Excavation goes BIM

Analysis of Egyptian Funerary Monuments with Building Information Modeling Methods

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Abstract: Geographic Information Systems (GIS) capture, edit, store, reorganize and present spatial data of model buildings and are widely used at archaeological surveys and archaeological information processing, such as prediction modeling. The process of Building Information Modeling (BIM) additionally includes methods to create and analyze spatial structure and is therefore promising to study also historic buildings.
To evaluate BIM analysis methods in the context of archaeology the funerary monuments of Harwa, Anch Hor, Karabasken and Irtieru were chosen as an experimental test bed. The Theban monuments date to the 25th and 26th Egyptian dynasty and were built by high officials. They represent the monuments of the type of Late Period private funerary complexes in Thebes.
An essential question was, if the building or usage concept of a tomb can be defined from an architectural point of view by analysis methods. Starting with a survey of existing structures of the Egyptian funerary monument, a space model (BIM model) is derived from the surveyed data that can be obtained by 3D scanning or photogrammetry. The next step was the selection and development of architectural analysis methods that were applied to this space model. These included: space and daylight accessibility and analysis of spatial zones such as offering sites. The creation of a BIM model in combination with an interactive visualization of the antique structure additionally offered visible information about the visibility and accessibility of rooms, areas and decoration positions as well as the display of metadata obtained from analyzing the BIM model.
This presented approach of analyzing architectural properties may be applied for other sites, cultural domains and building types.

Keywords: Building Information Modeling, space modeling, architectural analysis, Egyptian funerary monuments

Introduction

The aim of this paper is to examine design principles of ancient Egyptian architecture, using interdisciplinary methods from Egyptology, architecture and computer science. Specifically, the tradition and evolution of architecture of the Late Period private funerary monuments of Thebes are analyzed. The private funerary monuments are of the type of rock-cut tombs with open courtyards (fig. 1), built with at least three levels of above ground superstructure, sub terrestrial levels of substructure and deepened burial structure. These structures are complex and partially heterogeneous yet share a pool of similarities and a formal canon.

The analyzed monuments date to the late 25th and 26th dynasty (apr. 664 BC) and were built by high officials on the West Bank of Thebes, the modern Luxor.

The 25th dynasty marks the bridge between the 3rd Intermediate Period and the Late Period. The Intermediate Period followed the reign of Rameses XI., the last Pharao of the New Kingdom. It was a period of polyarchy when the central state of Egypt temporarily no longer existed. Already in the New Kingdom the priests of Upper Egypt especially of Thebes became powerful and influential. With the Nubian conquest of Egypt by Kushite Kings the period of kinglets and principalities ended and the 25th period was founded by Piye, who rules Egypt from the center of Memphis. Summarizing it can be stated that this period of Egyptian history was characterized by former rulers from Libya and Nubia but nevertheless was shaped by Egyptian culture. In Upper Egypt the Theban priesthood was still powerful and the new Pharaos sent female relatives to hold the position of the God´s Wife of Amun. (JANSEN-WINKELN 2000 p. 1, JANSEN-WINKELN 1992, JANSEN-WINKELN 1994, KITCHEN 1986).

Fig. 1 – Funerary monument of Harwa, Courtyard (Copyright: Anja Wutte)

While most Late Period monuments were studied previously and with a focus on culture-historical aspects, this project concentrates on architectural aspects and formal design principles. Information about the configuration of architectural space are analyzed in a digital manner in order to deliver a novel perspective of the subject. Related research work shows that there is a need of a systematic approach in terms of a development study of Egyptian architecture. Barely procedures are applied to compare Egyptian architecture in a systematic manner to build typologies or to determine design parameters. The premise of this paper is that an interdisciplinary approach between Egyptology, architecture and computer science can offer novel insights of Late Period funerary monuments. This first attempt tend to develop comparative analysis of Egyptian architecture to recognize a semantic canon of Late Period funerary architecture, which is not documented.

Archaeological History of the Site

The earliest documentation of visiting the site of Late Period private funerary monuments in Thebes dates to the 18th and 19th century (POCOCKE 1743; BELZONE 1821). Further expeditions and excavations followed in the 20th century (LECLANT 1961; BIETAK 1972; BIETAK 1973; BIETAK and REISER-HASLAUER 1978; BIETAK and REISER-HASLAUER 1982; GRAEFE 1973; GRAEFE 2003; DONADONI 1973; TIRADRITTI 2006, GOMAÀ 2004, GOMAÀ 2006).

In his work D. Eigner renews and complements existing plans and reconstructions from monographs and building documentations (EIGNER 1984). J. Dorner published manually shaped plans and collected geodesic data. D. Eigner defines construction specifications of every monument separately and makes it clear that there is no existing uniform prototype of Late Period funerary monuments (EIGNER 1984: pp. 145ff). Nevertheless he offers a prototype with characteristic elements and spatial context as a concept of Late Period monuments of a bilateral symmetry, space groups of five elements (superstructure, vestibule/ antechamber, atrium/ courtyard, sanctuary, grave structure), sequence of space groups, three-strip-concept, a vertical alignment, axial concept and a canon of proportion (BADAWY 1965; LAUER 1968).

None of the mentioned publications discuss structural relationships or address formal similarities and variations.

Problem Statement

The main goal of this project was to separate design principles and parameters of the mentioned rock-cut funerary monuments by analyzing and comparing their architectural spaces.

To understand the meaning of the architectural elements of the monuments the fundamental architectural properties and concepts of usage are studied. To understand the ideas behind those aspects, recognizable distinctive features have to be converted in an abstracted format. To illustrate this point, consider the following example about the lighting system: Usually Late Period funerary monuments are oriented along a straight main axis but also a moving axis can be identified, which is not necessarily a straight line. The questions coming up are: Which parts of the monument are directly lit? Which parts have indirect lighting and why? Are there parts of the monuments unlit? What is the significance of those parts? Is there an idea behind the natural lighting system? How did deviations occur, and why? Furthermore questions about the difference of the main axis and the moving axis in conjunction with the light guide and light direction system occur.

The primary goals are the specification of structural relationships, the evaluation of extracted formal similarities and variations and the comparative architectural analysis of a group of monuments while building on and extending existing work. We introduce a Building Information Modeling (BIM) based approach to analyze and compare ancient Egyptian funerary architecture and present a solution to visualize the results.

Related work also shows that there is a need for extracting and specifying parameters and rules of architectural design of Late Period funerary monuments of Thebes to associate their appearance to each other (EIGNER 1984). When studying ancient architecture, especially funerary monuments, the social context of the owners, the cultural context and the architectural tradition need to be considered. Also the concepts of usage, the meaning of the architectural elements, the meaning of decoration in relation to the spatial structure become important aspects of the study.

Therefore detailed research questions are: What is the relationship between natural lighting and the decoration? How and for whom are spaces accessable? How does accessibility relate to lighting and decoration?

To get reliable answers to these questions the spatial relationship between the spatial structures, natural lighting, the pedestrian access and decorations need to be analyzed. Results from each monument need to be related to the others to perceive the conditions of similarities and variations between the monuments. This should enable an adaptive and easier to manage way to compare and study several monuments and to receive a structured semantic model of the building-type. This leads to a better understanding of design concepts and the intention of the funerary monument.

The number of monuments to be analyzed is restricted by the timeframe (25th and 26th dynasty of the Late Period), location (Theben West, modern Asasif), social context of the builders (High Officials) and type (monumental rock-cut funerary structure).

Methodology and Technical Solution - From Structure to Model

As we are analyzing ancient architecture, surveying the existing structure is an important first step to get an overview of the state of the building, to document the decoration program and to draw a layout plan, if none is available.

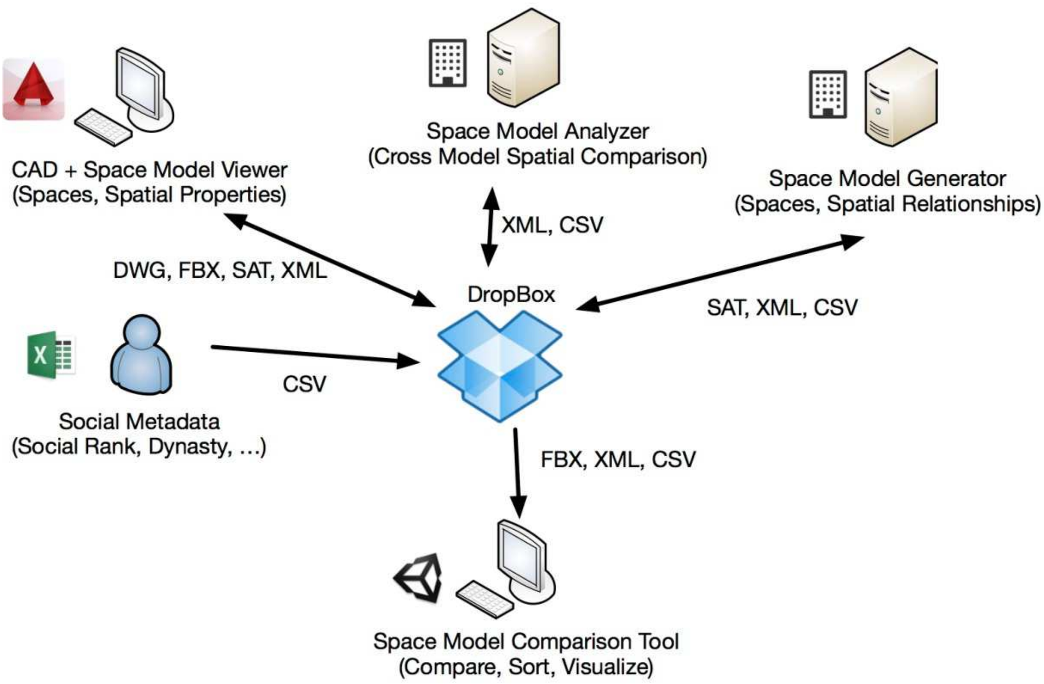

Fig. 2 – Technical Solution, internal working process and organization

The next step is to build a space model as a source layout in an existing BIM system. The relationship between physical objects (doors, openings etc.) and spaces and adjacency relation between spaces are modeled this way. The configuration of architectural spaces (e.g. space like rooms, enclosing like windows, doors or openings) is represented by detailed geometric, topological and functional information. To generate such a model, a layout plan and descriptions about physical objects like doors and openings are essential (fig. 3). To analyze the adjacency relation between spaces there is also a distinction to be made between interior rooms with openings or doors, open spaces like courtyards and external spaces. Fig. 2 shows the elements of the space analyzing process, which are responsible for analyzing and comparing the spatial structure: *space model generator* and *space model analyzer.* While the *space model generator* analyzes the spatial relationships between spaces, the *space model analyzer* offers a cross model spatial comparison. The space modeling system generates a multi-view space model from source layouts passed to the system, which can be visualized in the BIM system by directed and weighted graphs. Layout elements are represented by nodes and spatial relation elements are shown as edges (SUTER 2013, SUTER et al. 2014).
For example the 'Natural Lighting' view evaluates access to daylight. This targeted view is generated from a single source layout including spaces and physical objects. If a space has access to direct or no access to natural light is determined by the distance of internal spaces to the nearest external spaces, while the path length is used as a distance metric - a distance greater than 2 means indirect lighting (fig. 4) (SUTER 2015).

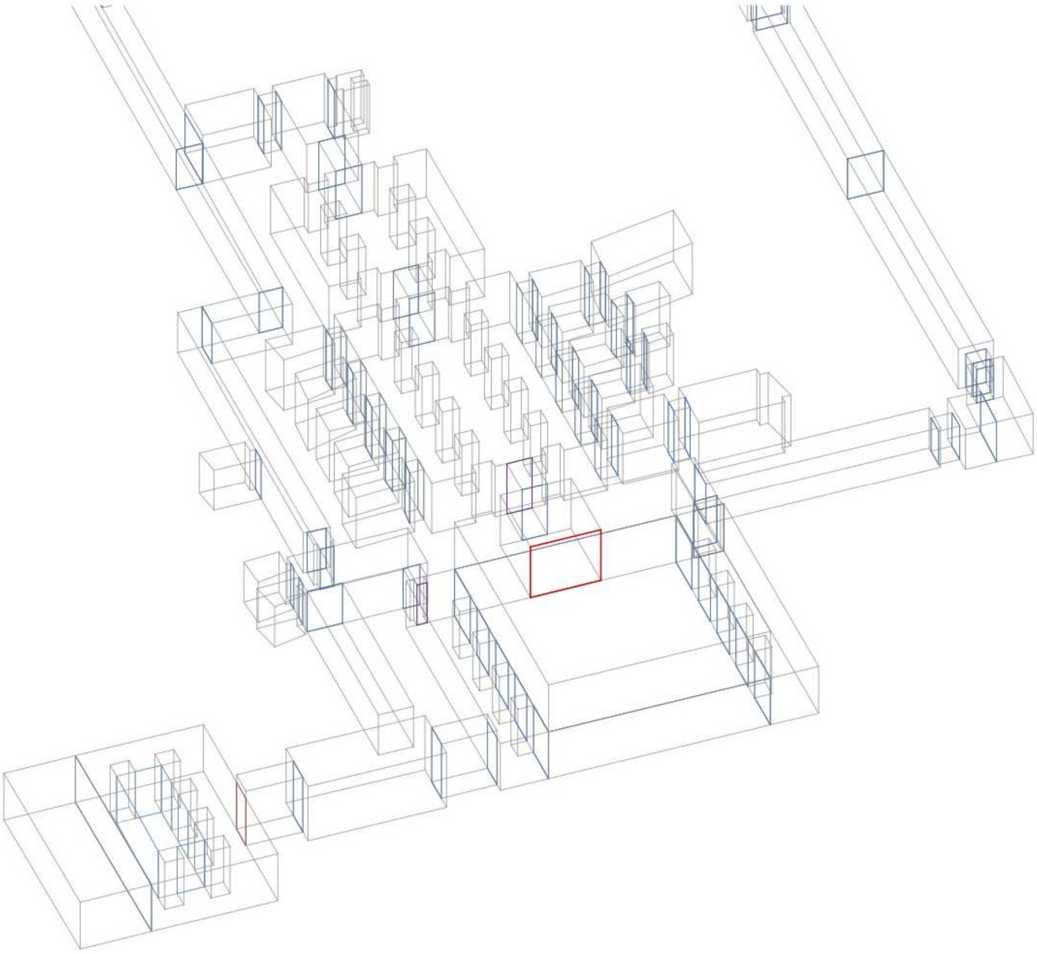

Fig. 3 – Space model of the monument of Harwa

Combined with metadata related to social and cultural aspects and information about the type of decoration, room label, position and type of sanctuary elements the results can be visualized, sorted and compared with the *space model comparison tool (SMCT)*. In the category of social and cultural metadata falls the social rank, the dynasty, the Pharaoh ruling in the time the monument was build, chronology and the extent/area of the building. The decoration program of each analyzed monument was sorted by topic categories and visualized in the SMCT (fig. 5):

- Daily life scenes (biography)
- Scenes and texts out of the "Book of the Death"
- Offering formula (*Htp dj njswt*)
- Sanctuary elements like false door, statue of the owner, shrine for the Gods or the Pharao

Fig. 4 – Natural Lighting View, Harwa

Results

For this paper four ancient Egyptian funerary monuments were analyzed: Harwa (male), Anch Hor (male), Karabasken (male) and Irtieru (female). Harwa and Anch Hor were both Chief Stewards, Karabasken a Mayor of Thebes, and Irtieru an Attendant of the God´s Priestess. They lived and functioned in Thebes during the Twenty-fifth (Harwa, Karabasken, Irtieru) and Twenty-sixth (Anch Hor) Egyptian dynasty. In their positions of High officials in Thebes they had access to the coveted funerary area of the Asasif, near the temples and funerary complexes of former Egyptian rulers.

The analysis of the architectural structures revealed not only detailed results about the natural lighting system the pedestrian circulation of each monument but also about the relationship between the different premises and natural lighting, the position of categorized decoration or the accessibility of the parts of the funerary monuments. Fig. 5 shows the visualization of daylight areas of the four studied monuments in the order of rank of the owners. It can be stated that the naturally lighted parts are also the areas of the building which were at least semi-public (fig. 4). In the case of a funerary complex semi-public means, it offered access to sacrifice to the dead. Compared to non-public areas which were reserved for the dead and not accessible for human beings. This parts of the monuments were closeable with doors (EIGNER 1984) and were likely sealed. Among these semi-public areas are the entrances, if they are monumental as in the complex of Harwa and Anch Hor and the open courtyards. The interior rooms contain the sanctuary and the burial area, which is, if existing, located in a third vertical level of the monuments and is not incorporated in this study. The natural lighting view shows that these sections are enclosed and not naturally lit. Which is also reflected in the decoration program because the results of the analysis also show that the decoration program, categorized as abovementioned, relates and correlates with the lighting and accessibility system.
The implemented Space Model Comparison Tool integrates metadata about the decoration program and visualizes the relationship between lighted or not-lighted rooms and the decoration category. It can be stated that reliefs with daily life scenes, here also defined as biography, occur only in lighted areas like the open courtyard. Also located in this semi-public area was at least one sanctuary element to offer sacrifices to a god or to the dead. If the funerary complex was not decorated, as the monument of Karabasken was (PISCHIKOVA 2009 p. 14), the system of lighting and accessibility was retained.
The Space Model Comparison Tool, which allows an abstracted spatial representation of the buildings, not only illustrates analyzed results about the lighting system and the pedestrian circulation system but the integration of social metadata (e.g. social rank, dynasty, chronology, sex) as well as quantitative analysis (e.g. area, spatial depth) also enable to sort, compare and visualize the monuments on the basis of those information (fig. 5). These analytical methods offer insights into the design principles of the often studied monuments.

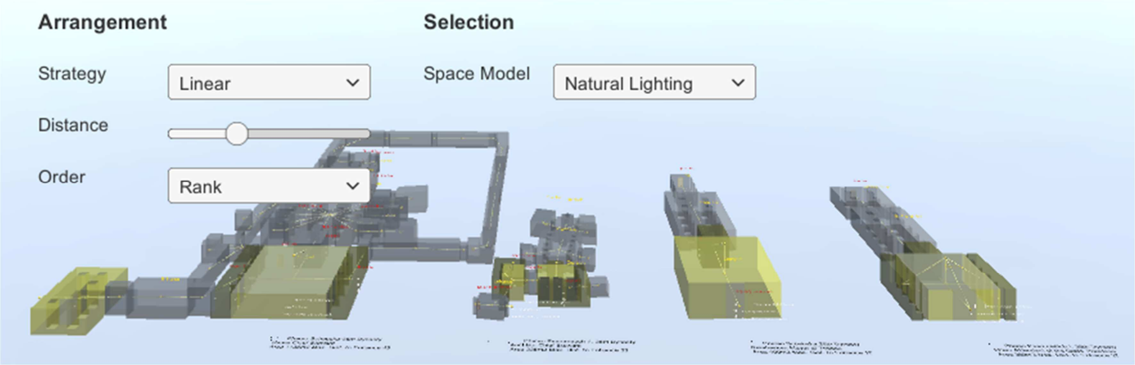

Fig. 5– Space model comparison tool (SMCT), funerary monuments sorted by rank (from left to right: Harwa, Anch Hor, Karabasken, Irtieru), visualization of daylight areas

Conclusions and future work

This paper introduces developed architectural analysis methods using BIM to generalize a space model, analyze and compare Egyptian Late Period funerary rock-cut monuments of Thebes. Furthermore the paper offers a possibility to visualize and compare ancient architectural heritage through an implemented Space Model Comparison Tool integrating not only architectural information but also social metadata, architectural quantitative analysis and metadata of the decoration program. The developed tools are independent of archaeological content and type of buildings.

For this paper and first attempt four monuments were related and their architectural results were compared to each other. In consequence a larger corpus of data will be part of future work. There is a number of fifteen related monuments within the same timeframe, local occurrence and social status class. In a further step also the geographic context, like location, orientation and terrain should be considered, because the orientation - as mentioned before - is significantly influenced by older monuments in this area. There is also no evidence or primary information about the mapping of the building grounds. Integrating information about the location and orientation in relation to older monuments could offer answers about those questions.

For the analysis of the architecture and spatial relationships of the funerary rock-cut monuments further results about the proportional and geometric status will be indispensable. This also leads to further analysis of the pedestrian access and circulation system to get more information about circles and restricted accesses. The desired results also intend an extension of the natural lighting system, which is related to the pedestrian access system as well as the decoration program, which also has to be complemented by accessible metadata. This should also lead to a development of the visualization tool with the integration of fresh survey data, like 3D-laser-scans and photographs. The integration of the locatable room inventory, like finds, should offer material for quantitative analysis.

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