# SPATIAL INFORMATION SYSTEM FOR THE GEOMETRIC DOCUMENTATION AND RESTORATION STUDIES OF MONUMENTS: AN APPLICATION TO THE WALL OF ANCIENT MESSENE


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**ABSTRACT** :

The conventional methods for the collection and processing of the geometric information needed for the restoration studies of ancient monuments, are costly and time demanding. An alternative modern approach is the establishment of a Spatial Information System (SIS) in combination with the use of digital methods for 3-D detailed representation of the monument and its scattered blocks.

An application of the above approach on a small section (70 m length) of the Arcadian Gate and the ancient wall that surround the ancient town of Messene in the Peloponese, is given. This archaeological site is one of the most significant Hellenic monuments. At that specific point the wall's height varies from 1.5 to more than 7 m, sporadically distorted, while there are about 400 pieces of the original material scattered over the surrounding area. For the geometric documentation, a combination of conventional and photogrammetric methods has been used. The photos were taken from the air (by a helicopter, by a special balloon and by a bipod) and terrestrial, for the facades. Approximately 280 photos were taken in total. The coordinates of the control points were calculated by aerialtriangulation. Rectification and mainly stereorestitution methods were applied on a PC-based digital photogrammetric system.

A relational Data Base was created, with architectural information about the scattered blocks of the wall. The processing of the material according to some key-parameters concerning its construction, lead to the 'composition' section of the study and definition of a documented restoration proposal. The original location of approximately 150 scattered blocks was determined.

For the restoration of monuments the application of a SIS in combination with profound knowledge concerning the monument can give best results, through a semi-automated procedure, where the SIS will be the main tool for reliable and quick correlation work.


## 1. INTRODUCTION

The complexity of monuments and archaeological sites, even if they are preserved in a pretty good condition, is such that imposes the innovative use of technology and the employment of all possibilities of geometric documentation methods, for the improvement of the conditions for the elaboration of a restoration study. The traditional methods for data collection and processing are laborious and time consuming. Any kind of acceleration of the process, or of automation of parts of it, is significantly useful.

The background for a restoration study of a monument consists of its complete and detailed geometric documentation of its parts that are in situ, in museums or storerooms. In order that the result be of better use and as flexible as possible, it is useful for it to be a digital, three-dimensional survey of high accuracy. The use of photogrammetric methods, in parallel with the conventional technology of field survey, and direct measurements on the monument surface, is well accepted, even desired, by the specialists –archaeologists and architects. The additional alternative solutions, with vector or raster products, help a more integrated and true documentation of the monument's blocks. This doesn't refute the irreplaceability of direct measurements which give the possibility of initially-derived information and real contact with the monument.

In parallel, the development of the Information Systems (IS) technology has been applied in several cases in this field during recent years (Allen et al 1990, Potsiou et al 1992, Lock et al 1995, Bruessler et al 1998 etc.) The IS are mainly applied for multi-level and multi-purpose documentation of particular categories of monuments, i.e. temples, theatres, castles etc, for the multimedia recording and interconnection of historic, geometric, archaeological and other information. For the pure geometric documentation the use of an IS is limited. For restoration projects the usage up-till-now of an IS for decision making is primitive.

The preliminary study for the proposal of block matching of a part of the Wall of the Ancient Messene, offered an opportunity to evaluate the application of the above mentioned technologies.

## 2. THE WALL OF ANCIENT MESSENE

Ancient Messene was established by the Theban General Epaminondas in the year 369 B.C. and became a significant political and cultural centre of the Peloponese until the $3^{rd}$ A.C. century. The ancient city is known from the description of Pausanias and through the impressive ruins of its monumental fortification. The wall surrounted the city, with a length of 9km, had two main Gates, the Arcadian Gate, where the road coming from the ancient city of Megalopolis ended, and the Laconic Gate at the southeast.

What remain from the ancient city are the Asklipieon, the Stadium and other public buildings. Also, part of the fortification of the Acropolis (Ithomi) is conserved, together with ruins of the temple of Ithomata Zeus. This consists one of the largest and most significant archaeological sites in Greece.

Yet, the most impressive remains, today, are of the enclosure wall. The wall consists of a model of Hellenistic fortification-skill. It had 17 towers and the beautifully constructed Arcadian Gate, also an outstanding example of hellenistic construction. Its better preserved sections lie to the north and northwest. The part under study lies in this sector and extends 70m in length, from the Arcadian Gate, northeast, to the first meeting-tower (Fig. 1). It consists of two stone sides, whose vacancy was filled by stone-blocks and rubble. It follows the style of so-called “compartment wall”. The construction system is irregularly rectangular. Its width varying between 2.45 – 2.80m (Chlepa 1998).

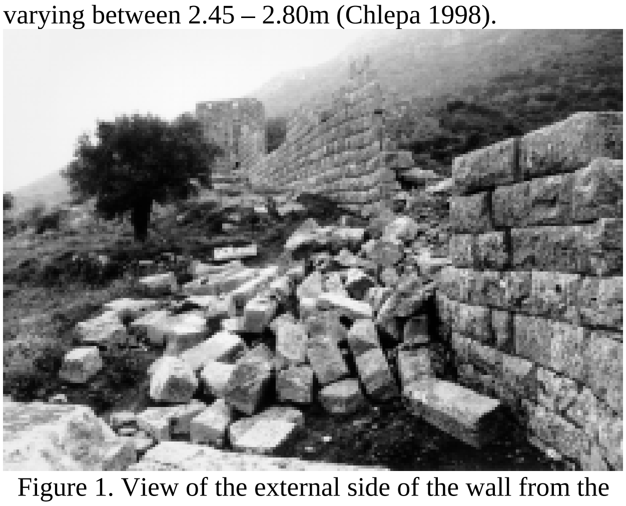

Figure 1. View of the external side of the wall from the Arcadian Gate

Before the beginning of the survey work of the monument and its scattered blocks, a numbering of the scattered architectural parts, which lay in an area of 0.2 he around the wall, took place. 355 blocks were numbered, surveyed and photographed separately for documentation purposes.

## 3. GEOMETRIC DOCUMENTATION

### 3.1 General

For the survey of such monuments, the application of a combination of photogrammetric, field surveying and direct measuring is usually necessary (Ioannidis et al 1997). For this particular monument, this was considered absolutely necessary, due to:

- The large size area of the monument
- The significant elevation differences
- The height of the wall, which in some parts is taller than 7m
- The difficulty of approaching particular parts of the wall
- The damage to the stones and the distortions of the body of the wall.

Yet, regardless the surveying methods and the visualisation techniques through an IS, the result must be a 3-d recording of the monuments. The parallel existence of raster imaging (photomosaics, orthophotos) is useful for the better photographic documentation of the monument, as this offers the opportunity for a direct and easy comparison, on the screen, of the monument or its section with earlier photos, that is to say the available documents.

The accuracy needs, for the creation of the background for the restoration study, are usually high. Special emphasis is given to the relative accuracy between the neighboring blocks, small parts of the masonry or the constructive characteristics of a single block, where the accuracy demand is of the scale of 1cm.

### 3.2 The photogrammetric process

#### 3.2.1 Executing photography

For the accuracy needs and for the three-dimensional coverage of all parts of the monument, it was necessary to take both aerial and terrestrial photos. For the airphotos especially, careful planning for stereoscopic coverage was done, based on an existing topographic map at a scale of 1:200. Conventional metric cameras and almost all possible platforms for large scale photos were used:

- Photos taken by helicopter from an altitude of approx. 30m above ground, for full coverage of the area of interest. In total, 7 photos were taken in 2 strips, with an UMK 13x18 camera, c=100mm, specially mounted on the helicopter skid (photos’ scale 1:300)

- Photos taken by a special balloon (Fig. 2) with a Rolleiflex 6006 camera, c=80mm, format 5.5x5.5cm. All the area of interest was covered with multiple photos, from 4 flying heights according to the object and its scatter. Photos were taken:

Figure 2. The balloon used for the air-photography

- From an altitude of 7m above the object, photoscale approx. 1:90, for the coverage of the upper surface of the preserved wall (Fig. 3) and the eastern side of the Arcadian Gate (in 3 strips). These are the parts with the highest accuracy demands
- From an altitude of 10m above the object, photoscale approx. 1:125, for the coverage of most of the scattered blocks (Fig. 4) and the western upper side of the Arcadian Gate. The irregular shape of the area of interest and the large overlapping needs (for security reasons and for better restitution of the blocks) –70% forward and 20-40% side overlap- resulted in the formation of 13 strips

Figure 3. Airphoto of part of the upper surface of the wall (scale of the negative approx. 1:90)

- From an altitude of 13.5m above ground, for the coverage of the scattered blocks in the inside area of the Arcadian Gate (2 strips) and the north part outside the wall , where the blocks are sparsely scattered (2 strips)
- From an altitude of 16m above ground, photoscale of 1:200, for the coverage of small individual groups of blocks, relatively distant from others. These photos were taken in stereo-pairs
- Photos taken by bipod, with the Rollei camera, from heights 6-8m. The topography of the area and the location of the scattered blocks made the movement of the bipod significantly difficult. As a result of this, only 24 photos were taken and most of them finally were not used for the stereorestitutions.

Figure 4. Airphoto of scattered blocks of the external side of the wall (scale of the negative approx. 1:120)

The inner and outer façade of the wall and of the Arcadian Gate were covered by terrestrial mono- or stereo- photos according to the relief of the object. Photos were taken by Rollei camera at scales of 1:100 to 1:150.

In total, more than 280 photos (200 airphotos and 83 terrestrial) were taken. In the main, the method of stereorestitution was applied, for almost 170 stereopairs. In 40 photos digital rectification was used. At any case, premarked control points were used, with rectangular targets of 5x5 or 7x7cm, that were stuck either on the object surface or on special poles on the ground.

**3.2.2 Processing and results**

A dense network of approx. 750 control points was premarked for the airphotography needs (5-10 control points per stereomodel). The initial plan was to calculate their coordinates by airtriangulation. Finally only 600 of them were calculated by airtriangulation with bundle adjustment and the rest 150 points were measured by conventional surveying methods, due to following reasons

- In order to achieve an overall accuracy at (X,Y,Z) of 1-1.5cm we need a large number of points measured by field survey
- Because of the irregular shape of the whole triangulation block (due to the object's shape)
- The significant scale differences between (even neighboring) photos led to separate solutions of three airtriangulation blocks
- For the photo-coverage of isolated stone-blocks or the highest points of the upper side of the wall, independent stereopairs were planned, whose control points were measured by field survey
- For some points on the ground very close to each other, the field measurements are the quickest method.

The approximately 150 premarked control points for the terrestrial photos were also calculated by field surveying, since it was the quickest and most simple method in that case.

The stereo-restitutions were done on the PC-based digital photogrammetric station VMAP. The negatives were scanned at a resolution of 600, 800 or 1.000 dpi, according to the photoscale. All the photos taken by balloon and a few from those taken by bipod were used. In some cases the same blocks or parts of the wall were restituted 2 or 3 times by using different stereopairs, for better recording of their characteristics and for result checking. The photos on a smaller scale, taken by the helicopter, were used only for the completion of some parts of the blocks which were hidden in other large scale photos.

Thorough field checking proved that the results of the restitutions had met the high accuracy demands (r.m.s. <2cm) in more than 98% of the cases.

The flat sections of the wall façades were restituted by digital rectification, using the ARCHIS software of SISCAM. Also, in these cases, the third dimension was given to the points of the outline of stones, so that they would be combined with the results of the stereo-restitutions. All coordinates have been calculated on a unique reference system. So, the combined result of all photogrammetric procedures was the creation of a 3-d model of the stones of the masonry for the wall and a 3-d model of each one of the scattered blocks, with the appropriate geo-reference. Hidden parts of the blocks were left open.

In parallel, digital photomosaics were compiled for all the external and internal surfaces of the section of the wall under survey (Fig.5).

### 3.3 Field measurements

The field survey measurements include:

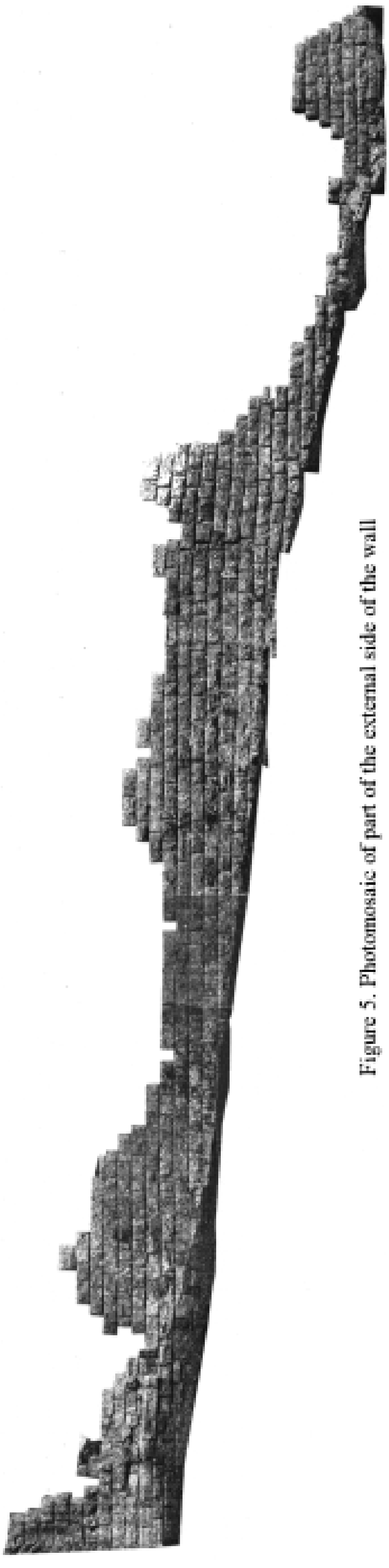

Figure 5. Photomosaic of part of the external side of the wall

- Establishment of a network of 17 points, dependent from the national reference system. Their coordinates were calculated with an accuracy of 1cm
- The calculation of coordinates of 300 premarked control points, for the aerial and terrestrial photos, as mentioned above
- Definition of a great number of detail point coordinates, for the completion of the photogrammetric restitutions in parts which not shown in the photos. This is a laborious and time consuming procedure, for such large monument, yet necessary, for the completion and integration of digital 3-d modelling of the wall and the blocks
- Thorough control of accuracy and completeness of the photogrammetric processing products, so that the results are reliable and acceptable by all scientists involved in the restoration project.

By the completion of the survey work, the geometric documentation of the wall and the scattered blocks in their location has been completed. Numbering of the blocks and their detailed study in the field, by the architects, followed: according to their way of falling, the direction, their characteristics, the location of the landing surfaces and the façades of each block in combination with the well preserved part of the wall. These data properly coded comprise the basic attributes of the blocks for the establishment of the IS.

Further on, 355 numbered scattered blocks were placed at particular locations in a neighboring area, with the purpose of:

- Field investigation of each one separately, direct measuring of all surfaces, photography and in-fill of a special form (completion of the 3-d recording)
- Easy re-establishment on their original places in the case of restoration.

The analog representation of the geometric digital data produced:

- Planimetry of the wall, the Arcadian Gate and the in situ scattered blocks (before their storage), on a scale of 1:25 (Fig.6)
- Façades (external and internal) of the wall and the Arcadian Gate, on a scale of 1:25 (Fig. 7) and photomosaics of the façades of the wall
- Intersections at selected points
- Forms with fully, detailed and accurate surveys of each block.

## 4. DESIGN OF SPATIAL INFORMATION SYSTEM

### 4.1 General

The Geographical Information Systems (GIS), that are the most known IS, place emphasis on geographical reference as being more important than the attribute element. For applications on monuments and especially for restoration studies, it is more useful and accurate to refer to Spatial

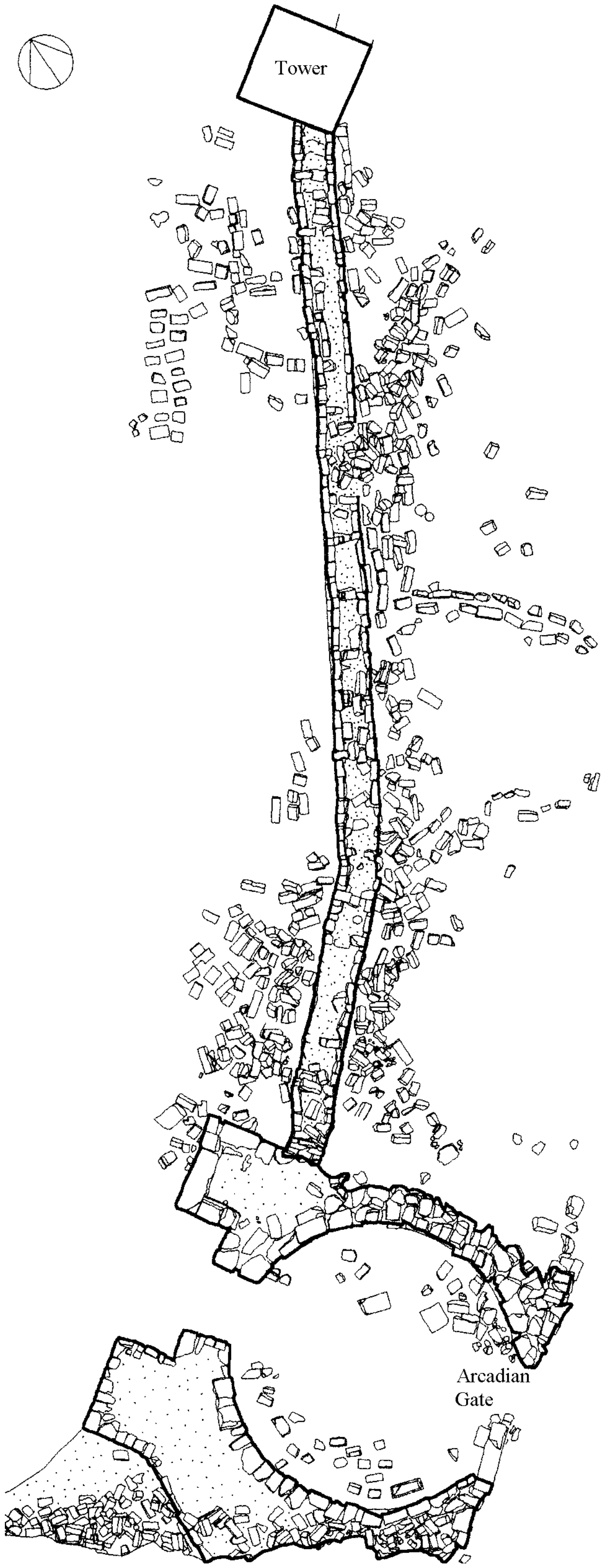


Figure 6. Planimetry of the wall, the Arcadian Gate and the scattered blocks (decreased to a scale of 1:500)

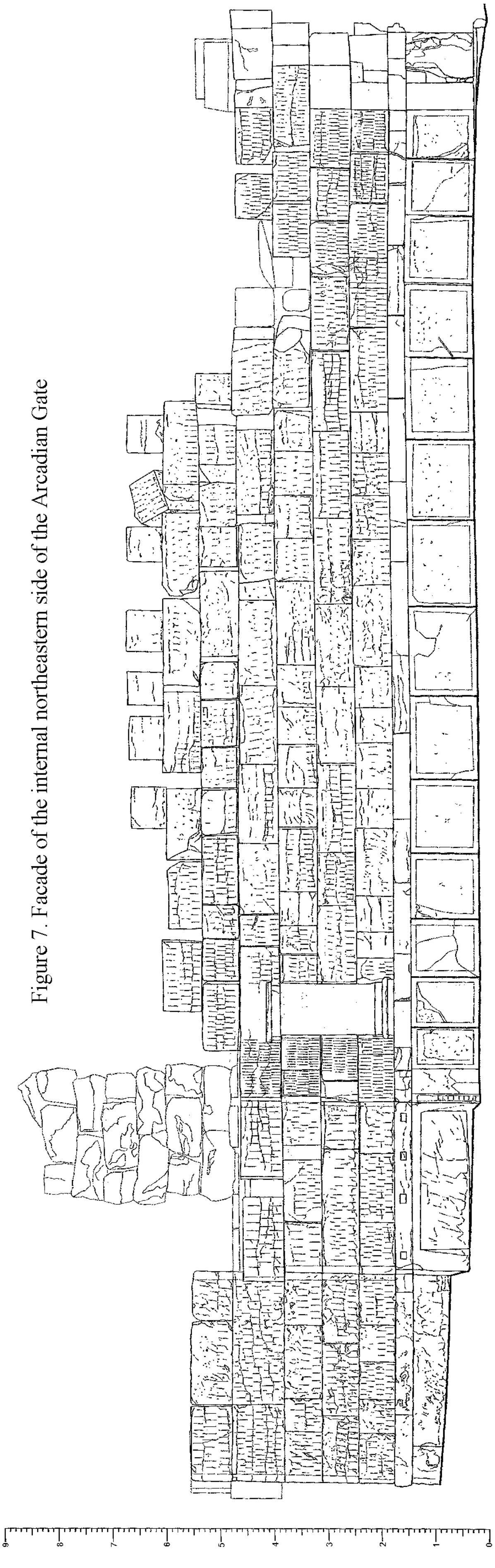

Figure 7. Facade of the internal northeastern side of the Arcadian Gate

Information Systems (SIS), as:

- The attribute element is equally as important as the geographical element
- The spatial datum of the monument and its sections is the local environment of the archaeological site (i.e. a local coordinate system).

According to the needs and the demands of the work, the design of the SIS is done and its contents are defined. Critical for the definition of the IS is the implementation of a transaction processing system, so that emphasis is placed on data recording and data manipulating, or of a decision support system, where emphasis is placed on data analysis and modeling (Btuessler et al. 1998). The Data base structure and the querying capabilities of the system are relatively influenced.

### 4.2 Components of the SIS

Typically we may distinguish four subsystems in a SIS: data entry, data storage and retrieval, data manipulation and analysis, data visualisation.

For the present application, the SIS was not used for the final decision making, but only for assistance purposes, for the better management of the collected data. Consequently emphasis was placed on the first two subsystems, since the development of the other two was limited. The data of the IS are the final digital geometric documentation of the wall and the blocks, and the attributes contained into the related Data base, which are necessary data for the restoration study. The ability to storage a large volume of data, especially geometric data in 2-d and 3-d, must be used, since during the development of a proposal for restoration purposes it is necessary to know and observe all details of the monument's parts. So, the subsystem of the IS for storage and manipulation of data is critical for the success of the study.

The complexity of the object and the type of the project defined the limits to the use of a fully automated system. Only the interactive process between the SIS and the scientist-user can give scientifically acceptable results. So, the subsystem of data analysis is the most doubtful, with reference to performance, or even to the real need for its development in such a study. Our efforts remained at a research and experimental level.

Referring to the subsystem for data visualisation, no effort was made for developing special tools. The inherent visualisation and multimedia tools of the commercial IS software packages were used, which already are more than adequate for our needs.

### 4.2 Data base for the scattered blocks

Special reference must be made to the RDB for the scattered blocks. Based on the above mentioned needs analysis, the definition of its logical data model was made. Generally a Data base is a properly organised collection of information. The created data model describes entities and attributes, their relationship to one another and the process used for their management.

In the present application each of the geocoded blocks, entered to the IS, consists of a record of the Data base, represented by a set of fields with the important elements of information for the restoration study needs. This information refers to the morphologic, structural and geometric characteristics, with identification key the numberings which has been made on the blocks (as mentioned in the 3.3). The data type at the SIS is as:

- Point, with attributes data referring to the whole block and geo-reference to a point in the interior of the block
- Polygon, that refers to surfaces of the block. Attributes: structural characteristics of each surface.

Into the planning of the Data base, no storage and manipulation of raster data (images) of the surfaces of each block was foreseen. It was considered that the digital manipulations do not help the study any more than their analog observation. Yet increases immensely the volume of the data.

## 5. CONTRIBUTION OF THE SIS TO THE RESTORATION PROJECT

The data used for the application of the SIS for the wall of Ancient Messene, were derived from a study which consists only the first phase of an integrated restoration project. This phase contains the data collection and preparation, the recording and storing of the scattered blocks, and results with the compilation of an initial proposal for the blocks matching. Consequently, although the planning of the Spatial IS tried to meet all the needs of a restoration project, the pilot application was limited to the first stage of that plan. Nevertheless it has shown clearly the need of making use of the IS technology and of researching for the possibility of their further involvement.

Fig. 8 shows a product of the initial proposal for block matching at the development of the south half part of the external side of the wall's section that was studied. The linear scale of the drawing shows absolute elevations. The blocks, that the positioning of their original location on the wall was made, are marked with their numbering (more than 60 for that section –comparison of the drawing with the photomosaic of Fig. 5 where the existing situation is shown).

The basic remarks from the application of the SIS are:

- The system's ability for entering geometric data from various sources and the combined management of those data are necessary. Photogrammetry provides the basic restitution for the whole monuments, but the measurement of the detail characteristics must be done by other means

- The existence of a flexible 3d-editing software for the geometric data is critical. The creation of hidden-line wire frame images of blocks is basic component for the execution of quick and reliable comparisons on the screen
- The design and use of visualisation tools must be defined by the purpose of the project. The simple existence of such tools doesn't necessarily lead to their application: walking or flying through a simulated monument, photorealistic renderings are attractive but less useful for the execution of the project
- The level of automation of the processing for the compilation of the restoration proposal is a critical question. The development of Information Technologies varies the answering continuously: powerful immersive features such as 3-d visualisation, real-time virtual object manipulation, virtual databases, knowledge based interpretation of data with intelligent agent software programmes for 3-d reconstruction, consist new equipment for possible future use in such projects. Obviously all of them can be simply a sophisticated and flexible interface for the communication of the scientist-user with the object. Human factor, profound knowledge about the monument in combination with user's experience and scientific background, consists and will consist in future the basic parameter.

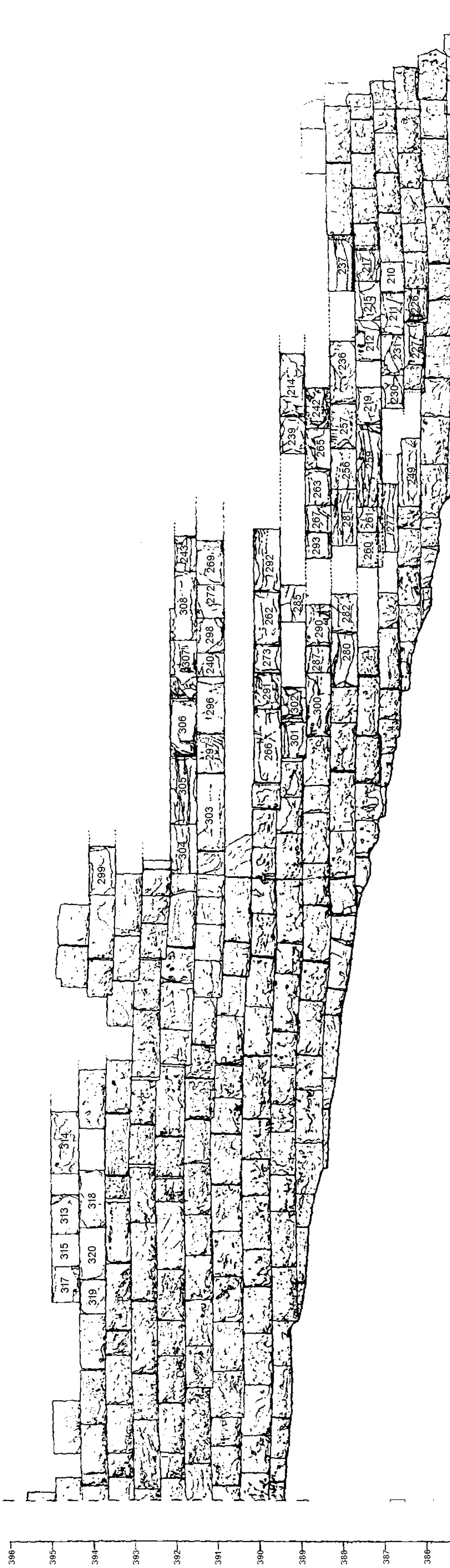

Figure 8. Part of the development of the external side of the wall with the suggested matching blocks (decreased to a scale of 1:150)

## 6. CLOSING REMARKS

For the first phase of restoration project of a section of the wall of Ancient Messene, the possibility of introducing the Information System technology was investigated, for the support of such kind of projects. Basic motive for that was the need for various kinds of data collection, management and combined observation. This situation resemble with the characteristics of IS. For the compilation of the digital background, the combined use of photogrammetry, field surveying and direct measuring on the object was selected.

The results for the geometric documentation were very satisfactory and proved the need for three-dimensional representation and editing of blocks of the monument. The design and development of a relational Data base, with morphologic and structural characteristics of each block, has helped significantly for the categorisation and the combination of the material. The use of other tools of IS offer a wide range of possibilities for flexible manipulation of the monument and the scattered blocks.

The application of the new management and visualisation methods together with the development of the most sophisticated tools, will help for the broader use of SIS on the substantial part of the restoration projects.

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