A Case Study of Using BIM in Historical Reconstruction

The Vinohrady synagogue in Prague

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Abstract. *This article reflects on the digital reconstruction of the Vinohrady Synagogue in Prague, which was demolished in 1951. Based on an international collaboration through the Erasmus program, expertise derived from other Viennese synagogue reconstructions at TU Vienna was combined with a resource organization methodology developed at KU Leuven. The reconstruction process is carried out using BIM software, which poses some particular attention on the software methodology and model structure, but at the same time illustrates the added value of a BIM approach, when comparing with more traditional CAD modelling systematics. Of particular interest is the approach for modelling complex geometry, integrating with more traditional 2D documents and for visualizing reconstruction assumptions within the 3D model representation.*

Keywords. *Virtual reconstruction; destroyed synagogue; 3D-modeling; BIM; urban context.*

INTRODUCTION AND MOTIVATION

When a certain building no longer exists and a new function has been found for the property, a physical reconstruction no longer makes sense. However, a virtual reconstruction has the power to unveil the existence of this building to the main public, albeit in a non-physical manner. In this sense, the conference theme of "Digital Physicality - Physical Digitality" is represented in contemporary virtual remodeling of buildings of a foregone era.

The project is mainly brought forth by the ongoing research at the TU Vienna on computer-assisted reconstructions of non-existent (architectural) objects and their surroundings, in particular (Viennese) synagogues. Years of experience in this area have led to the development of a systematic procedure regarding the virtual reconstruction of synagogues. By way of the ERASMUS international exchange program, a symbiosis could be established between the synagogue-oriented workflow of the TU Vienna and the more general research work on digital historical reconstruction at the KU Leuven. The latter focuses mainly on a systematic approach concerning the thorough analysis of the architectural object and the structured archival of the reconstruction project.

Though virtual reconstruction is not a novel development, this paper will elaborate on both the expansion of a methodological structure to organize historical resources and the application of BIM for modeling and information presentation in various formats.

Historical context

Královské Vinohrady was a "young" neighboring city located southeast from Prague, that was incorporated by the capital in 1920. After the civil and economic emancipation in the mid-19th century, the Jews could settle in the newly created districts and suburbs of the rapidly growing city. Even in these new urban areas, they established the Jewish houses of worship, cemeteries, and synagogues. The largest and probably most spectacular synagogue was designed by the Viennese architect Wilhelm Stiassny and erected between 1896 and 1898 in Sázavka Street. The entire building was an expression of wealth of the local Jewry. The synagogue could accommodate about 2000 believers, thus being the largest synagogue in Prague and one of the biggest in Europe as well.

In contrast to many other Jewish Sacral buildings, the "typical" dilapidation was not achieved in the course of the pogrom night of November 1938. During the Nazi occupation, religious services were banned in autumn 1941. In that period a furniture store was established inside the building, selling what had been confiscated from the Jews. The sacral building was severely damaged during an unexpected air raid on February 14th, 1945, and finally torn down in 1951.

Nowadays, Prague still possesses a large number of synagogue buildings from different eras, centrally located. However, the Vinohrady Synagogue - with attached side wings, belonging to the property - incorporated a richly decorated appearance and a particularly interesting lighting situation in the interior, despite the improper orientation of the piece of land.

MORPHOLOGICAL BACKGROUND

The Vinohrady synagogue, as mentioned earlier, was the largest synagogue in Prague and stood on a plot of land of 2.550 m^2. The building was designed in neo-renaissance style and represents a rather symmetrical plan and elevation. Two 60 m high towers visually divide the building in three parts: the main nave, which consists of the prayer and ceremony hall, and two more plainly decorated two-story side buildings.

Not only the architecture of the building is of interest in the project, but also the surrounding area was investigated. Figure 1 displays the evolution of the urban tissue in different eras in time, based on the *Web Map Portal* of the *Historical Town Atlas of Prague* [1] - a project of the Historical Institute of the Academy of Sciences of the Czech Republic.

At the time of its foundation, Vinohrady was separated from the downtown area by city walls. After these were taken down in 1866, the construction of this new suburb would start booming gradually. This implied a more structured vision on city landscaping; thus, an orthogonal street pattern with more or less equally sized plots was laid out. Building blocks consisted of terraced housing, of four stories or more, with their gardens facing towards each other. The town square of *Náměstí Míru* was the starting point of ten surroundings streets radiating

Figure 1
Evolution of the neighboring area.

outwards. In between these radii, an orthogonal division was set.

METHODOLOGY

Main strategy

Out of past experience with synagogue reconstruction at the TU Vienna (Martens and Peter, 2002), a certain strategy had already been distilled to approach this type of project in a valid manner. The following steps were identified:

1. Research work concerning plan documents, picture material and descriptions
2. Comparing plans with photographs
3. Definition of a story structure
4. Determining a layer structure
5. Compiling used materials
6. Determining textures
7. Compiling library elements and modules
8. Archiving project files

Processing resources

It is essential to develop structuring to the project, relying on the available sources prior to commencement of producing the virtual model. Therefore the first two steps were supplemented with findings at the KU Leuven, namely that proper archiving of source material is not only crucial, but strongly assists to assess the validity of assumptions and interpretations, to create a solid base for the rest of the project.

The organization of all possible resources is based on a methodology that was developed (Vandevyvere et al, 2005) and applied (Boeykens and Neuckermans, 2009) during a series of previous reconstructions. A listing of all possible sources is referenced in a so-called "metafile", which acts as a resources metadata table. This is handled in a spreadsheet, which is quick to set up and easy to adapt. Such flexibility would be lost in a strict database structure, as the structure is commonly project-dependent. Whereas the categorization of resources might be following a chronological structure in one project, it might be shifted towards a functional or spatial structure for another project. Instead of simply listing all possible material in a long, but mostly unstructured list, the table is constituted mostly of facts and claims, with varying levels of accuracy attached to it. This allows e.g. building parts or project phases to be linked to multiple fragments from texts, drawings, and sketches and to assess the probability, which aids the reconstruction process. The table is mostly textual, however, it serves as a direct reference sheet for the modeling and visualization.

Most of the material for this reconstruction was obtained from the archive of the Prague Jewish Museum and included plans, documents, drawings and pictures. However, due to the demolition of the temple, a proper interpretation of these resources has to be performed carefully, e.g. regarding the actual built situation or color information. As the synagogue no longer stands today, survey of the site was impossible and the reconstruction was based solely on information records. The objective tabular listing of facts makes it possible to better understand the decision-making process to assist assessment and interpretation of resources that the reconstructor goes through, which does require certain assumptions and interpretations.

Categorization of facts happens on a case-by-case basis. In this reconstruction study, we were confronted with an overflow of graphic entities and a lack of specialized literature with hard facts. The main goal was to identify the content of each image, (visually) compare them based on certain properties and derive properly funded conclusions to start the virtual reconstruction in the modeling software of choice. For easy processing and accessibility in the future, this entire process had to be well documented. The following properties (metadata) of each image were identified:

- *Type*: addresses the type of image that the file presented (plan, section, photograph, drawing, design or view e.g. elevation)
- *Purpose*: describes what the image aimed to do: document a certain fact or view, (re)construct/alter (part of the building), propose de-

Filename	Type	Purpose	Location	Floor	Date	Year	Group	Author	Source	Comment
p0001	plan	heating	right side building	1	unknown	unknown	1	unknown	JMAP	
p0002	plan	heating	right side building	1	unknown	unknown	1	unknown	JMAP	
p0003	plan	heating	right side building	1	unknown	unknown	2	Leopold Ehrmann	JMAP	
p0004	plan	heating	right side building	0	unknown	unknown	2	Leopold Ehrmann	JMAP	
p0005	section	heating	side buildings	N/A	unknown	unknown	2	Leopold Ehrmann	JMAP	
p0006	plan	heating	right side building	-1	September	1937	3	Saniterma	JMAP	
p0007	plan	heating	right side building	0	September	1937	3	Saniterma	JMAP	
p0008	plan	heating	right side building	1	September	1937	3	Saniterma	JMAP	
p0009	plan	heating	right side building	2	September	1937	3	Saniterma	JMAP	
p0010	plan	heating	right side building	-1	unknown	unknown	N/A	Saniterma	JMAP	
p0011	plan	heating	center	0	19 January	1896	N/A	unknown	JMAP	
p0012	plan	heating	center	1	18 January	unknown	N/A	Wilhelm Bröckner	JMAP	
p0013	plan	heating	center	0	18 January	unknown	N/A	Wilhelm Bröckner	JMAP	
p0014	plan	heating	center	-1	18 January	unknown	N/A	Wilhelm Bröckner	JMAP	
p0015	plan	unknown	left side building	2	unknown	unknown	4	unknown	JMAP	AB, CD
p0016	section	unknown	left side building	2	unknown	unknown	4	unknown	JMAP	AB
p0017	section	unknown	left side building	2	unknown	unknown	4	unknown	JMAP	CD
p0018	plan	unknown	right side building	2	unknown	unknown	4	unknown	JMAP	A'B',C'D'
p0019	section	unknown	right side building	2	unknown	unknown	4	unknown	JMAP	A'B'
p0020	section	unknown	right side building	2	unknown	unknown	4	unknown	JMAP	C'D'
p0021	plan	unknown	left side building	1	unknown	unknown	5	unknown	JMAP	notes
p0022	plan	unknown	left side building	2	unknown	unknown	5	unknown	JMAP	notes
p0023	plan	heating	center	-1	unknown	unknown	N/A	Jul. Jelínek	JMAP	
p0024	plan	heating	center	0	unknown	unknown	N/A	Jul. Jelínek	JMAP	
p0025	plan	heating	center	1	unknown	unknown	N/A	Jul. Jelínek	JMAP	
p0026	plan	heating	center	0	09 June	1911	6	Theodor Löbker	JMAP	
p0027	plan	heating	center	1	09 June	1911	6	Theodor Löbker	JMAP	
p0028	plan	heating	center	1	09 June	1911	6	Theodor Löbker	JMAP	zoom on name
p0029	plan	heating	center	-1	09 June	1911	7	Theodor Löbker	JMAP	
p0030	plan	heating	right side building	1	09 June	1911	7	Theodor Löbker	JMAP	
p0030	plan	heating	right side building	2	09 June	1911	7	Theodor Löbker	JMAP	
p0031	plan	heating	right side building	0	09 June	1911	7	Theodor Löbker	JMAP	
p0032	plan	heating	center	0	unknown	unknown	N/A	unknown	JMAP	
p0033	plan	heating	center	1	unknown	unknown	N/A	unknown	JMAP	
p0034	plan	cadastral data	plot	N/A	unknown	1893	8	unknown	JMAP	overview (large)
p0035	plan	cadastral data	plot	N/A	unknown	1893	8	unknown	JMAP	scale
p0036	plan	cadastral data	plot	N/A	unknown	1893	8	unknown	JMAP	overview (small)
p0037	plan	unknown	left side building	2	31 October	1938	9	unknown	JMAP	wash- and bathingroom
p0038	plan	unknown	left side building	2	31 October	1938	9	unknown	JMAP	zoom on date

Figure 2
Excel screenshot of the meta-file and filtering process.

sign ideas for certain (light) fixtures, propose a layout for the seating chart, officially marking the contours of the plot of land and its building (cadastre)

- *Location*: specifies the location of the content of each image: center (main nave), (right or left) side building(s), plot (of land), façade, interior, and certain building parts like the tower, roof or the fence
- *Floor*: divides the certain position of the images in different story's: cellar and foundation (-1), ground floor (0), first floor or gallery level (1), attic and upwards (2)
- *Date*: specifies if any day or month is mentioned on the document
- *Year*: specifies if any year is mentioned on the document
- *Group*: forms certain collection of images e.g. documents that belong together
- *Author*: mentions the author if any is given
- *Source*: defines where the image was found e.g. archive, the internet, etc.
- *Comment*: adds any extra information needed.

In just one file (see Figure 2) all the gathered information was collected to lighten the workload of remembering and comparing the content of well over 100 different files. Within the spreadsheet format, different columns could easily be filtered to show the diverse properties of the images. For example one could immediately see all the synagogue plans on a certain level or combine the search of certain properties to make a useful list of comparable documents. The undergone evaluation process and visual comparison was archived as well and comments or updates could be added in the future, if new findings would occur.

Fragmentizing the work

In a project of this size, one can expect to be creating very large files when trying to obtain a certain level of detail. This delivers also an argument to apply BIM and some parametric design concepts to optimize and control geometry generation. The presence of many different, complex objects in a single project file, tends to prolong the computer's calculation time, which would be an unwanted side effect as it slows down the work significantly. Therefore, it was opted to divide the process further into two stages: first, a basic building structure was set up, based on the documented findings and afterwards, the complexity of the model was expanded. The latter stage, was then again divided into the modeling of exterior and interior elements.

By carefully dividing and archiving the work, indeed a large amount of data is still created, but the reasonable size of each file makes it easier to work with and access and/or alter specific elements in the future.

APPLICATION OF BIM

3D modeling

While CAD and generic 3D modeling software is widely used for historical reconstruction, we have deliberately chosen an approach using BIM software. Although BIM is mostly oriented to current construction praxis, there have been some attempts to investigate its applicability in reconstruction projects. Murphy et al (2009) describe the use of terrestrial laser scanning as a surveying technique for existing structures and how to further integrate the captured point clouds in a BIM workflow. However, as the Vinohrady synagogue is demolished, this was obviously no option for this project.

Graphisoft ArchiCAD [2] provides a number of functions that meet the demands of the required geometric modeling, story administration, layer allocation. While less relevant for historical reconstruction, the software provides a vast library of materials and parametric objects. Although ArchiCAD has already proven to be a usable modeling system in previous projects, it is fair to say that recent software updates have enabled a more flexible and extensive arsenal of modeling features, which was quite lacking in older releases. Especially the improved support for more organic geometry, such as the *Shell Tool*, has proven to be of utmost importance to gain a more detailed and accurate result. Furthermore, compatibility with external modeling and visualization software where even more extensive 3D modification can be carried out, such as Maxon Cinema4D [3], has proven to be very useful in this reconstruction.

Another interesting tool is the *Renovation Filter*. Even though its main focus lies on contemporary renovations, it has the potential to become a very powerful tool if further developed. While the current options are rather limited - an element can be given only three types of fixed properties (existing, to be demolished and new) - this tool could potentially be used for more fine-grained “tagging”, e.g. to show different building stages. While this function was presumably not intended to be used for historical projects, in this case it was used to nest different sets of objects with different materiality into one single model. The objects can be shown or hidden according to the *Renovation Filter* that is chosen.

While ArchiCAD 15 has indeed been seemingly developed to be more accessible and user-friendly for projects differing from current building practice, the provided set of tools still presented certain flaws and limitations. The *Shell Tool* still contains certain bugs or errors and the *Renovation Filter* has a high potential but is too limited. Also the link to other 3D modeling software can be very useful in some cases, however, it can produce (polygonal) geometry that is too complex for ArchiCAD to process, e.g. when generating vectorial shadows and hidden line views. One of the initial goals of the project was to make full use of the power of BIM and create intelligent, parametric objects applying ArchiCAD’s internal, Basic-like, GDL scripting language (Nicholson-Cole, 2000) that could be re-used in other similar reconstructions, but the size of the project proved to be too vast to actually achieve this with more complex objects. Chévrier and Perrin (2009) present an approach of using parametric modeling for historical reconstruction, using the Maya generic modeling and animation software, but this was not integrated in a BIM workflow.

Documentation

The possibility of BIM to manage a model that can serve different outcomes is one of the biggest strengths of this approach. The same model can be

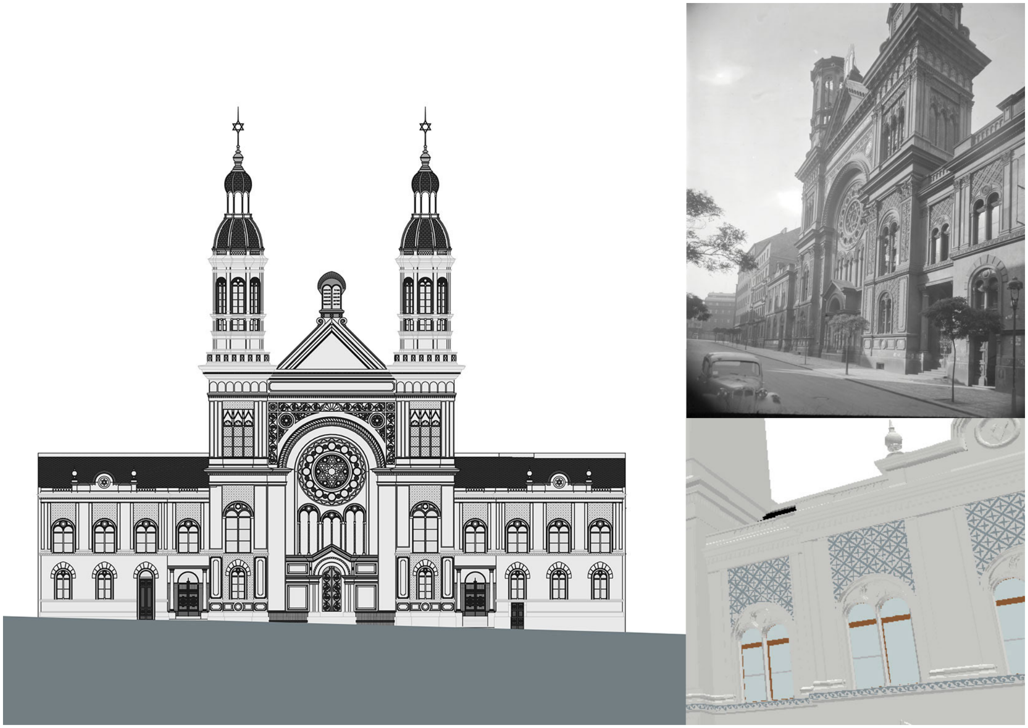

Figure 3
Materiality of the model (left) elevation showing off the custom materials (upper right) original photograph (lower right) custom materials seen with the internal 3D engine.

used for the generation of drawings, 3D representations, but also a listing of objects or materials and dedicated filtered views, e.g. the core structural system or a spatial model. A 2D drawing can instantly be seen in 3D and vice versa.

An implementation example of using BIM for the documentation of the Vinohrady Case Study can be seen in the custom wall patterns, which complete

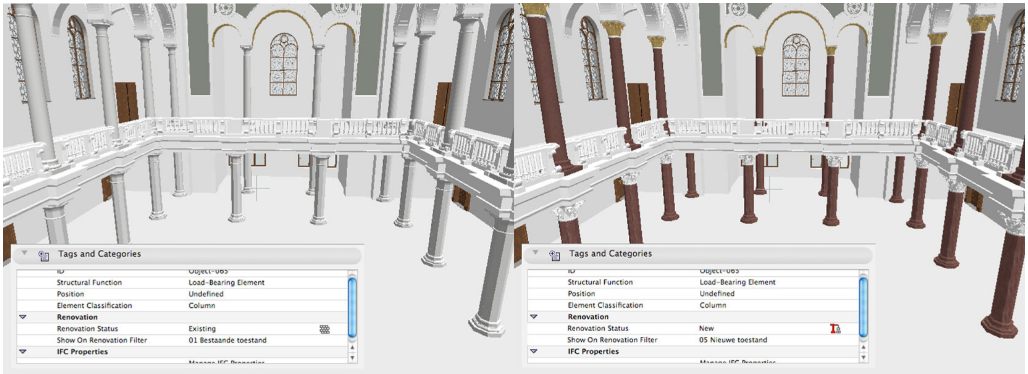

Figure 4
Visualization of assumptions.

Figure 5
The reconstructed model placed inside the street context.

the façade drawing as well as the 3D model, with no additional drafting effort. If possible, the pattern of the new materials can be straightly deducted from on site photographs, but since no high quality pictures were available, simple geometric shapes were drawn with 2D polygons and saved as vectorial hatches that can be applied to an existing standard ArchiCAD material to deliver an added dimension (see Figure 3). In a later stage, when creating realistic renderings, these simple two-tone drawings of the vectorial hatches can be used to create matching bump maps.

Visualization

Even though the methodology that was implemented during the reconstruction gives the model a factual backbone, the repetitive visual assessment that was part of the reconstruction process remains very subject to interpretation if there is no physical evidence left of the building as it once was. Since pho-

Figure 6
Comparison between historical photograph and interior rendering.

to-realistic rendering is the most tangible output of the project, it is important that the public is correctly informed about this. Different sets of renderings are produced to clarify any assumptions in materiality. Of course these renderings are mostly still made to trigger the imagination of the viewer. The more muted model, where no assumption in materiality has been made, loses its sense of realism, whereas the colored model, which suggests materiality in an obvious way, is a make-believe mockup to attempt to recreate a plausible reality (Figure 4).

Also time restrictions and hardware possibilities present to be problematic in this case. Perkins (1992) already asked the following prominent question two decades ago: "How good is good enough?" Even today, there are still limitations to the visualization of historical reconstructions, beyond the control or knowledge of the person generating the image. There are no well-defined visualization requirements set, and the reconstruction is carried out to the best of the abilities of the reconstructor to create a balance between the quality of representational data and realism that is credible for the main public, all achieved in a certain limited time frame.

Renderings are an easily accessible representation of the assumed historic context, although one has to take care of not suggesting interpretations as facts. Non-photorealistic techniques or schematic diagrams can be applied to clarify assumptions. An exterior rendering, positioning the model in a more schematic white context, is depicted in Figure 5.
While all original photographs bear no color, they can be compared with the renderings to assess the lighting quality and overall ambience, as shown in Figure 6.

CONCLUSIONS AND OUTLOOK

Virtual reconstruction is not a novelty as such. To restore cultural heritage, computer visualization technology is able to facilitate virtual reconstruction. Since this process is influenced by personal decisions, experience and expertise, a solid backbone based on facts has to be created. This project merges the research results of two universities and uses the extended methodological framework to tackle the virtual reconstruction. A key principle in this process is documentation: it is of vital importance to properly archive and document all resources and decisions that were subsequently made. Following this approach, the reconstruction remains accessible to outsiders and the defense of certain interpretations can still be argued in the future if needed.

Using a BIM environment in general has a few advantages: custom geometric modeling, story administration, layer allocation, etc. Also, the use of parametric and adaptable objects within ArchiCAD has the potential to lighten the workload of future reconstructors. To effectively support historical reconstruction however, some adjustments will have to be made. Although a positive evolution can be seen within the software, most tools are still exclusively focused on contemporary building practice. To accommodate the needs of historical reconstruction, the reconstructor should be able to have access to an even more user-friendly set of tools to create custom objects and perhaps a cloud, to share these objects with other academic or personal users. Though a significant number of the objects are project-specific, they could profit from parameterization so that small alterations to parameters could make the object suitable to use in a different, yet similar project i.e. synagogue reconstruction. As of today, most historical modeling libraries are made ad-hoc, on a project-specific basis.

In addition to these improvements, the scope of visualization techniques could be expanded to present an even more realistic (i.e. closer to a past reality) reconstructed setting to the main public. While photo-realistic images or even 3D prints could suffice to satisfy the expectations of the average viewer, a more interactive visualization technique could perhaps recreate a sense of digital physicality-physical digitality in a more immersive way (see Martens and Peter, 2011). In this way, the viewer could discover the model himself, instead of only getting the information from predigested rendering shots.

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