DEVELOPMENT OF AN INTERNET-BASED INFORMATION SYSTEM FOR ARCHAEOLOGICAL RESEARCH AND STUDIES ON URBAN HISTORY IN BAALBEK/LEBANON

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ABSTRACT

The project „Urban development in Baalbek“ aims at reconstructing the urban development of the settlement site in the northern Beqa'a and its socio-economical foundations from prehistoric times to the 20th c. Specialists of different disciplines from German and Lebanese research institutions and universities are enrolled in this project. The integration of documentation and data from more than 100 years of scientific research at this site present an important challenge. Since 2001, the German Archaeological Institute (D.A.I.) conducts additional archaeological soundings and architectural documentation of historical building remains in Baalbek, and thus extensive new archaeological and architectural data was added in those four years to the existing documentation
In order to give the different research groups access to the ongoing research and results of the individual projects, the creation and implementation of an internet-based information system adapted to archaeological and architectural research was initiated. Through this tool, interdisciplinary teams working from different locations can be provided with immediate access to the databases and the possibility to jointly continue their updating, and in structuring the different data categories it facilitates their further analysis and interpretation.
In Baalbek, different strategies and tools are used to provide a geometric analysis of the historical cartographic and photographic material, and new solutions are sought for the modelling and structuring of research results, from the central document administration to the web-based databases and finally the integration of all the data and tools into one web-based GIS. The cooperation of users and IT-specialists was crucial for the integrative conceptual process and creation of the databases and the geographical model. The use of open-source software was preferred in view of the potential application of this work for other research projects.

1. BAALBEK

Baalbek is situated in Lebanon in the northern Beqa'a plain at the foot of the Anti-Lebanon mountain range, and has been continuously settled since prehistoric times. In 1984 Baalbek was inscribed on the World Heritage List. The city is famous and a tourist attraction especially for its monumental sanctuary of Jupiter, one of the largest preserved temples of the Roman world.

Figure 1. View from Sheikh Abdallah to the modern city of Baalbek

The sanctuary is more than 300 m long, and the so-called Trilithon stones of the podium were among the largest stone blocks used in construction. The monumentality and good preservation of the ruins impressed travellers of earlier centuries. At the end of the 18th century the english James Dawkins and Robert Wood as well as the french Louis Francois Cassas were the first to provide scientific observations on these remains of Roman culture (Wood, 1757). But nevertheless many questions have remained unsolved regarding specific buildings as well as the cities development and settlement structure as a whole in the context of its economic environment.

2. THE RESEARCH GOAL

The current research initiated in 1997 is based on a cooperation between the Lebanese Antiquities Service and the German Archaeological Institute (DAI).
Since 2001 fieldwork has been undertaken in Baalbek under the direction of Margarete van Ess, scientific director of the Orient department of the DAI. Different German and Lebanese research institutions and specialists are involved. This interdisciplinary cooperation of specialists in Near Eastern archaeology, classical archaeology, ancient history, architectural history, geodesy, hydrology, geomorphology and oriental studies will lead to an understanding of the topographical, urban, economical and social evolution of the sanctuary and the town of Baalbek over a timespan of 5000 years in its surrounding social and regional context.
The research in Baalbek deals with heterogenous remains of different time periods. The beginnings of Baalbek can be traced to a small tell settlement in the 3rd millenium BC (M.v. Ess, 1998), but in the town remains of a hellenistic temple, a monumental Roman sanctuary and representative public buildings of the same time period, a Byzantine church and buildings from Medieval times up to the late Ottoman city of the early 20th century have been found. A multitude of finds from different time periods as well as infrastructural elements, water supply systems and quarries mainly from the Roman period await further study. The geographical area of research not only

encompasses the ancient city and the surrounding region, but also an important number of different time horizons. The stratigraphic sequence of different chronological layers can best be demonstrated in the main sanctuary. The Roman sanctuary and its scarcely known predecessors cover a prehistoric settlement mound. In the Byzantine period a large basilica was built into the great courtyard, and in medieval times the whole sanctuary with its two courtyards and propylon was integrated along with the temple of Bacchus into an Islamic fortress, which in the late ottoman period was partly reused by a settlement inside the preserved building remains (Ragette, 1980; van Ess, 1999).
Some of the structures mentioned above are only known to us from documentation of earlier expeditions, as the modern city nowadays covers large portions of the ancient sites. Furthermore, earlier excavations often irrevocably destroyed younger strata in order to get to the levels of the Roman imperial period. Thus, the documentation from more than 100 years of research forms an important base to our current research, and we can draw from a diverse record of maps, architectural drawings, photos and finds.

3. HISTORY OF RESEARCH

In 1898 the German emperor Wilhelm II. visited the ruins of Baalbek (Neuwirth, Scheffler, Sader, 1998) and was so impressed, that he immediately afterwards initiated excavations and research on the site. Under the direction of Otto Puchstein extensive archaeological and architectural research was undertaken in the sanctuary from 1900 to 1904. The excavation results led to a plan of the sanctuary, that is mostly still valid to this day (Wiegand, 1921-25). Architectural studies, survey photographs and plane-table measurements from this time are at the basis of new complementary studies and measurements, and give us a lively impression of Baalbek at the turn of the 19th century.

Figure 2. View from Sheikh Abdallah to Baalbek, Historical photograph from *Meydenbauer Archiv*, 1904 (Brandenburgisches Landesamt für Denkmalpflege und Archäologisches Landesmuseum, Bildarchiv, Neg.-Nr.: 2083.20)

In the 1920ies the research in Baalbek was carried on by french archaeologists (Collard-Coupel, 1951), and finally after the II. World War the Lebanese Department of Antiquities took over. The main focus was now on the development of tourism, and new excavation areas were opened in other parts of the ancient town. Aiming at fast visible results, large archaeological areas were opened and restored under the direction of H. Kalayan from the 1950ies to the 1970ies (Jidejian, 1975/1998). As the methods and reconstructions are nowadays disputed also among Lebanese specialists, the ancient photos taken during these years as well as the plans provide valuable information about the original situation of architectural fragments before restoration. The work in Baalbek was interrupted by the outbreak of the civil war, and large amounts of finds from these Lebanese excavations were left unpublished and in a preliminary state of analysis.

4. CURRENT FIELDWORK

The long history of research as well as the growing modern town of Baalbek on top of the ancient city were largely responsible for the specific focus of the new fieldwork project undertaken since 2001.
The current project aims at providing a final documentation and scientific analysis of the excavation areas of previous missions, and on studying the material in the depots. On the other hand, new fields of research such as the study of the traditional architecture in Baalbek, work on the quarries and a survey in the surrounding region have been launched.
In the former excavation areas with Roman monumental architecture and remains of the Mamluk and early Ottoman period, these historical maps and photos complement the new architectural plans and studies, all in the goal to understand their shape and function, the different building periods and the relationship between different buildings. In addition, limited soundings are undertaken in order to collect finds from stratified contexts and dating criteria for the associated architectural features.

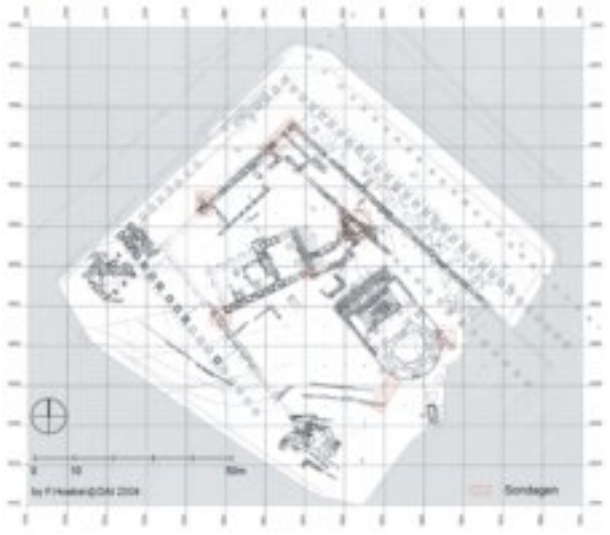

Figure 3. Area of St. Barbara, general plan, documentation by H. Kalayan (grey) and additional measurements (black) and soundings (red)

In addition to the study of finds from current excavations large quantities of unstratified material from older excavations are inventoried, and some detailed studies of specific find groups such as architectural decoration, sculpture, medieval frit ware and ancient lamps have been undertaken (van Ess u.a., 2003).
But the work is not limited to the excavation areas: with the aim to document and understand the development of the town up to the late Ottoman period at the beginning of the 20th c. , research is carried out all over the modern city of Baalbek. For this, the coordinates of preserved buildings are determined on the map, and they are measured and documented regarding their building technique and built-in features.

Besides, specific clusters of the town and representative buildings are documented in more detail in order to establish criteria for typological models and older building traditions.
Through these detailed studies of the traditional building remains and the photogrammetric analysis of the historical photographs the social and demographical structure of Baalbek in the Ottoman period can be eventually reconstructed.
On the other hand, comparisons between the different urban and architectural layout of the city in different time periods can help to elucidate if there were continuities in the development of the town or functional aspects of specific areas through the ages.
New information on the development of ancient Baalbek can also be gained through survey in the surrounding countryside. In 2004, a new survey project was started with the aim to gather information about the economic and agricultural potential of the territory, settlement patterns and communication routes since prehistoric times. For example, one of the questions is how important trade was for Baalbek's economy in relation to the agricultural wealth of the region.
The field survey concentrates on the lateral valleys and hills of the Anti-Lebanon, where numerous well preserved if looted settlements and industrial installations were discovered. In the next years, the archaeological investigation of these settlements will be accompanied by an intensive survey from the hills into the plain and geomorphological studies for this region, which could provide new information on the anthropogenic change of the landscape through deforestation and land use.

4.1 Geodetical Work

A georeferenced geodetic network is at the base of a GIS capable of integrating the results of the different research teams in all of the study area. Beginning with the aforementioned excavation areas, the entire city centre covering about 2 x 2 km as well as the survey area had to be incorporated into this network. Until now, only local grids had been used for the excavation areas of Bustan el Khan, Bustan Nassif, the area of the Venus temple und the Sheikh Abdallah. In the field season 2002 a three dimensional geodetic network was created with tacheometric measurements and integrated into the national system. To further anchor the net geometry important points were confirmed through DGPS measurements. In the course of subsequent campaigns this net was consolidated through further measurements, especially in the city centre, and enlarged towards the surrounding regions.

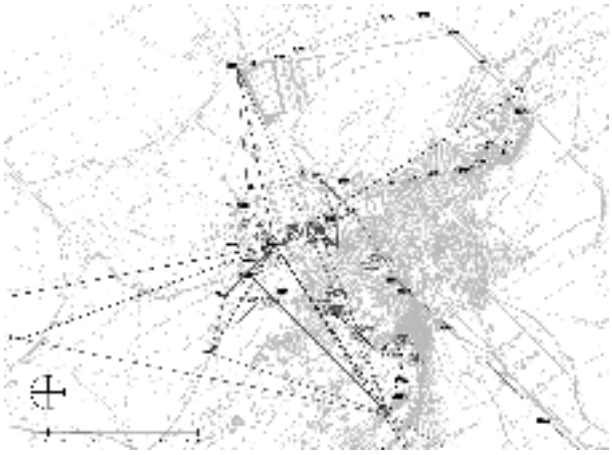

Figure 4. Network geometry over the georeferenced plan of Schumacher from 1904

4.2 Using Historical Material

In addition to the integration of new research results and finds it is the exploitation of preserved documentation from earlier excavations that is at the core of research on the urban development of the town.
The numerous maps and architectural drawings of H. Kalayan from the 1970ies that render the architectural state of preservation at the time are an important source for the detailed study of these buildings.
From the time of the first German excavations at the beginning of the 20th c. 800 large scale photos of Baalbek have been preserved in the *Messbildarchiv des Brandenburgischen Landesamtes für Denkmalpflege und Archäologisches Landesmuseum* (BLDAM). These illustrate details of the ancient buildings as well as panorama views of the town taken from the adjoining hill of Sheikh Abdallah, a mountain ridge of 100m of elevation to the southwest of the town. These panorama views allow through photogrammetric multi image analysis the reconstruction of the Ottoman town, only partly preserved now.
Among the aerial photos of the french mandatory period between 1920 and 1947 stored at the *Institut Français du Proche-Orient* (IFPO), aerial photos of Baalbek from the years 1927, 1933, 1937 and 1940 are preserved, which allow through photogrammetric analysis a substantial reconstruction of the urban development at different moments in time.

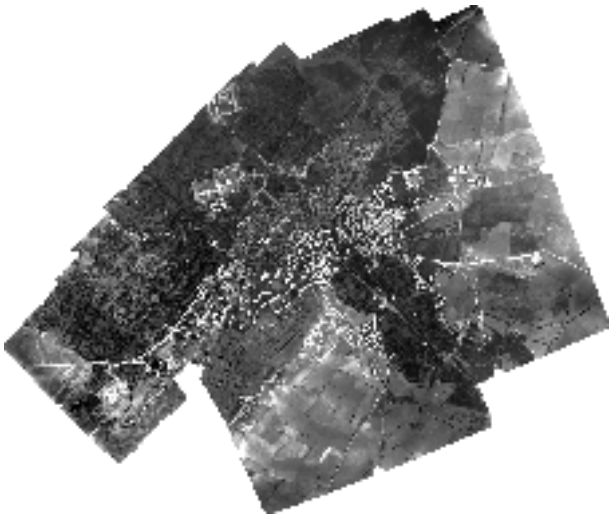

Figure 5. Orthoimage map of Baalbek, generated from historical aerial photographs

While rectified and georeferenced historical maps can be integrated into the overall system and used directly as geometrical basis in a GIS, the geometrical information from historical photos have to be retrieved through a multi image analysis or a stereo evaluation. An exception to this is the creation of orthorectified maps from suitable aerial photos using the height levels from a digital ground model. These photographic maps can also serve as a map layer in a GIS.
Independently from the chosen procedure, the information for the referenciation of maps and photogrammetric analysis determined by the geodetical network enables the immediate integration of any geographical information into a general system of coordinates and absolute height.
In addition to the geometrical analysis of this historical material for the reconstruction of historical buildings, these maps and photos are an important documentation material and should be made accessible in specific databases for further use and research.

5. USE AND SPECIFIC REQUIREMENTS OF AN INFORMATION SYSTEM

The large amount of historical material was complemented during the last fourf years by a multitude of new observations and documents, architectural drawings, catalogues of architectural fragments and finds. A growing number of collaborators and specialists from different national and foreign institutions should be able to access this material in order to be able to integrate it into their research.
The documents are at different levels of elaboration and processing, as it is especially the case for the CAD-drawings, and the heterogenous nature of the geometrical data and the lack of standards for a common data structure have necessitated at a very early stage of the project a central information system. Such a system should prevent problems such as double data sets, different preserved works in progress on otherwise identical data sets and the lack of an immediate access to the continously updated databases by different research teams.
As basic requirements for such an information system we defined a central administration and storage of all the data and documents, extensive search tools in these databases as well as the possibility of visualization of all geographical information. The system should provide an easy, user-customized access through the internet and not require any additional programs to enter the main database portal. The connection to the user should be designed in a way, that data input, research and analysis can be performed directly by the user. For a web-based system like this the questions of access restriction and data security are of uttermost importance. In order to ascertain a long term use of such a system in the future, standardized formats and protocols for the data itself as well as the access to the system and the data exchange have to be chosen. It has to be made certain that access to the data is granted also in the future, and that backups of the stored data are easy and performed on a regular basis.
Finally, the costs of the necessay hard- and software for the implementation, administration and continous care of such a system should not be too high in relation to the costs of the research project and fieldwork.

5.1 Open Source Software for an Internet Based Information System

Especially in the field of web-based database systems there are very powerful open-source varieties such as MySQL (http://www.mysql.de/) and PHP (http://www.php.net), that have been established as standard and are also used with success by large companies. This general acceptance ascertains a longterm future development of this software and thus a continous access to the systems based upon them. Open source software furthermore makes possible an individual adaption and further development of programs. Through the large and independent „community of software developers“ intensive tests of new or enhanced program features take place with an acute concern for aspects of security and stability of the software. In contrast to a number of commercial products, open source software uses mostly standardized formats and protocols for data and communication, so that no dependence on proprioritarian programs occurs and incompatibility between different versions of a program are not to be feared. On the other hand it has to be carefully weighed, if the advantages of open source programs justify the often time consuming effort needed for the installation and adaption.
For the use of web-based systems, the user usually does not need any other software than an up-to-date internet browser. All program features can be used with the usual internet protocols and scripts in the browser, while the software and data are stored on a central server unit. All users are thus working with the same datasets and use the same version of the software. The system may be accessed from any computer with internet connection. For publications in the fields of history of architecture and archaeology this technology has further possiblities of analysis and research regarding other projects on the net. Projects and server programs can be enhanced and updated if necessary, without the necessity for the user to get new software versions. The use of normal internet technologies can on the other hand bring some restrictions in the program features and functions, especially for graphical programs such as CAD and GIS and the uploading of large data files, as they occur for example with rasterdata and images.
But all things considered, the advantages of the use of open source software for the creation of the information system took precedence over these problems.

5.2 Implementation

From the above catalogue of necessary features the following agenda for the creation of the information system was formulated:
1. First all the documents such as drawings, pictures and texts were fed into a web-based document management system.
2. For the integration of specific data on buildings, finds or further information on documents, specific databases were created.
3. For the visualization of the geographical data and in order to provide additional tools for analysis, a web-based GIS was created.
All components are internet based and, except for an internet browser, do not require additional software on the user's end. In the following, the actual implementation of these three components will be presented.

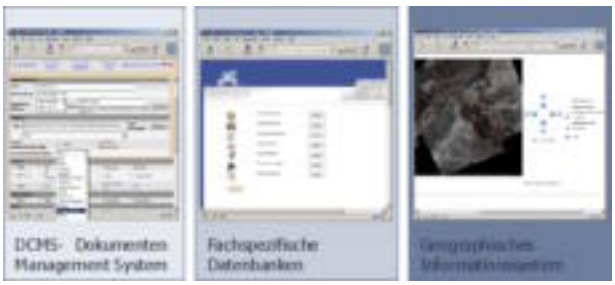

Figure 6. Components of the central information system

5.3 Document Management System

The basic requirements for an information system such as central data storage, common data structures, data backup and editing are already included in a web-based central document index. If this index structure is combined with possibilities to classify according to different properties and research these documents, the result will be a so called document management system.
As software for such a system, the DCMS developed by the *Institut für Bauinformatik* (http://dcms.bauinf.tu-cottbus.de/) at the BTU Cottbus as a research project was selected. This open source software was designed as a Server-Client-System and is made up of a java based administration module („Obelix“), the user module („Asterix“) and a XML-based data base structure (http://www.w3.org/XML/), which are installed and run on a server accessible through the internet.

Through the administration module new projects can be installed, and the organizational principles and document properties (ontology) can be defined for the project. Here takes place the administration of the user accounts and the release and publication of documents. The administration module can be handled through a graphical user interface and can be accessed via network connection.
The user module generates from the query run by the user through his internet browser a set of dynamically generated search results, that can be viewed through the internet browser. Registered users are provided with the possibility to browse through the index structure, to search for documents through defined criteria (ontology), to feed new documents into the system or to delete existing ones. Changed or newly inserted documents are initially saved to an inaccessible part of the system and are only cleared for publication in the system after a check by the administrator.

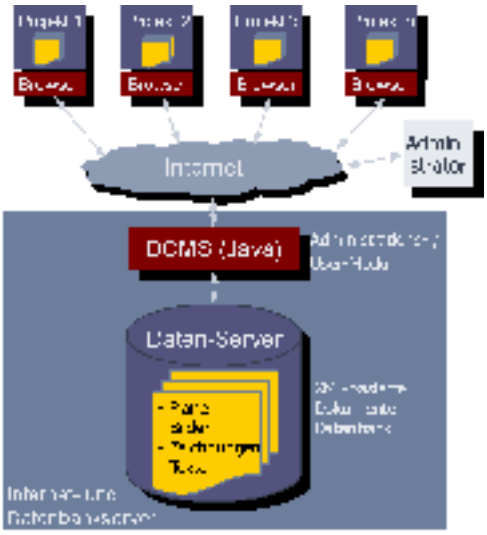

Figure 7. Design and functionality of the Document Management System

All information on the project in question, the index system, the documents and their properties as well as the users are administrated in an XML-based data structure.

5.4 Databases

The storage of complex data sets and added properties of documents as well as the extensive research tools for the analysis of data can only be achieved through specific databases. The conceptual phase for the creation of such scientific databases is of uttermost importance, as complex objects such as buildings or archaeological finds have numerous specific features, and their interrelations and hierarchies have to be structured in a consistent way. For the system presented here an intensive cooperation between users, i.e. archaeologists, architects, geodesists and IT-specialists took place, in order to agree on the potential quantity of the data sets to be incorporated, the complexity of data interrelations and hierarchies, as well as the form and scope of search tools and research possibilities, and in the end to set up a list of required features for the programming of the databases in question.
The kind of database system adapted to archaeological and architectural research is divided into different data base modules. Some modules function as elementary databases and share their data with more specific databases. Basic modules are in this case a photo database, a database for maps and drawings and a bibliographical database, but of course these can also be used independently as individual databases.
Complex objects such as buildings with rooms and additions, stratigraphic and 3-D referenced archaeological finds and architectural fragments and decorations are inserted and edited in three different, specially adapted data base modules. The necessary pictures, maps and bibliographical references are imported from the respective other basic modules, or, if not yet in them, newly added.
For the implementation of these web-based databases the open source server system MySQL was used, as it has established itself as the quality standard for internet pages and platforms for commercial enterprises. The connection between user and data base server is provided by the open source software PHP.

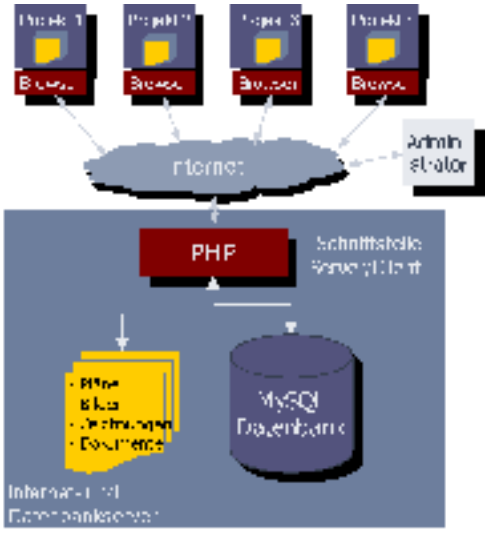

Figure 8. Design and functionality of the internet databases

5.5 Geographical Information System (GIS)

Many of the objects inserted into the databases are geographically referenced and can be integrated into the geodetic network of Baalbek. The analysis and presentation of these geographical relations can be achieved through a Geographical Information System - GIS.
Essential for the actual integration of research results into a GIS is the definition, which data are going to be visualized, to what ends the system is to be used and in what way the selected data need to be structured. In the planning stage it is thus important to include IT-specialists as well as users in order to be able to define the requirements, content and structure. This is often hampered by the lack of experience on the side of the users, so that it is primordial to define goals and weigh the necessary effort in relation to the practical use.
In the case of the Baalbek project, the GIS will mainly be used for scientific analysis and the presentation of research results. Based on maps, plans and aerial photos three-dimensional relations and distributions of objects can be visualized. The underlying maps will be sorted thematically and integrated in different scales to enable varying degrees of detail resolution. New research results such as phase plans for buildings are integrated, and in addition selected geographical areas can be connected to further data sets such as reconstructions, photos or descriptions. Specific search results on the databases should be visualized, and through the GIS referenced objects should be linked to respective informations in the databases. The query possibilities in the databases regarding the information on specific objects could be enlarges through the analysis of

geographical relationships. In a web-based system the access for all the project collaborators is possible, and in a restricted form or for presentation purposes they can also be opened to a broader public.

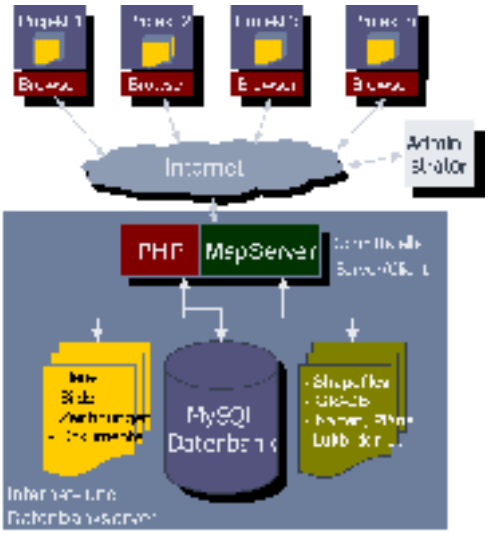

Figure 9. Design and functionality of the internet-based GIS

To implement web-based GIS functions the software MapServer (http://mapserver.gis.umn.edu/), which was created amongst others as an accessory to PHP, will be used. This software provides a large number of functions to process already edited GIS data through the internet. The creation of the GIS data is done using a genuine desktop GIS, such as ArcMAP or Autodesk MAP. The created shapefiles are generated through MapServer, depending on specific database queries or selected display features into a dynamic map view on a web browser. Through the use of PHP as common communication port for the databases and the MapServer a direct access of both systems to each other can be easily configured. Query results from the database can immediately be generated and displayed as map views on the MapServer, and on the other hand properties or informations on objects can be relayed displayed as a data sheet from the respective database.

6. RESULTS AND FUTURE WORK

After one year of work on the information system for the Baalbek project the first modules of the database are working, the web-based GIS is in construction, and the links among the different components of the databases and with the MapServer-GIS have been established. At the current state of work, the scientific gain of this system has yet to be tested, but the implemented modules show already that the previously defined requirements towards the information system can be fulfilled. Through the close cooperation between users and IT-specialists, and due to the intensive discussions and ground work for the conception of the databases, functional modules have been designed that can be combined and linked flexibly. The web-based solution and use of open source software have indeed proved themselves to fulfill the required functions, and the main goals of independent access from any research institution as well as avoiding the purchase of expensive software licences for all the different working groups have been achieved. The modular conception of the system makes possible any number of additions to the system and the used standards guarantee as much as possible a continous functionality of the system in the future without necessitating regular system updates.

Currently numerous archaeological and architectural projects are working on the presentation of their research results in the form of geographical information systems, and although the details of requirements and data structure differ according to the subject, the basic structural requirements are the same. It would be highly useful to work towards common standards and modules, that can be adapted to the specific needs of the different projects.

The goal is not to create one finished and universal information system, but rather a toolkit, out of which the appropriate model can be assembled. The agreement on one standard would in addition potentially provide enhanced research possibilities, such as the simultaneus research in the databases of different projects.

In view of these possiblities, the Baalbek projects tries to document extensively the process and evolution of the system as well as its specific functions and different components. For this, a project related online diary on the evolution history (Weblog) and an online manual based on the Wikipedia technology (http://wikipedia.org/) are integrated into the information system.

In cooperation with the Palatin/Rome project of both the departments of History of Architecture and Geodesy of the BTU Cottbus, an extensive information module on architectural details and features as well as a bibliographical database module and a module for architectural elements is currently being developed. Other cooperations are sought with the aim to build a growing consent on the standards to be used in the future.

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