

Frank Henze

A Distributed GIS Architecture for Research in Baalbek Based on CISAR

Abstract: Research underway in Baalbek extends from the immediate vicinity of the excavation areas to the monumental temple complexes in the centre of the city, covering the entire historical city of Baalbek and its surrounding areas. For the examination of such large-scale areas, geographic information systems (GIS) have been used in archaeology for some years, as these allow geometrical and topological data to be related to thematic information and attribute data. Based on a previously discussed web-based database system, CISAR, a GIS infrastructure that allows the use of both a desktop GIS and a browser-based GIS was established by the Chair of Surveying at BTU Cottbus for research into building archaeology in Baalbek. One important condition for such an infrastructure is the use of standardised procedures for the storage of geo-data, for data exchange and for communication between database systems and client applications. The GIS infrastructure for the Baalbek research project and its individual components, as well as the modelling of geo-data and its integration into a geo-database is presented. Although the infrastructure is still under construction, the server components already installed allow for the creation and demonstration of prototypical applications.

Introduction

Research in Baalbek started in 2002 with several studies with the excavation areas (*Fig. 1, marked in blue*) in the centre of the city. Architectural remains and structures were recorded here during recent years with a high degree of accuracy, complementing numerous historic maps and drawings. In addition, limited soundings have been undertaken in order to collect both finds from stratified contexts and dating criteria for the associated architectural features (VAN ESS ET AL. 2003).

Since 2004, research has been carried out all over the modern city of Baalbek (*Fig. 1, inside the red polygon*) with the aim of documenting and understanding the development of the town up to the late Ottoman period at the beginning of the 20th century. To do this, the coordinates of preserved buildings were determined on the map, and the buildings measured and documented regarding their construction technique and architectural features.

In 2004, a new survey project was started with the aim of gathering information about the economic and agricultural potential of the territory, settlement patterns and communication routes since prehistoric times. The field survey concentrates on the lateral valleys and hills of the Anti-Lebanon, where numerous well-preserved settlements and industrial in-

stallations were discovered (LEHMANN / HENZE / FISCHER-GENZ 2006). The research area extends in a 10 km radius around Baalbek and encompasses three different scale levels for the GIS: a detailed level for the excavation areas, a city level with an area of 2 x 2 km and a large-scale survey level.

Geodetic Reference System

The geometric base for the integration of all maps, plans and research objects into a GIS is a superordinate geodetic coordinate system with connection to a national or global coordinate system. This guarantees a consistent reference for all geo-objects, irrespective of the measurement technique used. The geodetic work for the creation of an accurate reference system started in 2002 and the network geometry was consolidated in the following years, through further measurements, especially in the city centre, and was extended toward the surrounding regions. The network was integrated into the national system using given reference points and important points were confirmed through DGPS measurements, which allows for integration into a global coordinate system (HENZE / RITTER 2003).



Fig. 1. Aerial image of Baalbek with extent of the urban research area marked in red and excavation areas marked in blue. Size of the printed area approximately 2100 m x 1400 m.

CISAR Modules as Thematic Databases for a GIS

The main difference between a simple CAD system and a real GIS is the ability to add thematic information to geo-objects for further analyses. With the CISAR modules, an extensive database system for the storage and analysis of the thematic information already exists for several research objects. Therefore it was a matter of course to use these databases for the planned GIS infrastructure as well.

In principle, all objects, materials and information that have a spatial reference can be integrated into a GIS. Currently, GIS functionality is needed for the following CISAR purposes:

- Information about the borders of excavation areas and soundings as well as the position of single findings is needed from the archaeological module.
- The positions of architectural fragments and findings must be accessible.

- The ground plans for hundreds of buildings measured on site or digitised from aerial photographs should also be available within the GIS.
- All geodetic points with their coordinates, descriptions and sketches are needed for further recordings and measurements.
- Last but not least, the results of the archaeological survey should be available in the GIS for further analysis.

Topographic and Cartographic Bases

Besides these dynamic database objects, several topographic and cartographic bases without database references are needed for a map representation of a GIS. For Baalbek and its surroundings, a large amount of geo-referenced raster data is available in photographic and cartographic form:

- Ortho-rectified historical and modern aerial images show the development of Baalbek at

different points in time at a very high resolution.

- The scanned topographic maps are needed in the GIS for the analysis of the archaeological survey results around Baalbek.
- Numerous historical and current architectural drawings exist of the excavation areas inside the historic city.

From this original raster data, several derived vector data sets were generated for the integration into GIS:

- The infrastructure, land-use and zoning maps for Baalbek were digitised from geo-referenced maps and orthophoto maps.
- A surface model was generated using the digitised contour lines of the topographic maps together with automated stereo-measurements from aerial images.
- Finally, simplified CAD drawings of architectural remains inside excavation areas were created alongside highly accurate hand drawings.

CISAR Core and Extended GIS Infrastructure

The core of this GIS infrastructure consists of the CISAR database modules, where all the objects for GIS integration are stored. The web-based GIS functionality extends the established client-server architecture based on the GIS functions of the UMN MapServer (<http://mapserver.gis.umn.edu/>, see Fig. 2).

UMN MapServer

MapServer provides OGC-compliant interfaces and formats for web-based map presentations, but it is not a fully-featured GIS. The server-based software generates typical web-based map services such as Web Map Services (WMS) or Web Feature Services (WFS) from several sources of geo-data. Besides a cartographic presentation of popular raster and vector data formats, like TIFF / GeoTIFF or ESRI shapefiles, it is also possible to integrate geometry from a geo-database such as PostGIS. The basic structure of

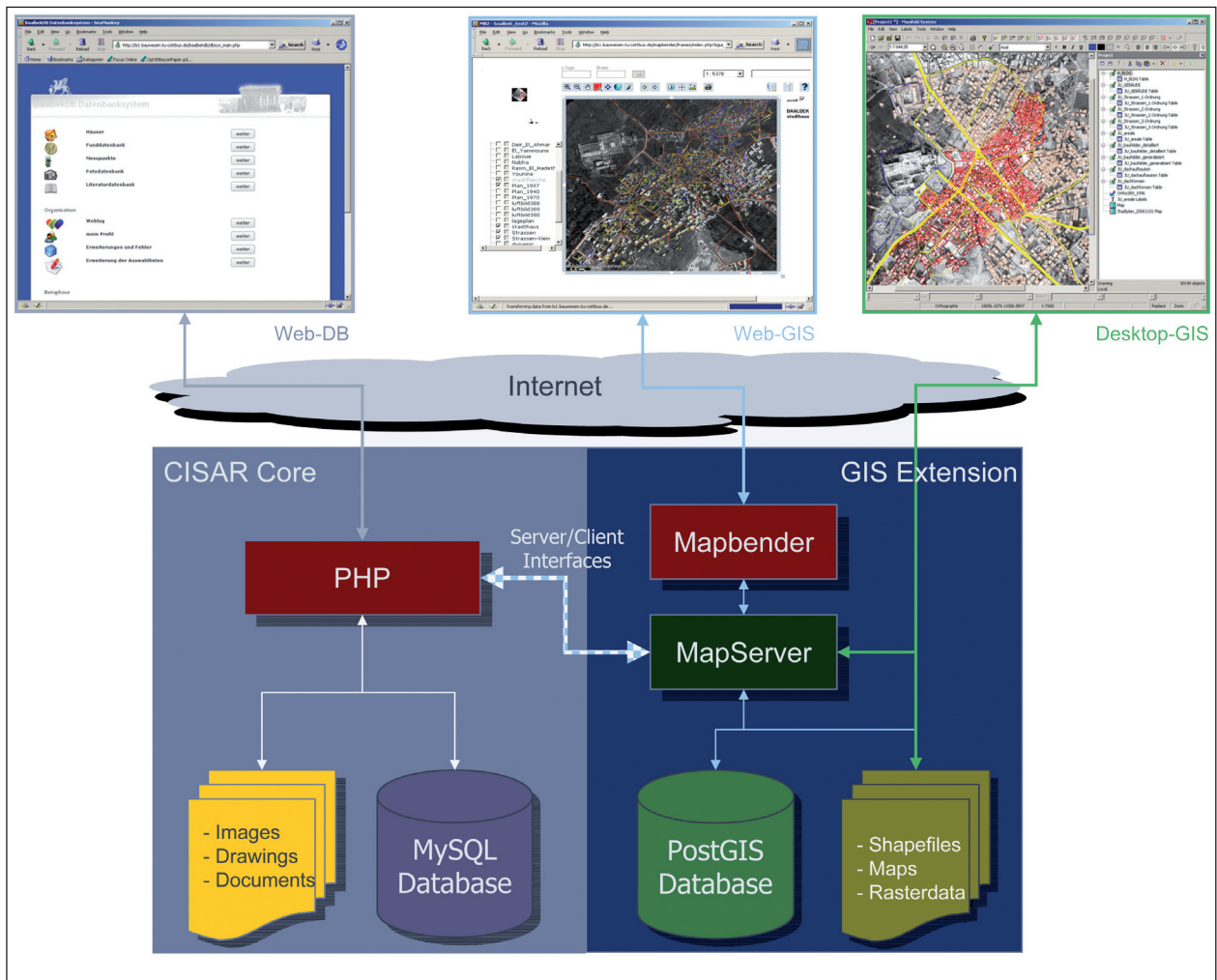


Fig. 2. Web-based GIS extension of the CISAR database system.

a MapServer-based GIS application is defined within an ASCII control file, the so-called map file, which contains information about the integrated vector and raster layers, the projection used, scaling limits, map extents and so on.

Unfortunately, there is currently no graphical user interface for the creation and editing of map files, and so extensive knowledge about their structure and syntax is necessary to build a MapServer application.

PostGIS

The geometry management of a real geo-database offers a higher flexibility for online editing and expansion of geo-data than storage using shapefiles. For this reason, the geometry for all linked objects from the CISAR modules is stored inside a PostGIS database (<http://postgis.refrations.net/>) while additional topographic information is integrated using shapefiles or GeoTIFFs.

Mapbender

Mapbender (www.mapbender.org) serves as the interface between MapServer devices and client requests. Mapbender has functions for creation, view-

ing, navigation and query of shared map services for UMN MapServer and it can provide a web-based graphical user interface (GUI) for Web-GIS applications. This means zooming, panning, measurement and layer management can be easily included into the Web-GIS GUI. A typical Mapbender user interface consists of a navigation bar, a layer tree for viewing and query selection, a legend and the map area. All these basic GIS functions are accessible within an up-to-date Internet browser.

Integration of a Desktop GIS

Besides these web-based GIS functions, this GIS architecture allows access to the geometric data using a desktop GIS such as Quantum GIS, an open-source software, or ArcView, Manifold or other commercial programs. There are two ways to access the web-based GIS data:

The first is to integrate the discrete vector and raster layers stored in PostGIS or within the server file system directly. This offers the maximum flexibility for editing and adding geometric data online and for the creation of thematic maps using the latest server-based data set.

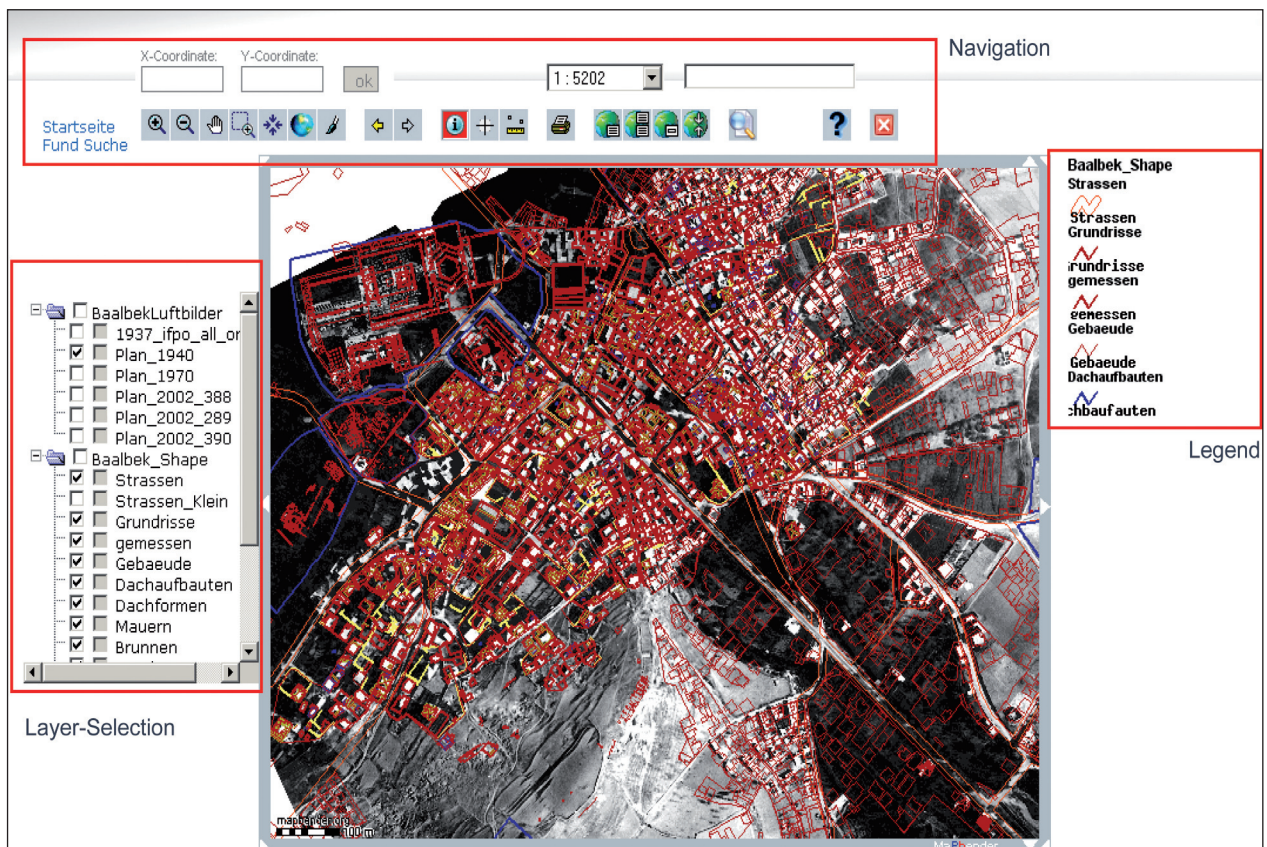


Fig. 3. Typical Web-GIS interface created with Mapbender.

The second method is simply to use the desktop GIS as a WMS client, which is comparable to the functionality of a Web-GIS. Here, a raster image map is generated from MapServer using a defined layer set, but there is no access to a single layer.

Basic Functions of the GIS Infrastructure

The GIS infrastructure for the Baalbek research project provides the following basic GIS functions for creation, editing, viewing and query of geometric data.

Generation and Storage of Geometric Objects

The first step in a typical GIS workflow is the collection and processing of geometric data. For simple geometric data such as single find locations, the geo-objects can be generated directly from the measurements. Complex object geometry for buildings or infrastructure can be better derived from aerial images or maps using a CAD or desktop GIS software. The results of both procedures are object geometries stored in shapefiles. These shapefile geometries with references to CISAR objects can be easily imported into a PostGIS database using Quantum GIS with the Shapefile to PostGIS Import Tool plugin (SPIT).

After setting up a connection to the geo-database server, several shapefiles can be chosen from a local file directory and transferred into PostGIS with the SPIT plugin.

For all geometries without additional thematic information, it is possible to store the shapefiles within a directory on the server.

Relationship between Geometry and Database Objects

The imported PostGIS geometries can now be visualised either in desktop GIS or via the Web-GIS user interface, but there is no connection between the geometry and database objects at this time. To link the geometric objects with the appropriate database information, the web-based concept of the CISAR information system is retained unchanged.

The internal PostGIS IDs for geometric objects can be retrieved within the Web-GIS using a "GetFeatureInfo" request: the user clicks inside a closed object polygon or near another geometric object and the MapServer sends back the corresponding PostGIS ID. This geometric object ID is now stored for the CISAR object and the user has created a real geo-object, consisting of the thematic CISAR information and the object geometry.

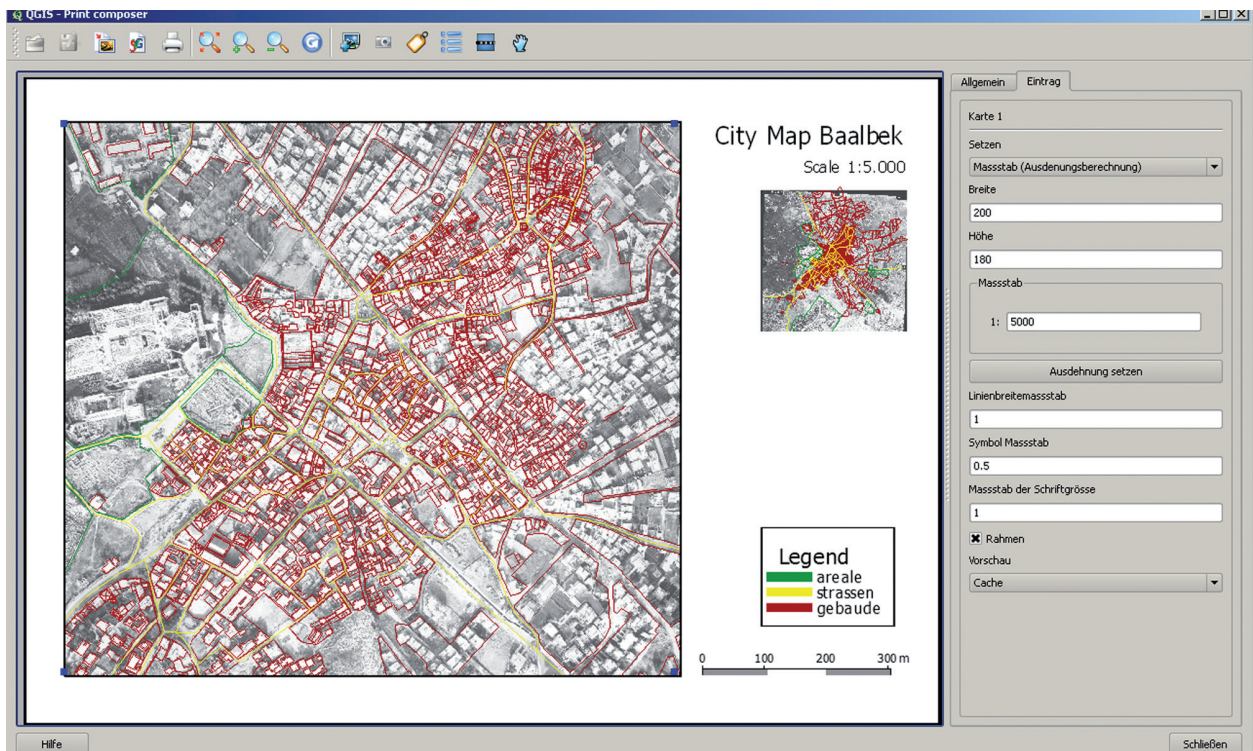


Fig. 4. Map creation using Quantum GIS.

To control this process, it is also possible to load a PostGIS layer into a desktop GIS, in particular Quantum GIS, and to select the same object within the attribute table.

Visualisation of Database Query Results

Once the geometric and thematic data are related, the Web-GIS obtains full GIS functionality. Using a "GetFeatureInfo" request within a map view, i.e. by clicking on a geometric object, it is possible to view the associated object information in CISAR, and vice versa: the position of a single CISAR object or the results of a database query can be visualised within the map view of the Web-GIS using an ordinary SQL SELECT command in PostGIS to find the correct geometry. The main application of this browser-based Web-GIS is thus the visualisation and spatial analysis of query results from CISAR.

Map Creation Using a Desktop GIS

By importing the server-based geometries into a desktop GIS, individual thematic maps can be created for various research problems. The extensive layout functionalities of this desktop GIS allow the user to create customised maps to scale, using all cartographic elements such as scale bar, north arrow, legend, coordinate grid, labelling and so on, and it is possible to choose colours and styles for all the geometric objects, depending on the object features selected (see Fig. 4).

Currently, this flexibility is hardly realised with this Web-GIS technology, but further developments using AJAX and SVG could integrate these layout functionalities into a Web-GIS user interface. Other web-based services such as Google's "Writely" or Google Maps demonstrate the potential of this technology.

Conclusions

Using the technologies presented here, the web-based information system CISAR can be developed into a web-based GIS architecture for archaeology and building archaeology. The server modules PostGIS, UMN MapServer and Mapbender, together with the MySQL database, are established open source solutions for the creation of web-based map services which follow the guidelines and formats of the OGC.

While thematic information is stored within the MySQL-based CISAR modules, a real PostGIS geodatabase was integrated for storage of the appropriated object geometries. On one hand, with this solution, it is possible to maintain the web-based functionality of CISAR, while on the other, processing, editing and analysis of geo-data is also possible within a suitable desktop GIS program. With Quantum GIS, an open source desktop GIS is available that better integrates into this GIS infrastructure than other commercial desktop GIS. It offers similar functionality for the creation of individual thematic maps and it allows for easy online adding and editing of PostGIS geometries. Although it was unintended, we obtained a GIS architecture that consists exclusively of open source software that is freely available and widely used.

Currently, these GIS functions are just prototypical implementations, which demonstrate the principles behind the technical configuration and the components needed for a web-based GIS infrastructure. Work on this development has shown that extensive knowledge is necessary to create and process the map files as well as to administer and run web servers. To adapt the GIS solution presented here to other CISAR projects, it is necessary to develop tools that can simplify or automate the setup and administration of a project-oriented Web-GIS, and it is the aim of further developments to integrate the web-based GIS functionality into CISAR as another module in order to obtain a comprehensive spatial information system for research in archaeology.

*References**Frank Henze*

VAN ESS ET AL. 2003

M. VAN ESS (WITH CONTRIBUTIONS FROM T. BUNK ET AL.), Archaeological Research in Baalbek. A preliminary report on the 2001–2003 seasons, *Bulletin d'Archéologie et d'Architecture Libanaise (BAAL)* 7, 2003, 109–144.

HENZE / RITTER 2003

F. HENZE / B. RITTER, Geodetic and photogrammetric research in Baalbek. In: VAN ESS (WITH CONTRIBUTIONS FROM T. BUNK / V. DAIBER / B. FISCHER-GENZ / F. HENZE / K. HITZL / F. HOEBEL / B. RITTER / H. WIENHOLZ), Archaeological Research in Baalbek. A preliminary report on the 2001–2003 seasons, *Bulletin d'Archéologie et d'Architecture Libanaise (BAAL)* 7, 2003, 111–114.

LEHMANN / HENZE / FISCHER-GENZ 2006

H. LEHMANN / F. HENZE / B. FISCHER-GENZ, Aufbau eines internetbasierten Informationssystems zur archäologischen und stadtgeschichtlichen Forschung in Baalbek/ Libanon. In: A. RIEDEL / K. HEINE / F. HENZE (EDS.), *Von Handaufmaß bis HighTech II – Informationssysteme in der historischen Bauforschung* (Mainz 2006) 127–135.

*Brandenburg University of Technology
Chair of Surveying
Postfach 101344
03013 Cottbus, Germany
henze@tu-cottbus.de*