A GIS Based Application for the Management of Monuments and Antiquities of Cyprus

Aris Kydonakis, Angelos Chliaoutakis and Apostolos Sarris
Laboratory of Geophysical Satellite Remote Sensing, Institute for Mediterranean Studies, Foundation for Research & Technology-Hellas (F.O.R.T.H.), Nik. Foka 130, Rethymno, 74100, Crete, Greece

Abstract. This paper discusses the implementation of an integrated CHM/GIS system that is used for the efficient manipulation of information regarding the ancient monuments and movable antiquities of Cyprus aimed towards the protection of the Cypriot cultural heritage. The archaeologists access the system through a client application, developed using Microsoft.net framework. ESRI technologies were fully integrated into the Windows form application using Arc Engine/Arc Objects, thus achieving a seamless and intuitive incorporation of the archaeological data and its metadata with the spatial data of the system stored as separate databases on Microsoft SQL Servers. The client application has a full feature set accessible accordingly after authentication and authorization of users, based on predefined permission levels. The client application also serves as a central repository and allows for the management of supplemental assets such as various image formats, AutoCAD files, etc. Within the environment, users have access to spatial data features including local plots "of interest", underlying cadastral data based on Cassini or LTM models, archaeological data outlined as Ancient Monuments of First and Second Schedule, Controlled Areas, Areas under Temporary Requisition, Survey Areas, Movable Antiquities, and supplemental feature sets, some of which are editable, such as a "GPS" layer for points resulting from a surface survey. A key feature is the live communication via web services with the Department of Lands and Surveys (DLS), providing access to current spatial data including administrative units, plot outlines, orthophotographic and geomorphological features. An additional feature of the client application is the ability to synchronize and identify changes between the local cadastral spatial data ("tagged" plots) with the DLS cadastral spatial data as it is subjected to frequent changes.

Keywords. GIS, Cultural Heritage Management, Cyprus, monuments, antiquities, interactive archaeological maps.

1. Introduction

In the past years, there has been a continuous effort to develop applications that can be used for the effective management of archaeological sites and findings (cultural heritage). It is important joining different items like archaeological monuments and Information Technologies, as it allows a better management of cultural heritage [1]. Until now, various applications dealing with the Cultural Heritage Management have been proposed spanning from simplistic databases to GIS based applications or even more sophisticated platforms that are trying to include various aspects of geomatics (GPS technology, satellite remote sensing, a.o.) [2]. Other applications make use of the Web and visualization tools (e.g. VRML) for the dissemination of information, images, videos and 3D reconstruction models. These may be used either for research purposes (e.g. exploration of the ancient landscape or terrain, modelling of structures and environmental settings, etc), or for more simplistic purposes that satisfy the needs of the promotion of the cultural heritage to the wider public [3], [4], [5].

A few of such CHM applications have been developed in the past years in Greece and Cyprus, incorporating some of the above modules. Initially, Web GIS technology and satellite remote

sensing were employed in an innovative effort of constructing a digital archaeological cadastral registry of Lasithi prefecture in E. Crete. The geographic database contained a catalogue of the known archaeological sites of the Lasithi district (about 900 sites), environmental information, chronology, general information, references and photographic material. The GIS platform offered the capability of synthesis of different information layers and the creation of thematic maps of the archaeological sites in the region [6], [7]. Following the momentum of the Digital Archaeological Map of Lasithi, a dynamic archive of the archaeological sites of the island of Crete has been formed, constituting a central data warehouse to be used for information retrieval and the management of the cultural heritage of Crete. Archaeological information was collected by published documents and was entered in a specially designed database. The latter allows communication with the cartographic infrastructure of the system, built on a GIS platform. In this way, archaeological features are projected on different thematic map clusters, which make possible the correlation of the archaeological sites along with their environmental, topographical, geological and statistical contexts. Customization of the GIS environment was necessary in order to produce a hierarchical time-usage sequence of the represented cultural monuments [8], [9]. In Cyprus, the first integrated platform for the regional management of the cultural heritage was developed for the area of Palaepaphos, based on GIS and Web-based database management systems aiming towards a more efficient management of the antiquities and the suggestion of policy guideline to the public and administrative agencies [10].

Based on the above and after the analysis of the cultural heritage of Cyprus and the geospatial resources available to the Department of Antiquities, a custom integrated Cultural Heritage Management/Geographical Information System (CHM/GIS) application was developed using Microsoft .Net technologies and ESRI products. Emphasis was given to usability in order that archaeologists, without extensive GIS training, can geospatially reference archaeological resources without needing hours of extra training outside of their discipline. It was also important to synchronize data between local and remote sources while maintaining the integrity of both.

2. Concepts and requirements analysis

The Department of Antiquities (DA) of the Ministry of Communications and Works of the Republic of Cyprus internally catalogued cultural heritage resources, and areas of interest are inventoried into the following categories: Ancient monuments, Movable antiquities, Controlled areas, Survey areas, and Areas under temporary requisition. The DA which is the competent authority for any archaeological related work, including excavations or surface surveys carried out in the entire territory of the Republic of Cyprus, is responsible for the declaration of all monuments in the territory. Each monument officially declared is published in the Cyprus Government Gazette and described according to the plots it occupies geospatially. Therefore, the system uses this association to extend and identify cultural resources in a geospatial context.

The DA has previously requested geospatial data according to the associated plots (sheet/plan/block/plot). These data are available locally and will be available through the local GIS system. Additionally, geospatial data not previously associated with archaeological resources are not available locally but will need to be available to users of the system. These data are provided remotely from Department of Lands and Surveys (DLS) as web services. There is also the likelihood that previous associated geospatial data becomes updated and current local copies consequently become outdated. In this case, a process exists to verify and manage inconsistencies.

Overall, the system assists DA staff in management of antiquities and the carrying out of their tasks according to archaeological procedures as described in detail below. Functional requirements of the system are outlined in the subsections below.

2.1. General functional requirements of the CHM/GIS application

The system allows the registration of new users to the CHM/GIS application. The registration process ensures the confidential transfer and storage of all personal information of users. This functional requirement relates to the ability of the CHM/GIS application to store personal information of the registered users. Users are able to update their personal information, if required. This personal information can be used for several other functionalities of the system, including reporting, etc. Also, each user is associated to a unique identifier, which can be used by the audit trailing facility of the system, in order to record all user activities, and to identify the initiator/actor of each activity. Moreover, user profiling can allow users to setup their preferences when using the system, in terms of how data is searched, displayed, etc.

User authentication is also necessary for the system to display the appropriate data to users, as well as to make available the appropriate activities to be executed according to a user's role in the system. In order to gain access to the system, a user logs on the system by entering his/her credentials (username and password). Each user of the system is commonly associated with a certain role. Depending on the rights for each user, the system must control which activities a user can perform, as well as what data a user has access to. After a user logs on the system by providing his/her user credentials, the system authorizes him/her to use certain modules/functions of the system according to his/her role.

Moreover, the system provides the user with the necessary means to import or export data with ease. Data could be of different types (topographic, satellite images, AutoCAD images, etc.). GIS data could be layers which include polygons, points, cadastral maps, etc. Possible source of data import is the Department of Lands and Surveys-DLS (cadastral maps, plots, etc.) whereas data export could be required to update information stored in the systems of the DLS, or store data on the GPS handheld device used by the archaeologists (data on Areas of First or Second Schedule, etc.). For all the data stored in the system, the user is able to create, edit, delete, and search the database through text, numeric fields and images. Additionally, the users have the ability to add user defined fields that can be used for reporting as well. Some functionality is restricted to specific users (public, researchers) based on their user authorization.

All users are able to zoom in and out of a map of Cyprus which contains information related to a cultural heritage resource. They are also able to view descriptions and photos of the sites/antiquities, while information with restriction is available to the public and the researchers through the web application. Furthermore, a user is able to select a specific archaeological site/antiquity and request through the system to display his/her selection on Google Earth or other similar well known and used tools.

Finally, the CHM/GIS application is bilingual (Greek & English). This applies for the cultural heritage data, as well as the user interface of both the client application and the web application. The system allows the administrator to create and restore backups in a straightforward manner and at automated time intervals or when required.

2.2. Functional requirements for archaeological surveys, survey areas, areas under temporary requisition, controlled areas, ancient monuments and movable antiquities

Typical database functionality including the ability to create, edit, delete and query the existing cultural heritage resource records. The application provides the user with the ability to create a record for the respective resource/task (ancient monument, antiquity, archaeological survey, etc.) which will include the data as outlined by the DA and according to descriptions provided for each category of cultural heritage resource.

An authorized user is able to search through the system's database using pre-defined fields (e.g. plot number, cadastral map number, etc.) and collect information that will be useful for the

respective task. The user is also able through the use of the GIS component to select and print maps of a area, as well as choose the type of information contained therein (ancient monuments of the first or second schedule, grids, controlled areas, etc.)

Finally, archaeologists have the ability to record coordinates of findings from GPS devices, and measurements can then be collected and imported with ease into the client application.

3. System design and implementation

The implementation of the system follows well-known and widely accepted technologies and best practices in order to ensure interoperability, ease of use and scalability. The system implements the common 3-tier architecture (data, application and presentation tiers). The system is only accessible to researchers connected to the Government Data Network (GDN) (for the archaeological officers in Pafos and from a Local Area Network (LAN) for the archaeological officers and administrators within the DA building in Nicosia) as showed in Figure 1 below.

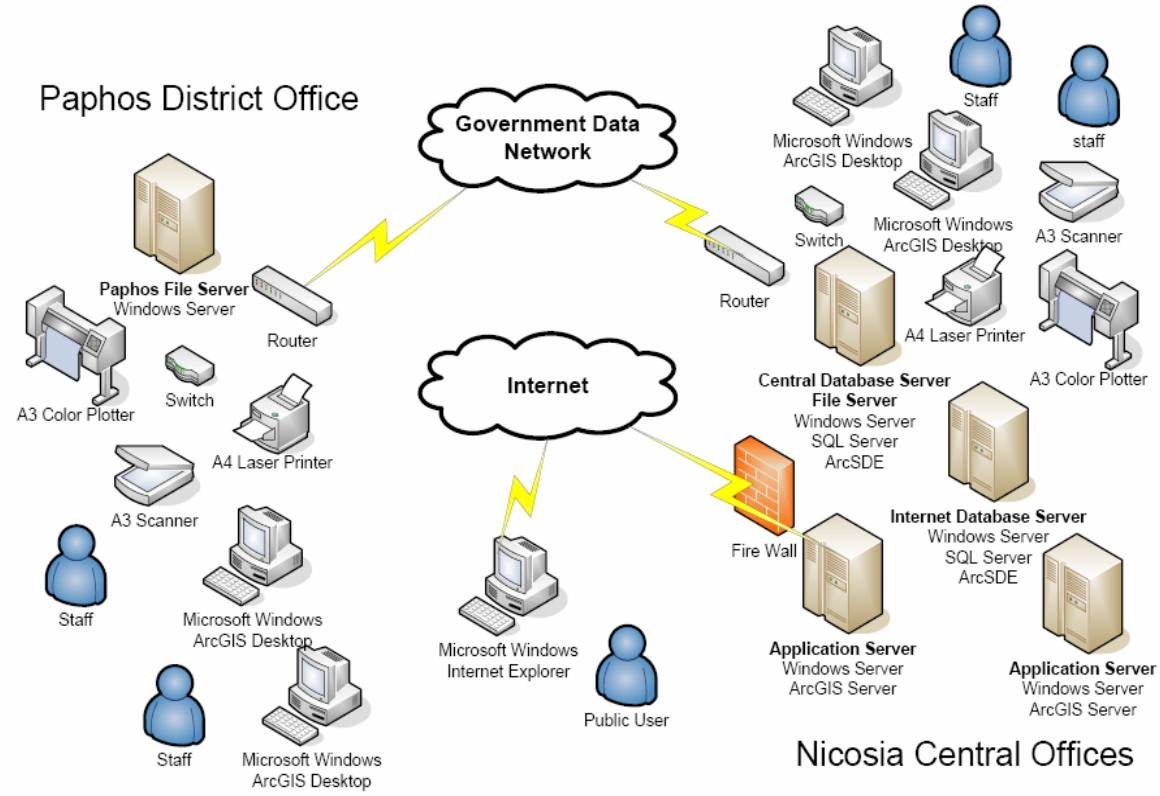

Figure 1: Diagram describing the system architecture. Note that remote users are connected through secure Government Data Network (GDN).

The system is supported by a central relational database management system (RDBMS) of Microsoft SQL Server 2008 R2 which is hosted at the Nicosia offices on a Microsoft Windows Server 2008 R2 operating system. This is accompanied by the installation of ESRI ArcSDE to support the geospatial data. A second server with a similar operating system hosts the installation of ESRI ArcGIS server 9.3.1 known as the application server. Both the database and application servers are replicated on a second set of application and database servers for the purpose of replication which acts as the proxy for the public dissemination of the cultural heritage resources.

The client application of the CHM/GIS is the interface in which the user accesses and manipulates the various tiers of the system. The system integrates the various local and remote

sources and aggregates the data in one place that is easily accessible to authorized users through the client application (Figure 2).

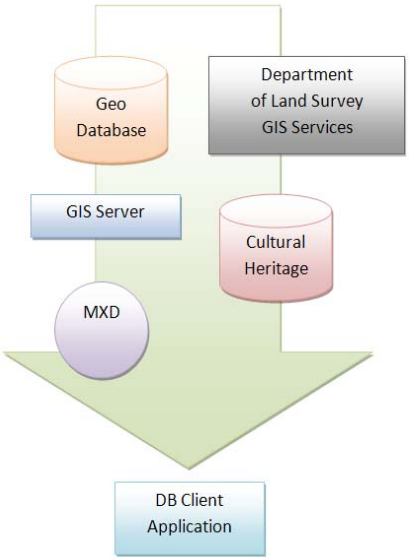

Figure 2: Aggregation of various sources all accessible from the client application.

The main data sources utilized by the system are the cultural heritage inventory stored as an autonomous RDBMS, and the geospatial data utilizing ArcSDE technologies on a distinct RDBMS, neither of which existed in digital form prior to the inception of the project. The cultural heritage inventory followed a data model established by the DA while the geospatial database is a replicate of the cadastral data model used by the DLS. As such, the system follows pre-established processes for information exchange between the two departments.

The separation of cultural heritage data and spatial data is integral to maintain the integrity of the data and fully utilize available features for versioning and data management. Maintaining the integrity of the various heterogeneous data models is vital to the design of the system in order to fully utilize the available features of each distinct source, maintaining bi-directional compatibility, and version controls.

4. Functionality of the system

The client application provides the system with a single interface for the entire workflow of the department and its various users and their tasks, while the web application on the other hand provides an interface for the public to access the available cultural heritage data information in a geospatial context. The various components of the system are described below.

4.1. Client application

The application was implemented with the Microsoft .NET framework utilizing ArcEngine API[1] and ArcGIS .NET SDK[2]. An installation executable is provided for the DA faculty by the system administrator.

After the user authorization and authentication which takes place upon initialization, typical and basic processing tasks such as creating, editing and querying existing cultural heritage inventory items can be accessed through a familiar user-friendly windows interface (Figure 3).

[1] http://www.esri.com/software/arcgis/arcgisengine/index.html
[2] http://resources.esri.com/help/9.3/ArcGISDesktop/dotnet/concepts_start.htm

Complimentary tasks such as advanced searches, result filtering, digital asset management, in this reciprocal communication interface context according to user authorization. The single interface provides concurrent access to the centrally located data with a shared bibliography while also providing controls for data validation (consistent shared vocabulary and uniformity), concurrency (prevention of simultaneous edits) and versioning (edit history and time stamping providing users).

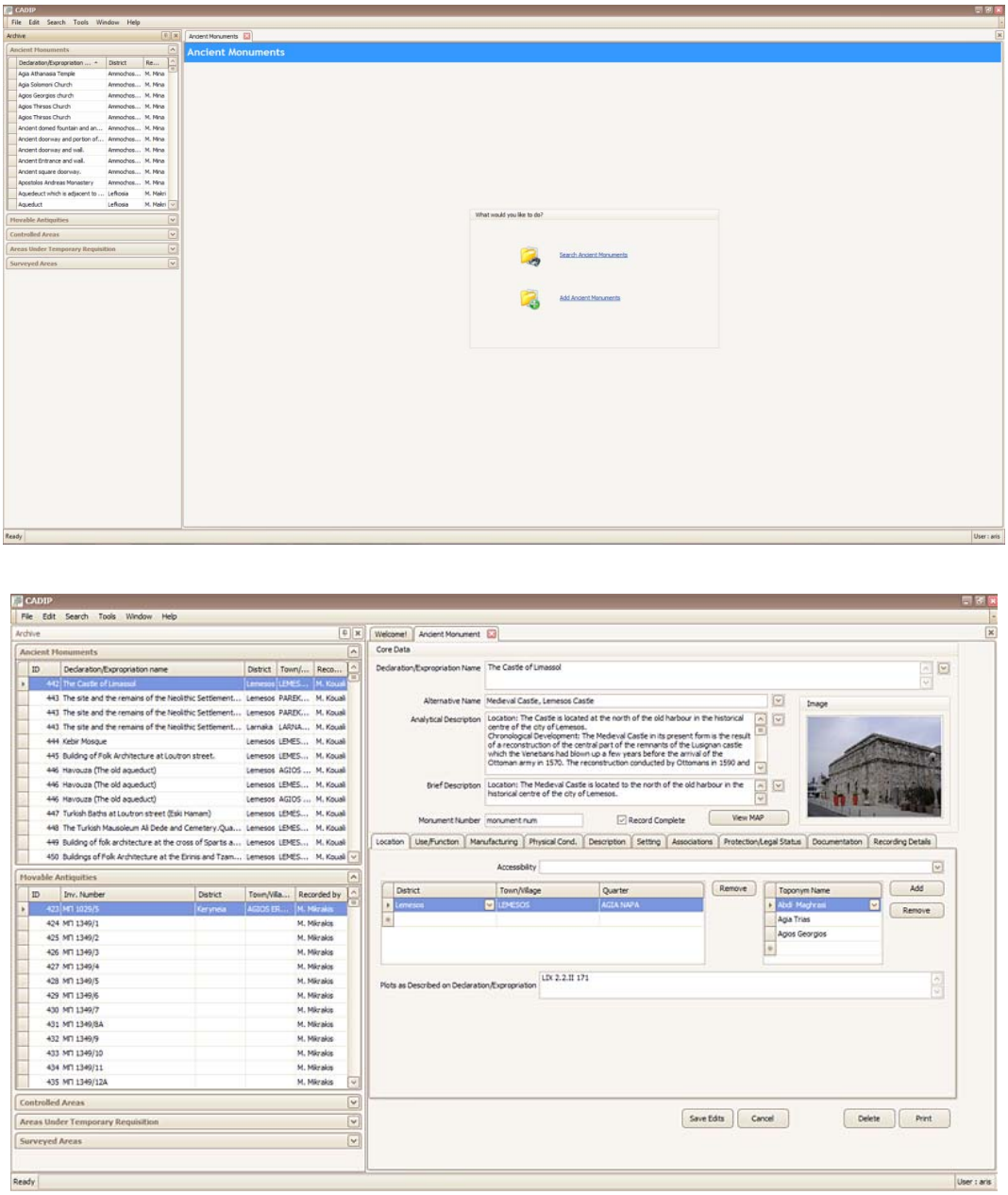

Figure 3: Familiar graphical user interface (GUI) for cultural heritage management.

The client application integrates a GIS component for the synchronization between the two data models mentioned, printing and reporting functionalities, and map visualization.

4.2. GIS component

The GIS component in the client application has two basic functions:

- Enables the user of the application to quickly associate plots to cultural heritage records.
- Provides a context for the cultural heritage record and assist archaeologists in the understanding of the cultural heritage record.

Seamless integration is achieved through the utilization of ArcGIS Engine API and .Net SDK into the windows form environment. A default MXD[3] file is installed alongside each installation containing preselected layers and symbology with predefined connections to local and remote services which are loaded with the initialization of the GIS modal window. Scale and elevation are automatically adjusted according with the associated spatial features of the record (Figure 4).

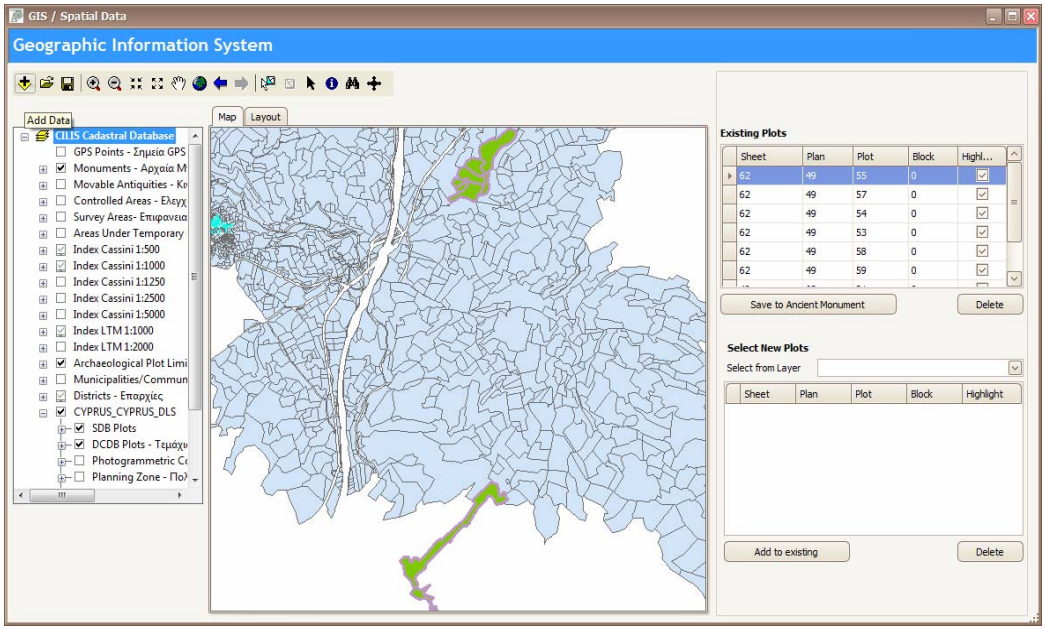

Figure 4: The modal dialog window for the GIS component from within the client application.

The environment provides non-experts without extensive training in GIS applications, the basic toolset to add value to the cultural heritage record. Additional feature layers supply topographic and cartographic information for reference. At the same time, advanced use is not prohibited but encouraged in a controlled user interface. The advanced user is able to add data and save custom changes without affecting the integrity of the shared spatial data. Nevertheless, authorized users have the ability to visually associate spatial data to inventory items or cultural heritage records.

The feature layers use the local cadastral plot data along with dynamic queries to the cultural heritage database to geo-tag the ancient monuments and movable antiquities in spatial context. A map based plot selection process assists the user to visually identify related plots and select then save associated geospatial data to a cultural heritage record as shown in Figure 5 below.

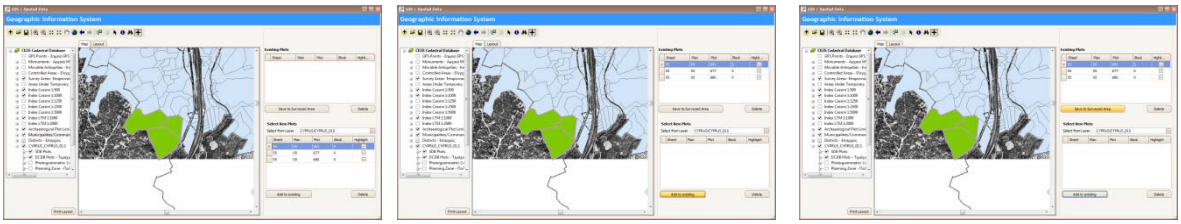

Figure 5: Process of selecting/associating spatial data based on cadastral information Sheet/Plan/Block/Plot.

[3] File extension for an ESRI ArcMap document (map project file).

The map includes cadastral plot outlines, administrative units, geo-morphological and topographic features including Index Cassini and LTM models at different scales by default. The GIS component draws from both local GIS services, while utilizing queries across databases to present local data, and remote web services provided by GIS servers at the Department of Land and Survey. Additionally every user has the ability to customize each client MXD so as to include any spatial data according to user preference such as GPS points, satellite image data, aerial photographs, orthophotographs, including CAD files or site specific spatial data which may add value to the cultural heritage record by saving documents as attachments to the resource record from within the client application.

Fully integrated print and reporting functionality assists the authorized user in creating and exporting maps of specific areas of interest, including related information that may then be taken offline to assist in real world applications such as excavations or surveys (Figure 6), streamlining the workflow of the DA, which until now might have been a cumbersome process between departments.

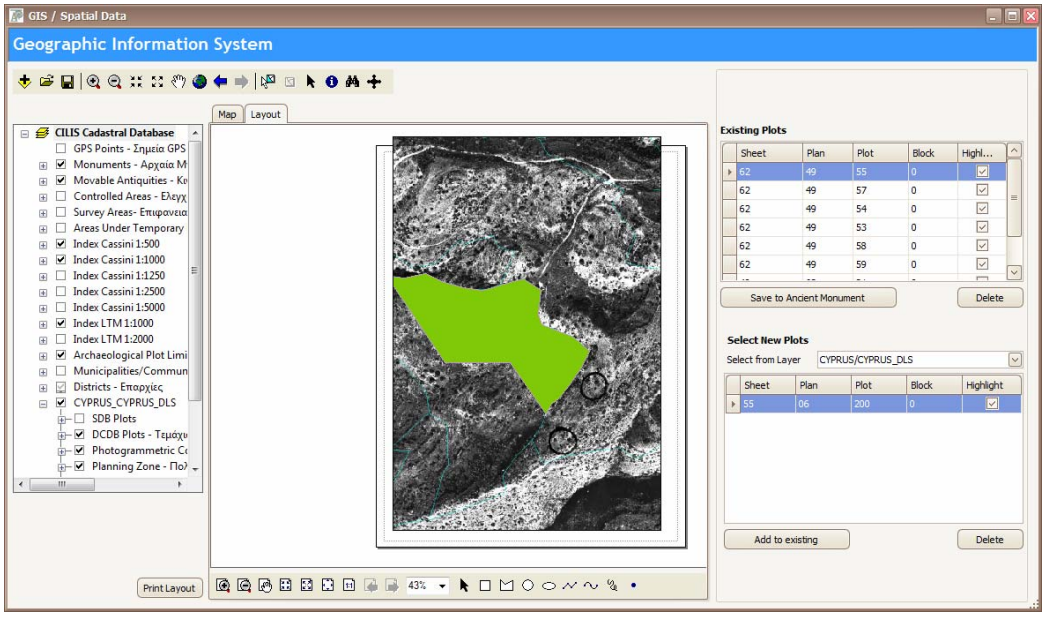

Figure 6: All ArcGIS desktop print functionality is integrated into the application GIS component.

4.3. Synchronizing data between sources

Upon initialization of the GIS dialog the consistency between local spatial data and remote spatial data is checked as a background process. If the "business logic" cannot validate the spatial data on remote services, it is likely that the spatial data has been updated and local spatial data is determined to be outdated. The visual emphasis that is given to inconsistent spatial data then relies on the user for manual correction (Figure 7).

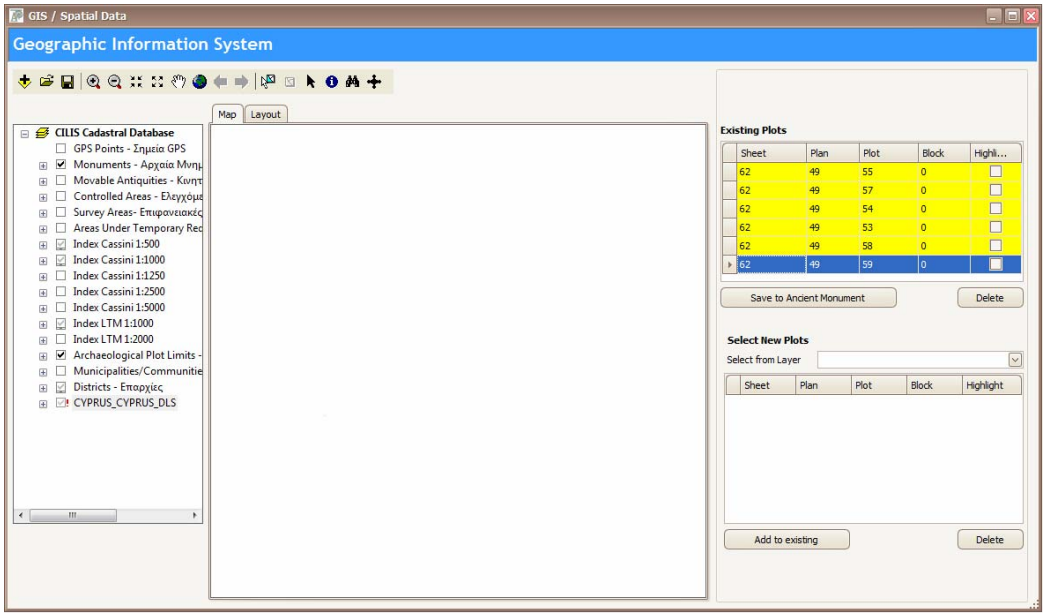

Figure 7: Upon initialization of GIS dialog selected/associated spatial data is cross referenced with remote spatial data to validate consistency. Spatial data that cannot be confirmed is highlighted for the attention of the user.

There are separate processes available to users with administrative privileges that may run synchronization business on demand and create reports with outdated or newly selected cadastral plots to assist the DA in the offline process of request and acquisition from the DLS according to policy.

4.4. Web application

For web publication, a parallel system has been established replicating the main system but within a perimeter network (otherwise known as demilitarized zone [DMZ]) as recommended for securing confidential data for web access. Both the geospatial database and the archaeological database are replicated excluding data not suitable for public dissemination. This secures the confidential data of archaeological inventory, according to internal policy, exposing only those plots of the first schedule and the monuments contained therein including any antiquities that have been approved for publication.

Considering the audience of the web application to the “citizen” and non-expert, the navigation provided is both map based (zoom in/zoom out, pan, etc) using known regions, administrative units and thematic routes and text-based utilizing queries through free-text forms to access publicized data and consequently auto focus extent of map based on results (Figure 8).

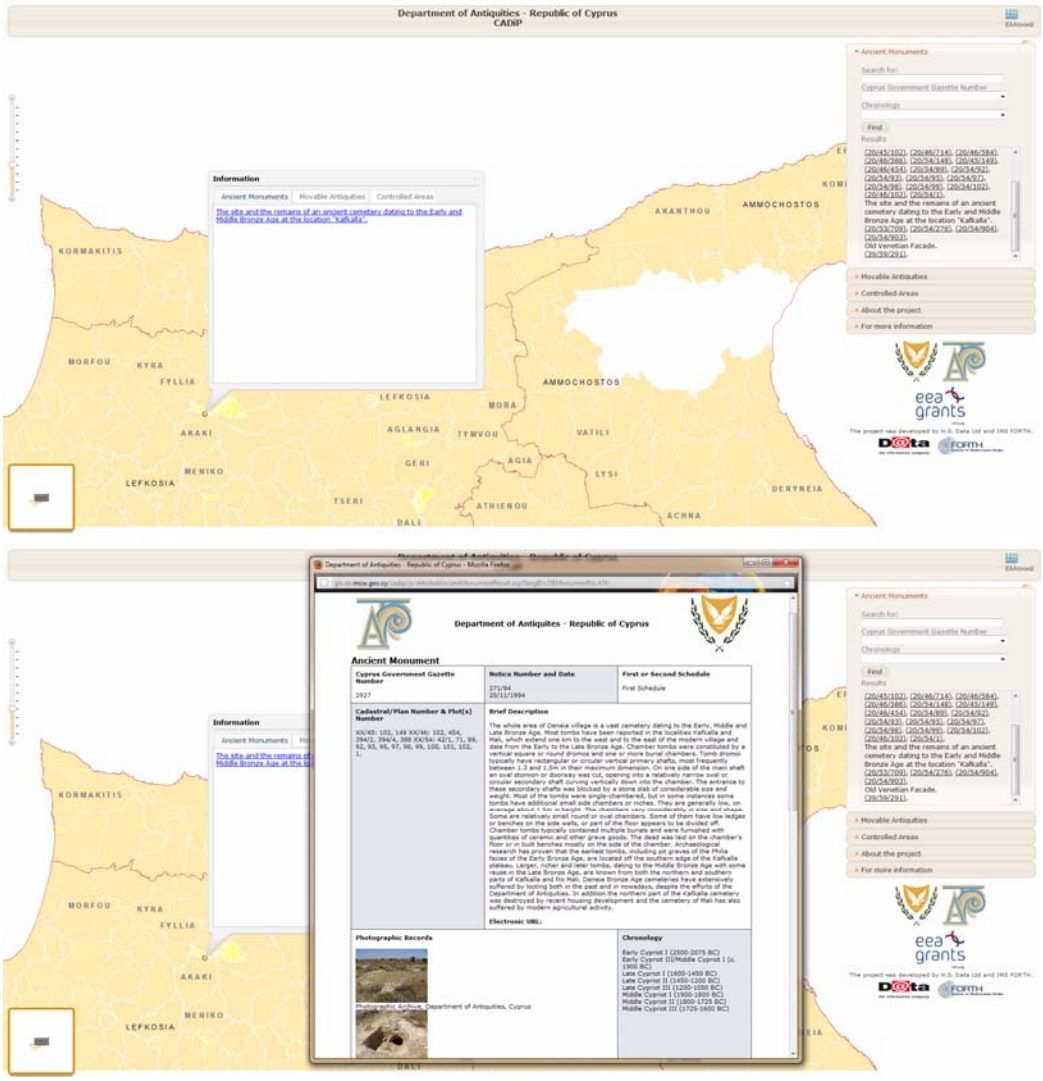

Figure 8: Top: The info window of visually selected plot displaying list of ancient monuments. Bottom: Detail info window of the ancient monument.

5. Conclusions

The particular research was made possible in order to have a fully integrated application for the cultural heritage resources of Cyprus. The system is capable of managing both movable antiquities and immovable monuments and all the diverse information regarding them by integrating a customize database with a dynamic GIS that is able to refresh its geospatial database at regular time intervals and by various authorized users.

The system promotes better management of the cultural heritage of Cyprus and accomplishes this by respecting and supporting the existing workflow while offering features and tools that simplify existing processes. It is the first time that a cultural heritage management solution aggregates such functionality and components, including the various heterogeneous data models and sources from GIS and web services into a client application with a visually intuitive environment familiar to the user thus allowing for the quick adaptation of non-experts into the geospatial context. The system allows also the future upgrade of its components and the extension of its functionalities.

The particular application will be of major importance to the cultural heritage managers of Cyprus, allowing them to form a detailed archaeological cadastral that can be of help for the preservation of the monuments and the better organisation and planning of large scale construction works through the island. At the same time, the application has an added value for researchers who will be capable of accessing an exhaustive inventory of the archaeological sites and the accompanied monuments and finds of them, together with any related information and bibliography. Finally, the Web accessibility of the bulk of the archaeological sites will be of importance for the promotion and dissemination of the cultural heritage of Cyprus.

Acknowledgements

Special thanks go to Constantinos Philiotis of H.S.Data, Chrysanthi Kounnou of the Department of Antiquities, Demetris Hadjigeorgiou of the Department of Lands and Surveys of Republic of Cyprus and to Giorgos Papadakis.

References

[1] Tantillo, M.D., 2007. GIS Application in Archaeological Site of Solunto, *Proceedings of the 21st CIPA symposium*, Athens, Greece.

[2] Lo Tauro, A., 2010. Geomatics: Research of Novel Applications in Heritage Management, Vector1 Media & V1 Magazine (http://www.vector1media.com/article/features/11520-geomatics-research-of-novel-applications-in-heritage-management.html, accessed on 29.4.2012).

[3] Gillings, M. and Goodrick, G. T., Sensuous and reflexive GIS: Exploring visualization and VRML, *Internet Archaeology*, no 1, (http://intarch.ac.uk/journal/issue1/gillings_index.html, assessed on 29.4.2012).

[4] Meyer, E., Grussenmeyer, P., Perrin, J-P, Durand, A. and Drap, P., 2007, A web information system for the management and the dissemination of Cultural Heritage Data, *Journal of Cultural Heritage*, volume 8, issue 4, pp. 396-411.

[5] Van Leusen, P. M., 1995. *GIS and archaeological resource management: A European agenda, in G. Lock, Z. Stani (Eds.), Archaeology and Geographical Information Systems: A European Perspective*, Taylor and Francis, London, pp. 27–41.

[6] Sarris, A., Bichta, K., Giasta, M., Giourou, A., Karimali, E., Kevgas, V., Margetousakis, K., Peraki, E., Soetens, S., Topouzi, S., Tripolitsiotis, A. & Tzaneteas, K., 2002. A Web-based Digital Archaeological Map of Lasithi, E. Crete, *Archaeological Informatics: Pushing the Envelope – CAA 2001, Computer Applications and Quantitative Methods in Archaeology, Proceedings of the 29th Conference*, Gotland, April 2001, edited by Goran Burenhult, BAR International Series 1016, Archaeopress, England, pp. 309-324.

[7] Niccolucci, F., 2001. Archeologia in Rete, *MondoGIS*, p. 64-65, Giugno 2001

[8] Sarris, A. , Peraki, E., Chatzoyiannaki, N., Elvanidou, M., Kappa, E., Kakoulaki, G., Karimali, E., Katifori, M., Kouriati, K., Papadakis, G., Papadopoulos, N., Papazoglou, M., Trigkas, V., Athanasaki, K., 2009. Time Drilling Through the Past of the Island of Crete. In *Technology and Methodology for Archaeological Practice: Practical applications for the past reconstruction / Technologie et Méthodologie pour la pratique en Archéologie: Applications pratiques pour la reconstruction du passé, edited by Alexandra Velho, Hans Kamermans. Proceedings of the XV UISPP World Congress* (Lisbon, 4-9 September 2006) / Actes du XV Congrès Mondial (Lisbonne, 4-9 Septembre 2006), Vol. 37, Session C04, BAR -S2029, pp. 115-123, 2009.

[9] Sarris, A., Trigkas, V., Papadakis, G., Papazoglou, M., Peraki, E., Chetzoyiannaki, N., Elvanidou, M., Karimali, E., Kouriati, K., Katifori, M., Kakoulaki, G., Kappa, E., Athanasaki, K., Papadopoulos, N., 2008. A WEB_GIS Approach for the Cultural Resources Management of Crete: The Digital Archaeological Atlas of Crete, *in A. Posluschn, K. Lambers & I. Herzog (eds.), Layers of Perception. Proceedings of the 35th International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA)*, Berlin, Germany, April 2–6, 2007. Kolloquien zur Vor und Frühgeschichte, CD publication – p. 242, Bonn 2008.

[10] Iacovou, M., Stylianidis, S., Sarris, A. & Agapiou, A., 2009. A Long-Term Response to the Neen to Make Modern Development and the Preservation of the Archaeo-Cultural Record Mutually Compatible Operations: The GIS Contribution, *22nd CIPA Symposium*, Kyoto, Tokio, Japan, October 11-15, 2009.