PFC

Gestión del Patrimonio Cultural
Nuevas Tecnologías

Year of realization:	November 2007
Method/Equipment	Archaeological area on surface/ Laser scanner end classical topography

Subject: Topographic survey of a funeral site of medieval time by means of laser scanner 3D in the scale 1:200 and of a archological area of Conimbriga in the scale 1:500

CONTENTS

1. INTRODUCTION

1.1. Objectives

This project had for objective the application of various techniques during the acquisition of data for the realization of a topographic sunrise of an archaeological deposit to Conimbriga (Coimbra, Portugal), while elaborating the cartography stemming from the totality of this archeological site in the scale 1:500 and of the paleochristian basilica in the scale 1:200.
For it we realized measures with the total station TCR-705 and we applied the methods of classic topography, with equipments such as the GPS and what it can bring, and with devices such as the scanner laser 3D GX-200 of Trimble.

1.2. Location

The site of Conimbriga is in the district of Coimbra, in Portugal, more exactly in the region of Condeixa-a-Nova.

Figure 1: Location of Coimbra

Figure 2: Location of Condeixa-a-Nova

Figure 3: aerian photography of the site

1.3. Historic summary

Conímbriga was one quoted classic art steelyard situated on the military way leaving Olisipo (Lisboa) to Bracara Augusta (Braga), within Conventus Scallabitanus, Roman province of Lusitania. Numerous studies suggest that her origin comes from a Celtic castle of the tribe of los Conios. What is sure on it subject is that it was occupied by the Roman during the campaigns of Décimo Junio Bruto, in the year 139 before J.C.

During the administration of the emperor Cesar Augusto (I° siècle), the city underwent of numerous transformations as for example the construction of public terms and that of the Forum.

Figure 4: Reconstruction of the Foro

Figure 5: Terms

In the year 468 los Suevos attack the city and from there, Conímbriga begins to be abandoned and loses her status of episcopal seat and was replaced by Aeminium (Coimbra), this one possessed better conditions of defences and survivance. The inhabitants who stayed then based Condeixa-a-Nova, more in the North of the site of Conimbriga. After the barbaric invasions the life pursues its course in the city quite as seem to confirm it an inscription of the VIth century, witness of the era wisigoth and Arabic.

The first excavations began in 1899 thanks to a subsidy granted by the queen of Portugal, Amelie of Orléans, but it is from 1955 when the rhythm of the investigations became intensified.

2. GPS NETWORK

The first realized stage was the check of the local area network of the field to endow the cartography of appropriate local direction and coordinates. The observations were realized with equipments GPS. We obtained a number of signposted borders which allowed to check the quality of the network so create specially for the archeological site. For it we compared the direction and coordinates of the points which configured the network with those obtained during the campaigns of measurement.

2.1. Description of local network existing in the field

The network was established by a pupil of the university of Hamburg, Marcus Knorr, and its work constituted his Project of the End of Career in October of 1990. The name given to the network was Knorr. The planning of the network was brought to a successful conclusion in the grounds as an independent local area network, because the calculations were so much made on the planimetric plan that on that of the altimetry. In this way, this one contains only errors due to instruments and to employed methods.

We used some mortar of cement as base and an iron helm in its inside. The extremity will represent the geodesic point. The positions of points were or in the top of the wall or near the archaeological field to prevent damages in the following excavations.

For the planning of the network the condition to guarantee a general precision of 10 cms was imposed, value which was considered throughout the works. According to the author of the network, the experience established which all the points determined from the others contains an error three times as big as that obtained according to the references. According to this principle, we had to guarantee a precision of 10/3 X, Z, that is, 3 cms in that case there points of the basic network.

By observing the graphic document in which we place all the marks inside the site, we decided to select five marks, four of them form a polygon the perimeter of which represents almost totality of the site and the fifth inside.

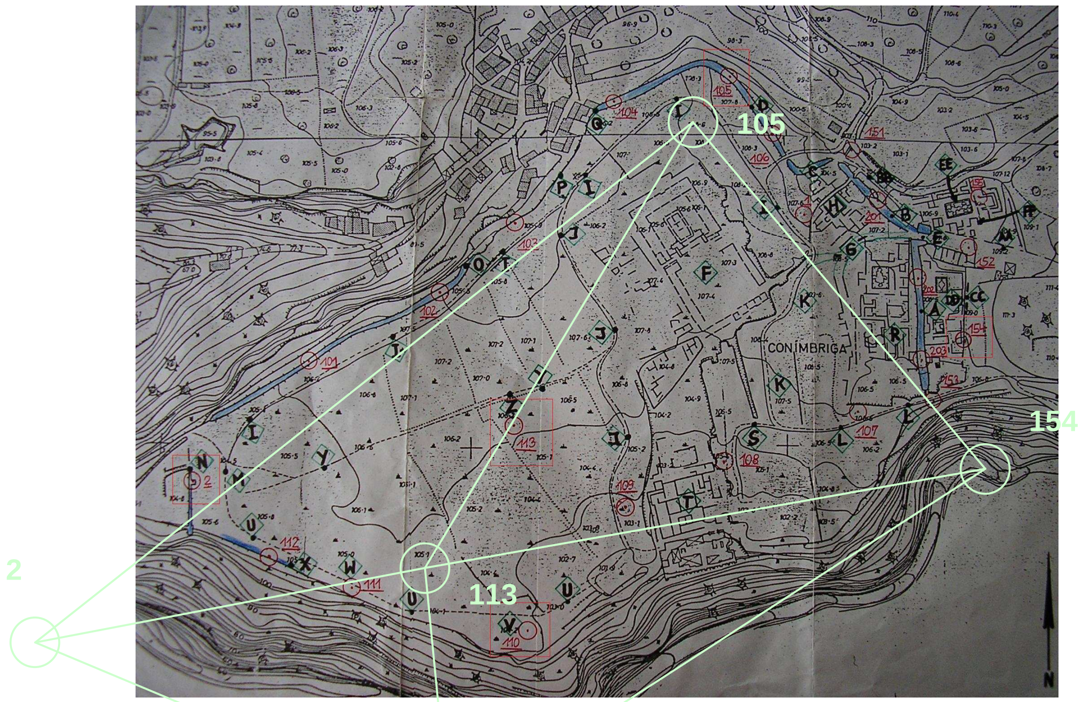

Figure. 6: network's drawing

The observation was realized with three receivers. To improve it at most and arrive at the biggest possible redundancy, we parked the device on three marks of the network. We left the necessary time weather approximately 10mn devices in simultaneous observation. Once the ended time we interrupt the observation of one or two of them, we register the observations and we move the equipment on the following mark to begin again. Once the convenient ended time we take place on the mark following with the device which was not moved yet and we park to observe again, and so successively until the process is complete.
During the use of three receivers in simultaneous observation, in a first observation we have points intersected by two sets of increments by direction and coordinates (by two basic lines). By moving the one and by parking on the following one those who remain fixed become intersected, so we measured their incréments of direction and coordinates by four different progresses.

We observed the network in agreement with the following planning of the sessions:

	GPS 1	**GPS 2**	**GPS 3**
Session 1	110	105	154
Session 2	2	105	113
Session 3	2	110	113
Session 4	2	154	113

Because GPS networks have a certain redundancy in the measures, these must be adjusted to make the differences of direction and coordinates coincide. This adjustment of the basic lines of networks GPS is made by realizing the method the slightest square the equations of observations of which spell according to the moderate incréments of direction and coordinates and its residues.

Then we realized the transformation of direction and coordinates. We used the transformation of a single stage, what consists of a transformation of resemblance bidimensionnelle for the planimetry and an interpolation for the altimetry. This type of transformation is the unique allowed with a system of flat direction and coordinates.

2.2. Network of support of the basilic

Once makes the control of the local area network of the site and when we are assured by his quality, we proceeded to the realization of the observation and to the calculation of a network which will be the cover for the sunrise following by the basilica with the methodology laser to scan.

The objective of the creation of this network was to obtain near the basilica a series of points with direction and coordinates known in the local system which had to serve as base for the observations and the calculation of the network of reference points for the sunrise with the laser to scan.

We decided to place three pickets, situated near the corners of the basilica, so that the possible intersections are in all the directions (we foresee a station in the corner the closest to the wall because of the impossibility to obtain a long-lasting realization in the time. The place was found on the road where pass the visitors of the archeological site and for it it was subject to possible modifications.. The distribution of stations was the following one:

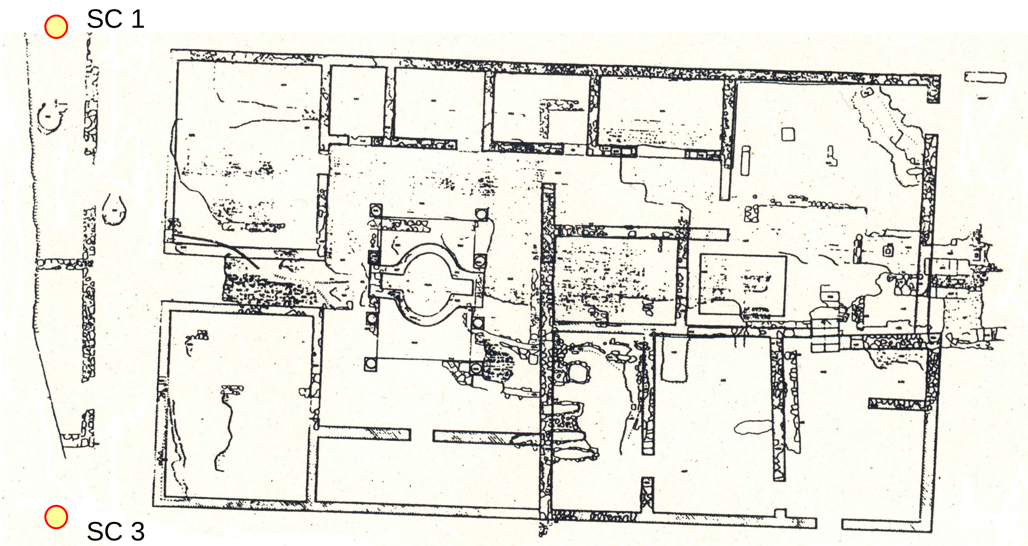

Figure 7: Drawing of the pickets's location

We realized the location with the relative method in all the bases. A receiver is situated on the point 113 and the others were placed on the points which form the network of support. Every point was observed during a minimum time of 10 minutes.

3. SURVEY

Once verified the quality of the network, we realized the sunrise of all the site (approximately 12 hectares) by means of the methods GPS kinematic real-time (RTK). The goal was to place in a topographic context the basilica. For this type of topographic sunrise we opted for the use of the GPS with the method RTK (raised real time). The GPS system brings of the speed to the sunrise by tacheometer, although it presents limits to the level de ce qui entoure les objets trop hauts du fait de l'obstruction des signaux des satellites.

We leave the broadcasting device in the point 113 by having introducing into the receiver the adjusted direction and coordinates calculated by the network. The mobile devices had risen on two metre ranging-poles and we proceeded to the sunrise of the totality of the archeological site about 12 hectares.

The set was taken with both devices in observation at the same time. We acquired points in large number in the zones of irregular ground that the others which are less damaged and with a constant slope, to arrive so at a correct definition of the ground. There were some difficulties at the time of taking points too close to the wall of the central zone of the site because the height makes lose the signal**.**

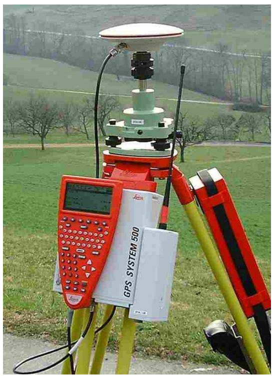

Figure 8: Fix receptor GPS

4. CLASSICAL TOPOGRAPHY

For the sunrise in the laser scanner we have create a network of reference points for georeference the cloud of points acquired since the station scan. We endowed with direction and coordinates this network thanks to the total station by using the method of mixed intersections with angles and outstrip. Thanks to the direction and coordinates of these reference points we were able to transform the cloud of points of the instrumental system of reference to the system of local direction and coordinates of the site. In this way we manage to unite the various clouds of points stemming from partial acquisitions of the basilica and we create a global three-dimensional model with which one little to work afterward.

We implanted a series of nails situated in the zone of excavation which had direction and coordinates in the system of local direction and coordinates of the site to obtain the defects of orientations in the stakes in station of pickets. Secondly and while the scanner sweeps the indicated sectors, we observed with prisms reflectors situated in places where we had placed the necessary spheres for the meeting of the various acquisitions. As the center of the sphere and the optical center of the prism did not coincide, we proceeded to the calculation of the difference of height which we had to apply and add during the data processing.

$$m_{prisma} = 8\ cm$$

$$m_{esfera} = 5.5\ cm$$

Figure 9: Spheres used for the georeferenciation

Consequently we applied a 3.5 centimeter difference. We aimed at 14 nails to have a better redundancy in the data and to be able to eliminate the erroneous observations because certain nails could have been moved by their original position.

When the surveys were made, we proceed to the calculation of the direction and coordinates of the centers of spheres by means of the adjustment by lesser squares where we bring in the equations of direction and distance. The redundancy was very big because there were 8 points to determine (24 unknowns) and we could configure a total of 72 standardized equations (24 of the direction, 24 of the distance and 24 of made uneven).

5. SURVEY WITH LASER SCANNER

For the sunrise of the basilica the presence of the scanner in various positions was necessary, it was so a question it could cover the totality of the object to be scanned. The choice of these places was complicated because of the morphology of the basilica, because the rests of walls got(touched) the neighboring zones. The density of the cloud of points was established for a point both centimeters; in this way we assured one sufficient precision for the realization of the cartography in the scale 1:200, which for a distance considerable minimum would be 4 centimeters, the double of the precision given for the resolution of the scanner.

Figure 10: data acquisition in the basilica with laser scanner

All in all 6 scans were realized, with the following distribution:

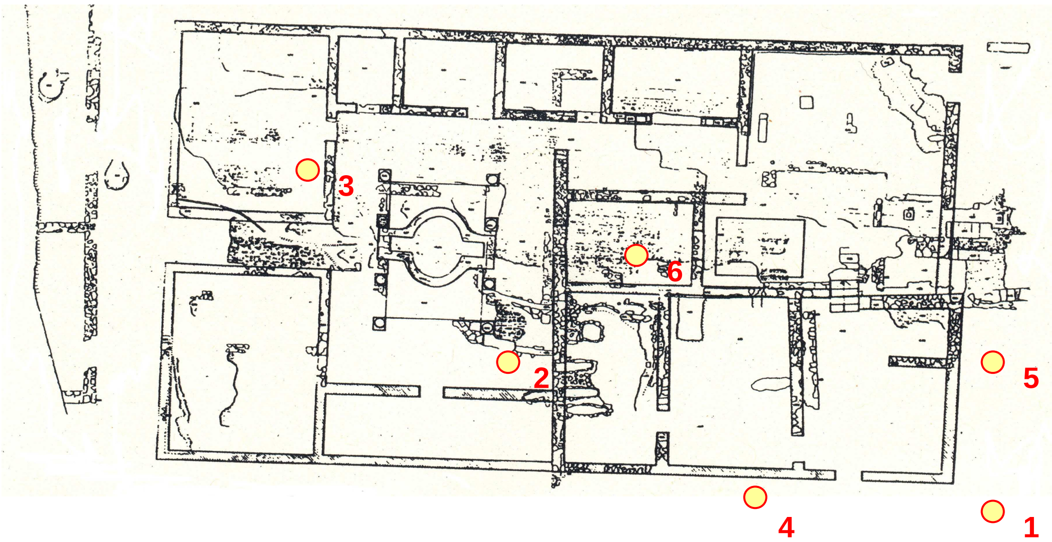

Figure 11: Acquisition drawing with laser scanner

For every point of view we proceeded to the car park and to the leveling of the device laser to scan. With the program appropriate for that of the equipment (Pointscape) we configured the parameters of the scanner for every acquisition (angular zone of horizontal and vertical scanning, resolution and number of points to be taken). The observations were realized in the following order:

1) Scanning of 360 horizontal with a low resolution and an acquisition of photos for a possible extraction of textures for the three-dimensional reconstruction.
2) Scan of each of the spheres placed for the georeferenciation.
3) Selection of the angular opening for the information looked for with a complete resolution.
4) Scan of the selection with the complete resolution.
5) Change of station in another point of view of the zone of study.

Then we obtained a simplification of the acquired points differentiated according to the point of view with various colors.

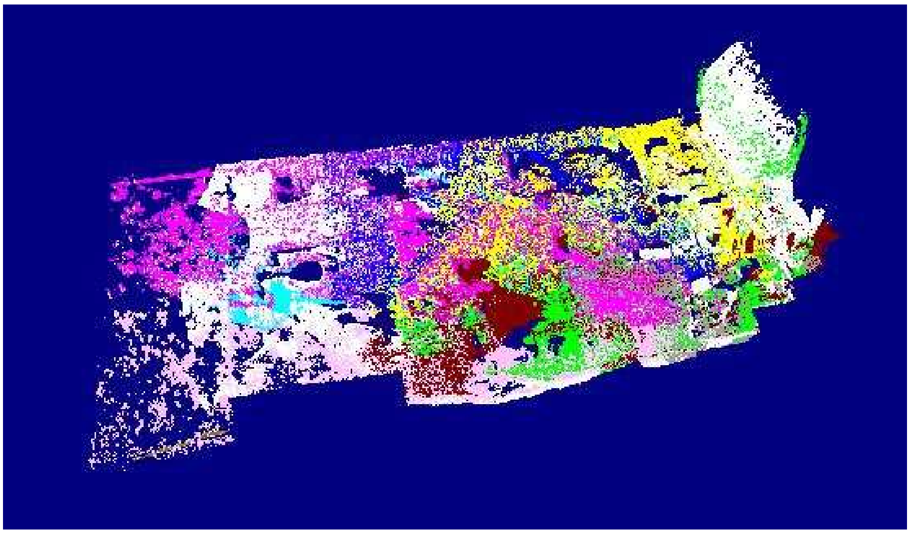

Figure 12: Cloud of points by stations

All in all we took more than 9 million points, what indicates the enormous capacity of this type of equipment.

The process of the data obtained by laser scanner was realized with the program of Trimble Realworks.

The scanned points are kept in a system of direction and coordinates relative to the instrument. The point origin of this system is the place where the laser beam coincides with the mirror. To hand them in a only global system for all the made acquisitions, we need to know the position and the orientation in the case of panels of the coming into play spheres. We call register of the scanner the fact to assign values of the new system of direction and coordinates to these objects. Spheres were endowed with direction and coordinates as we indicated it previously. For every cloud of scanned points we have of the definite the position of the center of all the reference marks in the system of the instrument. The program determines the position of each of the spheres of interactive shape.When we selected the zone of the cloud of points where is situated the sphere we analyze the position of the center of the sphere by selecting a number of points which form the outline of the sphere. The program of the device offers a quantitative information of the precision with which we determined points.

Once measure of the spheres complete, we endow with direction and coordinates calculated thanks to this measure by the classic method the station(resort) number 6. Then we contain the cloud of points of the acquisition made in 6 (already in local direction and coordinates of the site) with the cloud of points stemming from the station(resort) 5. Then the clouds of points of 5 and 6 with 4 and so successively. In this way we obtain a cloud of georeferenced points in local direction and coordinates of the site.

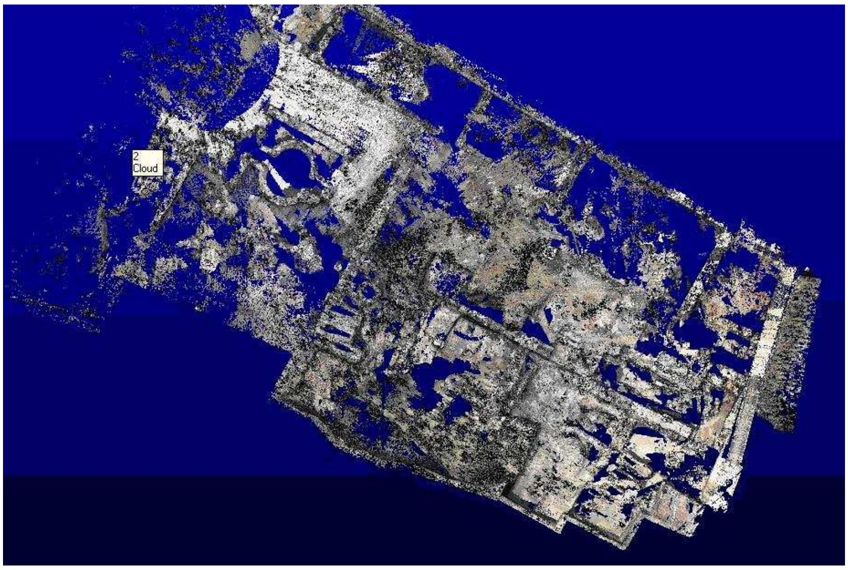

Figure 13: nuage de points de toutes les acquisitions réunies et géoréférencées

When all the clouds of points are in the same local system appropriate for the site we can model the object of the study. The Real Works program allows to model and to extract certain geometries, but space that requires of type of files makes impossible the export in a program CAD whatever it is for a posterior treatment. With this program we can show and turn the cloud of points to observe it under différentes perspectives.

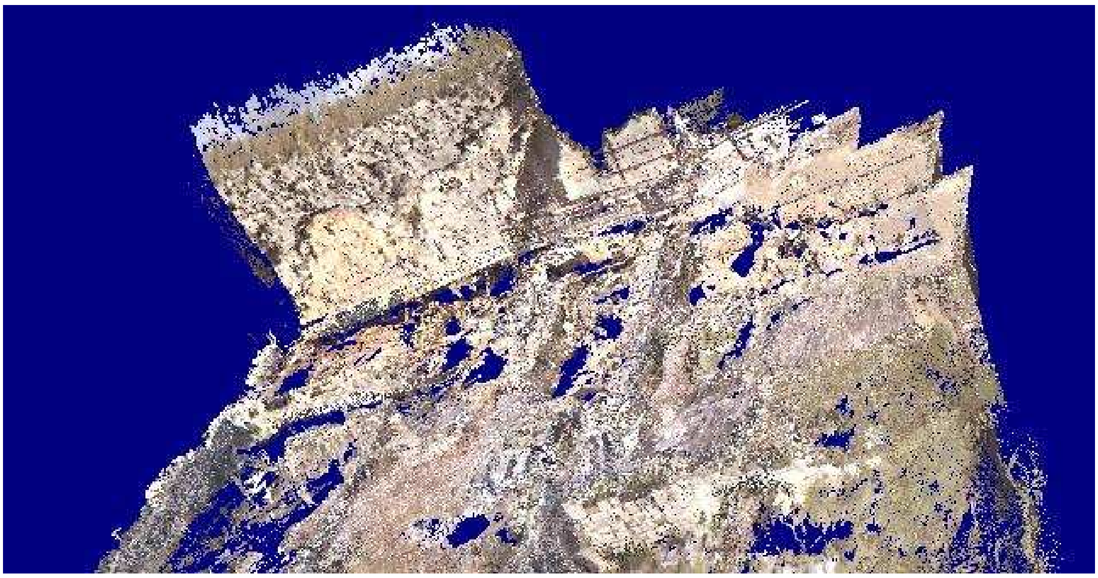

Figure 14: Perspective of the zone of the wall

For its treatment the cloud of points presents various problems among which important two. The first one of them is the existence of zones where were missing points of the fact that the other objects intervened between the laser beam and the zones of points. This problem was especially met in zones close to walls or in zone of the basilica where was a multitude of bushes of small height which hampered(bothered) the acquisition of points because they were got on the place of the deliberate object. The main work thus consisted in cleaning the cloud of points of these bushes. For it we followed the following process:

- Segmentation of the cloud of points in small zones to handle them more easily and to avoid eliminating points involuntarily..

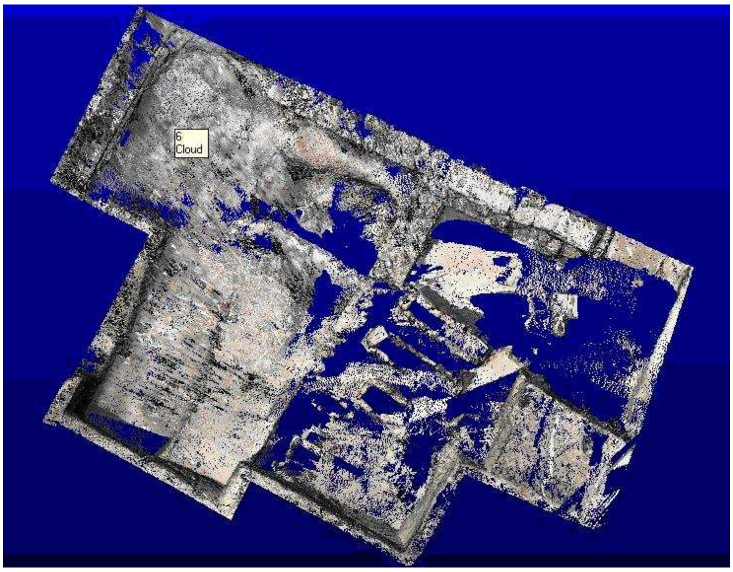

Figure 15: Segmentation of the zone of the excavations

- Purify the zone of bushes by removing the biggest quantity of possible points for the posterior treatment, as a triangulation for the generation of a digital model can be it.
- Combine again fragments with the totality of the cloud of points.
- Digitize the elements which will appear on the plan.

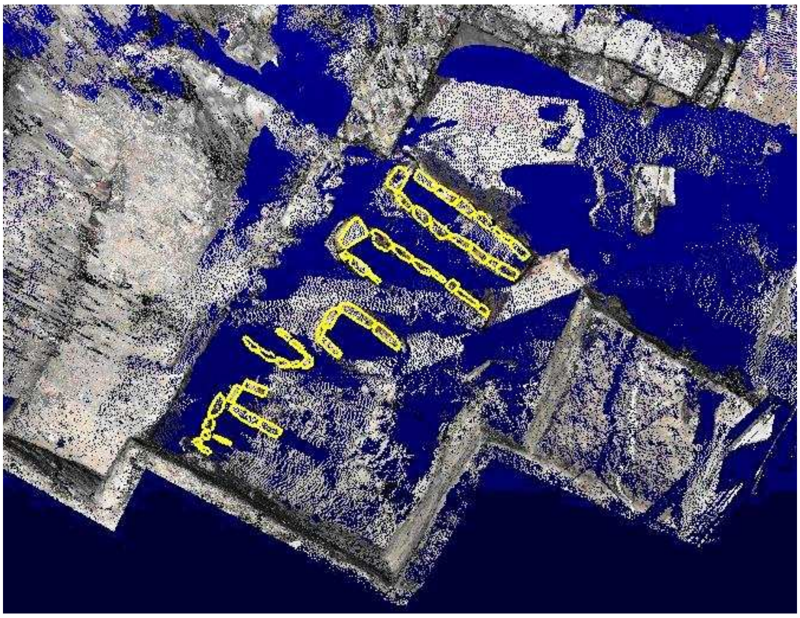

Figure 16: Digitalization of graves

When the cloud of points is cleaned and when elements are digitized, we export the data in files .dgn and .dxf to be able to realize the cartographic plan.

6. CARTOGRAPHIC DRAWING

The last phase of the project consists in obtaining a cartographic plan of the first level of the basilica.

For the edition of the basilica we took as source of data the cloud of points edited in the post process of the laser to scan. With this cloud we proceeded to a digitalization of walls, stones, graves which are in the basilica.

For this digitalization we used the cloud of points which thanks to its definition allows the differentiation of stones, while using the sketch realized by the archaeologists and the numerous photos of the zone.

The digitalization is made with the program Real Works, which has a tool which allows to draw the important lines which will then be exported in a .dxf file for the post treatment with programs CAD. The digitalization was realized in two dimensions because the final object is a cartographic plan of a single level.

We can also realize with the program of Real Works a plan with contour line. We thus obtained two plans with contour lines the one with an equidistance between curves of 10 cms and other one of the 20 cms. Once seen the result, and as we could deduct it in view of the complexity of the zone, the plan cannot be so accepted because contour lines are chaotic and because we do not appreciate clearly the altimétrie there.

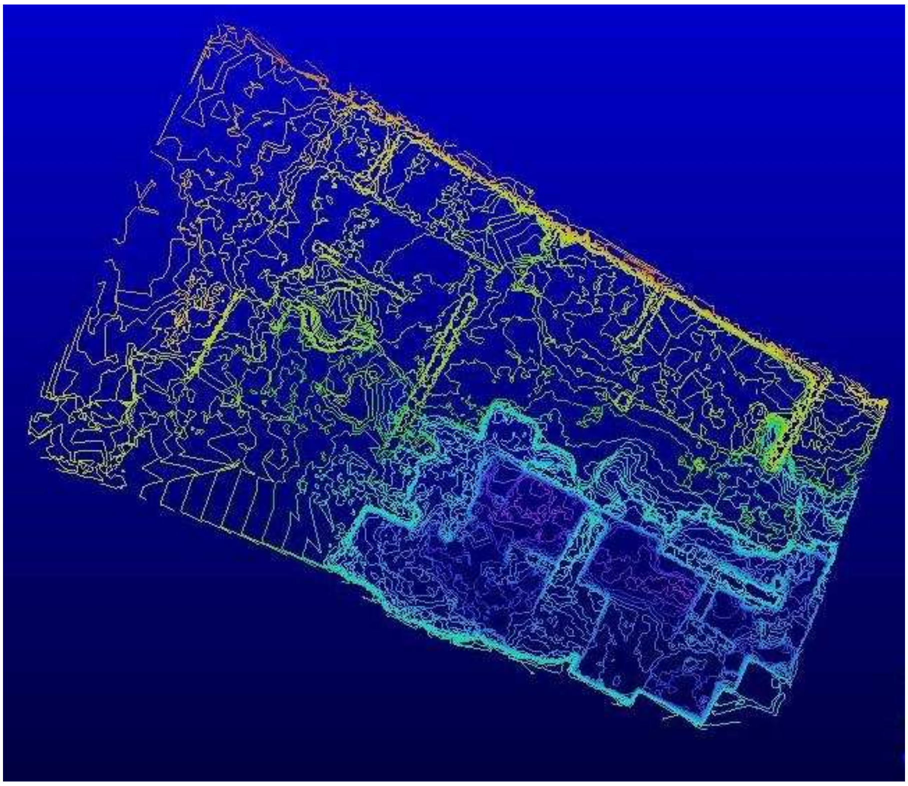

Figure 17: Equidistant curves of 10 centimeters

In front of this situation we decided to represent the altimétrie not with contour lines but with highly-rated points. Points are distributed on all the basilica, but also in the zones of walls to allow to appreciate the dimension of these. We also densified points in the delicate zones (with more relief and more details).

Figure 18: Highly-rated points

7. COST

The cost calculated for the realization of this project is described for each of the activities.

ACTIVITIES	COST
Preparatory phase	590
GPS	2860
Laser scanner	3983
Network calculation	312
Data processing of the scanner	1296
Cartographic edition	1990
Memory edition	2874
Movement	184
SUB-TOTAL	**14089**
Benefice + I.V.A.	5.574,52
COST TOTAL	**19,663,52 €**

8. CONCLUSIONS

The system laser to scan allows to spare time during the acquisition of data and makes possible certain works originally impracticable by the classic method. However, his usage pulls a big quantity of inconveniences, which in certain cases exceed the advantages. In particular:

- Profusion of data, what pulls the elimination of points and the obligation to work in a lower resolution as regards the cloud of points.
- Heavy files impossible to read for the most part of computers.
- The used programs are unique for each of the builders; it would be preferable to have exchangeable programs.
- The equipment is very fragile and it is necessary to take precautions during its manipulation on the ground; in our case we lost numerous working hours because of the overheating of the device. We thus disadvise to work with equipments laser to scan during too warm days.
- His usage for very irregular surfaces (as in the case of the paleochristian basilica) generate a cloud of points very difficult to treat.

Generally, the most mattering is that instrument laser to scan reduce the working time on the ground but pull a surplus of long and boring treatment. On the other hand devices laser to scan allow to model in 3D of objects and to recreate buildings, matter that we did not realize in this project but which would have been able to be made.

The tool that is the laser scanner has a big future for element of acquisition of data. This project served for a simple acquisition with new methods.

Acknowledgment

To the students Bruno Pérez Martín and Jesús Mª Garrido Sáenz de Tejada, and all the supervisors and students who made possible the project and this report.

ENCLOSE I. Identification sheets of the network's marks

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Reseña vértice red Knorr

NÚMERO: 154
NOMBRE: 154
DISTRITO: Coimbra
FREGUESIA: Condeixa-a-Velha

FECHA DE REALIZACIÓN:
Agosto 2007

TIPO DE SEÑAL: Clavo

COORD. GEODÉSICAS WGS84
LONGITUD: 8° 29' 34.53879" W
LATITUD: 40° 05' 55.90272" N
H.ELIPSOIDAL: 162.719 m

ACCESO

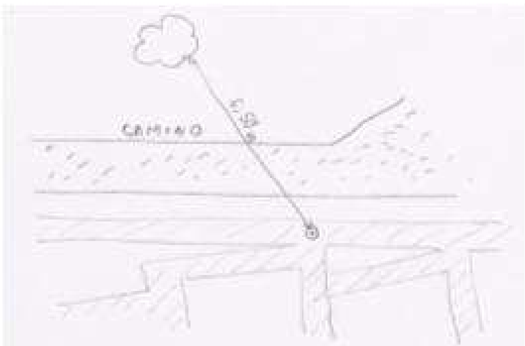
En el exterior de la muralla antigua, junto al camino que va paralelo a la muralla y a los setos.

COORD. LOCALES KNORR
E: 1074,810 m
N: 888,077 m
H: 49.782 m

PLANO DE SITUACIÓN

FOTOGRAFÍA

CROQUIS



ENCLOSE II. PLAN

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General site's plan.