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HIGH PRECISION BUILDING DOCUMENTATION: ELEMENT DEFINITION AND DATA STRUCTURING

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ABSTRACT

In this paper a methodology of building documentation is presented which is focused on the development of a 3D GIS. The methodology is based on the description of buildings by means of hierarchically structured architectural elements. This form fulfills the requirements of spatial databases and thus enables the implementation in 3D information systems.

INTRODUCTION

A complete documentation of a building comprises both the description of the outer parts, i. e. facades and roof, and the inner parts of the building, i. e. staircases or rooms. From 1990 onwards even complex buildings were documented in 3D-CAD models. The data were administrated through thematic layers which structured the model. With growing complexity of the building the number of layers increases, and the administration becomes more and more difficult and complex. This is particularly the case for architectural relics.
In such cases an independent use of the CAD models by other disciplines, such as architects or archaeologists, is not possible.
CAD systems were developed as tools for construction purposes. They are, however, not appropriate for a complete building documentation.

The future of building documentation – and the adjoined tasks of modelling, visualization, and keeping evident – is prescribed by the use of information systems, like 3D GIS.

PROBLEM DESCRIPTION

Database principals: In building documentation by 3D GIS the huge 3D data sets are managed by hierarchically structured data bases such as R-trees or quad trees [ZLATANOVA et al., 1998].
In contrast to CAD models data in a 3D GIS must comprise a thematic or logical reference along with the spatial relations. To accomplish that, it is necessary to explicitly define the relations and conditions present in reality. This "formalized knowledge" as a base, the process of generalization is undertaken by observance of the semantic and topological consistency [BARTELME, 1995].

Architectural analysis: The architectural analysis divides a building in uniquely defined architectural elements. An *element* in that context means a representative unit which is part of the whole object NORBERG-SCHULZ,1970. These elements are classified into different categories (mass, space, and area) and denominated by unique (architectural) terms. The term can either mean a single independent representative unit as a whole (room, roof, etc.) or as a combination of its subordinated elements (e. g. room as made up of walls, floor etc.).

Systematization is mandatory in order to efficiently analyse thousands of elements in an environment set up of both different objects and architectural styles.

Geometry of ancient buildings: With ancient buildings the main difficulties of the mentioned systematization arise in the definition and separation of the individual mass-elements. Many historically important buildings were built up over long time periods, with up to 500 years and in several stages. Thus a structural decomposition into individual mass elements is nearly impossible (Fig. 2). The documentation of complex buildings such requires new ways of element definition.

Objective

From the above it can be seen that heritage documentation calls for a concept of data structure that describes complex architecture by structured elements, respects the structuring methodology of architectural analysis, and fits the needs of spatial database formats.

The practical application was done for the Architecture of the Ancient Maya culture.

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ABSTRACTION AND STRUCTURE OF ARCHITECTURAL ELEMENTS

Element definition by delimiting surfaces

Objects like pyramids cannot be described and modelled by the idea of solid mass-elements. Rather, a new method is necessary: In a first step the an expanded division into architectural elements is undertaken. Starting from the element definition of HOHMANN-VOGRIN [1992], the individual mass-element is no longer viewed at as a single unit, but is defined through its visible delimiting surfaces.

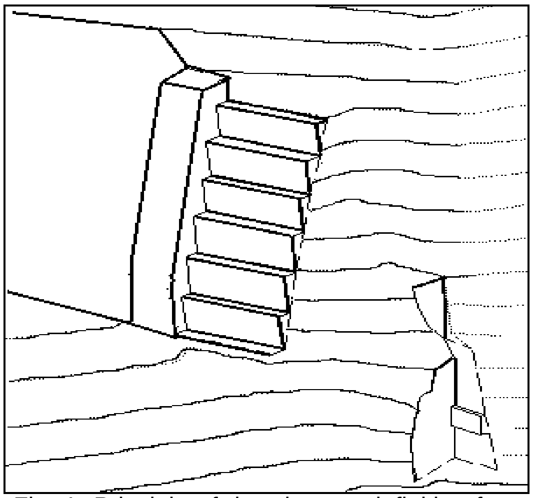

Fig. 1: Principle of the element definition for a ruined facade with rests of a stairway

The steps of the stairway (Fig. 1), for example, would be described by its frontier and its horizontal plane. The surface flanking the step on the left side belongs to the element group „ramp“ and that on the right side to „amorphous structure“.

So it is no longer necessary to "invent" the invisible parts or parts that were fallen down to construct a complete model. The model is completely described by the visible surfaces of the different elements and by following this structuring method (rules) the consistency of the database is secured.

Structuring of the architectural elements

The transition from the definition of mass-elements to delimiting surfaces is the base for the second step, i. e. the organization in hierarchical form.

An element of higher level is comprehensive and uniquely defined by the delimiting surfaces of the lower level. For example, the combination of the individual small steps (i. e. their surfaces) and of the ramps (again, their surfaces) (elements of 3^{rd} order) defines an element of a higher level, the staircase.

The architectural elements were subdivided until the 4^{th} order. An synopsis of the architectural elements and their orders is provided in table 1.

Another advantage of the method is that the dispositional structure can be adapted to the requirements of the particular case. It is, for example, possible to change the nomenclature to the ancient Arabic culture of Andalusia (Spain) and to add missing architectural elements

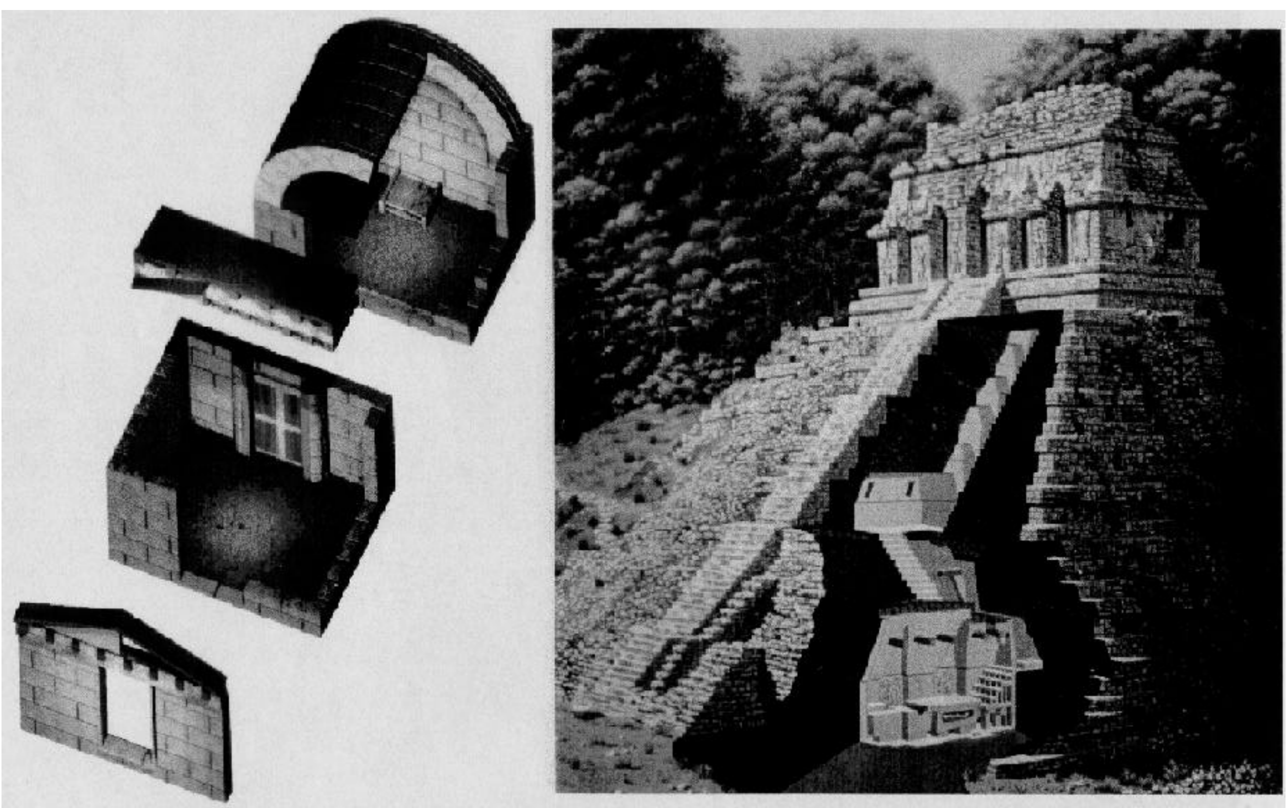

Fig. 2: Mass-elements of a vault building and a pyramid building.

elements of 1st order	
mass elements (delimiting surfaces)	space elements
pyramid-building	plaza
building	courtyard
monument	causeway
free-standing wall	terrace

elements of 2nd order	
mass elements (delimiting surfaces)	space elements
terraced facade	hall
stairway	room
facade	tomb
platform	interior stairway
amorphous structure	connecting-room (door)

elements of 3rd order	
mass elements (delimiting surfaces)	space elements
roof	niche
ceiling / vault	cordholder
wall	holes (for vault beams or rods)
floor	
megastep	
minorstep	
ramp	
pillar, column	

elements of 4th order
mass elements (delimiting surfaces)
wall sculptures
building material (plaster)

Table 1: Hierarchical structure of mass elements (actually: delimiting surfaces) and space elements of architecture

The definition of relations and conditions relative to the object thus allows for a structural abstraction of the real object.

The result is a model that comprises all information of the heritage recording , and fits the needs of spatial database formats because of its logical structure.

Example "wall in palace"

The hierarchical structure is explained through the following example of a wall of the Maya construction "palace" (Fig. 5). The wall was covered by plaster and comprises a sculptured panel and two panels with colonnettes. It is part of room cell "01" which in turn is part of building "B1". The different buildings "B1" to "39" and several detached walls make up the building complex "palace".

Figure 3 shows the hierarchical structure in graphic form. It can be seen that the hierarchical structure not only is an optimal method to decompose a building, but it furthermore allows to organize data in several "levels of detail" (LOD).

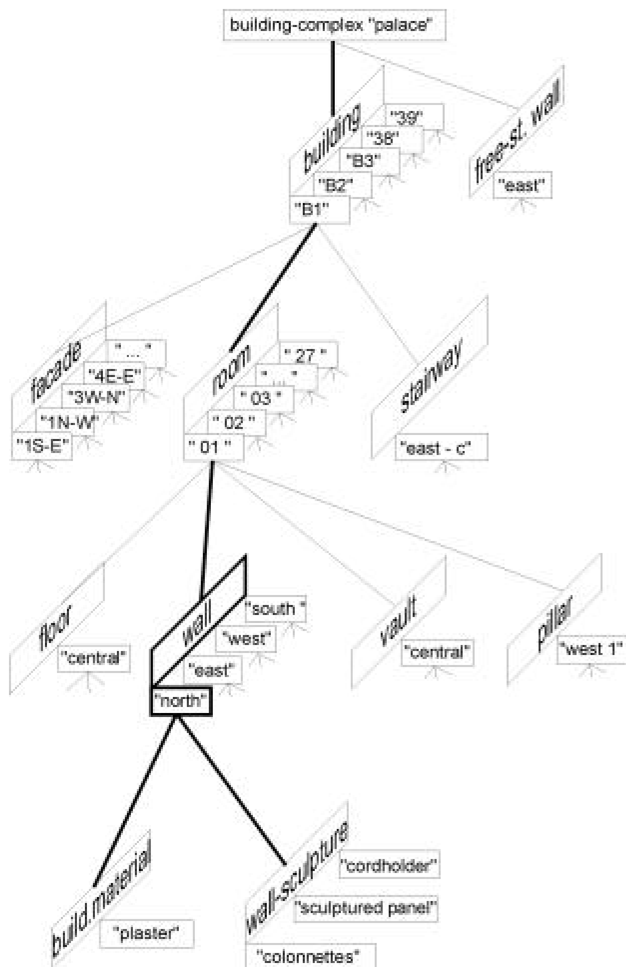

Figure 3: Hierarchical tree of the architectural element for the northern wall in room 01 of the building.

THE "LEVEL OF DETAIL"

The LOD is a well known computer graphics technique for navigation through large data sets for visualization purposes. The main idea is to reduce the amount of data in higher levels compared to the lower ones.

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In our case the method can be used in order to generate a model of a building whose elements have been surveyed with different accuracy and detail levels. The elements that have been collected with less accuracy are assigned to higher levels in the model structure than those that have been captured more accurately.

This way of documentation is especially suited for all those objects which have been surveyed only partly and whose missing description has been derived from old maps or sketches (Fig. 3).

Another advantage is that even the different data quality does not compromise the consistency of the data base. Besides, should the "inaccurate" part be surveyed more accurately one day, update of the data base is very simple.

FORMALISATION OF THE DATABASE STRUCTURE

Questions of data organization are placed one step below the modelling task, thus closer to the computer realization (i. e. data base). The object orientation of the CAD data base and the hierarchical structuring of the architectural elements offer the possibility to create an appropriate model structure for the data base.

The lowest level of the model structure consists of the objects composed of the basic graphical elements (*primitives*). These primitives represent the architectural elements of the lowest level. Analogous to the architectural model (*primary model*) the next levels result from the combination of the respective lower ones.

For the data structure of the architectural model the above means that (Tab 2)

- its *geometry* is defined by the metric and topologic information of the architectural element,
- the *object classification (semantic description)* is provided by type and order of the element,
- and the *object identification* is given by the name or the number of the element.

Abstract model of the real world	Data structure and model definition	
	in the data base system	in the CAD-system
architectural element	graphical data	
metric / topologic information from surveying	object geometry	object resulting from graphic *primitives*
order and type of element	object classification	objectname (*surrogate*) { group
name of element	object identification	name

Table 2: Data structure after formalization of the architectural element information

Object key

A combination of object classifiers and object identifiers, called *surrogate*, provides a unique key for each object. The key uniquely references the object by means of its group name, layer name, etc., independent of the method that has been chosen for the semantic model description (Fig. 4).

This data structure fulfills now the requirements of spatial databases and thus enables the implementation in 3D information systems.

GENERATING A BUILDING INFORMATION SYSTEM

In the previous paragraphs the steps were defined that are necessary to generate a "building information system".

Because of the simple but consistent structure of the data it is possible to import the data into heritage documentation systems, e.g. like the one published by NICKERSON et al. [1997].

Using the data base programming interface of the CAD system such a information system was realized in a CAD environment. Figure 5 shows a part of the object. The whole model concludes more than 25,000 elements HEINE [1997].

RESUMEN

While for modern architecture in general it is easy to obtain hierarchical structures of the architectural elements by dividing a building step by step, it is nearly impossible to do so for ancient buildings. The complex shaped structures of such objects often cannot be described by standard architectural elements as can be found in architectural literature or in most CAAD products.

The basic approach for element classification as proposed here is not focused on the mass element but rather on its visible bounding surfaces.

This form of element definition enables the description of complex architecture in a structured form.

Using this approach of model creation significantly simplifies the surveying task. Even partly destroyed buildings – with floors covered by rubble, for example – can easily be documented without the surveyor being troubled with speculative assumptions about the original forms. Rather, only the actual situation needs to be documented, thus both safeguarding data consistency and enhancing the efficiency of data collection.

The hierarchical structure furthermore allows the definition of highly complex element-specific queries by standard data base tools.

Analyses of structures and dimensions can be performed specific for elements of any kind and number featuring direct transfer to statistical analysis software.

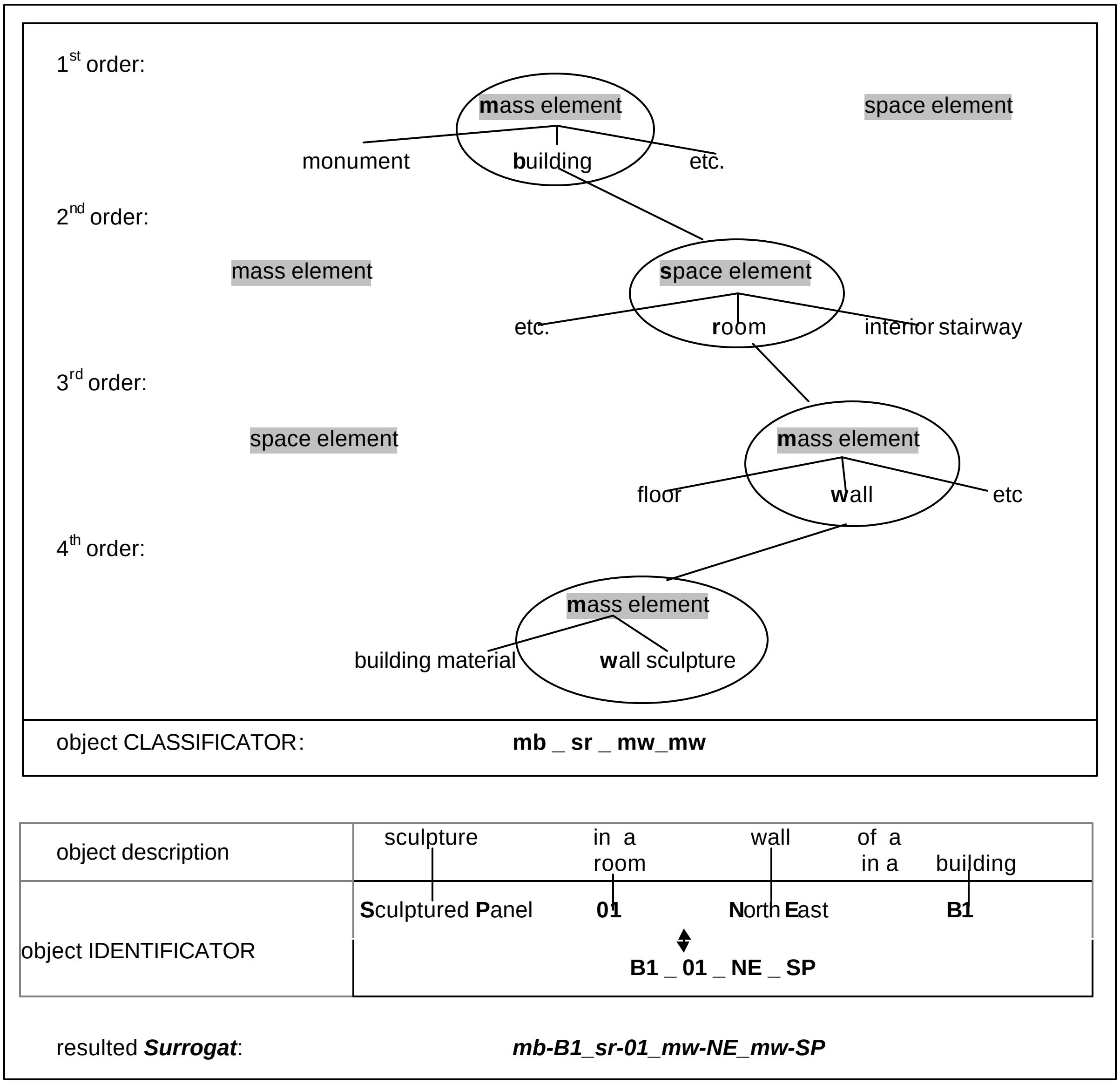

Figure 4: Derivation of the unique object key (*Surrogat)* for the architectural element „sculptured panel“

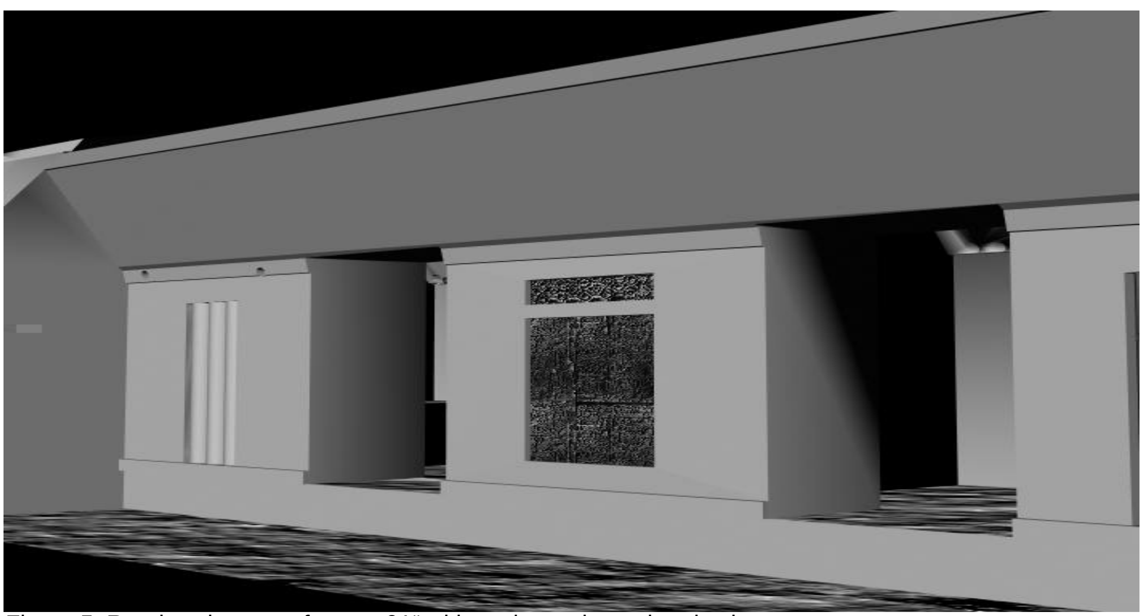

Figure 5: Rendered scene of „room 01“ with sculptured panel and colonnettes

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