RESEARCHING THE ORIENTATION OF MONUMENTS THE CHURCH OF THE GREAT METEORO MONASTERY

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ABSTRACT:

This work presents a method for the thorough research of the orientation of monuments, based on state-of-the-art geodetic and astronomical measurements. The proposed measurement and data reduction procedures are rigorous and lead to an accurate determination of the orientation of a monument. The term "orientation" collectively refers to: the astronomically oriented plan of the monument, the diagram of the perceptible horizon around the monument and the diagram of the apparent path of the Sun (or other star) as it rises above the horizon at characteristic dates. Then, the orientation is interpreted in terms of other, mostly cultural, information about the scope of the monument and in combination with its time of construction. In retrospect, therefore, the proposed method provides a new, independent way for the confirmation or the determination of the time of construction of the monument within a narrow chronological range.
An analysis of the method is given (including geodetic and astronomic observations and data reduction). The presentation of the method is best illustrated by the parallel discussion of a particular application, at the church of the Great Meteoro Monastery (within the "Meteora Monastic Community" in Central Greece). The performed measurements are described, accompanied by the corresponding geometrical diagrams. The orientation of the church is discussed in connection with the celebration date at the time of construction. Finally, useful conclusions are drawn about the geometrical characteristics of the monument and the meticulous attention shown by its constructors.
Application of the proposed method to other monuments is of great significance, since it will provide the geometric framework for a database of oriented monuments (in the form of a Geographical Information System), which will be very helpful for the study and preservation of our cultural heritage.

1. INTRODUCTION

The term "orientation" refers to the position and the direction (e.g. azimuth) of a monument at the site of its construction. Social or religious rules and traditions explain the relation between the orientation of the monument and the point of sunrise or the point where a star rises on a specific date. The solstices, the equinoxes or the date that the monuments celebrate have great significance for the builders. With regard to buildings, their placement, orientation, shape, material, the time of decoration, all give us important information about the cultural activities of a civilisation (Hoskin, 2001).
Archaeoastronomy has delivered insights about the orientation of prehistoric and historical tombs, temples and other buildings world wide. Several celestial bodies were used for the orientation of buildings in many cultures, the one mostly preferred among them being the Sun. This rule was already followed on Neolithic (Hoskin, 2001), Egyptian (Spence, 2000), Ancient Greek (Papathanasiou, 1994), Minoic and Mycenean (Liritzis, 2000) and Byzantine monuments (Pantazis, 2002).
Sunlight has been very important for Byzantine architecture. The natural light and the direction of illumination of the altar of a temple influence the choice of its orientation. Specifically, the orientation of Byzantine Orthodox Churches is determined by the illumination of the holy altar (Potamianos, 2000). The altar is of special importance in the Orthodox Church because the priest stays mostly there and performs the Holy ceremony, so its position is very well defined. All churches, as determined by tradition, should fulfill the proper illumination of the altar during the time of Eycharist. Generally speaking, according to Patrologia Greaca (4^{th} century AD) the recommended orientation for a church was set by the Holy Fathers to East – West (Migne, 1863).

2. METHODOLOGY

The method described in this work is based on the combination of the following procedures (Pantazis, 2002):
- The geometric determination of the main axis or of any other special direction of the monument, which is achieved by establishing an accurate geodetic network around the monument and creating its digital plan produced by accurate geodetic methods and instruments.
- The determination of the astronomical azimuth of a base of the network using observations of Polaris and transferring it, by geodetic methods, to the main axis or any other direction of the monument.
- The geometric determination of the boundary line (silhouette) of the perceptible horizon, as seen from a specific position of the monument, through geodetic measurements.
- The reconstruction of the apparent diurnal path of the Sun, or any other star, for characteristic dates (e.g. celebration day of the divinity to whom the temple is dedicated, solstice, equinox etc.) related to the time of construction.

Combination of the above data permits the determination and the interpretation of the orientation of a monument with the appropriate precision and reliability. There is also the possibility to date a monument according to its orientation with a narrow chronological range that depends mainly on the magnitude of the monument.

3. THE CHURCH OF THE GREAT METEORO MONASTERY

3. 1 Historical Information

The ″Meteora monastic community″ is situated in the area of Kalabaka in central Greece. It is the second biggest group of Byzantine monuments in Greece. Today only six monasteries are open, from the twenty that had been erected there in a period of three centuries (14^{th} to 17^{th}) (Sofianos, 1990). The Great Meteoro Monastery is the biggest one and is founded at the top of a rock, 588 m above mean sea level. The main church of the monastery is dedicated to the ″Transfiguration of our Lord″ which celebrates on August 6^{th} .
According to historical sources (Sofianos, 1990) the first small building, which was located at the place of the church's holy altar of today, was erected in 1360 by Saint Athanasius the Meteorist, who was the first inhabitant of this rock. After his death in 1388, the monk Ioasaf enlarged the building and erected the big church that exists today. This church is the biggest of the Meteora monastic community and has all the main characteristics of the late Byzantine architecture. The building is 25.8 m in length and 10 m in width. The frescos on the walls are dating from the 15^{th} and 16^{th} century.
At the South-East side of the church a little chapel was founded, dedicated to Saint John the Baptist and celebrating on January 7^{th} each year. According to (Theocharidis, P, 1979), this building was constructed simultaneously with the main church and, initially, it had some other use. Its length is 7.25m and width 5m. It was converted to a chapel after the completion of the big church.

3.2 Surveying the monument

A polygonometric network was established inside and outside the monument, in order to survey it for a scale of 1:50. This network consists of 12 points (figure 1) which are placed at appropriate positions in order to measure all the detail - points of the monument.

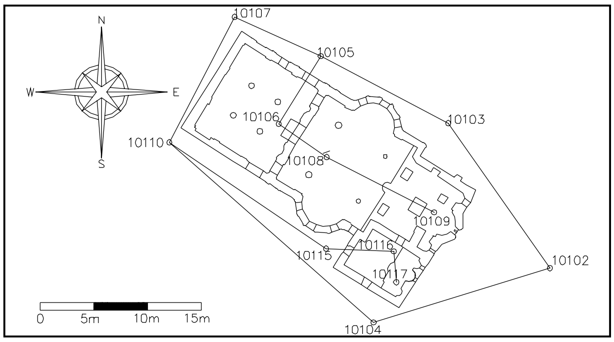

Figure 1. The polygonometric network.

The elements of the network were measured using the method of the ″three tripods″, in order to eliminate the errors of centring and levelling of the instruments. The measurements of the detail points of the church were made using an integrated Total Station that measures without retroreflector and has a laser pointer, in order to mark each point accurately. The X, Y coordinates of each point of the monument were determined with an accuracy of ± 3 mm in the GGRS 87 (Greek Geodetic Reference System 87).
The orthometric heights H of the points were also determined, with a little lower accuracy (about ± 1 cm). The digital drawing of the plan has all the details of the building. This plan is used for the determination of the main axis of the church, as well as for the extraction of any other geometric information of the monument. The final plan of the monument is presented in figure 2.

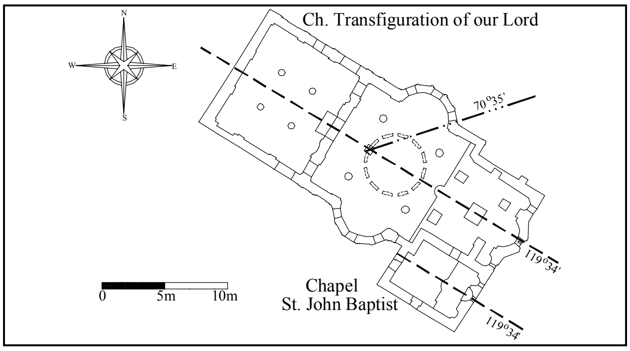

Figure 2. The plan of the two Churches

3.3 Determination of astronomical azimuth

The investigation of the orientation of a monument requires the determination of the astronomical azimuth of a characteristic direction of the monument. This direction may be the main axis of the monument or another special direction, e.g. the direction between the middle of the Holy altar and the middle of an altar's window or a specially placed line. For the determination of the astronomical azimuth of these lines, the plan of the monument needs to be astronomically oriented. This is achieved by determining the astronomical azimuth of one side of the polygonometric network, through astrogeodetic observations to the Pole Star (Polaris, aUMi). In this case, the observations consisted of 40 – 50 sightings of Polaris within 15 minutes, which enabled the determination of the azimuth with an accuracy of 0.5arcsec. This accuracy is much higher than the one achieved by classical methods, with poles and compass. The adjustment of the polygonometric network was done holding the azimuth of this direction constant to the value of the determined astronomical azimuth. Therefore, the plan of the monument was oriented with regard to the astronomical north. The astronomical observations were done using a new system which was especially developed for the purpose and consisting of a high accuracy digital total station, Leica TDM 5000, connected to a Trimble 4000DL GPS receiver, providing accurate UTC time. This system permits the determination of the astronomical azimuth of a direction in short fieldwork time and with high accuracy (Lambrou, 2003).
In order to study the orientation of the church of ″the Transfiguration of our Lord″ two characteristic lines were examined. The first was the main axis of the monument, joining the middle of the holy altar with the middle of the main entrance (at a distance of 22m). The astronomical azimuth of this axis was found to be 119°34′ ± 0′.6.
The second line is inscribed on a flat marble stone, different from all other flagstones (Picture 1), embedded on the floor in the middle of the church.

Picture 1. The flat marble stone.

This stone is placed under the dome, on the main axis of the church (figure 2). The inscribed line has a length of 70 cm and seems to indicate something, so its orientation was examined. The derived astronomical azimuth of this line is 70°35′ ± 20′.
The main axis of the chapel of Saint John the Baptist, defined by the middle of the Altar and the middle of the central window where the light enters, was also examined. This axis has the same orientation as the main axis of the church of "the Transfiguration of our Lord".

3.4 Determination of the perceptible horizon

The perceptible horizon of a monument is of high importance because it permits, or restricts, the view of the Sun and the entrance of the sunlight in the holy altar. It is defined by natural terrain, mountains, rocks, and sea or by buildings that already existed at the time of construction of the monument.

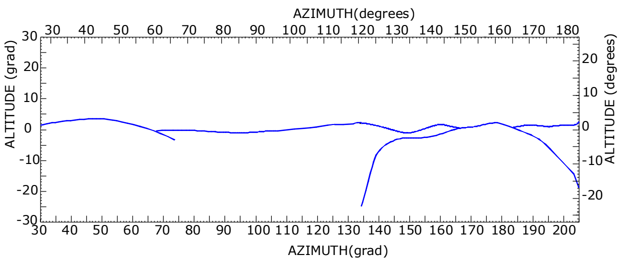

Figure 3. The diagram of the perceptible horizon towards the East

Measurements of azimuth and altitude of characteristic points permit the creation of the diagram of the perceptible horizon. The measurements were done from a point of the network in front of the Altar. It is indispensable that all these measurements refer to the middle of the Altar, so that the drawing of the perceptible horizon corresponds to the view of the horizon from the Altar.
The eastern horizon of the church is at a mean distance of 1000 m and the determination of its diagram was done with an accuracy of 2 arcminutes, due to pointing uncertainties. The adjustment was easily calculated, since the coordinates of the points of the horizon, the network points and the altar were all known from the geodetic network and the digital plan of the church. The diagram of the view of the perceptible horizon to the east of the church is presented in figure 3. The x-axis shows the azimuth and the y-axis the altitude (in degrees and grads) of the horizon.
Picture 2 is the photographic documentation of the horizon.

Picture 2. Photographic panorama of the eastern part of the horizon

3.5 Determination of the path of the sun

The determination of the apparent diurnal path of the Sun, as seen from this monument and for a given date, was done using the SkyMap Pro 8 software (digital almanac & virtual planetarium, Marriot (2001)). Necessary input data are:
- The astronomical coordinates Φ, Λ of the church (determined with satisfactory accuracy from the GPS measurements of the geodetic network).
- The date (any date between 4713 BC and 8000 AD) and the time interval between successive points of the position of the Sun in the sky.

A local ephemeris of the Sun was produced, listing altitude and azimuth of the Sun, accurate to about 2 arcseconds (Meeus, 1991), as a function of local time.
The church of the "Transfiguration of our Lord" celebrates on August 6th and the chapel of Saint John celebrates on January 7th each year. As already mentioned, the first building was erected in 1360 and contained the holy altar of today and the chapel. The extension of the building was done in 1388. Therefore, the calculation of the path of the Sun was made for these particular dates and years.
Figure 4 combines all available data, showing the path of the Sun and the azimuths of the examined lines superimposed on the diagram of the perceptible horizon. The rectangular insets in the figure show, in magnification, the intersection of the three characteristic lines and the resulting accuracy of the orientation.

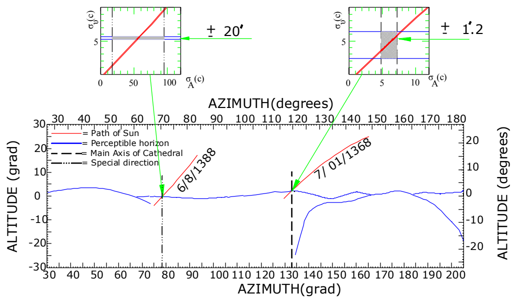

Figure 4. The diagram of the perceptible horizon towards the East and the apparent paths of the Sun

The combined error of the orientation of the main axis, represented by the dark area in the middle of the inset, is about 1′.2 and the combined error of the orientation of the line inscribed in the flat marble stone is about 20′, due to its short length. The magnitude of the combined errors depends on the errors of the azimuth of the lines, of the path of the Sun and of the line of the perceptible horizon.

4. DISCUSSION

As it is apparent from the diagram in figure 4

- The intersection of the vertical line, representing the azimuth of the main axis of the two churches, and the line of the perceptible horizon coincides with the point of sunrise on the 7th January 1368 ± 18 years. This agrees well with the year of construction (1360 AD).
- The intersection of the vertical line, representing the azimuth of the line inscribed in the marble stone, and the line of the perceptible horizon agrees well with the point of sunrise on the 6th August 1388, when the church was extended.

This implies that the first building, which contains today the Altar of the "Transfiguration of our Lord", was originally dedicated to Saint John the Baptist. This is in accordance with the traditional rule that the orientation of the church should be towards the sunrise on the celebration day of the Saint to whom it is dedicated. When the church was enlarged in 1388, the founders could not change the orientation of the building, so they placed this marble plate with the line in order to indicate the point of sunrise on the new celebration day when the church was dedicated to the ″Transfiguration of our Lord″.

5. CONCLUSIONS

The combination of geodetic and astronomical data, measured using modern digital total stations, allow the determination of the orientation of a monument with high precision and reliability. Combining them with historical data referring to the time of construction, the final interpretation of the orientation of the monument may be achieved. Furthermore, there is also the possibility to date a monument by the proper combination of historical, cultural and geometric data (Pantazis, 2002), (Pantazis et al, 2003).

This method may be useful for creating a database of oriented monuments, containing the geometric documentation of each monument, its orientation with the appropriate historical evidence, as well as historical documents referring to the monument. This database will be of great international importance.

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