

AN INTEGRATED SPATIAL INFORMATION SYSTEM FOR THE DEVELOPMENT OF THE ARCHAEOLOGICAL SITE OF MYCENAE

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Commission V, WG 6

KEY WORDS: Documentation, GIS, Spatial data infrastructure, Orthophoto, Animation, Visualisation

ABSTRACT:

Digital and automated photogrammetric methods and procedures developed for the collection and management of spatial data have been well introduced on archaeological applications. The use of terrestrial laser scanning systems provides new capabilities for 3D visualization of the present situation of a site. Recently, special tools in Spatial Information Systems (SIS) and management systems of virtual world models (VR) have been developed. Their combination can provide relevant scientists and users with a variety of possibilities for the creation of integrated systems capable for documentation, restoration and cultural development of archaeological monuments and sites, with: the detailed 3D documentation of the present condition of the site, the development of a multi-purpose SIS and the introduction of modern digital products at a local museum, such as 3D representations, creation of virtual environment, Web applications.

Application of these techniques and systems was made to the archaeological site of the Mycenae, one of the most important sites worldwide. Photogrammetric procedures and laser scanning were used for the data collection. Airphotos were taken by helicopter and a large number of terrestrial photos by analogue and digital cameras. Orthophoto production for the site and detailed 3D vector restitutions, horizontal plans, facades and sections were made. In addition 3D views of vector data and textural scenes were produced by automated procedures.

The development of the SIS is based not only on the data and products of the photogrammetric processing, but also on various other data sources, as the structure of the system contains historic, archaeological, architectural and technical information, with texts, digital images (recent and old pictures, old graphic representations etc.), video, 2D or 3D views plans, 3D representations of particular parts of the site, visualization of tour paths.

The establishing of a local museum at the Mycenae is one more challenge for applying photogrammetric procedures, object modelling techniques with laser scanning, texture mapping, 3D representations, VR applications and Web-related issues. The paper investigates all these possibilities in relation with the data of the particular archaeological site concerning the information supply, the difficulty in demonstrating moveable findings of great value, which are exposed in other museums, and also the knowhow and the financial parameters.

1. INTRODUCTION

The collection, processing, management and visualization of spatial data is the core area of research activities and application fields of all methods and techniques of geoinformatics. As digital and automated photogrammetric methods develop their application possibilities increase, always in combination with other techniques which are developing in parallel with a higher or lower ratio, such as: laser scanning, GPS and other. The documentation of monuments or archeological sites, which usually are complicated constructions with a demand for detailed data, was the traditional privileged application field of photogrammetric methods. The recent developments offer additional new alternative techniques, systems and methods. After all, the needs for integrated surveys and documentation of the archeological sites, in a faster and more detailed way, have increased radically. The compilation of horizontal plans, facades, and intersections consist only a necessary layer, which much be integrated with raster products, 3D representations, thematic maps, photos, textual information, video, audio data, reconstructions, animations, movement in virtual environment

etc, to mention some of the continuously increasing list of possibilities.

The first step of the documentation process is to structure all the above-mentioned data into a Spatial Information System. This is not a new demand and the basic principles for a SIS structure for archeological sites have been already analyzed and applied, i.e. Bruessler et al 1998, Ioannidis et al 1999, Alberty et al 2001, Counsell 2001. Yet, the new demands and the new data sources, such as the terrestrial laser scanners of high accuracy, the virtual world models products etc, use improved methods for data management and especially for data visualization. According to the user of the system _specialized scientist, visitor of the site, tourist_ the level of access to the systems' data and the data visualization methods should vary. Major challenges to be faced are:

- to avoid the unreasonable acquisition to the SIS of all kind of existing data simply because they are related to the monument, and
- to use the SIS as a decision making tool to recreate the archeological site or to support the research and excavation work.

Special mention should be made for the new capabilities provided by the integration of digital re-creation of 3D shapes of buildings and objects to the archeological SIS. The construction of virtual environment, with digital representations of objects from hypothesis about the development of the site at particular historic periods, or the construction of virtualised environments, by modeling existing small or big objects of the physical world, offer the possibility of expanding the capabilities of specialist for planning, creating and experiencing new surroundings (Beraldin et al 2000). At the same time, the use of Web allows the individual to visit as a virtual tourist a remote site or sites that have been closed to the public.

An application of all the above mentioned ideas was made to the archeological site of the Mycenae, one of the most important sites at global level. Mycenae, located 150 km southwest of Athens was the most important and biggest center of the prehistoric Hellenism during the second millennium BC. Habitation there started since 19th century BC. The most developed period of Mycenae was between 1300-1100 BC. Despite the two disasters, at the 10th century BC and at 468 BC, Mycenae continued its existence until the Roman times when it was finally abandoned. The site includes the Acropolis, an area of 3.2 hectares surrounded by Cyclopean Walls and containing ruins of palaces, temples, houses etc and the famous Lion Gate which carries the first known sculpture in history. At the western and south-western side of the Acropolis there is an area of approximately 60 hectares, which has significant archeological findings, scattered around mainly large grave constructions of great art and store-houses. A special characteristic element is a number of moveable findings of excavations and mainly the golden objects that were found inside the graves and now are kept away from the site, at the National Archeological Museum of Athens.

An integrated approach for the presentation of all data of an archeological site as such, demands:

- the detailed 3D documentation of the present condition of the site
- the development of a multi-purpose archeological SIS, to be used by professionals but also by visitors of the site
- the enrichment of the local museum with digital products which can be produced by modern technology (VR, Web applications).

2. GEOMETRICAL DOCUMENTATION OF THE SITE

The optimal approach, from technical and economic point of view, for the complete 3D documentation of the area of the Mycenae is the combined application of automated digital photogrammetric methods (using large scale airphotos and terrestrial photos), with field surveys (using GPS and conventional means) and with terrestrial laser scanners (both for large surfaces as well as for small objects with high accuracy scanners of 100 μ m). Vector and raster products (orthophotos and texture mapping) in 2D and 3D for the whole archeological site and especially for the Acropolis, details for its most interesting parts, colored raster facades of the

Cyclopean Walls and intersection and horizontal plans of the ceilings of the underground constructions (water-tank and tholos tombs) can thus be produced. The appropriate application of each method is the only solution to cover the large volume of data and the necessary accuracy for the documentation of significant details.

2.1 Photogrammetric procedures

A number of airphotos taken for the full coverage of the archeological site, from an especially modified helicopter capable to carry the large format metric camera UMK 13x18 of Zeiss of a focal length $f=100\text{mm}$ (Georgopoulos 2001):

- 45 photos in 6 strips, at north-south direction, for the full coverage of the archeological site at a scale of approximately 1:2000
- 6 photos, at scales varying between 1:500-1:1000, for the coverage of significant element lying inside the Acropolis (palace area, grave circle A', etc)
- 7 photos in 1 strip, at a scale approximately 1:600, for the coverage of an area which contains store houses and lies at the southwestern side outside the Acropolis
- 3 photos for each of the 6 main semi-destroyed tholos tombs, at scales between 1:200 – 1:300.

In addition to the above, a large number of terrestrial photos, by analogue and digital cameras of varying formats and focal lengths, were taken. To satisfy the photogrammetric needs, the facades of the most significant monument of the Acropolis (internal parts of the Cyclopean Walls, palace walls, staircases, parts of the Grave Circle A') and the external facades of each tholos tombs were covered.

For the approximately 50 stereomodels, which were created from the air photos, 25 control points were measured by GPS and the coordinates of the other 150 necessary control points were calculated by bundle adjustment airtriangulation, using the BINGO software. A detailed DEM was automatically compiled and breaklines were manually digitized for the whole archeological site, using 2 DPS: the SoftPlotter of Autometric and the ARCHIS PLUS of SISCAM. The following steps were:

- the production of orthophotos and the compilation of orthophoto-mosaic for the whole site (Figure 1)
- detailed 3D vector restitutions of all stereomodels, with an emphasis on the main monuments of the Acropolis and the tombs.

So, 3D views of vector data (Figure 2), horizontal plans and 3D textural scenes with draping of the orthophoto-mosaic were produced.

For the terrestrial mono- and stereo- images, a great number of pre-signed control points were measured by conventional field methods. Rectifications and stereo-restitutions for the compilation of raster and vector products _facades and sections_ were made at the photogrammetric station ARCHIS PLUS (modules Archis and Stereometric). This 3D information was combined with the coordinates of the points of aerial restitutions for the creation of a unique data system for all the geometric characteristic of the archeological site.

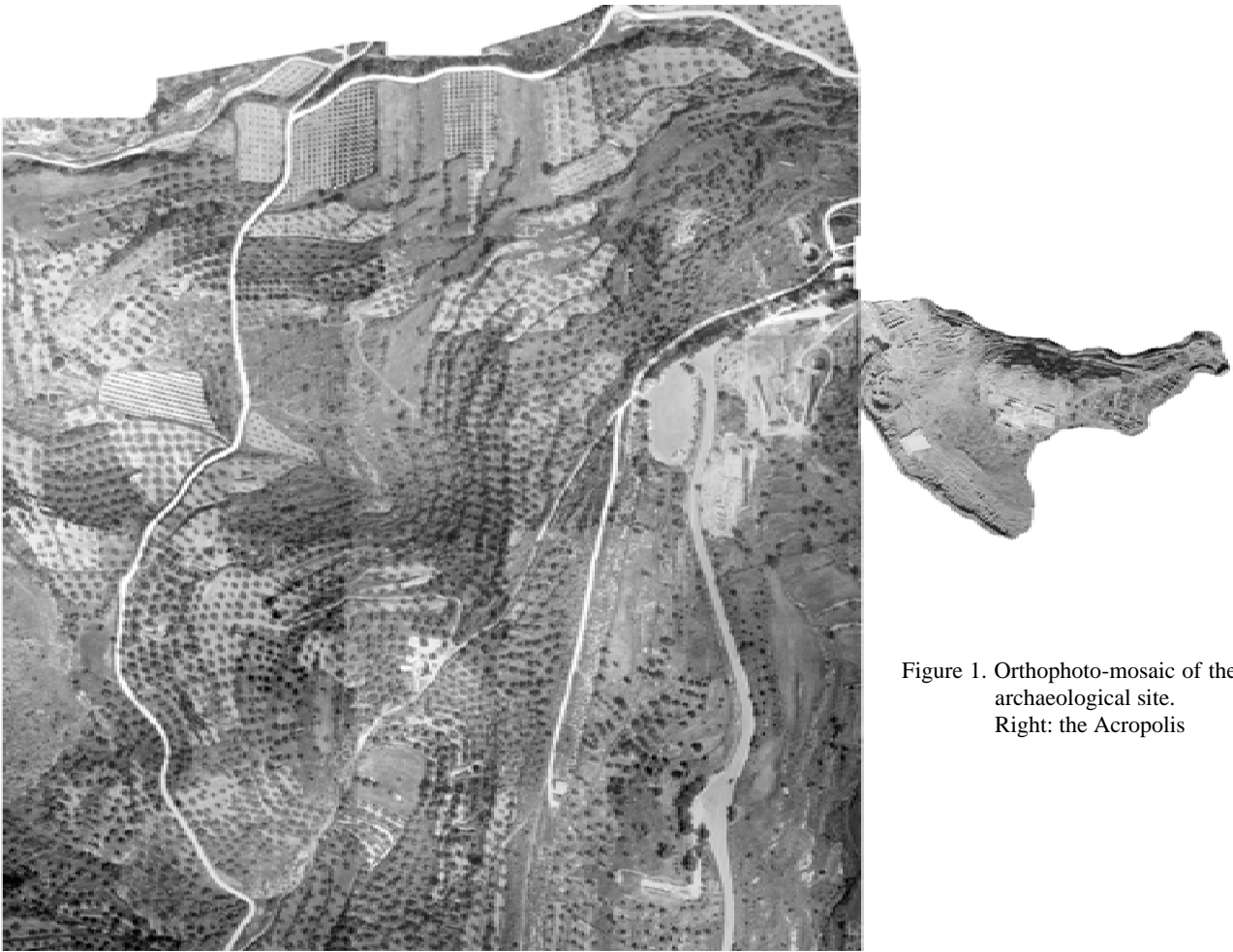


Figure 1. Orthophoto-mosaic of the archaeological site.
Right: the Acropolis



Figure 2. 3D view of the vector data of the Acropolis

2.2 Additional field surveys

The above mentioned spatial database was completed by conventional field measurements in situ, for the parts which either cannot be rectified by photogrammetry, as for the underground constructions, or a more detailed recording is needed, as for wall foundations which can only be defined by field observations. The result is the collection of a large volume of data _there are more than 12,000 elevation points only for the Acropolis_ which includes the spatial information of the existing situation at the site, with an accuracy which varies between 1:50 for the significant monuments, up to 1:500 for the surrounding area. These data were the basis from which the 3D vector model of the existing constructions were compiled using semi-automatic methods (Ioannidis et al 2000). Figure 3 shows a rendering axonometric view of the Palace with the included constructions. The next step is the textural coverage of the surfaces by laser scanning for a better visual result.



Figure 3. Axonometric view of the Palace

2.3 Laser scanning

Since their origin, at mid nineties, the terrestrial 3D laser scanning systems, with the ability of quick, accurate and reliable recording of the shape and the characteristics of the surface of the objects, has been applied on the recording of monuments. The first initiatives and the successful development of some prototype instruments (Beraldin et al 2000), was followed by the normal production of scanners by various companies. GS100 of MENSIS, Cyrax 2500 of Cyra-Leica, Callidus 1.1, LMS-Z210 or Z360 of RIEGL are some examples proper for the scanning of large surfaces or objects, with a point accuracy of georeferenced 3D coordinates better than 1.5cm. A recent application of such systems on a large archaeological site is mentioned at Afsher et al 2002.

Such applications at the archaeological site of the Mycenae refer to:

- the Cyclopean Wall which fully surround the Acropolis, with a perimeter length of 980m and maximum height of 7.5m (Figure 4 shows a photo of part of the wall around the Lion Gate)
- the palace, with perimeter length of 200m and height 2-6m
- the stelae at the upper part of the Grave Circle A (Figure 5)
- the internal side of tholos tombs.

The scanning demands are only a few days of work for the production of millions of points, and the post-processing _data filtering, creating of 3D file and re-sampling_ cannot be compared in time with the production of orthophoto-mosaics. In addition, it is impossible to take appropriate photos at the eastern external side of the Wall yet it is quite easy to use the scanner since its range is greater than 50m.



Figure 4. Photo of a part of the external side of the Cyclopean Wall with the Lion Gate

3. SPATIAL INFORMATION SYSTEM

3.1. Structure of the system

To develop the archaeological SIS of the Mycenae, the ARCVIEW v3.1 of ESRI with the extension 3DAnalyst, which provides excellent tools for 3D visualization, animation and navigation through 3D textured models, was used. The structure of the system was based on the purpose that it should be usable both by tourists/visitors of the archaeological site and by professionals, who study the development of the site and the restoration of damaged parts of the monuments, as well. So, a tree-structure was developed, which can be further enriched with data and information. The access to the data of the IS can be achieved by the five (5) alternative ways:

- vertically, from general to specific. Figure 6 gives a schematic development of the SIS based on this access method, with an example of a search path for data that refer to a particular monument of the "Late-Helladic period"
- through specific to the general, i.e. from a thematic characteristic of a monument, predefined to a menu, to the selection of all other monuments of the site which have the same characteristic
- sequentially, following a predefined path of SIS 'screens', for a user-friendly access to the basic information by the tourists
- by choosing a key element, i.e. some thematic, time period, quality or other characteristic, from a list of levels of information. There is the capability of selecting a monument according to a thematic categorization (such as "tholos tombs") or chronological reference (i.e. "Late-Helladic") or a combination of characteristics (i.e. "Late-Helladic tholos tombs") or a quality characteristic-choice from a menu (i.e. "Existence of reconstruction plan")
- through correlation of similar characteristics of various monuments, i.e. linkage to different kind of information or to other monuments of the site.

The installation of information kiosks, with computers where the data and the software of the SIS are loaded, at the entrance and other locations within the archaeological site, but also at a specific place inside the local museum, will contribute to the better service and information of the tourists.



Figure 5. Development of the western part of the stela of the Grave Circle A'

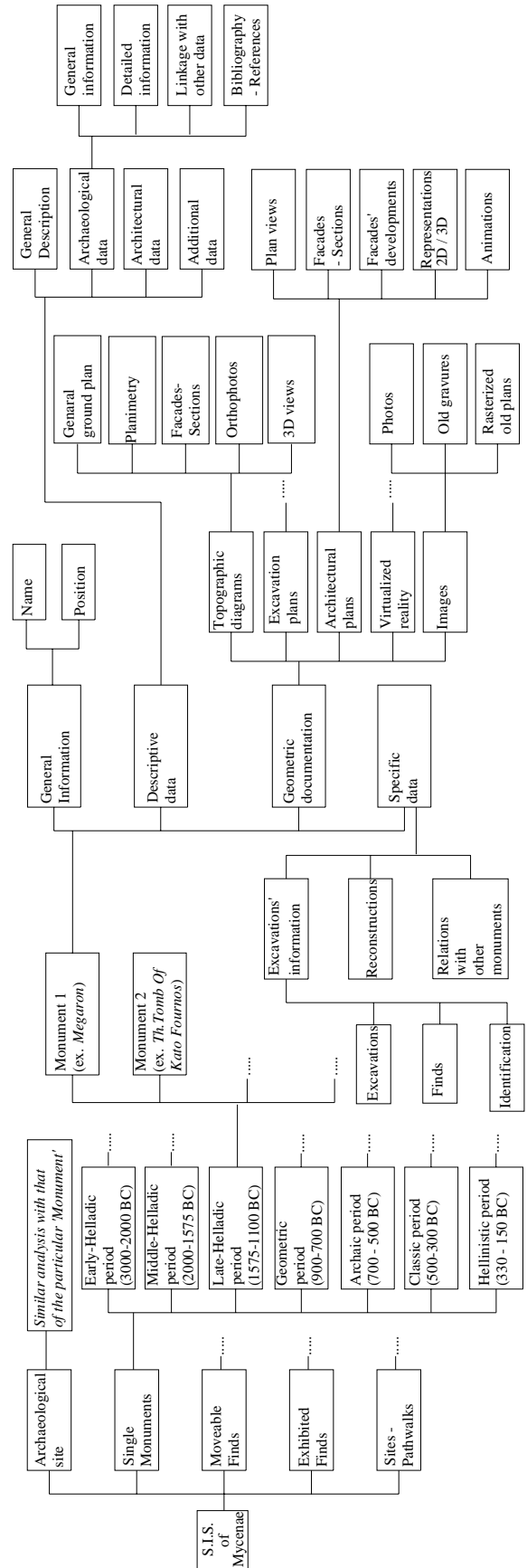


Figure 6. Structure of the SIS content, by using vertical access to the data

3.2. Data of the system

Data that have been inserted and are managed by the SIS, generally include:

- all products of the detailed geometric documentation, as they are described at section 2: 2D plans and 3D views at various detail levels, time periods and historic phases,
- texts derived from historic sources and literature (Mylonas 1952, Wace 1949, etc)
- digital images, from recent and old photos of the site and the excavations, or old graphic representations and video
- visualization of tour paths, with predefined walk-through and flyovers.

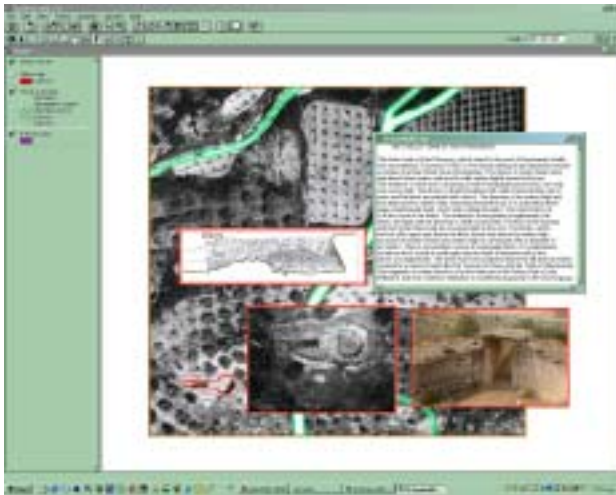


Figure 7. Screen of the SIS

Figure 7 shows a screen which is derived through a proper access into the SIS and data combination of geometric documentation, textual description and photos (aerial and terrestrial) of a grave. Figure 8 and Figure 9 show 3D screens derived from a fly over the Acropolis and a walk-through around the Grave Circle A, by using 3d Studio MAX Software for model visualization and Adobe Premiere for video producing and editing (Petropoulos 2001).

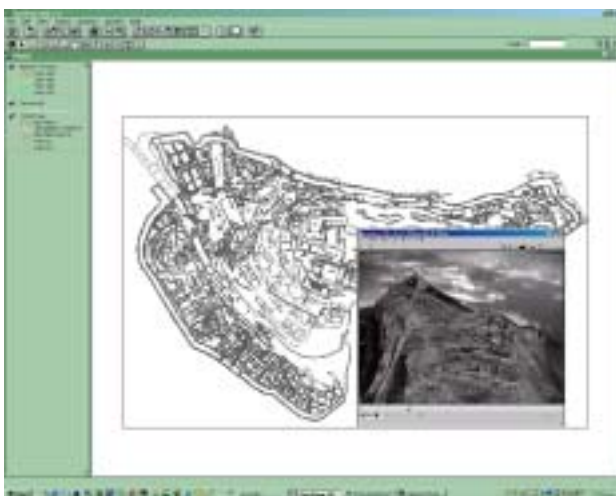


Figure 8. View derived from a flyover, through SIS



Figure 9. View from a walkthrough

4. GEOINFORMATION IN THE LOCAL MUSEUM

Longtime effort resulted to the establishment of the local Museum of the Mycenae. The building is located next to the archaeological site. The use of digital technologies and the amount of computer-compatible data generated, are a challenge to improve the operation of the museum and the structure of the exhibits, introducing novel approaches to archaeology (Hall et al 2001).

By making good use of the new media (Economou 2002) museums can now:

- provide more information on the context related to the artefacts presented
- draw conceptual links between various artefacts of the museum's collection or with other collections, using SIS tools
- provide 3D virtual representations of objects, which are too fragile to be displayed or which have been found at the excavations of the archaeological site but are displayed in other museums. Especially at the Mycenae, the latter is a real problem, since all gold (and not only) finds of great value are exhibited mainly at the National Archaeological Museum of Athens. So, at the local museum there is a large number of exhibits, approximately 1600 pieces, but almost all of them are ceramics
- make complex phenomena more clear and understandable to a non specialist audience. Digital representations and stereoscopic view at VR environment constitute valuable tools
- trigger the interest of users normally not interested in archaeology _especially of children which are familiar with video games and the Web_
- visualize different interpretation theories for professionals and researchers.

In the following, two of the most interesting applications of modern technologies, which are proposed to be used at the Mycenae museum are given.

4.1. Virtual 3D representation of the finds

There are approximately 500 artifacts of small size from the Mycenae, made of gold, copper, ceramic and other, of various types and dimensions (examples are given at Figure 10), which

either are displayed in other museums or are stored. Besides simple photos, the only possibility to present them to a visitor of the local museum is their 3D digital representation at a computer screen. The complexity of the objects and the small dimensions of their details define as the only practical solution for their digital modeling the laser scanning.

(a) Mask from Grave V (b) Ring (c) Ryto



Figure 10. Gold finds from Grave Circle A'

At this case, there is a need for scanners, i.e. Minolta VI-900, with a resolution higher than 0.2 mm, which are different than those used for the scanning of the external surfaces or the big objects. Several examples of applications on sculptures or other moveable objects, can be found at Web sites like: www.archaeoptics.co.uk, www.aranz.com, etc. The result of the visualization is of good quality and can be incorporated to the SIS information or it can be an independent element of the museum. Each visitor will be able to choose the object of his/her interest on the screen and observe it in space, selecting the point of view and the observation direction with a mouse or a joystick. The cost of scanning and modeling of the main moveable finds of the Mycenae is affordable, since the work can be done gradually.

4.2. Museum and the Web

Recently it is obvious that there is a confluence between museums, as social institutions with a certain historical tradition and mission, and the Web, a set of rapidly evolving technologies that combine image, text and multimedia hyperlinking with Internet addressing. Leading museums have introduced structures, technologies and business relations from the world of commercial organizations into the museum content management and have professionalized their Web operations (Bearman et al 2002). From the first Web period, when the Web was just a mean to advertise the museum, we passed to the second period, when the Web was an alternative venue in cyberspace to implement museum programs. Recently, the third period appeared, when the Web can affect the fundamental nature of museums. Studies, initiatives and similar pilot applications are already available in the international literature (Di Blas et al 2002, Zlatanova 1998, etc).

The level of activity that can be developed in a museum as such of the Mycenae area, mainly depends on the general policy of the responsible Ministry for the Web use in all museums of the whole jurisdiction. Nevertheless the use of Internet is of vital priority for

- the promotion of the archaeological site of the Mycenae,
 - the visualization of its objects, combining the use of laser scanning techniques, and
 - the e-business development for the sales of copies of finds.
- The existence of an SIS with the detailed geometric documentation of the site, constitutes the best foundation for the implementation of a project like that.

5. CLOSING REMARKS

It is obvious that the concept for the organisation and the operation of archaeological sites and the ideas about the structure and equipment of museums have changed radically. For that reason their characteristics and the newly developing relation between museums / archaeological sites and their space and the public should be redefined. Through the technological developments in management and communication, the development of an integrated SIS, data of high quality and density can be easily produced.

This new situation creates a series of queries, starting from the hesitation of some specialists, which are used to look at things traditionally, like the majority of archaeologists. Their concern refers to the correctness of the type and the way of presentation, to the understanding of the difference between the image and the in situ display, since these two cases are considered to be two concepts ruled by completely different principles. The Web as a potential threat to the on-site, physical, real world museum is confronted by moving the virtual exhibition (located somewhere else, most often approached from somewhere else than the museum homepage) closer to the physical space: by introducing the Web into the organisation and operation of the museum itself, and thus developing a "mixed reality". No one doubts the potential benefits of such an initiative, as long as this will be the result of cooperation between the public, academic and private sector. Much more data, than the traditional, can gradually be integrated to a system as such. Traditional tools used for the organization and planning of a site, which use common principles, directly related to the archaeological research, such as: hierarchy, centralization, continuity and relationship, can be applied only if they do not hinder the adjustability and alternation; principles which are now necessary for knowledge and information sharing.

There is one more category of queries and skepticism, which refers to the kind data that should be available, to whom, at what time, and to the way of representation of the past era. By providing a very confident visualization, there is a risk that users may think that there is an indisputable, single interpretation of everything. More research should be made to find how all these can be done in a way that attracts attention to the artifact and enables communication among visitors rather than inhibits it.

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