UNESCO/WHP -BELSPO Project Results:
(2003-2010 (2 WHP- cooperation phases))

CALAKMUL

Project fiche 'Calakmul 4D GIS' - BL/F3/UN23 – Geographic Information Management (GIM) and BL/02/UN24- Universiteit Gent (UGent) and BL/01/UN25 – Katholieke Universiteit Leuven (KUL) and BL/12/UN26 – Université de Liège (ULg)

Project title : **Development and use of a 4D Geographic Information System to support the conservation of the Calakmul site (Mexico)**
(Geographic) study area :Calakmul Biosphere Reserve and Calakmul Archaeological site (Yucatan Peninsula, Mexico)

Data used: **Formosat-2 and SPOT 5 and 4 satellite imagery**

Context and objectives

The R&D cooperation agreement signed in 2002 between BELSPO and the WH-Center aims to mobilize the Belgian scientific expertise to support the State Parties in the development of their capacity with respect to World Heritage site management and more specifically in the use of innovative technology such as remote sensing, ICT, 3D modeling, etc for the conservation of natural and cultural sites, while meanwhile enhancing Belgian research excellence and expertise in these fields. The Calakmul 4D GIS project was funded by BELSPO thanks to the budget available in the second implementation phase (2006) of this agreement.
A workshop entitled "International Workshop on the Use of Space Technologies for Natural and Cultural Heritage" was organized in 2005 in Campeche (Mexico). On this occasion, the first project idea was discussed between BELSPO, UNESCO and INAH and the Calakmul site was selected because of its "mixed" nature (both cultural and natural).
This forms the general context in which the Calakmul 4D GIS project has been funded.

The main objective of the demonstrative project was to develop and implement an Information Management System dedicated to World Heritage site managers. This system was intended to support the daily business of managers of natural and cultural heritage places by allowing them to create, record, share, visualise and analyse information relative to site conditions, conservation, restoration, management, monitoring and planning actions. Consequently, this system had to be developed according to the requirements of UNESCO and the local partners. Calakmul 4D GIS integrated a research component focussing here on the spatio-temporal analyses of archaeological data. Moreover, besides the development and the transfer of technology, it was important to build capacity at local level and to train the Mexican partners in order for them to become self-sufficient in the use of the delivered tools.
In addition to this main goal, the Calakmul 4D GIS project also aimed at raising awareness for conservation of heritage and at promoting UNESCO sites values.

Methodology

A Consortium of Belgian partners has been formed and worked in close collaboration with UNESCO representative Mr Mario Hernandez and with the Mexican institutions in charge of the management of the natural and cultural heritage respectively CONANP (National Commission of Protected Natural Areas) and INAH (National Institute of Anthropology and History).
A multidisciplinary approach was followed and the project was thus carried out by complementary research teams. The work was distributed according to the specific knowledge and expertise of the partners:

• Scientists from the Department of Geography of the Ghent University did research on spatio-temporal representation and analysis of archaeological data. In addition to this main task, they also contributed to the project by carrying out topographical measurements, generating 3D content and elaborating posters.
• Scientists from the European Centre of Archaeometry of the University of Liège were responsible for archaeological data collection and construction of the archaeological database, part of the Calakmul 4DGIS. They also offered their expertise in the management of archaeological data with respect to its integration in the system.

- Scientists from the engineering faculty of the Catholic University of Leuven (VISICS team) further developed the Arc3D web service allowing to create three-dimensional models based on sequences of standard digital photos. They also generated 3D content and participated to the R,T, I capacity building.
- GIM was in charge of the project coordination and was responsible for designing and developing the Calakmul 4DGIS "Information Management System", the analysis of satellite imagery (natural and archaeological aspects) and production of maps for the nature reserve. GIM experts ensured interaction with local users in Calakmul region and with the central INAH office in Mexico city , BELSPO and UNESCO and the 'capacity building' (education and training) pillar of the project.

Results

Throughout the project, the needs of World Heritage site managers have been carefully analysed and both the requirements of UNESCO and the site managers have been considered for the development of the Calakmul 4DGIS.

To achieve a good management of heritage, one needs excellent documentation. This means that data has to be generated, recorded and exchanged between the stakeholders at each phase of the process, from the assessment of the site conditions till the application of conservation measures. The integration of the time dimension is also of crucial importance for proper management. Until now World Heritage managers didn't have the adequate tools to perform the tasks in an efficient way.

We therefore first considered all the data types that were generated by the managers and the advanced system was designed to integrate them all as illustrated in the figure below.

The system finally is installed in Mexico City in order to be usefull for all (conservation) sites that might profit from the generated knowledge and the operational demonstration system.
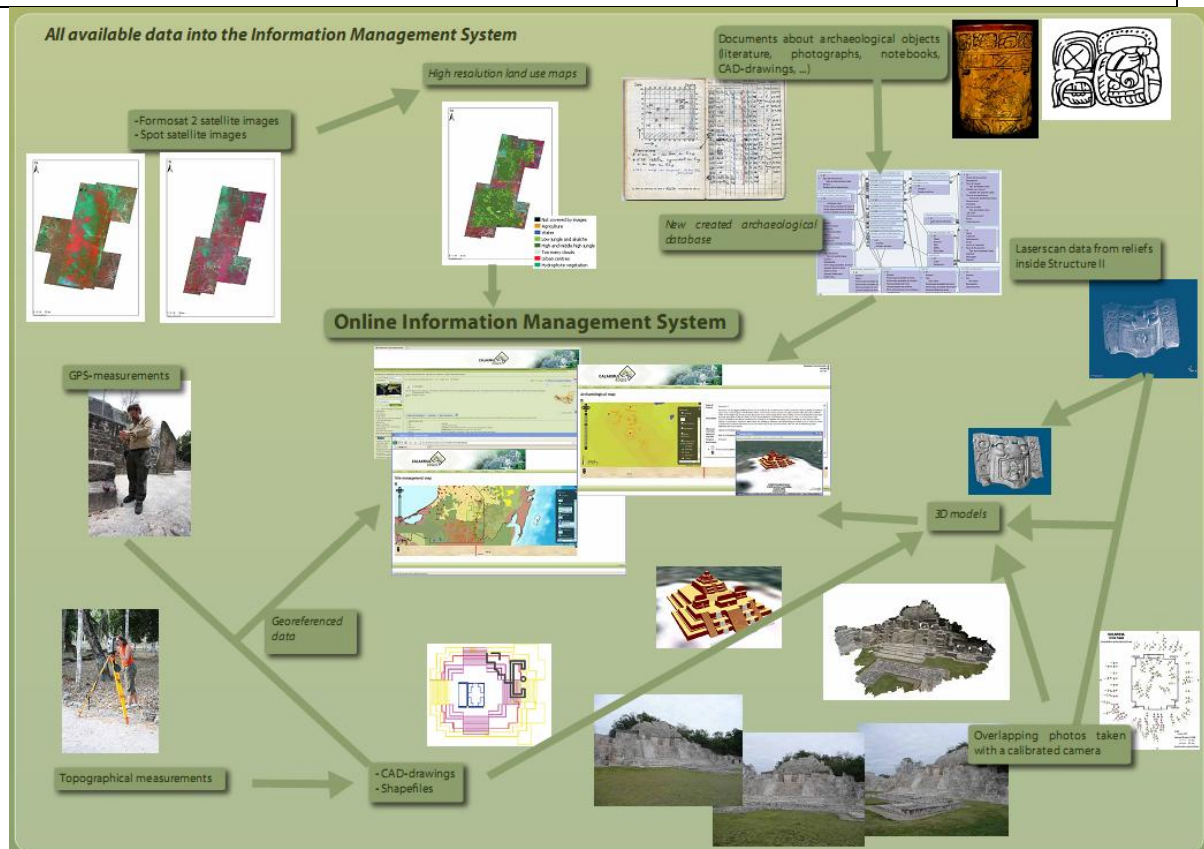
As management involves many departments and people, an online application is the ideal way to provide provide everyone the possibility to work from his workplace.

On the basis of the requirements analysis, the "Information Management System" Calakmul 4DGIS was designed and implemented. Because of the numerous objectives and the various tasks that the different users have to perform, no single one-fit-all software solution was developed. Instead, a flexible approach was selected and the different tools were grouped in so-called "environments" corresponding to specific objectives and thus providing for a specific set of tasks. Likewise, each of the three environments has specific operators with specific goals as illustrated in the figure below. This approach is characterised by a well defined flow of information and allow for a good control of data quality, access to the data and data presentation.
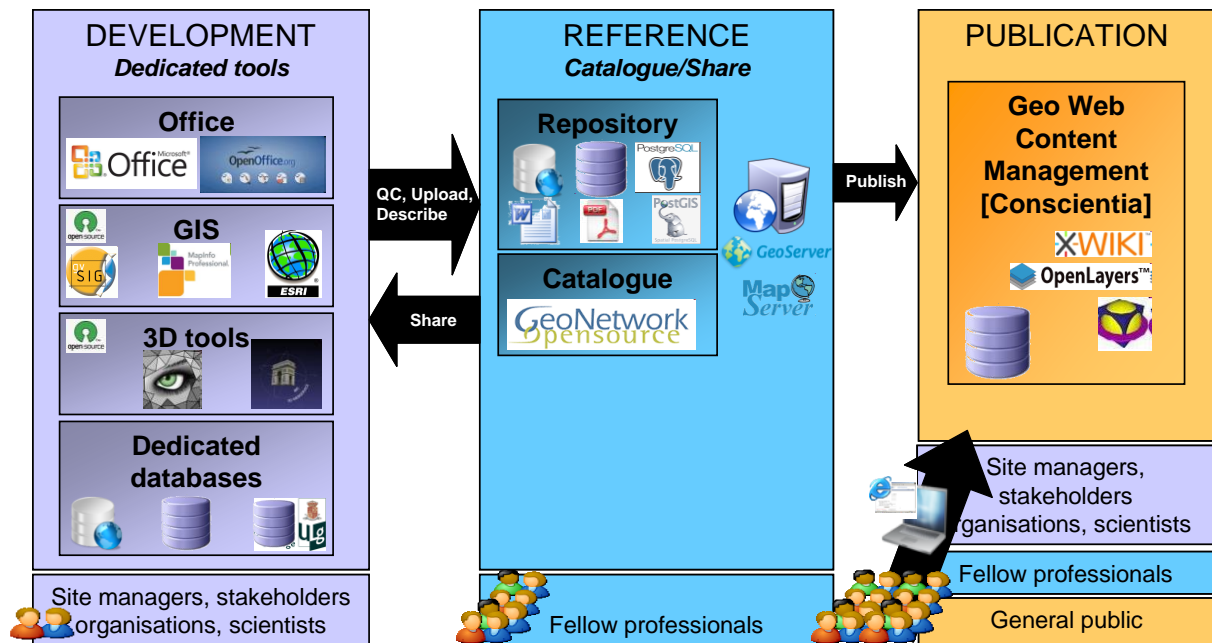
The results of the project are found in every "environment".

Partners from ULg and KUL contributed to the development of the "Development environment". They respectively developed or enhanced:

- A relational archaeological database implemented in Access software and available in Spanish. This relational database includes in different tables, information about archaeological objects, literature, historical events, conservation actions, etc. It supports the activities of the researchers by allowing spatio-temporal analyses and understanding of historical events. It also supports the work of the site managers as new findings as well as restoration activities or other types of intervention can be recorded and documented. Finally, it enables the elaboration of data that can be published in the online part of the system.
- The Arc3D webservice that is used to generate 3D models of archaeological features on the basis of sequences of standard photographs. This service was improved and further automated. Its use was also demonstrated during the different missions and the capacity building phase.

Partners from UGent also developed 3D modelling methods for the elaboration of 3D models on the basis of different types of measurements (photographs with calibrated cameras, total station, GPS, etc). As a result of this activity as well as the one performed by KUL, several 3D models of steles, pyramids, bas reliefs, etc have been generated and made available to the Mexican partners.

GIM developed the "reference and publication environments". Besides the selection and technical implementation of the different software components into an integrated system, GIM also developed specific data models able to handle archaeological and ecological data in a "temporal context" in order to take advantage of the time integration (availability of a dynamic time bar function in the system).

The two main components of Calakmul 4DGIS are the Catalogue and the Geo Web Content Management including the Map Viewer (see screenshots below). They allow for:

- Data/metadata management;
- Data exchange and dissemination;
- Access rights management;
- Large and small scale cartography layers integration;
- 2D GIS layers and 3D objects integration;
- Time integration.

To ensure perfect interoperability, Calakmul 4DGIS has been developed according to open standards.

The achieved result is therefore an advanced integrated Information Management System that has been delivered (with a users' manual) to the Mexican partners and installed on a local server.
Moreover, thanks to the capacity building, the Mexican partners are now able to update the content of the system and to use it in support of their daily business.
The project has been complemented by a BELSPO financed post-doctoral Mexican experts' fellowship at Ulg.
The research component ,conducted by UGent and focussing on the adaptation of the so-called "Triangular Model" for the analysis of archaeological data, has resulted in several scientific publications and presentations to international symposiums.

GIM conducted research on the use of Earth Observation data for natural and cultural heritage management. Land Use/Land Cover maps were elaborated and followed by a time series/change detection analysis. The potential of remote sensing to document Mayan ruins and to detect evidences of the presence of archaeological remains in a tropical forest environment was investigated.

Finally, the project and its results have been widely promoted thanks to:
- participation of the different partners to national and international events;
- elaboration of promotional material: leaflets, powerpoint presentations, posters, etc;
- elaboration of various scientific publications.

Products and services (peer reviewed article(s),weblink... if applicable: maps, database,)

Publications

A1:
- Qiang, Y., Delafontaine, M., Asmussen, K., Stichelbaut, B., De Tré, G., De Maeyer, P. & Van de Weghe, N. (2010) 'Handling Imperfect Time Intervals in a Two-Dimensional Space', Journal of Control and Cybernetics, vol. 39, no. 4, pp. 983-1010.

- Qiang, Y., Delafontaine, M., Logghe, S., De Maeyer, P. & Van de Weghe, N. (upcoming) 'Visualising and Analysing Time Series Data in GIS', Submitted to Journal of Visual Languages & Computing.

C1:
- Qiang, Y., Asmussen, K., Delafontaine, M., Logghe, S., De Maeyer, P. & Van de Weghe, N. 2010, 'Visualising and analysing time series data in GIS', paper presented to the Workshop of Geospatial Visual Analytics: Focus on Time (GeoVa(t)), Guimarães, Portugal.

- Asmussen, K., Qiang, Y., De Maeyer, P. & Van de Weghe, N. (2009) 'TRIANGULAR MODELS FOR STUDYING AND MEMORISING TEMPORAL KNOWLEDGE', International Conference of Education, Research and Innovation (2009), Madrid.

Asmussen, K., De Maeyer, P., Van de Weghe, N. (2008) "Geïntegreerd conceptueel tijdruimtelijk model (GCTM) voor werelderfgoedsites". Proceedings of the 3rd "Belgian Geographers Day: Geography on the Move". Brussels (Belgium).

Asmussen, K. Visualising Rough Time Intervals in a Two-Dimensional Space; conference paper, "Advances in Soft Computing for Spatiotemporal Information Systems" at the IFSA 2009 World Congress & EUSFLAT 2009 Conference in Lisbon, Portugal in July 20-24, 2009

C. Metral, R. Billen, A.-F. Cutting-Decelle, M. Van Ruymbeke, Ontology-based Models for improving the interoperability of 3D urban information, Proceedings of the Final Conference of the **Cost action C21-**Towntology: Urban Ontologies for an improved communication in urban development projects, (J. Teller, A.-F. Cuting-Decelle, R. Billen ed.), Liège, p. 69 – 84, (2009)

C. Metral, R. Billen, A.-F. Cutting-Decelle, M. Van Ruymbeke, Ontology-based approaches for improving the interoperability between 3D urban models, ITcon, Submitted: June 2009, Revised: August 2009, Published:

Tigny V., De Maeyer P., Billen R. and Van Gool L. 2010. Calakmul 4DGIS: an Information Management System for the Conservation of Natural and Cultural Heritage in Proceedings of the 30th EARSeL Symposium: Remote Sensing for Science, Education and Culture, UNESCO, Paris.

M. van Ruymbeke, V. Tigny, E. De Badts, R. Garcia-Moreno & R. Billen. 2008. Development and use of a 4D GIS to support the conservation of the Calakmul site (Mexico, World Heritage Programme) in Proceedings of the 14th International Conference on Virtual Sytems and Multimedia, Limassol, Cyprus.

M. van Ruymbeke, V. Tigny, E. De Badts, R. Garcia-Moreno & R. Billen. 2008. Development and use of a 4D GIS to support the conservation of the Calakmul site (Mexico, World Heritage Programme) in Proceedings of the 1st International EARSeL Workshop "Advances on Remote Sensing for Archaeology and Cultural Heritage Management", CNR, Rome.

Qiang, Y., Asmussen, K., Delafontaine, M., De Tré, G., Stichelbaut, B., De Tré, G., De Maeyer, P., Van de Weghe, N. (2009) "Visualising Rough Time Intervals in a Two-Dimensional Space". In: Proceedings van "International Fuzzy Systems Association World Congress / European Society for Fuzzy Logic and Technology (IFSA / EUSFLAT World Congress)". Lisbon (Portugal), 1480-1485.

Development and use of a 4D GIS to support the conservation of the Calakmul site (Mexico) V. Tigny, P. De Maeyer, M. Van Ruymbeke and L. Van Gool. Abstract, poster and oral presentation at the Belgian Earth Observation day 2009.

Roland Billen and Muriel van Ruymbeke. 2010. A global view on semantic enrichment of 3D urban models. Workshop of the Cost Action TU0801. Université de Liège. Communication: Semantic enrichment in the archaeological field: the case of Calakmul

Van Ruymbeke, M., Cervera - Xicotencatl, A., Billen, R., & Garcia-Moreno, R. (2011, April 13). Donner un sens aux données: Le cas de la modélisation de l'information archéologique du site de calakmul (Mexico). Paper presented at Archéométrie 2011. Colloque du GMPCA, Liège, Belgique.

In preparation:
Rough Time Intervals in GIS,
Yi Qiang, Katrin Asmussen, Matthias Delafontaine, Guy De Tré, Birger Stichelbaut, Philippe De Maeyer and Nico Van de Weghe to be submitted to International Journal of Integrated Computer-aided Engineering on Soft Approaches to Information Processing

Other publications
Article "Calakmul 4D GIS – La technologie au service de la préservation du Patrimoine" in Science Connection magazine from BELSPO (French and Dutch versions)

Article "GIM to provide Earth Observation services to UNESCO for management of World Heritage sites" in EOMag magazine from European Association of Remote Sensing Companies (EARSC)

Paragraph in The International Space Report 2011, the Space Foundation, USA

Article "4D GIS for World Heritage" in GIM Newsletter

4 Project presentation / promotional posters

PhD Thesis Geert Willems (KUL)

Master Thesis Yetkin Ozum Durgun
Evaluating the use of high resolution satellite imagery for the detection of archaeological features in tropical forests: the Calakmul Biosphere Reserve (Yucatan peninsula, Mexico). A thesis submitted to the School of Forest Science and Resource Management / Sustainable Resource Management Program in partial fulfillments of the requirements for the degree of Master of Science, Technical University München, 2009

Calakmul 4DGIS application
http://calakmul.inah.gob.mx

EO based LULC maps of the Calakmul Biosphere Reserve and change detection map

ULg Archaeological database

Execution

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Scientific Poster , international diffusion