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A new digital documentation tool for the 3D-reconstruction process

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Abstract: Digital reconstructions are becoming more and more common in archaeology and architecture. They visualize lost, but also present structures, can broaden the comprehension of a reconstructed object and point out historical and constructional relationships of the objects in consideration. Furthermore the process of reconstruction leads to an aggregation of knowledge and has become a substantial part of scientific work. However, such projects usually lack of a proper, traceable, and valuable documentation practice which is rigorously applied. In the final reconstruction state the reference of a source for a certain object may only been known to experts in the project. Understanding from an external point of view often becomes a cumbersome process. Until now, most research for documentation practice is concentrated to theoretical approaches; valuable practical tools are still missing. We introduce a documentation tool for 3d reconstruction supposed to accompany a project and to support frequent tasks in digital reconstruction processes. All used sources can be linked to the reconstructed objects. Simultaneously, the whole development process is logged automatically. The data is stored compliant to the CIDOC CRM in a graph database. With suitable navigation functionality the user can explore/compare the 3d-model together with the sources and information data. Furthermore there is a special mode for briefings and a version control to record all development steps. This tool not only may help enormously during the reconstruction process but also can be applied for final presentation of the results to experts or e.g. museum visitors.

Keywords: documentation, 3d-reconstruction, data exploration, graph database, version control

Introduction

Nowadays, digital reconstructions are becoming more and more common in archaeology and architecture. They visualize lost, but also present structures, can broaden the comprehension of the reconstructed object and point out historical and constructional relationships. Furthermore the process of reconstruction leads to an aggregation of knowledge and has become a substantial part of scientific work.

However, such projects usually lack of a proper, traceable, and valuable documentation practice and knowing from experience the willingness of the team members to document the project is rather low. In the final reconstruction state the reference of a source for a certain object may only been known to some experts in the project. Understanding from an external point of view often becomes a cumbersome process. Many projects have been analysed (PFARR 2010), but none of them has yet a comprehensible and complete documentation. The main focus of most projects is on the visual results. At best, used sources are only exemplarily declared (PFARR 2010). However, not only sources like plans, photographs, or literature, but also the development process, decisions and changes made to the model need to be documented.

The UNESCO Charter on the Preservation of Digital Heritage in general defines digital information and knowledge as part of the cultural heritage which needs to be preserved, documented and accessible to

public. The London Charter in particular declares principles for documentation of digital reconstructions and visualisations of cultural heritage. Both charters should animate to invest more energy into documentation, however they do not define any instructions how to achieve that.
As a start, a theoretical approach has been researched and applied for the digital reconstruction of the burial site of Zhaoling, Province Saanxi, China (PFARR 2010). However, valuable practical tools are still missing.

The documentation tool

Digital reconstruction and visualisation projects are usually an interdisciplinary cooperation between many specialists such as archaeologists, historians, and computer scientists at different locations. Without any doubt, communication between these participants is very important for the success of the project. However, they do not have the time to meet frequently and email correspondence is hard to comprehend or often a very cumbersome process. Thus, our tool has been designed on the basis of a web application using WebGL for displaying the 3d content.
Analysing diverse reconstruction and visualisation projects conclude that many procedures and work practices regarding the organisation and project management, modelling, and communication are similar or the same (MÜNSTER 2014). To this end, our documentation tool is supposed to accompany such a project and to support those frequent tasks in a helpful manner such that at the end, documentation and knowledge representation may become a natural part in the reconstruction process because the use is easy and the potential of the outcome convinces.
Though, the tool is still in early development. Only some of the following features have been implemented yet, others are still just ideas. Hence, the tool is not available for use or even testing purposes yet and lacks of a proper and recognizable name.

Project management

Usually, a project starts with its planning and organisation. First, it needs to be put in position and the project goals and a time schedule with milestones and deadlines (often from a project proposal) should be defined. The participants need to be assigned to their different roles (mainly the modeller and the historian). Open tasks and issues should be administrated. Still standards are lacking to formalize and ease this process.

Data acquisition

Before the modelling process can start, the primary task of some part of the team members, often the role of historians, is to collect and evaluate all sorts of sources. At least the most relevant sources, e.g. plans and photographs, should be inserted, such that the modellers can start their work. The sources should be supplied with metadata like the author and the year of creation. Maybe, some documents need to be prepared for the prospective modelling process, e.g. rectifying plans. Further sources can be inserted subsequently, e.g. literature or references to similar buildings from the same epoch.
The data internally is stored compliant to the CIDOC CRM, but on the interface the user will not see very much of any entity classes or properties. If the user is not familiar with this ontology, especially those entities with an abstract nature can lead to confusion: e.g. to draw a connection between an actor and a document,

the user would usually say that the actor created the document. But instead the CIDOC CRM defines a detour via the creation event. Those CIDOC conform connections are automatically created by the tool and the user is not bothered with confusing details.

Navigation / Exploration / Editing

One intention of our tools is to let the user work with as less text as possible. Visual presentations are more helpful in some context especially in the field of 3d reconstruction. Once the first objects are uploaded, the 3d view forms the central part of the tool. The user is able to navigate within the 3d content and gain information about selected objects. The model can be sliced and merged together with documents like plans (Fig. 1). Photographs can be positioned matching the view at the model. Moreover, the objects can be supplied with metadata, e.g. creation/destruction date or epoch. Consequently, a time slider or a colour gradient makes this information (e.g. the building history) data available and visible via an automatically generated time slider.

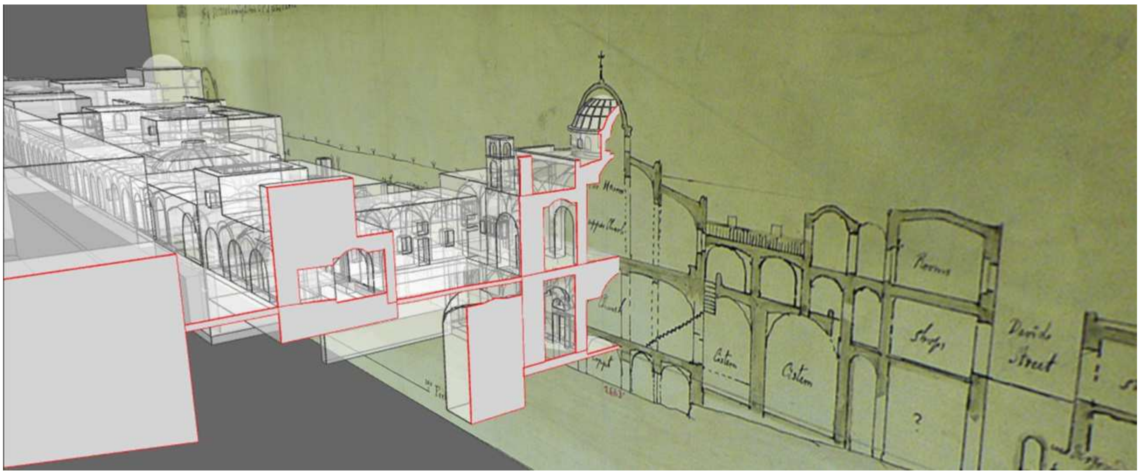

Fig. 1 – Comparing model and document for evaluation looking inside the Church of St. John, Muristan, Jerusalem (Copyright: Jonas Bruschke)

Finally, objects can be marked as hypothesis. E.g. if documents do not exist or are not available any more, the historians might want to visualise not only the remaining ruins which are still visible today, but a strong goal is the research of assumptions of how it could have been. Another aspect is also often neglected: uncertainty. Some sources may not be reliable due to the fact that the author put down his drawings only from memory or similar. So there needs to be the ability to assign a level of certainty to sources or objects.

Model hierarchy

Some sources refer to greater complexes or buildings whereas other sources refer to details. A detail may be only one object, but buildings often consist of multiple objects and greater complexes consist of multiple buildings. Hence, in our tool the user has the possibility to structure the model in a hierarchical way. By this way, the objects inherit any sources from their parents. In such a way, information about the source of some complex needs to be applied only to an upper level instance which is inherited to all the instances below. In addition, it is possible to select the different hierarchy levels in the 3d view (Fig. 2).

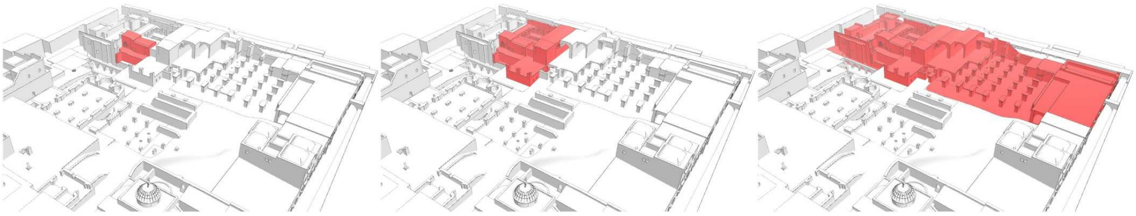

Fig. 2 – Selecting different hierarchy levels of the model of the Muristan, Jerusalem (Copyright: Jonas Bruschke)

Version Control

We strictly separate our tool from the actual modelling process which takes place in the preferred professional modelling tools of the user. If a publishable state is reached, the modeller exports the model to an interchange file format for 3d data (e.g. OBJ, COLLADA) and uploads it to our tool. The tool checks if the respective objects already exist or if there have been made any changes. The modeller needs to draw connections to used sources and report the changes possibly with respect to open issues which he now solved or decisions made by the historians. The historian in turn needs to verify the new uploaded objects and report any issues.

In the background of the system, all versions of an object are stored, such that earlier versions and hence the reconstruction history are still accessible. A specific time slider enables to view and comprehend also the development of the model such that the finding process for the present state of the model can be retraced.

Briefings

Not all issues can be resolved by leaving comments or reporting issues. Furthermore, some documents needs to be interpreted, especially when those documents differ from each other. Also, those interpretations might differ from person to person. Hence, meetings are a very important phase in the finding process. Here the interface between different groups is directly open and the different groups interact very intensively.

As the communication is verbal, a minute taker should log any relevant comments and statements. Otherwise it is possible to leave comments and decisions directly on the objects or documents. Sketches are helpful for the understanding of a problem. They can be drawn directly on (cuts of) the model or plans which will be available for the following modelling process. For this purpose an interactive pen display or digital drawing tablet is advantageous.

Data storage and processing

At the end of a project it will be possible to export the data (especially the semantic data) for further processing or archiving. To ensure somebody else can deal with it, the data is stored compliant to CIDOC CRM (as far as the data is actual cultural heritage information). Hence, there are lots of single datasets and lots of semantic relationships in between. Those data needs to be stored in an appropriate way to enable queries with good performance.

Relational databases

Relational databases are the most common type of database and have been in use since four decades now. As all the data is stored in tables, no direct connection between datasets in different tables exists. Relationships are stored in so called JOIN tables as a set of two IDs. However, those relationships are not available on request. The IDs of the datasets need to be compared and matched at runtime. A JOIN creates a Cartesian product of all potential combinations of rows, and then filters out those that are matching the WHERE clause. To gain the interested datasets all relevant tables are processed but in average 99 % of the datasets are discarded (PARTNER et al. 2013; ROBINSON et al. 2013). Additionally, more data content in those tables will result in more intensive load for processor and memory. Dealing with cultural heritage data and the CIDOC CRM often implicates highly connected data. Usually, the queries are compositions of several relationships, so there would be lots of JOIN clauses within one query. Handling with several thousands of datasets may then result in a severe performance decrease.

Graph databases

Graph databases are just one representative of NoSQL-databases (Not only SQL) and are especially suited for highly connected data. They consist of nodes and relationships, where the relationships are directed and properties can be stored on each node and relationship (ROBINSON et al. 2013) (Fig. 3). An ontology respectively the CIDOC CRM is basically a graph and so the CRM matches exactly the structure of a graph database. The logical conclusion is to use such a graph database for storing and querying cultural heritage data based on the CIDOC CRM.

Fig. 3 – Basic graph database scheme (Copyright: Jonas Bruschke)

In contrast to relational databases graph databases do not have the above mentioned JOIN performance issue as the relationships are stored directly within the database. The query starts from a node and then navigates along the relationships to the next nodes (i.e. traversing a graph). Only local operations on each node have to be performed regardless of the total count of nodes and relationships (PARTNER et al. 2013). Further benefits are the new types of queries. To comprehend the relation of two nodes, the shortest path between these nodes can be determined. Other queries are sub-tree matching or breadth-first search. In relational databases such queries are rather difficult as the table names have to be explicitly declared and there are no recursive JOIN statements.

Case studies

Digital reconstruction projects differ in many aspects. To ensure the tool can be applied to a range of projects the development is realized on the basis of three diverse projects. The first project is an example of lost structures. Just south of the Church of the Holy Sepulchre in Jerusalem is the area of the Muristan, a hospice for pilgrims at the time of the crusades being also the birth place of the Order of the Knights of St. John. Most of the plan material is delivered by Conrad Schick, a German missionary and architect, who has documented the site during the excavation in the late 19th century. Today the site is overbuilt with modern

structures, only few historical structures remain. The project reconstructs the state of the excavation, tries to visualize the hospice at its time of splendour in the 12th century and even goes back to Roman times when the site was a forum. The project deals with extensive source material and many hypotheses.
The second project visualizes thirteen drafts of the Zwinger in Dresden from the 18th century. Those structures never existed. In some cases only perspective drawings were available and a lot of symmetries and other rules of architectural style were considered to generate a comprehensible building. These considerations need to be documented in detail. Another characteristic is that the models are quite extensive, so this project is practical to stress the tool and to see how it can process big amount of data.
The third project deals with a still existing structure, the Cathedral of St. Nicholas in Fribourg, Switzerland. The main focus is not the actual reconstruction, but the visualization of the construction phases. Additional aspects that should be supported by the tool are the visualization of mason's marks and dendrochronological information of the roof truss.

Conclusions

Often in projects a lack of documentation can be stated. Many theoretical approaches claim to tackle this problem but still practical solutions are missing. Our presented tool improves and simplifies the documentation practice of digital reconstructions. It helps to ease this important part of the finding process and should raise to an indispensable part of reconstruction work. With the help of our tool, it will be possible to comprehend the development of the 3d model at the end of a project by reviewing used sources and made decisions. Furthermore it provides a method to present the achieved knowledge to specialists as well as to a broader public.
The use of a graph database is valuable for working with highly connected data. The CIDOC CRM conform storage of the data enables the possibility to process the data in further projects or museum facilities.

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