Mapping our Heritage

M. Farjas
E. U. I. T. Topográfica,
Universidad Politécnica de Madrid (UPM), Spain

M. Alonso
E.T.S. Arquitectura ,
Universidad Politécnica de Madrid (UPM), Spain

CARPA Research Team
Universidad Politécnica de Madrid (UPM), Spain

SEE THE CD FOR THE EXTENDED VERSION AND THE FIGURES   ABSTRACT

In this paper we present the results obtained during the search for cartographic methods, which can assist in the interpretation and dissemination of knowledge regarding Archaeology and our Heritage. Basing their research on techniques developed specifically for geodesic and cartographic engineering and architecture, the Polytechnic University of Madrid's Research Team LAR, are assessing how new tools applicable to their specialist can be used in an innovative way to capture and process information in the fields of archaeology and heritage.

To investigate different methods of portraying monumental edifices, we made use of new data capturing equipment in the Monastery of El Escorial, Spain for which traditional photogrammetrical methodologies were compared, taking advantage of the least square adjustment capability provided by the independent grids.

To investigate procedures for the treatment of cartographic data a study was undertaken, to develop a thematic cartography that combines the scientific results with a graphical presentation. The site used for this exercise was the archaeological site at Tuqueibah, in the Emirate of Sharjah, UAE.

All of the work referred to above strives to unite the disciplines of engineering and archaeology, using case studies to demonstrate the enormous potential that such interdisciplinary co-operation can offer.

Introduction

The research team CARPA (Cartography in Heritage and Archaeology) of the Universidad Politécnica de Madrid (UPM) was established in 1996 to explore new ways in which the cartographical sciences and archaeology could co-operate. The investigation adopts a dual approach. On the one hand we attempt to provide the archaeologists with basic cartography at different scales. On the other hand an attempt is made to provide cartographical documents which assist in exhibiting the information in paper format for static displays, or in digital format in the case of dynamic displays. In both cases our aim is to ensure that the topography, geodesy and related sciences serve to enhance the display material, and in this way expand the scope for application of our specialism.

We will present the results from three of our projects:

- Tuqueibah (U.A.E.)
- Escorial (Spain)
- Cibeles (Spain)

Cartography in Archaeology: Tuqueibah

The overall objective of our research is to determine ways in which new engineering technology, and especially cartography, can be applied to Archaeology, to study processes and analyse proposals for the optimisation of archaeological data capture, treatment and display. The area used for the study is the whole of the Emirate of Sharjah (Fig.1,2).

In the Emirate are founds the archaeological sites of Tell Abraq, Al Manakh, Muweileh, Al Hamriyah, Mleiha, Jebel Al Emaileh, Jebel Falla, Jebel Al Buhais, Al Tuqueibah, Al Madam, Wadi Al Hilu, Wadi Shi, Khor Kalba y Khor Fakkan. One archeological team has been assigned to each of these excavation sites. This case study deals written the archaeological remains of Tuqueibah. This archaeological site has a total area of more than 50 hectares, in which the urban remains of the first settlement in the Emirate, dating back about 3000 BC. The archaeological team responsible for this excavation belongs to the Universidad Autónoma of Madrid (Fig.3).

The site was mapped at a scale of 1:1,000, covering the full 50 hectares of the archaeological area. The limited time available to collect field data, as well not being able to make use of aerial photogrammetry, we decided to make use of static GPS methods to quickly establish the basic grid and the RTK for the site. The equipment used and resulting grid areas follows: (Fig.4,5)

More than 20,000 points were read, and processing. This large amount of data involved detailed hand calculations to accurately reproduce the smooth curvatures of the dunes. Special care was needed in representing the vegetation, as this is an indicator of the stability of the dune over time, and a key indicator of orientation. This work was different to what we were used to in mapping more familiar shapes and materials in our own country, and it was essential not to miss any paints. (Fig.6)

The results obtained from the cartographical analysis at the Tuqueibah site encouraged us to sep new methods to improve the final image. The mapping contained all the necessary detail and satisfied the required tolerances but the results was not clear to the end-user. We projected images over the bakkground and manipulated relief detail using perspective views, colour and shading was enhanced using Adobe Photoshop. A range of colours was developed and a coloured version produced, and the resulting image to a process of Gaussian methods and filtering. The image obtained was as follows (Fig.7).

The image was superimposed an the highlighting the relief and facilitating interpretation (Fig.8,9).

CARTOGRAPHY IN HERITAGE: EL ESCORIAL

The purpose of this exercise was to obtain a detailed mapping of the Basilica dome of the Monasterio de El Escorial in order to analyse the geometry. We carried out the mapping using topographical techniques that used one total-station without reflective prisms. Before undertaking this exercise the precise dimensions of the dome were not known. Only the lantern had been surveyed previously for the reconstruction of the needle in 1948.

We used a scale of 1:200 for the mapping, which is adequate for this type of work. Because the interior was an enclosed space and at a significant height above ground, the fundamental problem was to obtain coordinates for inaccessible points (Fig.10).

The equipment used was a Leica TCR305 survey station, an loan from Leica for this project. This equipment allowed us to measure points at a distance without a prism reflector, making use of a visible laser (LR). It also has an infrared distance meter for measuring with a prism (IR). In measuring distances it has an accuracy of 3mm + 3 ppm. The technical specifications for the equipment states that the range is dependant the same extent on the observed surface colour and surrounding light. The best results being obtained with white surfaces and in little background lighting.

From the points studied, 3 were chosen as survey stations for the mapping of the dome interior. The first of these was situated beneath the centre of the dome on the basilica floor, the second in the chorus left below the midday organ tribune and the third at the access to the cornice of the dome, 45 m above the basilica floor (Fig.11,12).

Our readings were taken from points situated at a distance of about 58 m fro points on a spherical surface, the angle of incidence of the laser on the surface being roughly orthogonal and therefore most favourable. We were aware that these readings were being taken at the practical limit for this station. The remaining points on the dome, being closer to the station, were measured without difficulty.

To carry out the mapping of the dome exterior, we positioned ourselves in the middle of the basilica bell towers, below the arches opposite the dome. From these two points we were able to view a little more than half of the dome exterior. We decided to base our work on readings from common points, and use Helmert 3D transformation techniques (Fig.13).

The first station we set up in the south tower, the clock tower. We started by taking 5 points which were used as a link to the second station on the north tower. We made sketches based on these readings in CD and CI. After that we attempted to define the cornice of the square dome base, for which 3 vertices were visible. We were able to measure the two closest vertices without problem, but not so with the furthest one. The distance was less than for previous readings but the complications stemmed form the fait that the view angle was acute. We guessed, and later continued, the importance of the angle of incidence on the suitability of the station.

The readings of the sternal surface of the dome from the clock tower hended to be complemented by corresponding readings from the north tower. We decided to take theses readings at dusle, with less light, as recommended by the manufacturer, to check whether under these conditions we would get better readings from the station which would allow us to obtain readings for the uppermost points on the dome (Fig.14).

Based on the data obtained in this way we were able to map the inside of the dome. The readings taken on the external surface had provide sufficient data on more than half of the dome. On the upper part, due to the acuteness of the view angle with respect to the surface, the laser station could not read. We could have used either bisection from the two towers or reach the surface of the dome armed with prisms. We decided on the later of the two options (Fig.15).

On this occasion we made use of a prism. We sere able to count on the help of Beatriz Mateios and David Dominguez, two E.U.I.T. Survey students and member of GEMAT, who climbed up the external face of the dome and fixed two safety cables around the perimeter. Using safety harnesses, secured to the cables and the lantern pedestal, they descended the external surface of the dome carrying mini-prisms. We took the equipment in non-prism mode, the laser distance meter. In this way we took co-ordinates for the missing points.

The time taken to obtain the readings was 7 working days, based on half days. The effective working time was 28 hours. We spent 19 hours on the inside of the dome where we took 3,250 points. The external surface required 9 hours to take 1,250 readings. After taking readings, as described above, we had the coordinates for 4,500 points on the dome. They were grouped according to survey station and in each case referenced to a local system (Fig.16).

The first step was to transform the data so that all the points for the external surface of the dome were referenced to a single co-ordinate system, and all those of the interior to another. After referencing all the points for the interior to a single co-ordinate system, we began to analyse the dome shape. The number of points strictly necessary to determine the centres

and radii of the two spheres is 6. We had readings of 154 points. For each of the points we developed an equation, giving us a system with 154 equations and six unknowns.

To solve the equations we started with approximate values for the sphere parameters. The results were used to adjust the coordinates for the centres and radii of the spheres. An iterative process was used until the variations in the coordinates for the centres and spheres parameters was within acceptable limits. The calculations were carried out using a computer program that we developed for this purpose.

The following step was to rotate all the points for the dome interior about its own axis to locate them as a single vertical plane, with the help of an analysis program developed for this purpose. The ASCII file, with all the rotated coordinates, was converted into DXF format for use with AutoCad. In this way we obtained a point representation of the different dome meridian sections. We therefore had at our disposal the plan layouts and meridian sections handed to generate the dome. In other words we had the necessary data to plot the interior of the dome (Fig.17).

We followed the same procedure for the exterior of the dome as for the interior. The first step was to refer the points, taken from the 3 survey stations, to a single system of coordinates. We carried out a Helmert 3D transformation and calculated the parameters from common points, making least square adjustments (Fig.18,19).

Moreover, we imposed an assumption that the axis of the dome was over the centre of the enclosing circumference formed by the leutern butresses, for which we had coordinates for 8 points, the centre of the circumference coinciding with edge of the cornise at the base, for which we had coordinates of 15 points, and the centre of the circumference of the cylindrical from around the balustrade, for which we had coordinates of at least fifteen points.

For this we obtained a set of 80 equations and 7 unknowns, which we solved using least squares adjustments. The process was similar to that used for the dome interior. The calculations were carried out using a computer program developed for the purpose.

Having fixed the external dome axis, we rotated the points to locate them as the same vertical plane. We then converted the ASCII file with the rotated coordinates into .dxf format for use with AutoCad, and obtained layouts for the different meridian sections of the dome exterior. On the other hand, we also checked that the data for the principal elements of the radial and plan layouts for the dome interior and exterior agreed, these elements being the widten of ledges distances between them and windows opening. Having done this we had the data necessary to plot the dome exterior, the radial and plane layout and meridian sections.

One the internal and external dome surfaces were drawn, we had to related the one to he other to complete the section. The first thing to make the centrelines coincide, which we did graphically with AutoCad. Then we had to locate the forms in their correct position relative to each other on the common axis. We calculated the correct displacement using differences between levels of the seven horizontal and the horizontal drum corresponding to the window bulltresses, which enerved their location at the same level, resulting in a standard deviation of 8.6 mm (Fig.20).

The mapping of the dome described above, was done using two point scatters: one for the exterior and one for the interior; points which we rotated to locate them in a meridian plane. It was necessary to translate these rows of points into line drawings. At the end of the process to define the dome section, we had perfectly identified the external and internal location of each and all of the points (Fig.21,22,23).

CARTOGRAPHY IN FUTURE: CIBELES

The manufacturer Leica Geosystem offered us to use a Cyrax 2500 instrument to test its data acquisitions capacity. We chose the Plaza Cibeles in Madrid as our site (Fig.24).

This instrument has a laser scanner for topographical, engineering and construction applications. Points can be surveyed to an accuracy of within ± 4 mm and angles within ± 60 micro-radians. Its capacity for data capture reaches 1,000 points per second, achieving an internal accuracy between points of 1,2 mm (Fig.25,26).

We carried out a data gathering test on the Cibeles statue. The team handed only fifteen minutes to read the scatter of points (Fig.27).

Having seen the way in which the data gathering was achieved and the capacity of this new instrument, we were challenged by the question: What benefit does this new instrument being to Archaeological and Heritage site? In our experience the Leica TC 305 instrument (used in direct mode without prisms) allowed us to work with discrete points interconnected by means of adjusting by quadratic minimus. The Cyrax instrument allowed us to go further along this lines, but now with almost continuous sequence of points. We found the challenge of analysing and experiencing two achieve results using two different methodologies.

CONCLUSION

In the 'Cartography in Archaeology and Heritage' Team we aim to apply new methods of information technology to archaeology. By recording the geometric relationship between data points, we try to assist in display. In this way, using digital models we enhance the reference site through three dimensional representation without prejudice to our ability to produce more conventional cartographic models. We are actually working towards introducing interactivity in spatial models, and at the same time integrate the progress of the excavation over time in the exhibit.

Once we started to work with archaeological teams we learned about the enormous difference between scientific rese-

arch and experimentation, and the use of technology as app-
lied to the Social Sciences. In engineering it is possible to
study, analyse and improve techniques and methods, but it is
not normal to apply them to a different field, and especially
to archaeology. It has been an experience in modelling and
prototypes that perhaps has allowed us to confirm that we are
learning archaeology and trying to discover ways to ensure
that cartography becomes an indispensable tool for archaeo-
logists.