realistic 3D model of the three inscriptions has been produced by mapping the oriented images onto the 3D point model after a surface generation (TIN approach). This represents the most important output of this kind of survey technique and allows a complete and exhaustive analysis of the object by the specialists.

Actually, the big amount of the data can give some problems during the management of the data themselves and requires high performing PC able to manage this big amount of information (3D points and high resolution images).

In order to avoid this kind of problems, our Research Group developed in the past a new concept: the solid image. The solid image in nothing else than a digital image defined by using the RGB approach. Each level contains the value of the Red, Green and Blue which define the colour of each
High resolution 3D survey of the inscriptions

Fig. 12 – 3D realistic model.

Fig. 13 – The solid image concept.
pixel of the image. If one adds a fourth level containing the distance between the centre of the projection which generates the image and the true point represented by each pixel it is possible, by using a photogrammetric approach derive the 3D coordinates of each pixel.

The solid image allow to interpret in a correct geometric view a traditional images where, as it is well known, it is not possible to make any measurement.

The amount of the data to be managed for each solid image is very poor so standard PC can be used in order to obtain the same information than from the 3D realistic model.

The software useful to explore and inquire the solid image has been developed by our Research Group and can be used free of charge.

4. Conclusions and future developments

The new generation of high resolution scanning systems can be profitable used also in Cultural Heritage documentation.

They allow to skip all the problems about the stability of the reference system. The time needed to perform the survey (in our case about 48 hours for a surveyed surface of about $40 \text{ m}^2$) is not so big if we consider the final results in terms of completeness and accuracy (approx. 0.2 mm).

The image acquisition and orientation is now still a problem because they are not phases integrated in the 3D point acquisition process but we think that in the future the technology development will allow this kind of integration as happened in the field of scanning system of lower accuracy.

As far as the practical use of this kind of surveys for the monitoring of the degradation of old stones we propose to repeat the survey of some sample of the surfaces in order to control the degradations due to atmospheric effects in a statistical approach.

Acknowledgement

Paula Botteri for her enthusiasm and scientific and practical collaboration during all the period: she had to teach to “hard” engineers the true meaning of the objects they are face and she had to solve all the problems those engineers were not be able to afford. Her humanity and friendship will remain in our experience as the best collaboration in the important field of Cultural Heritage documentation and preservation.

Beatrice Pinna Caboni for her friendship and care and Gabriele Fangi for all the information related to the previous surveys and for the invitation participate to this interesting work.

See also Tables O-T.