Development and use of a 4D GIS to support the conservation of the Calakmul site (Mexico, World Heritage Programme)

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ABSTRACT.

The present project proposes to develop and implement an "Information Management System" for the conservation authorities of the Biosphere Reserve and Archaeological Urban Centre of Calakmul. This online system will allow Mexican managers of Natural and Cultural Heritage, and scientists to store, share and create interaction between their data, in order to coordinate various actions of conservation, management, planning, monitoring and research undertaken in the area. It will benefit from new developments in the GeoICT, Archaeomatic and Spatio-temporal Analysis, Computer Vision and Earth Observation fields and will integrate 2D GIS layers, 3D objects and time. An innovative scientific protocol is proposed to incorporate complex archaeological data in a GIS.

1 INTRODUCTION.

1.1 *Aims.*

In the present project, the name "Calakmul" refers to an ecological reserve including an ancient Maya city. The study zone lies in the South East of the Campeche State, in the middle of the Yucatan peninsula (Mexico).

The Calakmul Biosphere Reserve was created in 1989. It covers an area of almost 7.300 square kilometers and constitutes one of the largest protected forests of the tropical zones. It shelters rare species of flora and fauna. It also includes many archaeological sites, Calakmul being the most important one. This pre-Colombian city has been registered on the World Heritage List (cultural part) in 2002.

Within recent years, settlement pressure, farming and new extraction of commercial timber caused threats to this natural and cultural heritage. In order to help the Mexican authorities INAH (Instituto Nacional de Antropologia e Historia) and CONANP (Comision Nacional de Areas Naturales Protegidas) to preserve it, UNESCO proposed to make use of Belgian expertise. Accordingly, four research teams were selected and funded by the Belgian Science Policy Office (BELSPO) and formed a consortium in charge of the project.

1.2 *Description.*

The so-called "Development and use of a 4D GIS to support the conservation of the Calakmul site (Mexico, WHP)" project started in December 2007. Following UNESCO requirements, the consortium proposes to develop and implement an "Information Management System" for the conservation authorities of the Biosphere Reserve and Archaeological Urban Centre of Calakmul. This system will allow Mexican managers and scientists to store, share and create interaction between their data, in order to coordinate various actions of conservation, management, planning, monitoring and research undertaken in the area. It will also assist them in their reporting activities and to apply for a nomination ("mixed site") at UNESCO in the framework of the World Heritage Convention.

2 4D GIS.

2.1 *Concept.*

The present project is based on the use of new technology and scientific developments for the conservation of natural and cultural heritage. Thus it will benefit from new developments in the GeoICT, Archaeomatic and Spatio-temporal Analysis, Computer Vision and Earth Observation fields.

The information management system will indeed be an online tool integrating 2D GIS layers and 3D objects, large and small scales layers and time.

To do so it will use recent advancements and emerging open standards, but also innovative method and data models to integrate archaeological data and carry out spatio-temporal analysis. It will combine new computer vision techniques to produce 3D models of buildings and works of art from digital photograph sequences. Finally, it will use newly available Formosat 2 satellite images to investigate the possibilities to document Maya ruins: buildings or evidences of man-made structures. This data set, together with SPOT, ASTER and LANDSAT data will also be used to elaborate a land use map of the entire Biosphere Reserve and for change detection.

The information management system will be used as the main data repository to store all data referring to the archaeological inventory, the individual cartography for Calakmul and the cartography of the large nature protection area. This tool will have the following capabilities:

- Manage and visualise data, small and large scale at the time, in 2D and 3D.
- Monitor processes, like eg. the restoration of the site and the land use changes in the surroundings.
- Perform spatial analysis, for the purpose of regional and local planning.
- Facilitate reporting (at national level and towards UNESCO (WHP/MAB...))

As the project has just started, technical choices concerning the system and open standards to be used (eg 2D Map Viewer with time slider coupled with a Content Management System; information models and data formats for 3D GIS: Collada, X3D, CityGML, etc. and OGC WebServices) have still to be taken based on the user requirements analysis. Following this short description of the whole project, we will thus basically focus hereafter on the Cultural Heritage data modelling question and on the use of Earth Observation data for Natural and Cultural Heritage management.

2.2 *GIS, Remote Sensing and World Heritage*

Remote Sensing offers many useful and sometimes indispensable data that can be integrated in a GIS for the mapping, monitoring and management of World Heritage sites, either natural (parks, landscapes...) or cultural (monuments, archaeological sites...). GIS and Remote Sensing are thus excellent tools to support the monitoring process that is required for the good conservation of World Heritage sites (BELSPO, 2002).

With respect to Cultural Heritage and archaeology, as far back as the middle of the eighties, Anglo-Saxon archaeologists were the firsts to take advantage of GIS, especially in a predictive modelling perspective. During the nineties, professionals involved in inventories of Sites and Monuments found in GIS a particularly attractive technology offering a map–based representation of sites' locations. Then came interest for spatial analysis dedicated to archaeological questions (Wheatley & Gillings, 2002).

Having overtook the technological appropriation phase, scientists are henceforth debating about theoretical concepts subtended their researches on GIS. Indeed, initial 2D representation gives way to an increasing involvement of volume and time dimensions, although current GIS vendor solution do not allow such variety of dimensions (Lefebvre, 2006).

On the other hand, it is more and more admitted that, in speaking of the Cultural Heritage domain, the principal challenge lies, not so much in collection or geo-localization or even modelling of the data, but in the manner of processing related non spatial information (Blaise & Dudek, 2006).

In this domain, very high resolution satellite images can be used to monitor archaeological remains or to map large sites not covered by vegetation thus providing valuable information for Cultural Heritage management as well.

With respect to Natural Heritage, remote sensing data can be used to create up-to-date maps even for the most remote and inaccessible places where no recent maps are available. It can help to delimitate management zones and to monitor land cover and vegetation changes caused by natural disaster or human activities.

3 DATA

3.1 *Archaeological data*

3.1.1 *History of discoveries*

Inhabited for more than 1500 years, left and even forgotten since the end of the ninth century, the Maya archaeological site of Calakmul was rediscovered in 1931 by an explorer: Cyrus L. Longworth..

The first cycle of real archaeological records took place in 1932, under the supervision of Sylvanus G. Morely, sponsored by the Carnegie Institute. Subsequent researches have been done by several teams. First of them directed their attention to topographical and mapping survey. Excavation operations really began in 1984, with William J. Folan (Universidad Autonoma de Campeche - UACAM), and since 1994 by Ramon V. Carrasco (INAH). To add to this, international teams are nowadays cooperating with Mexican scientists on some specific spots. (Giorgi & alii, 2006; Niccolucci, 2006; Šprajc, 2008).

The results of their works, combined with epigraphic studies, historical analysis and other knowledge domains, shows that we are in front of a very important place. Indeed, during its apogee at the early classic period, Calakmul was the largest city of the Maya region and had to assure its hegemony by any means, peaceful or not. It was a feared jungle chieftain until the end of the seventh century A.D. when Jaguar Paw, king of Calakmul, was defeated after a bloody battle against Tikal, the rival city. From that moment on, began the slow decline of the head snake kingdom (Folan & alii, 2001; Vidal-Angles & Domínguez-Turizza , 2003).

3.1.2 The urban centre

Spread over an area of 30 square kilometres, with more than six thousands archaeological structures, the city appears like a vanished urban centre now covered with vegetation. The core of the town has been built upon a great natural flat-topped hill, partially lain out to base platforms of pyramids, palaces and other temples. Those buildings are split up into several poles: a central place and smaller groups placed in spokes. Oriented along a north-south axis, the central place was a magical space used for ceremonies and rituals. Its north and south sides are occupied by pyramids (Folan & alii, 2001; Vidal-Angles & Domínguez-Turizza, 2003). The biggest one (Structure II, south side) rests upon a 140 meter square base and rises up to 55 m. The west side of the plaza is bordered by what archaeologists think to be an astronomical complex related to the solstices and equinoxes. This function is also taken on by another small building (structure VIII) just near the north side pyramid. The lengthy structure IV, situated on the East Side of the quadrilateral, was possibly associated with administrative and palace matters. In the middle of this rectangle, structure V divides the square into two sections and had ritual functions too. Around that pole, the other groups of buildings are dedicated to ceremonials and civil functions. Well away from that important core, most of archaeological remains have not been excavated yet. However, hydraulic settlements designated to supplying water have been discovered, like other logistical settlements (Vidal-Angles & Domínguez-Turizza, 2003).

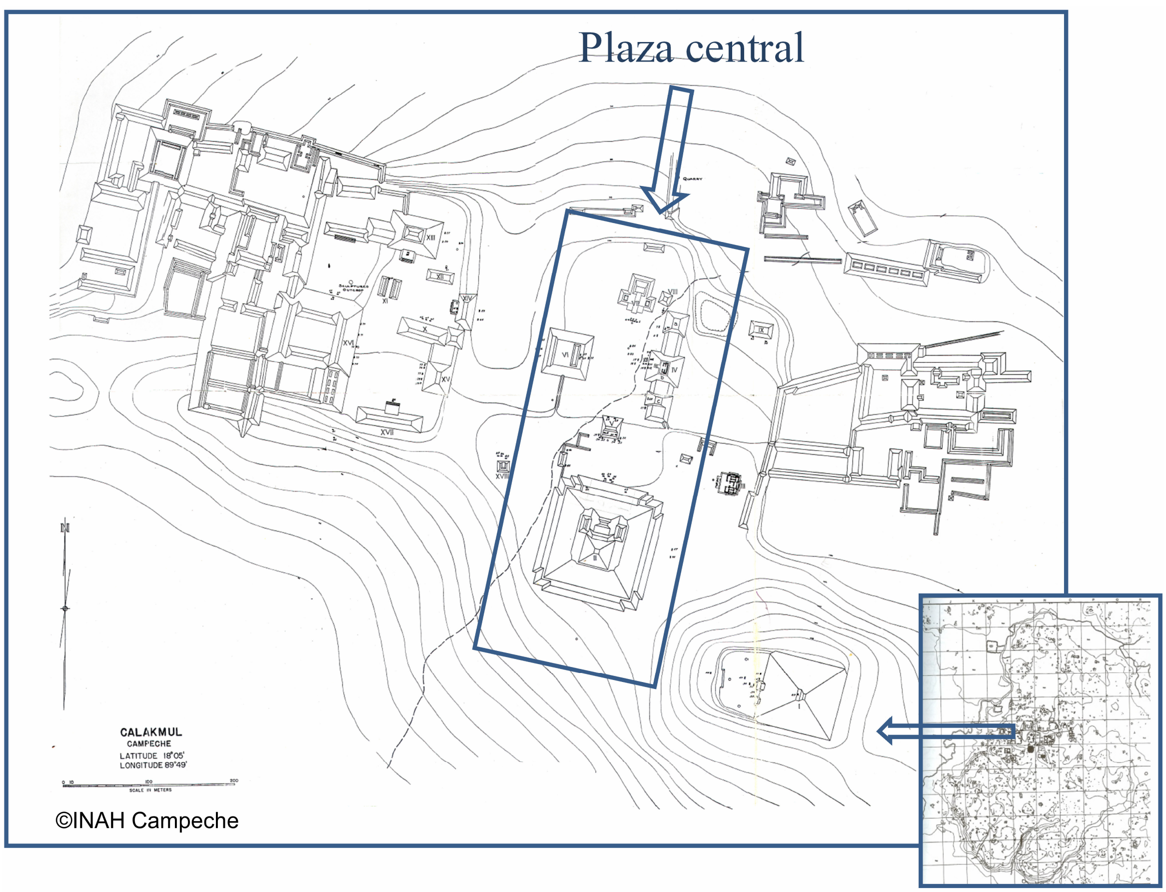

Figure 1 Urban Centre of Calakmul

As it is now, the site remains like it was before its disuse, during the Late Classic period. But the most surprising thing lies under the facades: each monument hides - and fortunately protects - one or more earlier building phases, often magnificently well preserved. On account of this, Calakmul is seen as an unrepeatable witness the daily life of a gone civilization: wall paintings, low reliefs, decorated ceramics depict unexpected scenic aspects like, for example, the funerary rituals.

3.2 *Remote Sensing data*

Thanks to BELSPO financial support, new Formosat 2 images are currently being acquired. Formosat 2 sensor is a new Taiwanese satellite launched in 2004 that offers 24X24 km images with 2m resolution (PAN – 8m MS). This will allow us to obtain the first very high resolution satellite mosaic over the entire reserve. In addition, LANDSAT, SPOT and ASTER archive data will be used.

4 METHODS

4.1 *Models for archaeological data*

To model archaeological data, we have planned to put into practice the scientific protocol recently proposed by H. Galinié, X. Rodier and L. Saligny (Galinié *et al.*, 2004; Rodier & Saligny, 2007). Based on the F. Bouillé's Hypergraph Based Data Structure method (Bouillé, 1977) and the Peuquet's triad (Peuquet, 1994), it requires, using a rigorously formalism, the transformation of heterogeneous data into robust entities (urban objects) delimited by three domains: the spatial, social and temporal features. This method aims at studying urban archaeological contexts, especially to get their dynamics of change. On that goal, it notably suggests avoiding information redundancies.

On the other hand, research about ontology undertaken by computer science and geomatics specialists (Zlatanova, 2000; Billen & Zlatanova, 2003) shows promising results and potential solutions with concepts like juridical, fictional and abstract objects. They should be useful to model data with or without incomplete spatial components. At last, new triangular model (Van De Weghe *et al.*, 2007) for time representation will also be tested.

4.2 *Image processing techniques*

The innovative method chosen here to extract information from satellite imagery is the object-oriented image processing technique. In contrast to traditional image processing methods, the basic processing units of object-based image analysis are image objects or segments, and not single pixels. The classification to produce the land use maps is thus not done on the basis of imagery pixels but on the basis of image objects detected during the segmentation process. This will increase the time-efficiency as well as the potential for products updating since segmentation and classification procedures can be transformed into standardized protocols and stored to be applied to other datasets.

5 CONCLUSIONS

While the main goal of this project consists in elaborating a whole and efficient integrated system combining various data, its major scope concerns Cultural Heritage in all its complexity. To take it into consideration, cooperation with Belgian and Mexican partners, know-how and knowledge transfer, flexibility and cleverness will be necessary. By bringing it to fruition, this project will produce results reusable for other Cultural Heritage sites.

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