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A 3D Solution for a Web-based Building Information System

Abstract: This paper presents an information system for the documentation of research results in building archaeology as applied to the example of "Domus Severiana" palace on the Palatine Hill in Rome. In connection with the development of CISAR – a modular open-source web-based information system for archaeological field work and building archaeology – a special solution with the focus on 3D building documentation was created. There are many commercial and non-commercial software products for 2D web-based information systems, whereas few solutions for 3D GIS are available. Therefore, an independent product was developed based mainly on open source components. The use of open source technology allows for the optimal adaptation to user requirements and a standardised data exchange. The information system is an effective working tool that facilitates the documentation of building characteristics and related data analysis; users do not need to have special knowledge of computer science or graphics.

Introduction

The documentation of buildings for the purpose of historical building research requires an information system that enables users to store both non-geometric, thematic information and the geometry of the building and its constructive components. The connection between geometric and thematic data can be achieved with geographical information systems. A large number of software products are available for the storage and analysis of 2D geometric data. They have been used for many years with success in the field of archaeology. However, 2D modelling is not sufficient as a rule, especially for complex building structures with many floors, which means in practice that the typical GIS programs are not suitable for current requirements. Very few commercial programs available on the market can process genuine 3D geometries (land surface models are explicitly excluded in that context).

This paper presents a web-based open source solution for a 3D building information system. This tool is a component of the information system CISAR, which is described in detail elsewhere (Lehmann / Henze / Langer 2008). CISAR is a web-based modular database system using MySQL and PHP technology that facilitates the documentation and analysis of information from archaeological research and building archaeology. The most important components of CISAR for this documentation are the room inventory database for the storage of thematic information about the building and the building elements (e.g. rooms), the constructive elements (walls, slabs, etc.) and the 3D geometry database, in which the geometry of the individual objects is stored. By linking the geometrical element information to the non-geometrical, the user can query several elements of the building. Furthermore, the objects of the room inventory database can be linked with the basic modules of CISAR (databases for photos, drawings and literature). More detailed information about CISAR is found on the CISAR website (http://www.tu-cottbus.de/cisar).

The Concept of the Database Module Room Inventory

The comprehensive documentation of a building includes information in different data formats *(Fig. 1)*. The 2D plans, consisting of ground plans, sections or view plans, are an important basis for the scientific investigation. However, not all information can be collected in these plans, which is why catalogues for the room inventory are necessary to document and archive all relevant information. Normally, these catalogues still exist in analogue form, so they cannot be used effectively for detailed analysis because of the extensive time required to search for and find various pieces of information.

It soon becomes clear that these catalogues, together with the manual or digital photos and plans, are not suitable for the analysis and documentation of a complex building. A digital room inventory database is a more effective instrument, allowing the researcher to archive and work with the large mass of non-geometrical information and to make selective queries.

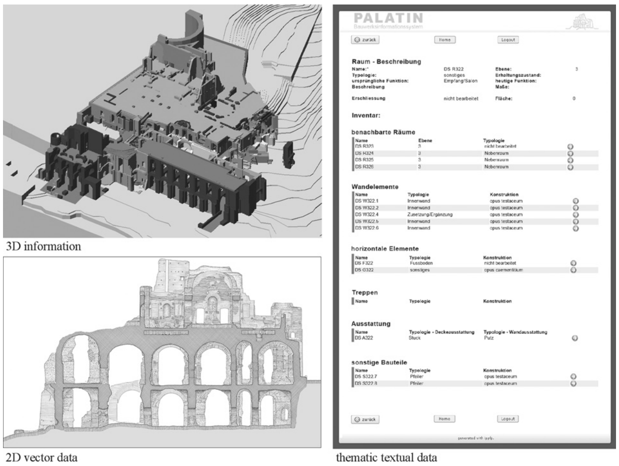


Fig. 1. The original data (Ch. Brasse, K. Heine, D. Zhao, U. Wulf).

Topology

The concept of the very flexible and comprehensive structure of the room inventory module is a basic condition of its functionality. The structure of the room inventory module is equivalent to the structure of a common building *(Fig. 2)*. The topology of a building defines the connections and interdependencies of the various objects, such as the wall elements that form the boundary of a room. But a room, which is the superior class of a traditional analogue room inventory catalogue, cannot integrate all attributes in a well-defined way. Because of this, a refinement of the structure of the database is necessary. A room becomes visible only with the surrounding constructive elements. These constructive elements such as walls, horizontal elements, other structural elements and stairs form equal classes that can be linked with different rooms. These elements contain more special construction information in turn, such as information about the openings (doors, windows or niches). Furthermore, they can contain important information such as brick stamps or the construction details which provide evidence for the building phase. These objects are collected in their respective classes and are linked with the constructive elements. Yet another class that has to be linked with the room is its decoration. Such a class may contain, for example, mosaics or plaster, which are connected with the constructive elements. Because a wall can have different decoration in different rooms, the decoration is assigned with the room and not with the constructive elements.

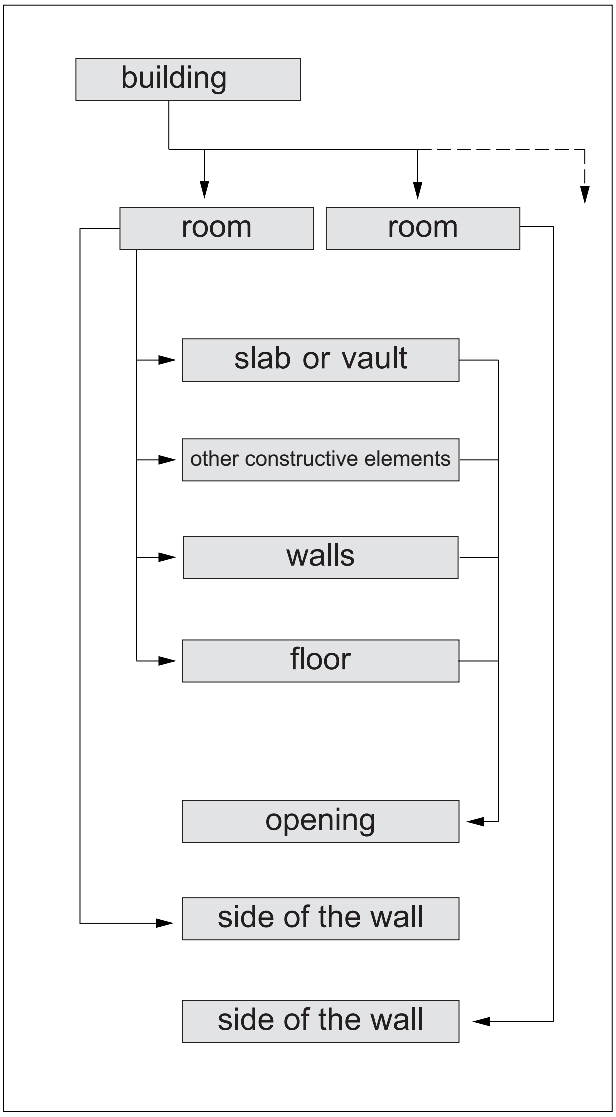


Fig. 2. Topology of room inventory structure (Ch. Brasse, K. Heine, D. Zhao, U. Wulf).

The result of these classifications and linkages is a well-defined storage system for all relevant information *(Fig. 3)*. Attributes may be archived dependent upon the different object classes. Furthermore, the separate catalogues can be included in this module.

To ensure the information can be used flexibly, various means for linking and creating objects are included. Some connections, corresponding to the structure of a building, are obligatory, e.g. the creation of an opening after creating a constructive element. Additionally, it is possible to enter information without any constraints; for instance, it is possible to enter constructive elements without linking them to a room. A third possibility is to link an object

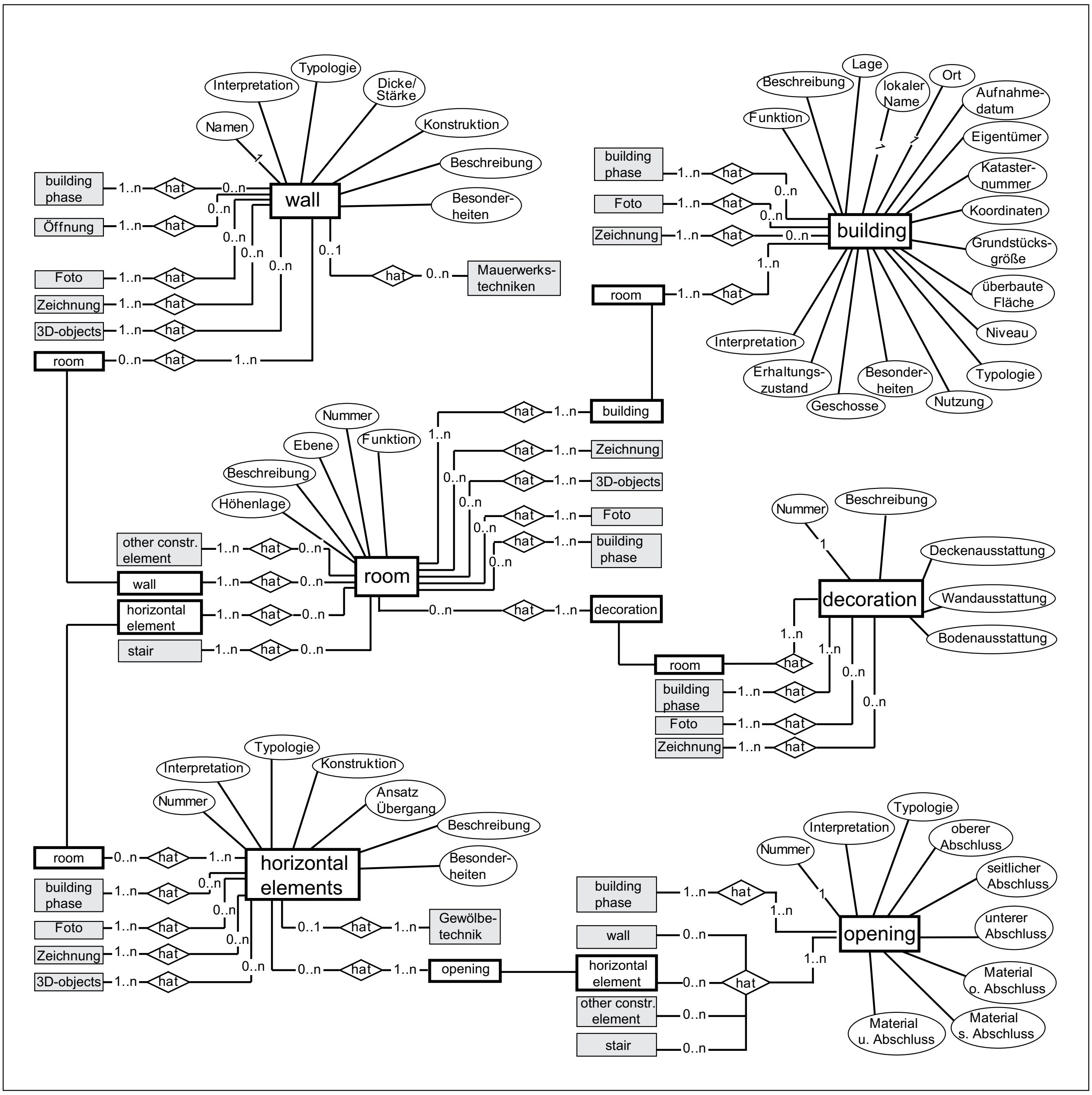


Fig. 3. Extract of the ERM of room inventory module (Ch. Brasse, K. Heine, D. Zhao, U. Wulf).

to several objects, such as a wall linked to several rooms.

For ease of use, every class consists of a similar structure with similar terms to describe the objects. For example, the terms typology, interpretation and state of preservation are used in all classes, though naturally with differing content.

Information from the basic modules can be linked with the objects of the room inventory module in the same way. Sketches or plans are collected in the plan database and photos are collected in the photo database. Plans or photos can be linked with the different houses, rooms or constructive elements.

The 3D CAD Model

A three-dimensional model can be used to visualise the complex geometrical information of a building. The 3D model facilitates navigation through the installation and offers a better visualisation of the existing building. In addition, the model can be used for the analysis of complex structures and serves a basis for reconstruction ideas pertaining to the different building periods. Ideas related to load-bearing construction, to construction sequences, and to use of and access to different units, can be checked quickly and can be represented three-dimensionally. Irregularities in the building structure (e.g. the position of load-bearing walls on the different levels) become clear as one creates the model. The main purpose of the model, however, is to verify the building phase, which is the most important attribute of each 3D object; the phase becomes visible through an assigned colouring. The structure of the model corresponds to the topological structure of the room inventory in order to integrate the 3D model into the database. Every 3D object in the geometric model must be linked with the dataset of the respective structural element in the room inventory module.

Visualisation of VRML Data

The VRML format is used for the visualisation of geometric information. VRML is a well-known standardised open source format for 3D graphics on the Internet. VRML format is a pure text file, meaning files can easily be created and manipulated. This is a great advantage, because it is necessary to separate the different shapes which relate to the structural elements of the database room inventory as well as the geometry and the appearance of these shapes. The separate storage of geometry and texture makes it possible to efficiently display different building phases without loading the whole 3D model again. This ensures consistent information storage.

So that the user does not have to enter each object and each texture manually, there is a parser program, which automatically filters all objects and textures of an entire VRML file and stores the information in the different tables of the 3D module. With a well-defined identifier, each object can be linked with the information of the room inventory. To display an object from the room inventory, a temporary VRML file is generated consisting of both geometry and texture. The second advantage of the VRML format is the very small file size. This guarantees fast processing in the World Wide Web.

It is possible to export .dwg or .dxf files to VRML format because almost every CAD or 3D modelling program includes an export function to VRML. These VRML files can be visualised by a 3D viewer which includes the fundamental navigation functions. The viewer also provides interior perspectives or virtual walks through the complex.

Queries

Queries are necessary to analyse and interpret the available information. It is possible to check the working result three-dimensionally by means of the visualisation of query results in a 3D VRML graphic.

The connection between non-geometrical data stored in the databases and the 3D geometrical model has to be realised in such a way that two tasks can be performed:

1. The result of a SQL query from the database has to be displayed.
2. It must be possible to retrieve information from the database about a special building object such as a wall while the user is navigating through the 3D model.

These requirements are implemented as follows and might be described as an interactive model, which can be divided into three levels: data layer, function layer and view layer *(Fig. 4)*.

The **data layer** serves mainly as storage of room inventory data and temporary data produced from the function layer. It also serves as the data source

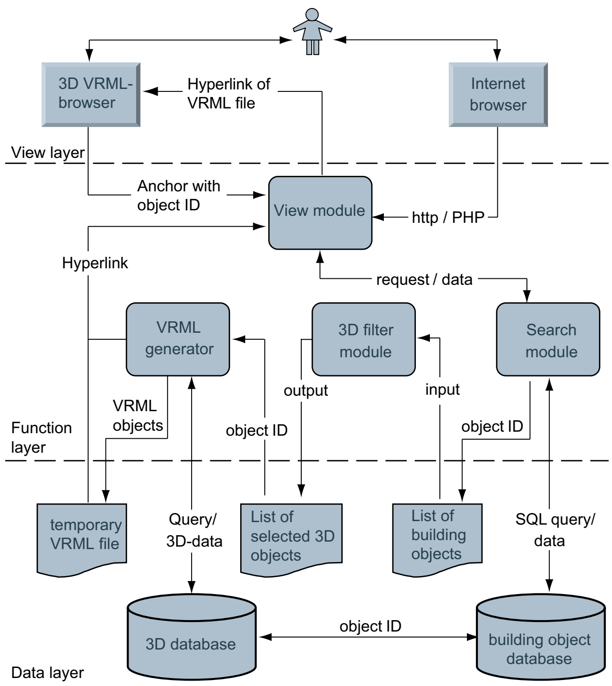


Fig. 4. Schema of connections between 3D object database and room inventory database (Ch. Brasse, K. Heine, D. Zhao, U. Wulf).

for the function layer. The building objects database stores non-geometrical data and the 3D database saves the geometric data in VRML format.

The **function layer** provides the functionality for the view layer. When a request is sent from the view layer, it retrieves the necessary data from the data layer. This data is manipulated and then sent back to the view layer, as well as being stored in the data layer. The function layer is divided into four parts:

1) **View module:** It requests the search module to pick up the required data and then presents the returned information in the corresponding web page for the browser.
2) **Search module**: After the request is received from the view module, it sends the SQL query to the building objects database, and either sends back the results directly to the view module, or passes them on to the filter module for further handling.
3) **Filter module**: This module is used only when a 3D model is required. The filter module supplies further 3D data based on the text query result of the search module. For example, in the search module there is a list of building object data such as walls, stairs, floors, etc., which are located on different storeys. The user can use the filter module to display the constructive elements from only one building period, for instance.

The **view layer** is the interface between system and user.

The most important part of the function layer is the **VRML generator**. The VRML generator builds up a two-way connection between the 3D object module and the building object data.

Firstly, the relevant information pertaining to room inventory objects has to be connected to the 3D objects of the 3D object database and displayed in the internet browser. To do so, the filter module produces a list of all 3D objects matching the query criteria. Assigning these a unique ID, the VRML module can collect all the 3D information and save on the server a temporary VRML file whose address can be seen in the view layer as a hyperlink. With a click, the 3D model can be displayed in the 3D VRML browser.

Secondly, information related to one object from the room inventory module has to be displayed while the user navigates through the 3D model. Each object in the VRML model is assigned an anchor node. To connect the VRML model and the room inventory database, the anchor node's URL attribute is defined as a HTTP GET request. The object ID is the parameter of this request. For example, if the user clicks on the object in the VRML browser, its URL link will be opened in a separate window. The view module is given the objective ID via the URL address, then the search module receives data through the ID and sends it to the view module. The view module then displays the data in the browser.

Fig. 5. Building complex of the "Domus Severiana" on the Palatine Hill, Rome (R. Wieczorek).

Fig. 6. The CISAR modules used (Ch. Brasse, K. Heine, D. Zhao, U. Wulf).

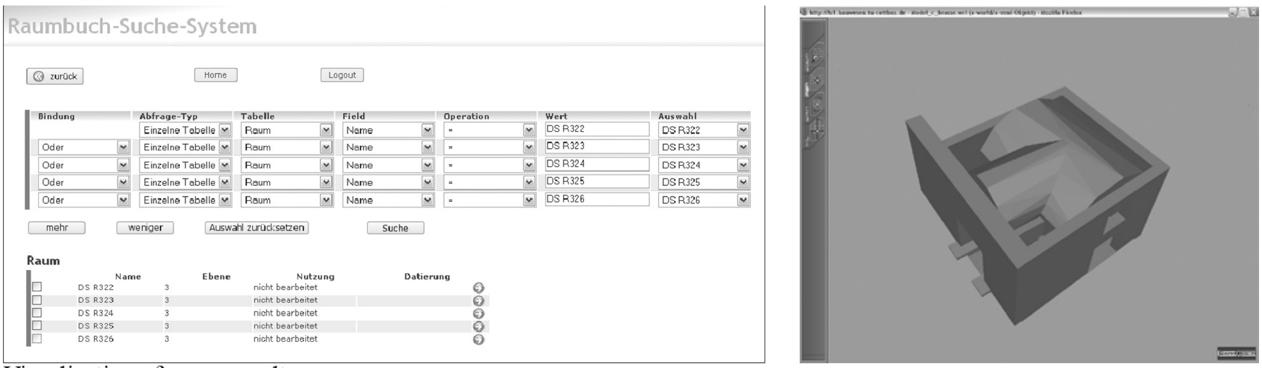
Difficulties with the VRML File Format

There are some difficulties associated with the VRML format that should be mentioned. The first problem is that the VRML specification is no longer being developed as a 3D standard. In the last few years, new 3D standard formats have been designed, such as X3D or Collada (Collada Community). The second problem is the creation of VRML files. Different results occur depending on whether the VRML file is created by a plug-in for AUTOCAD or by other software tools like Cinema 4D or 3D Studio Max. The file structure is quite different, and so these files cannot be uploaded automatically in the system.

Nevertheless, the above solution is an example of the use of 3D information in an open source system in projects of building archaeology. The integration of new 3D standard files such as X3D, an extension of VRML, will be a necessary measure. The relevant information about geometry and texture is stored in an X3D file in a similar way. The functionality of the system can also be used to integrate X3D files.

CISAR as Used at the "Domus Severiana" Palace in Rome

The CISAR information system has been used for the digital documentation of archaeological information collected during the investigation of the so-called "Domus Severiana" palace. This large build-



Visualization of query results

Information about objects of the 3D-model

Fig. 7. Data analysis (Ch. Brasse, K. Heine, D. Zhao, U. Wulf).

ing complex is situated near the Colosseum in the south-eastern part of the Palatine Hill, high above the Circus Maximus *(Fig. 5)*. Tall substructures up to 48 m in height are characteristic of the "Domus Severiana" building complex, which has more than 180 rooms in several storeys.

To document the research results, the basic CISAR modules – the photo, plan and literature databases – and the room inventory and 3D object database modules were used *(Fig. 6)*.

At the beginning of the investigations in 1998, several catalogues were produced in addition to the plans to collect all information about the building. The analogue room inventory consists of datasheets of all the rooms, which includes descriptions and sketches where all construction details are registered, along with important measurements and information about joints, building periods, earlier fittings or furnishings and data criteria. Furthermore, superordinate investigations of construction techniques of the foundations, walls and vaults and of the brick stamps are documented in separate catalogues. Now all of this information concerning rooms, constructive elements and construction techniques is integrated in the digital room inventory and can be linked with other information that has been collected in the basic modules.

In addition, a 3D model of the remains of the "Domus Severiana" palace was produced. Although the abstract model shows the irregularities and particularities of the building, it does not give a detailed rendering. The creation of the CAD model has already been described in detail elsewhere (Riedel / Weferling 2002). After creating VRML files from the .dwg files, all 3D objects can be integrated within the 3D object database and linked with the related information from the room inventory.

Suggestions for reconstruction can also be justified with the help of the 3D model and these would be integrated into the database in the same way. The design of a reconstruction module will be the next development step in order to present these reconstruction ideas not simply as "pretty pictures". The scientific reasons, like the method of reconstruction chosen, are integrated in the database, where they can be compared with the room inventory module. Meanwhile, the different reconstruction ideas can be displayed and checked in the 3D model.

Hence the complex spatial information system proved itself a useful instrument for editing, searching and analysing information on the "Domus Severiana" palace *(Fig. 7)*. The system can accompany the most important phases of an archaeological project, integrating room inventory data and reconstruction suggestions.

Acknowledgements

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