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Spatial and Temporal Visualization in Archaeology – Examples from the Excavation on Elephantine, Egypt

Abstract: Urban and topographic structures, profane and sacred buildings undergo minor and major changes on different temporal scales throughout their development. This paper describes several new spatial and temporal (4D) representation methods to provide interactive, dynamic access to archaeological data and to combine all of the required information into easy to use document formats. Examples from excavations in Elephantine, Egypt with different spatial scales ranging from a single building (like the Temple of the Goddess Satet) to city structures (the so called "Northern City") will be presented, as will the changes in settlement structures in Elephantine. On the technological side, various approaches like interactive 3D PDF documents and Google Earth based visualizations have been used to represent developments in space and time. A third approach created a custom solution for interactive analysis of archaeological building layers.

Introduction

The island of Elephantine/Egypt was chosen as an ideal area for exploring archaeological content because of its complex spatial and temporal development over more than 4000 years. Since 1969, the German Archaeological Institute has been leading excavations on the island in conjunction with the Swiss Institute for Architectural Research and Archaeology. The topography of the island changed throughout history as the ancient town developed from a pre-dynastic settlement with a small shrine between boulders to a city with houses, streets and a high density of sacred and administrative buildings.

Our work will focus on changes to architectural structures, ranging from a single building to parts of a town towards changes to the settlement structures of the island. For each scale we explored a different approach to the analysis and visualization of the corresponding architectural structures. The main strategy for all approaches was to expand existing software and document formats for our needs (e.g. adding temporal attributes and other metadata) so the resulting spatio-temporal visualizations could be explored with freely available software (Arcobat Reader, Google Earth Viewer and web browsers). Our approach is design-oriented and intends to explore the complex topic of four-dimensional (space and time) visualization techniques by creating visual prototypes together with necessary software extensions.

Development of a Single Building (Temple of Satet)

The temple of the Goddess Satet existed for more than three-thousand years, developing from a small place of worship between three boulders in prehistoric times, to a small mud brick building on top of a stone temple in the New Kingdom, to an extended temple in the Ptolemaic Period *(Fig. 1)*. Several phases of the development of the temple were reconstructed and partially rebuilt. Only two phases could be re-erected in their original location. The other phases, which originally occupied the same position and existed chronologically between the re-erected structures, had to be rebuilt elsewhere.

For this reason a digital visualization method was needed which could:

- combine all phases in relation to the original location
- compare remaining structures and reconstruction variations of all phases
- add metadata to important parts of the building.

An extended version of 3DPDF, which was employed in a previous project about visualizing temporal and spatial urban developments (Ferschin et al. 2006), was able to be used as a visualization framework (3D functionality has been available since version 7.0 of the Adobe PDF file format). 3D models with several of the above mentioned building phases were generated by digitizing the re-erected parts and completing them with virtual

reconstructions (Matejowsky 2007; *Fig.* 2). A color scheme was utilized to show the difference between the physical and virtual reconstructions. Color variations also coded for properties of materials. All 3D models have been combined into one 3DPDF document, which was extended by several menus that enable one to switch between the building phases as well as to select certain layers of the model like the virtual or the physical reconstruction. For each layer of a building phase, time attributes were assigned to the layer structure. Furthermore, metadata was added to provide additional information when the user moves the cursor over part of a model. To explain how the virtual reconstruction was obtained from the excavation documentation, relevant plans, sections and reconstruction variations were included in the 3DPDF document as well. The previously mentioned extensions to 3DPDF were developed as 3D JavaScript Libraries.

By using the electronic form abilities of PDF a user interface was created that allows the user to select specific building phases and variations of the reconstruction, choose between excavated and reconstructed parts and display additional metadata attached to the geometrical objects.

The 3DPDF file format provides an interesting solution to the storage of complex spatial and temporal data and allows different types of metadata to be attached to each object of each building phase. Due to the wide availability of the free Adobe Acrobat Reader, the 3DPDF file format is well suited to the exchange of archaeological data and has the advantage that it can explore content interactively. For more detailed projects, the Adobe Acrobat 3D software allows data to be explored with interactive 3D sections and the dimensions of an object to be identified with an interactive measuring tool.

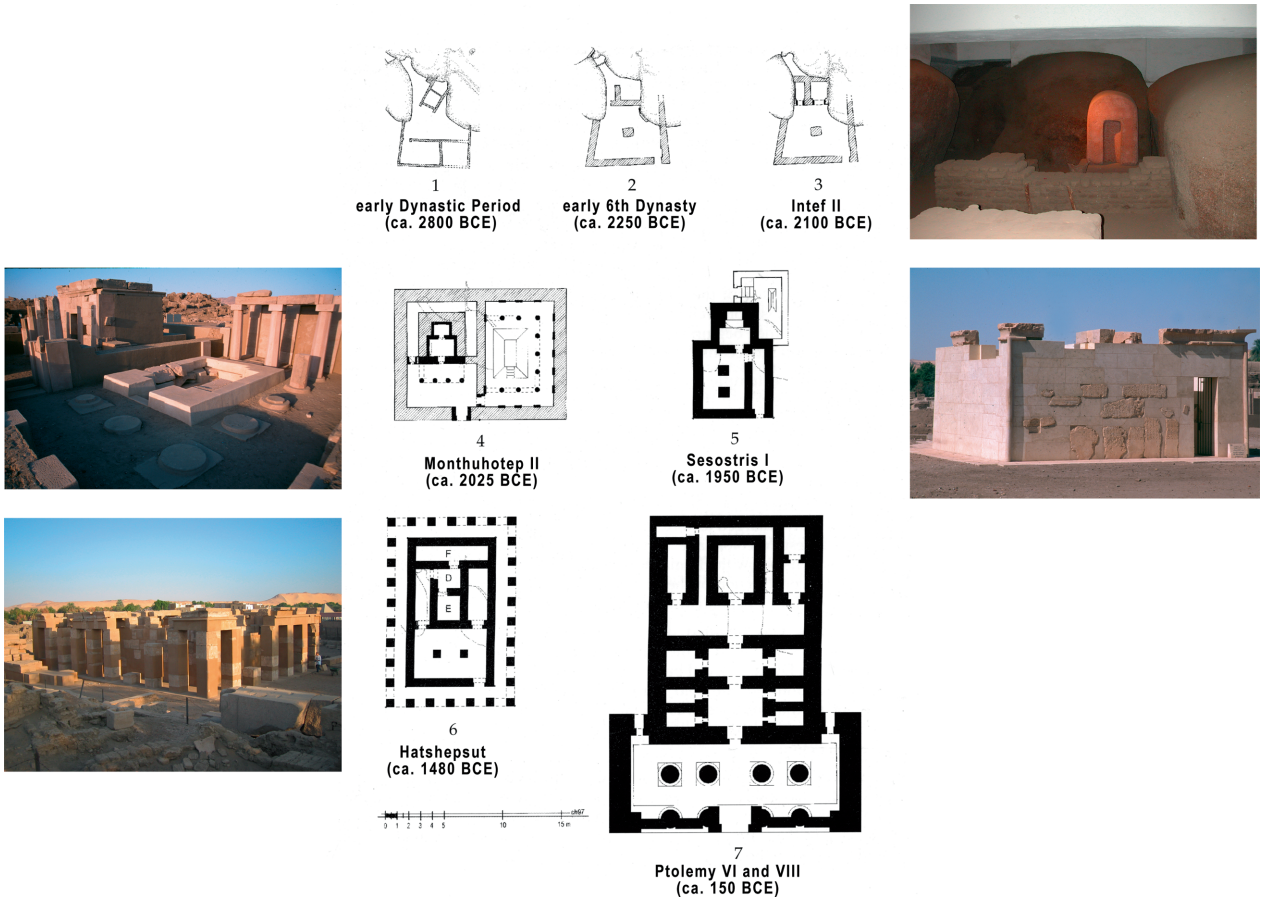

Fig. 1. Development of Satet Temple/Elephantine; floor-plans and images of physical reconstructions (Elephantine Reports; Kaiser 1998).

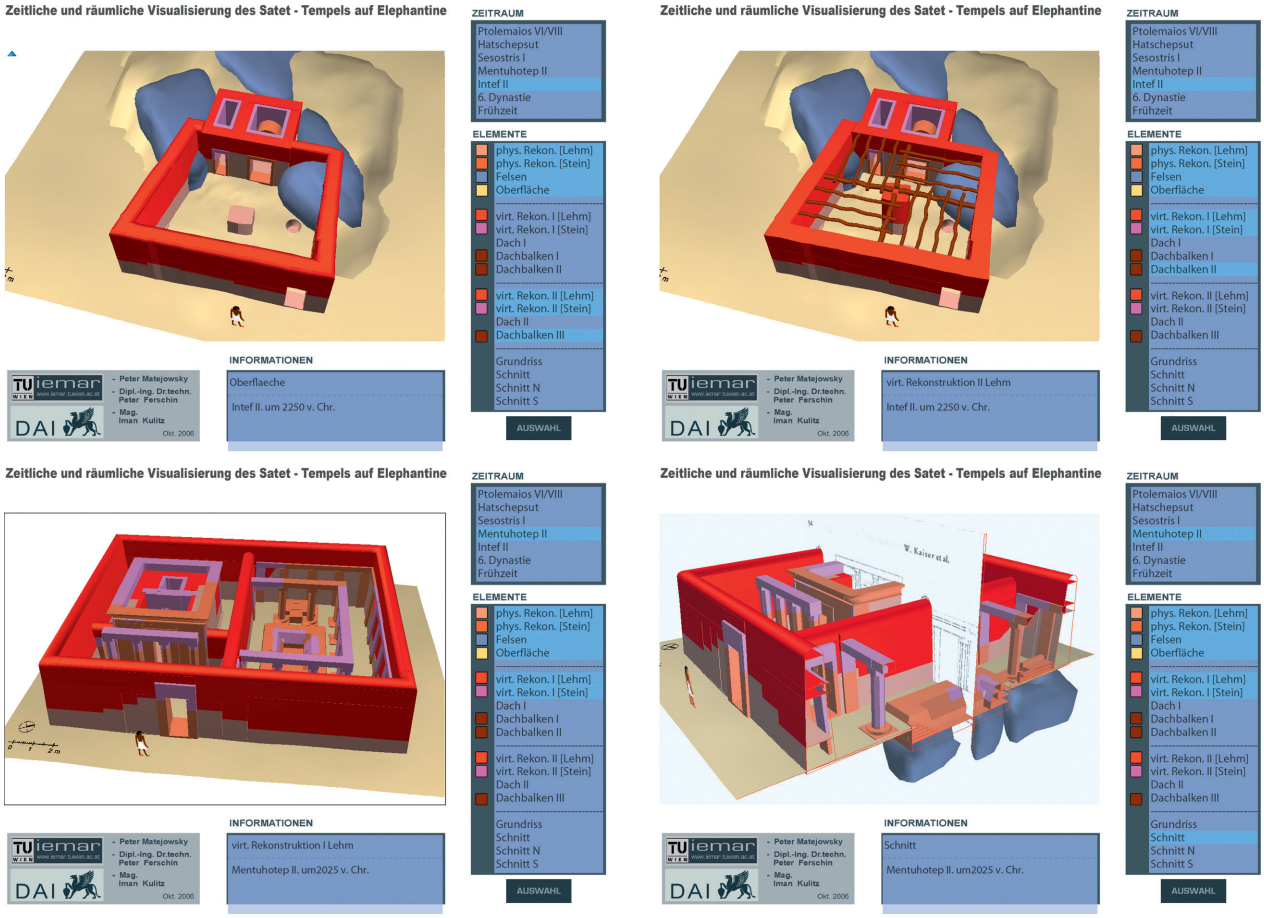

Fig. 2. Development of the Satet Temple. Screenshots of the interactive 3DPDF document: reconstruction variations of the same phase (top left – open court and altar at the center, top right – closed court with central column), a subsequent building phase (bottom left) and the same phase with interactive 3D-sections and section plans as reference (bottom right) (Matejowsky 2007).

Development of Urban Structures (Northern City)

As mentioned above, the ancient town of Elephantine changed dramatically over its history. It developed from a settlement of huts to a town with houses, sacred and administrative buildings and streets. Structures were built, replaced, dismantled and integrated into other structures. While some buildings and single walls remained practically unchanged for long periods of time, others existed only briefly.

The changes to the structures of the Northern City were shown in abstract diagrams called "stratigrams," which have been developed specifically for the archaeological studies in Elephantine (Pilgrim 1996; *Fig. 3*). However since the 3D data of the excavation has to be transformed into 2D drawings, several additional diagrams, images and descriptions were necessary to show the process of development. Diagrammatic visualizations of temporal relationships in archaeology have been generated using several approaches, as summarized elsewhere (Herzog 2006).

3D visualization methods were required to depict the complex structural changes to the city. An example of visualizing archaeological layers in 3D can be found in another paper (Green et al. 2001). In our approach, interactive stratigrams were developed to link the abstract 2D stratigrams to the 3D models of the several building layers, and to include various detailed information.

The interactive stratigram, which was developed by a group of students in the lecture course "information architecture," provides one example of such a visualization *(Fig. 4)*. The display of information is structured into three areas on the screen. On the top left part, the stratigram can be explored interactive-

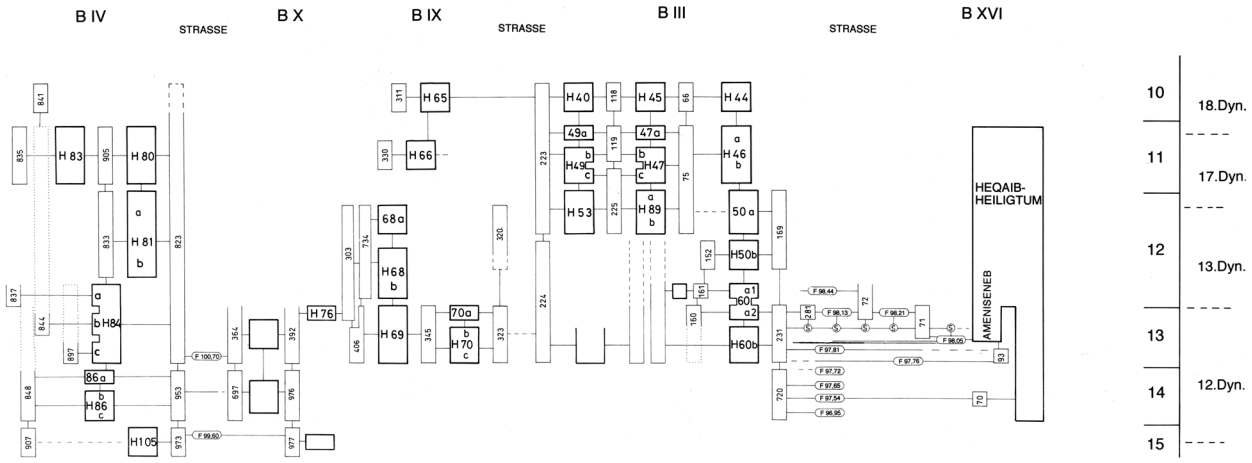

Abb. 47 Stratigramm der Bauentwicklung in der Nordstadt (W – O Schnitt)

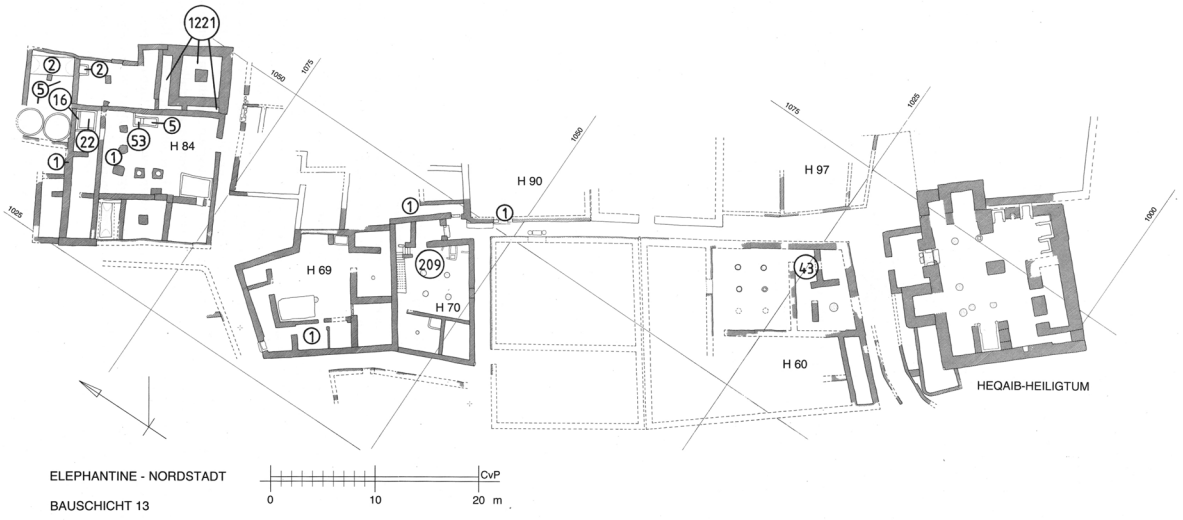

Abb. 110 Größe und Verteilung der Siegelverschlußdepots in der Nordstadt: Bauschicht 13

Fig. 3. Stratigram: W-E section of the northern city; floorplan of building layer 13 – northern city of Elephantine (Pilgrim 1996).

ly by moving the mouse over the block entries, thus highlighting the block with a color code. The bottom left part shows the building layers with transparent materials; entire walls and buildings can also be selected. The right part of the screen displays additional metadata providing detailed information about the selected objects. The example presented above shows that interactive exploration allows several structures to be highlighted. From an overview of a certain building layer (building layer 11 – dynasty 17) or the building phases of a certain architectonic object (the Sanctuary of Heqaib), detailed information can be obtained as well (house 46 – dynasty 17, or wall 75, which separated house 46 from house 47). The highlighting is done simultaneously, so by exploring the building layers, the corresponding entries from the stratigram are also highlighted and detailed information is displayed on the right side of the screen. As it was implemented as a web application, this example of an interactive stratigram, if extended with access to a suitable database system, might become a valuable tool for exploring changes in urban structures.

Development of Settlement Structures (Island of Elephantine)

In the earliest phase of its Pharaonic history, the island of Elephantine consisted essentially of a series of granite ridges. Only two large ridges projected above the waters of the Nile during the annual inundation. The first settlements developed on the eastern ridge. At the end of the Old Kingdom, the

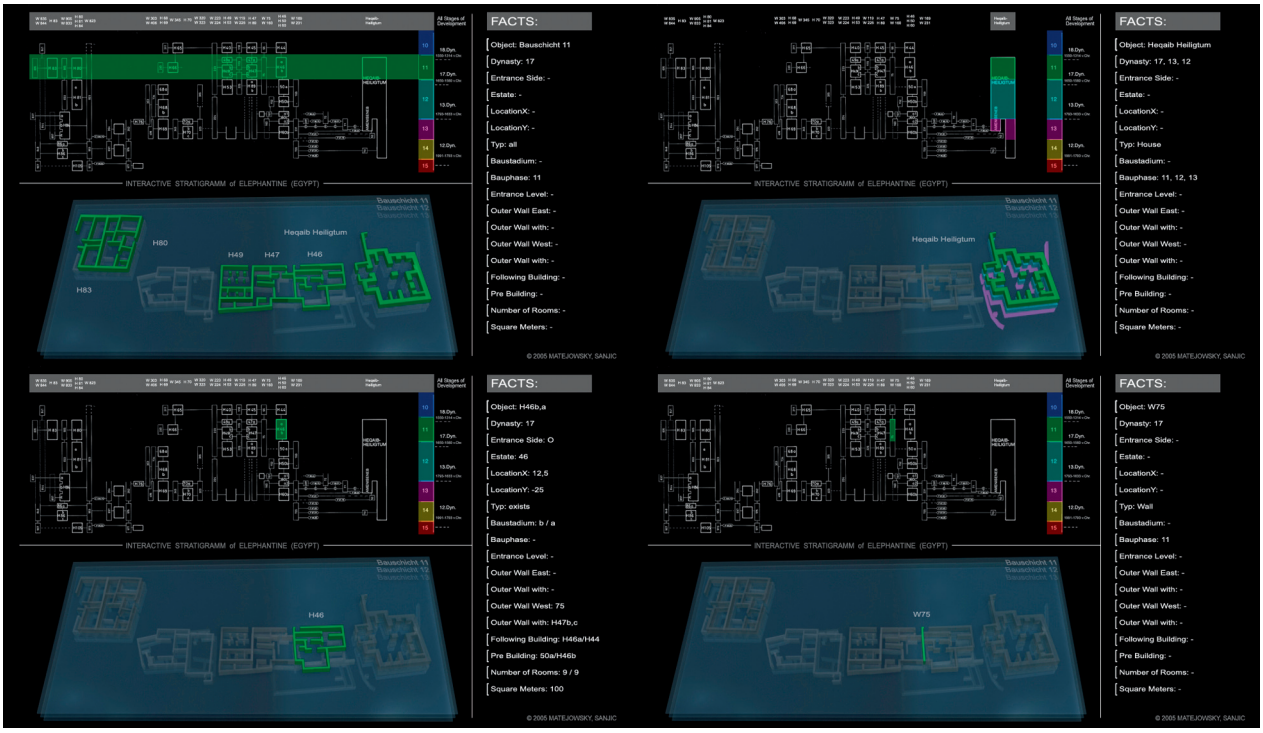

Fig. 4. Interactive Stratigram Visualization (Matejowsky / Sanjic 2005).

depression between the isles was filled to allow an extension of the settlement area.

To provide an overview of the development of the settlement structures, Google Earth was chosen as an interactive display environment. Using this program, the corresponding 3D models were converted to the KML file format and later attributed with the correct time span information. The resulting model, consisting of the geo-referenced maps, 3D models of the building structures and historical background information, can be explored interactively by navigating through time and space space *(Fig. 5)*.

An additional navigation control appears on the screen if time depended data is loaded into Google Earth. It allows the interactive display of time sequences as well as the concurrent display of data existing over a certain time-span. When the Google Earth Visualization is published to a web server, a network link allows worldwide access to the published data.

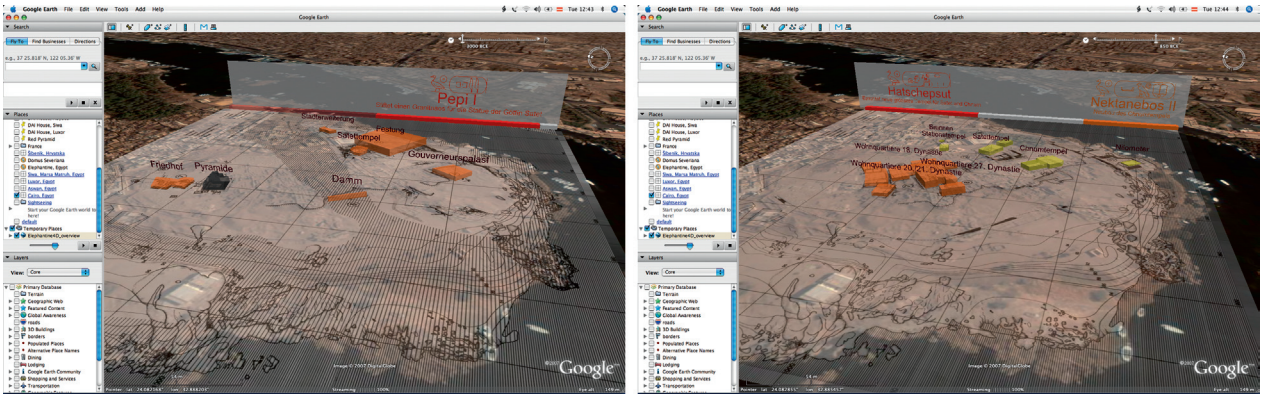

Fig. 5. Development of Elephantine, visualized in Google Earth; left: Old Kingdom – with separated islands in the flooding periods; right: New Kingdom – joined islands with enlarged urban structure.

Conclusion

We have introduced several examples of visualizing spatial and temporal developments on different scales. From our point of view it is essential to work with 4D models in archaeology, which can be generated from 3D models by adding temporal attributes. Various techniques (3DPDF, web applications, Google Earth) were tested together with different design approaches. Further work will include the extensions of the proposed visualization methods with database integration and integration into publication software for effortless publication on web servers. We would also like to integrate the aforementioned tools more tightly, so that interconnected pieces of data are appropriately linked.

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