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The registration and monitoring of cultural heritage sites in the Cyprus landscape using GIS and satellite remote sensing

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Abstract

In order to protect cultural heritage sites in the landscape from damage and destruction, authorities need to maintain a record (database) of the known sites in the areas for which they are responsible. The better the record, the easier and cheaper it is to minimise conflict between planning and the construction of new roads or any other development. Cultural heritage sites can comprise burial mounds, old settlements, old roads and numerous other features. A good and well-organized cultural heritage database can therefore facilitate sustainable cultural heritage management. The use of GIS and satellite remote sensing tools can assist such task. High-resolution satellites facilitate the development of methods for observing even the smallest features and thus promote a systematic utilization of satellite data in the mapping and monitoring of cultural heritage sites. This pilot project addresses these issues by initiating the development of a basis for a sustainable, up-to-date and cost-effective decision-support methodology which relies upon satellite remote-sensing for mapping and monitoring cultural heritage sites and then the use of GIS for cultural heritage sites registration

1. Introduction

The availability of cloud free images for operational projects is very important and depends on the geographical position and the prevailing weather conditions for the area of interest [KS90]. Countries such as Greece and Cyprus are characterised by good weather conditions and the availability of cloud free images. As shown by [HCR00] the high availability of cloud free images of Cyprus increases the potential of using satellite remote sensing techniques for any application in the Cyprus area. Indeed, satellite remote sensing can be also used as a supporting tool in conjunction with GIS and ground measurements (for example, geophysical, GPS measurements) for the monitoring and registration of cultural heritage sites [HTI05].

This paper provides an overview of the methodology adopted for monitoring cultural heritage sites and then using of GIS for cultural heritage sites registration. Results from the preliminary investigations have been also presented.

2. Satellite Remote Sensing

The basics and the pre-processing steps of satellite remote sensing are briefly presented below.

2.1 Introduction

The recent advances in remote sensing recording systems and image processing techniques, together with the development of high accuracy Global Positioning Systems makes the remote sensing technology as a valuable tool for the retrieval of archaeological information and the management of monuments and sites.

As shown by several other investigators, archaeological research uses satellite remote sensing for assisting the users for:-

- identifying environmental parameters related with the location of the archaeological sites
- identifying the topography of archaeological monuments

- Assessing the spectral signatures of archaeological sites with the ultimate goal of developing predictive archaeological models. In this way, satellite remote sensing constitutes a method of archaeological information retrieval, without the use of excavation or intensive survey procedures [SMG*98] and [Sar00] .

Landsat Thematic Mapper and SPOT satellite images are widely used for deriving information about the earth's land. Especially Landsat TM and ETM image data are widely used for several applications in Cyprus (see Figure 1) due to the fact that almost a single image covers the whole island [HCR00]. High resolution imagery from satellites such as IKONOS and QuickBird has been available for several years, and has proved its usefulness in the mapping and surveillance of remote areas.

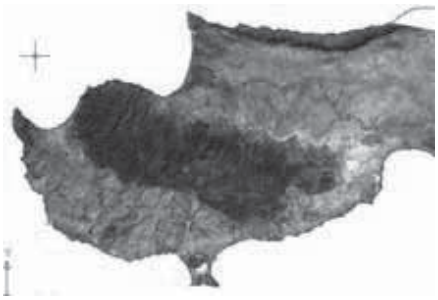

Figure 1: *Landsat-5 TM satellite image of Cyprus acquired on 3/6/1985 (partial scene). Distribution of some cultural sites is shown for Paphos and Limassol District areas.*

2.2 Pre-processing of satellite images

The images that will be used in this project must be pre-processed prior to the use with the GIS data.

Generally the main categories of pre-processing of image data are geometric and radiometric corrections, which are, performed prior to main analysis. Radiometric corrections are distinguished between those effects which are scene-related such as atmospheric, topographic and view angle effects, sensor calibration, illumination and target characteristics and those which are sensor related such as sensor calibration and de-striping [Mat01].

Geometric correction: Remotely sensed images are not maps. The transformation of a remotely sensed image so that it has the scale and projection properties of a map is called geometric correction. Geometric correction was carried out using standard techniques with ground control points and a first order polynomial fit [Mat01]. For the Landsat and SPOT image data of the Cyprus area, twenty well-defined features in the images such as road intersections, corners of large buildings, airport runways, bends in rivers and corners of dams were chosen as ground control points.

Radiometric correction: The use of multi-temporal scenes acquired at different dates or the use of satellite imagery acquired from different satellite sensor for example from Quickbird, IKONOS and Landsat ETM+ 7, radiometric correction must be applied so as to obtain the same comparable units [Mat01].

Calibration in units of radiance or reflectance is an important processing step before atmospheric correction can be applied. Satellite images were converted from digital numbers to units of radiance using standard calibration values. Then the next step was to convert the at-satellite radiance values into at-satellite reflectance using the solar irradiance at the top of the atmosphere, sun-earth distance correction and solar zenith angle.

Radiation from the earth's surface undergoes significant interaction with the atmosphere before it reaches the satellite sensor. The aim of atmospheric correction is to recover, as far as possible, the reflectance at the ground surface. In this study, the darkest pixel atmospheric correction was applied to every image [HCR03].

3. Geographical Information Systems (GIS)

In this project, the participants highlight the need to develop GIS cultural resources, with capabilities of processing and modelling digital images, for the whole island for any further application in which the cultural site is a part of their project. Indeed, this system will reduce the high cost of surface surveying and archaeological site registration and assessment during or prior the course of large scale construction works (for example highway construction, expansion of rural estates, construction of waste dump areas etc). Several other authors in the literature demonstrate the importance of using GIS in conjunction with the use of satellite remote sensing for monitoring cultural heritage sites [Gue99, JC95]. For example, the Laboratory of Geophysical-Satellite Remote Sensing & Archaeo-environment of the Institute for Mediterranean Studies/F.O.R.T.H. launches a WEB site that used to host the results of a project that works with the development of a GIS for the management of archaeological monuments and the mapping of archaeological sites of Lasithi region in Crete (Greece) [Sar00].

Indeed, the partners in this project suggest the following database of the system with the results to be hosted also in a Web-GIS site:-

- digitised geological,

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- topographic and land-use maps, any available thematic mapping information
- road network
- satellite imagery (Landsat, SPOT, Quickbird, Ikonos)
- accurate location of sites (achieved by a systematic GPS survey) and their visible extent and DEM products (for example, see Figure 2)
- accompanied by a dynamic data base regarding the archaeological information of each site, including photographic material and bibliography

The advantage of GIS lies in their ability of updating their geographical information index in a continuous and interactive mode, processing and storing large volume of diverse origin data and creating thematic maps based on specific inquiries. The above can be used in archaeological research for modeling the diachronic settlement patterns of a region, locating and outlining the limits of high probability archaeological candidate sites, studying the communication or defensive networks, specifying cost surface regions used for the exploitation of natural resources, etc. The construction of digital thematic maps that present various cultural and environmental information, could be extremely useful in solving problems resulted by the environmental and development plans, suggesting specific solutions for the protection, preservation and management of ancient monuments.

By using the Landsat TM image of Cyprus shown in Figure 1 and the GIS overlay shown in Figure 2, the thematic map shown in Figure 3 has been produced. The continuous insertion of information will create a complete system of monitoring cultural sites/monuments around the whole island of Cyprus.

Figure 2: *GIS map of Cyprus including some features from its current database.*

Figure 3: *Overlay of GIS location-information on a Landsat-5 TM satellite image of Cyprus acquired on 3-6-1985: Registration of the selected cultural sites based on the information provided by the developed database*

4. Pilot Studies

The following areas of interests have been registered using the methodology presented in the previous sections using Quickbird high-resolution satellite images:-

- House of Theseous in Paphos (see Figure 4)
- Aphrodite Temple at Kouklia in Paphos (see Figure 5)
- Kourion Theatre in Limassol (see Figure 6 a and b)

Figure 4*: Use of GIS in conjunction with satellite image acquired on 23/12/2003 for the 'House of Theseous in Paphos'*

Figure 5: *Here is a sample figure Use of GIS in conjunction with satellite image acquired on 23/12/2003 for the Aphrodite Temple at Kouklia in Paphos*

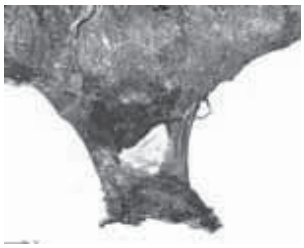

Figure 6a: *Use of GIS in conjunction with satellite image for the Kourio Theatre (cultural site in Limassol)*

Figure 7b: *Use of GIS in conjunction with satellite image for the Kourio Theatre (cultural site in Limassol)*

5. Conclusions and Future Work

This paper shows the methodology adopted as well the beneficial use of satellite remote sensing and GIS tools for the registration and managing of cultural sites in the Cyprus Island, as a part of the project themes that have been already agreed by the partners. The high availability of cloud-free images increases the potential for using satellite remote sensing technologies for monitoring and up-dating all the information required to build and enrich our GIS library. Further actions of the project are shown below:-

- Extend and enrich our GIS library with more data regarding information related with the topology, history, land-use changes etc of the cultural sites around the whole Island of Cyprus.
- Obtain spectral signatures using ground spectro-radiometers so as to assist our future satellite image acquisitions in the monitoring and up-dating the information nearby the cultural sites.
- Employ GPS ground campaign for obtaining more accurate locational details of the cultural sites.

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References

[Gue99] GUERMANDI, M.: Protection of the Archaeological Patrimony and G.I.S. Paper presented at the *International Symposium of Computer Applications in Archaeology*, Dublin, Ireland (1999).

EUROGRAPHICS Workshop on Multimedia (2004)
N. Correia, T. Chambel, J. Jorge and Z. Pan (Editors)

[HCR03] HADJIMITSIS D.G., CLAYTON C.R.I., and RETALIS A.: Darkest pixel atmospheric correction algorithm: a revised procedure for environmental applications of satellite remotely sensed imagery, *Proceedings 10th International Symposium on Remote Sensing*, 8-12/9/2003, Barcelona -SPAIN, organised by NASA, SPIE CONFERENCE, p.414 (2003).

[HCR00] HADJIMITSIS, D.G, CLAYTON C.R.I., RETALIS A. and SPANOS K.: Investigating the potential of using satellite remote sensing for the assessment of water quality in large dams, and irrigation demand, in Cyprus, *Proceedings of the 26th Annual Conference and Exhibition of the Remote Sensing Society, RSS2000*, University of Leicester, UK, 2000.

[HTI05] HADJIMITSIS, D.G, THEMISTOKLEOUS K. AND IOANNIDES M.: The use of Satellite Remote Sensing for the management of cultural heritage sites in Cyprus, *XX Symposium of CIPA, **The** ICOMOS & ISPRS Committee on Documentation of Cultural Heritage*, Torino-Italy, September 2005 (2005), p.356

[JC95] JACOLI, M. and CARRARA A.: GIS-based multivariate model for identifying archaeological sites, Calabria, Southern Italy. *Paper presented at the International Congress on Science and Technology for the Safeguard of Cultural Heritage in the Mediterranean basin*, Catania, Italy, 1995.

[KS90] KONTOES, C., and STAKENBORG, J.: Availability of cloud-free Landsat images for operational projects, The analysis of cloud-cover figures over the countries of the European Community, *International Journal of Remote Sensing*, 11(9), 1599-1608, 1990

[Mat01] MATHER P., *Computer Processing of Remotely-Sensed Images*, John Wiley, UK, 2001

[SMG*98] SARRIS, A., L. MARAGKOU, A. GKIOUROU, CH. KARATHANASIS, M. STEFOULI, TH. MAVROIDIS, E. KARIMALI, E. GIANNOULI, G. GAVALAS, G. ASVESTAS, K. GEORGILA, D. IOANNOU and VRONTAKI E.: The island of Amorgos: micro-scale & macro-scale remote sensing. Paper presented at the 31st *International Symposium on Archaeometry*, Budapest, Hungary, 1998

[Sar00] SARRIS A.: Cultural Resources Management Through the Application of Ground-Based and Satellite Remote Sensing and Geographical Information Systems: A New Digital Cultural World, *ECPR Conference on Culture and Regional Economic Development - Cultural, Political and Social Perspectives,* organized by the Department of Planning and Regional Development (DPRD), Centre for European Studies, University of West of England (UWE), ECPR, Standing Group on Regionalism, School of European Studies, Gardiff University in Wales, University of Thessaly, Volos, 28-30 September 2000.