Figure 1: Reconstruction of the Palais Stoclet in Brussels.

Peer-Reviewed

(Re-)Creating the past: 10 years of digital historical reconstructions using BIM

Stefan Boeykens, Sanne Maekelberg, Krista De Jonge

Abstract: Starting in 2003 the Department of Architecture of the University of Leuven (KU Leuven) has utilized digital reconstructions in several Masters Dissertations. Over the years different topics have been the subject of study, ranging from Burgundian residences to lost religious heritage sites, and addressing a range of methodological difficulties specific to the integration of historic architecture with modern technologies have emerged.

As Historic Building Information Modeling (HBIM) has found its way to a broader audience over the last few years, attention must be paid to the methods and means by which these reconstructions are presented to a wider audience. New technologies inevitably change the perspective of the viewer, shifting from a distant observer to a close inspector (sometimes providing visual access and virtual proximity to reconstructed elements that were never even supposed to be seen up close). New means of communication and visualization need to be realized that fully address the possibilities and limitations of the reconstructions.

Keywords: HBIM, Digital Historical Reconstruction, CAD, BIM, visualization.

Digital Historical Reconstruction today

Computer-Aided-Design (CAD) has changed the way that historians and architects interact with the built environment. In addition to the remarkable increase in detail, accuracy and efficiency, the use of CAD in heritage and conservation has also increased access to cultural heritage. The application of CAD implies using real measurements and scale, allowing for a deeper insight in the building and its construction. When recreating lost building states or constructions it is possible to get a better understanding of their perception by contemporary witnesses, especially of space.

Even though photorealistic visualizations are possible, Alkhoven[1] stated early on that the actual visualization (realistic, idealistically, fictitious) is not the main concern; rather, the underlying narrative and interpretation by the researcher, alongside the reconstruction methodology are of much higher importance. The question of *how* sites looked must always be coupled with the question of *why* they are being reconstructed. This narrative can be communicated by using a combination of techniques demonstrating different aspects of the building. Boeykens et al.[2] describe how architectural analysis may be aided by the use of a variety of 3D modeling and visualization techniques, for the most part applicable to historical reconstruction cases, including improved application of meta-data for model documentation.

In the reconstruction of Josef Hoffmann's Palais Stoclet in Brussels (fig. 1), a combination of direct 3D modeling, laser-scanning (for particular statues) and the extraction of textures from photographs was used on the reconstruction.[3] The final model also allowed the creation of photo-realistic renditions.[4] At the same time, and mostly derived from the same model, a real-time application was created to allow an interactive virtual visit to the building, even though the building itself is not publicly accessible (fig. 2). In this case, the Unity3D game engine provided a good combination of reasonably

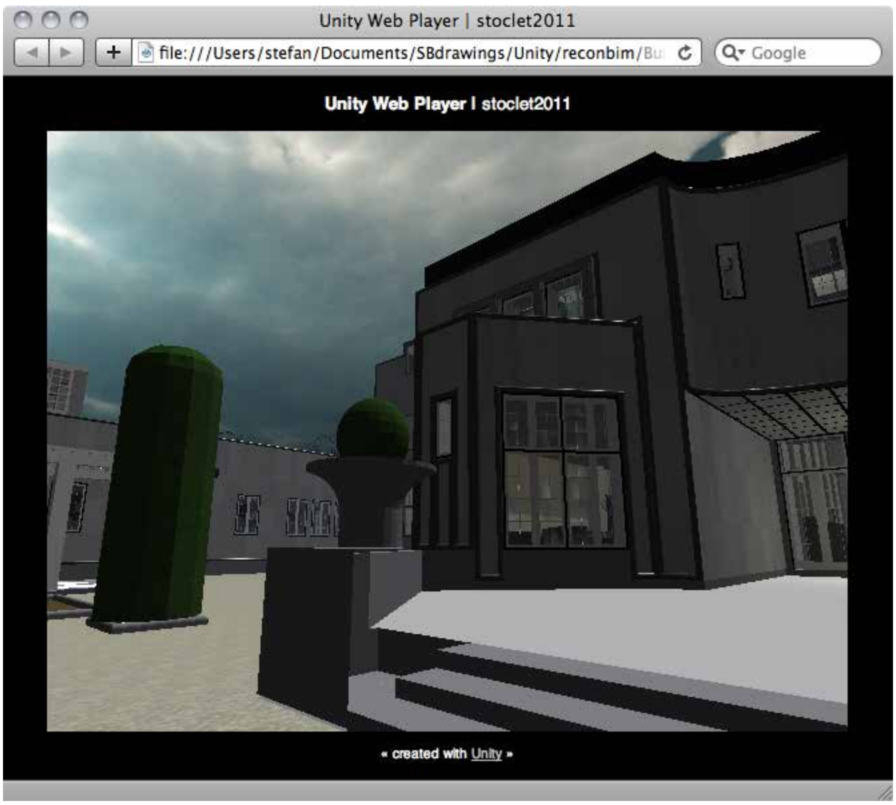


Figure 2: Reconstruction of the Palais Stoclet in Brussels in the Unity Web Player.

straightforward import of geometry from the 3D model while quickly adding the necessary interactivity, such as walking, gravity and collision detection. Early reconstructions involving such a game engine focused solely on real-time interactivity: material, color, light and movement. However, as later applications illustrate, more aspects of the information and embedded metadata could be leveraged.

In other cases the focus is different and various software combinations are being used. Galiana et al.[5] look at the methodology of topographical reconstruction from archeological sites for Ambassador Vich's Palace in Valencia, to reconstruct a morphological plot, main volumetry and layouts of façades, alongside the functional layout. The work of Anetta Kepczynska-walczak[6] looks at performance issues and aims at representing space, time, behavior and light in digital reconstruction models. The main challenge lies not in virtual reconstruction per se, but rather in the stimulation of new methods and fields that become accessible using these techniques. Other examples include the use of Virtual Reality to develop immersive environments for a historical context or Augmented Reality techniques to visualize artefacts as overlays of the current physical world. The use of surveying techniques and their integration in a BIM modeling environment is also widely studied and documented, e.g. with the work of Garagnani[7] discussing Terrestrial Laser Scanning (TLS) and how these results can be properly incorporated into BIM collaborative design processes.

These examples serve to illustrate that no unique, ideal solution exists; rather, the choice of method and software tools has always depended on the aims of the model.

The BIM revolution

The real methodological turning point in the context of digital heritage has come with the implementation of Building Information Modeling (BIM) in the field. BIM is first and foremost a methodology to organize construction projects, through the creation, evaluation and exchange of digital, virtual models. This process is being adopted worldwide and is already compulsory in some countries for public projects. There are many international efforts to organize the BIM process and to further develop the BIM methodology. This aspect falls, however, outside of the scope of this article. Here we focus more specifically on the use and added value of using BIM technology in historical reconstruction: the so-called BIM software tools to create and manage these models.

There are several commercial BIM Software applications available on the market today. They are all grounded in the same philosophy, but implement it in a rather varied way. The oldest and most mature software system still in use today is Graphisoft ARCHICAD: a BIM software for PC and Mac, with a clear focus on architectural design and parametric geometric description of objects. Autodesk Revit, a PC-only BIM platform, has become probably the most-used BIM system worldwide in recent years, partially due to the strong marketing powers of Autodesk. Other systems, such as Bentley AECOSIM or Nemetschek Vectorworks and Allplan are valid alternatives.

Currently, these BIM software systems present a wide range of functionality, with a combination of advanced 3D modeling, extensive documentation capabilities for drafting, and photo-realistic visualization. In addition, they allow for information management and extraction using embedded properties, extraction of quantities into schedules, and integrated evaluation tools for energy calculation. Most systems also support point-clouds from laser scanning and are compatible with the Industry Foundation Classes (IFC), an open standard (ISO 16739:2013) for interoperability and data sharing in the construction industry.

The difference when using BIM software—rather than CAD software—lies in the overall configuration of the model. Rather than separately making 3D models and 2D plans for different floors, sections and facades, BIM represents a holistic approach: the model and all of its related documents are inherently connected. From a single model all related plans, sections, elevations, perspective drawings, as well as the 3D model and schedules, can be derived. Moreover, BIM splits up the built environment into reusable parametric objects, allowing for a more thorough analysis and in-depth information concerning a project and the elements it comprises. These elements are the building blocks of the model and they can be enhanced with information concerning a wide variety of aspects, such as cost or the origin of the component.

The integration of 2D and 3D is also worth noting. In a traditional CAD approach, plans are completely disconnected from the model. They usually evolve independently and there are huge risks of inconsistency. The reconstruction of the garden pavilion of the Rubens House,[8] for instance, reveals several discrepancies between the different 2D survey drawings, which have been manually drafted during the reconstruction and restoration works. Embedding the scans of plans and sections into the BIM environment makes it possible to align the drawings properly, but also revealed their inconsistencies (fig. 3). A reconstructed BIM model has plans, sections, elevations and perspective drawings which are all aligned and consistent. The Rubens pavilion reconstruction also used a BIM technique to embed multiple alternatives into the same model, in particular to allow the comparison of the actual built state and an idealized perfectly symmetrical version thought to represent the architectural vision of Rubens more closely. Similarly, reconstruction has to deal with different levels of accuracy in surveying, depended upon the surveying tools used and the care with which the survey is carried out. In this respect CAD is analogous to drawing on paper as decisions have to be made while drawing. BIM makes it possible to combine different options, thereby taking in all the available information.

In the reconstruction of the Vinohrady Synagogue, which was demolished in Prague in 1951, specific attention was given to the concurrent availability of multiple representations.[9] Based on drawings from the archives and on older city maps, the main layout of the site was first recreated as a 2D CAD drawing, to be used as an underlayer for the BIM modeling. The actual model was used for photo-realistic rendering, which enabled a comparison between remaining black-and-white archive photographs and a realistic colorized rendition of the interior from the same perspective (fig. 4). At the same time, the exact same model was also used for the elevation drawing (fig. 5), ensuring full consistency.

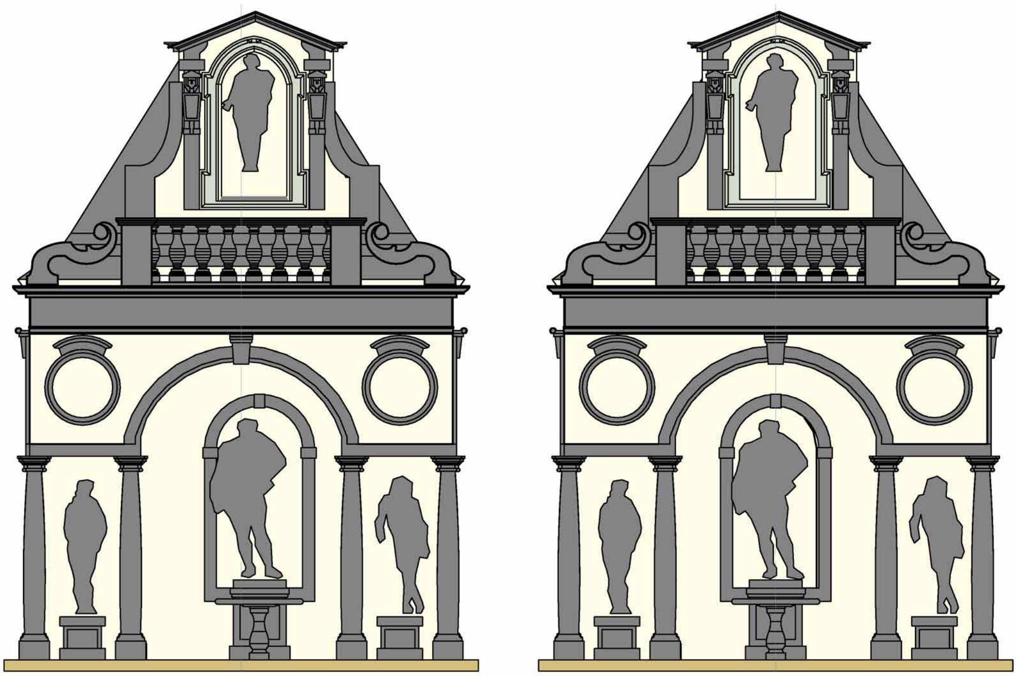


Figure 3: Schematic rendering of two survey drawings of the garden pavilion of the Rubens' House, showing slight differences in the placing of the statues.

Figure 4: Comparison old black-and-white photograph with a realistic rendition of the interior from the same perspective.

Figure 5: Elevation drawing, black-and-white photograph and render of the exterior of the Prague Synagogue.

In the context of digital reconstruction, BIM opens up an even wider range of possibilities. Models in the context of BIM are indeed not simply 3D geometric models. They also embed large amounts of attributes and properties: about materials, dimensions, composition, function, performance, among other characteristics. It is even possible to embed custom data, for any chosen purpose. As such, BIM enables a more data-driven approach: models can be used to query information, but the data can also be used to control geometry, detail and representation. The combination of geometry (dimensions, sizes, quantities) and embedded information offers a major advantage for reconstruction. The model thus becomes a rich knowledge base for a project, a 'thick description'[10] capturing and assembling data from different sources into a single and interoperable whole.

It is possible to formulate what-if scenarios: a single model may contain multiple variants of a reconstruction while staying coherent. This encourages the researcher to investigate possible interpretations more thoroughly, and also to communicate them more adequately and with less effort. In the past, as shown by many reconstruction projects applying regular CAD or 3D visualization systems, this often required the creation of several, disconnected models. While feasible for final, fixed models, the reality is that models are continuously refined over the course of a reconstruction, thus rendering the synchronization of changes over several models hard to manage.

Moreover, the very nature of embedded data in a BIM approach allows for a more flexible series of possible representations. Rather than having a single model with fixed geometry and materials, alternative representations and thematic views are possible. Martens and Peter,[11] for instance, have developed a large series of digital reconstructions based on ArchiCAD BIM as a virtual archive of lost Jewish synagogues. They have mostly focused on the structured methodology and best practices of the software environment, alongside the 3D modeling and visualization results that are offered that way. While this and other cases cover a wide range of possibilities, a KU Leuven student work from the past decade continues to demonstrate its research potential.

HBIM best practice: historical validation

As BIM is still maturing, it requires more methodological research to develop best practices for HBIM also. An important issue concerns the 're-traceability' of every element in the model, in other words its critical underpinnings. Whatever method is chosen for data acquisition, the decisions made during the digitalization process must be documented precisely. The challenge here lies in the historic validation of the decision process and its communication towards any third parties, particularly the viewers of the digital model. At KU Leuven the first part of properly organizing and documenting the reconstruction process has been achieved by establishing a so-called "metafile": an accompanying report recording the information used for the model and the decisions made in the process.[12] The following table (table 1) shows a small fragment of the metafile for the reconstruction of the Saint Walburgis Church in Antwerp.[13]

The meta-file is implemented as an Excel table, with a custom setup, which varies between reconstructions. Each row represents a known fact and its sources, whether archaeological, archival or iconographic, alongside the source reference, analysis and interpretation, linked to a part of the building complex. Recreating a lost building or building phase invariably means making hypotheses and suppositions. Each part is graded according to the quality and reliability of the source. The elements in the model can thus be evaluated relative to the information in the meta-file. The resulting "level of (un)certainty" can also be represented by a color code, ranging from green to red. As a separate document, the metafile is less attractive to the viewer of the digital model. Therefore, the model needs a second layer showing the level of certainty achieved for each part. This can be considered the 'conclusion' of the metafile.

Building Part	Part / element	Source/Rating	Comments Source	Interpretation / Arguments / Consequences for model	Hypoth. degree
Ground floor		Obj ID 16 (1735?) Obj ID 32 (1798-1803) Obj ID 12 (<1816?): +	Unknown creator & data. Iconography mentions accurate and quite detailed. Assumed drawing created before demolition of the church (before 1816)	Most usable ground plan from catalog, to be used as basis for model. Photograph from document, straightened in Photoshop. Plan was scaled according to Obj ID 16 and OBJ ID 32	2
	Position columns on plan	Obj ID 16 (1735?): ++ Obj ID 18 (1741?): +++ Obj ID 12 (<1816?): +	Detailed discussion Obj ID 16 and 18 iconographic study. Obj ID 18 assumed more reliable. Obj ID 16 mentions dimens. in feet.	To position columns in the longitudinal direction of the plan, the average of the distance between all columns on plan Obj ID 12/	1

Table 1: fragment of the metafile for the reconstruction of the Saint Walburgis Church in Antwerp.

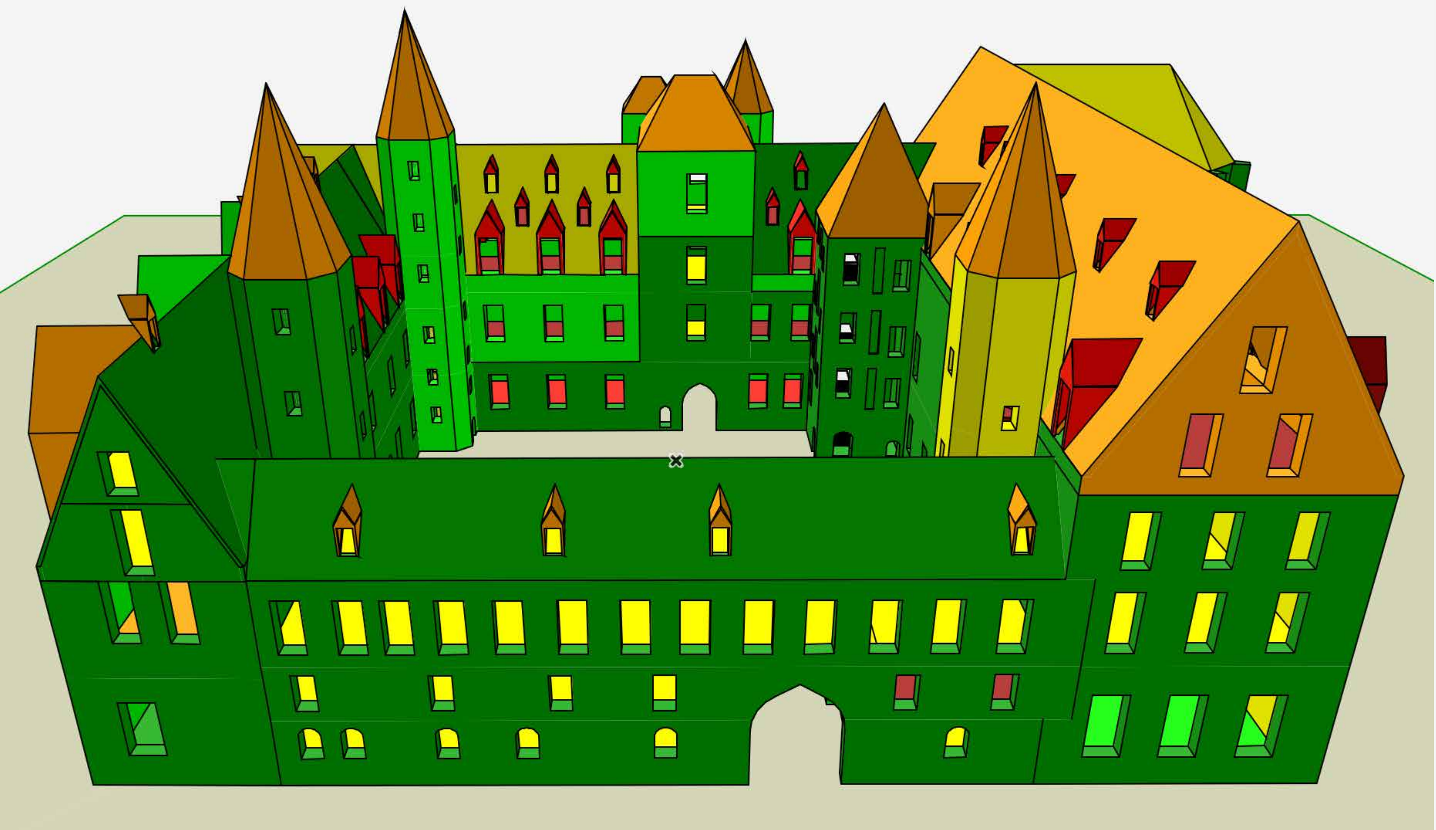
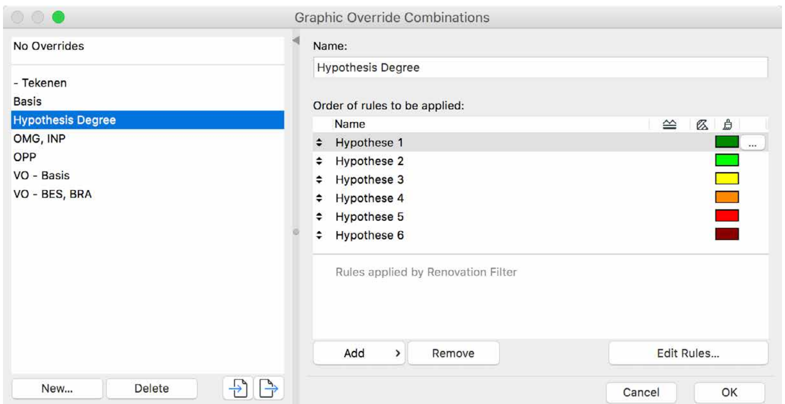
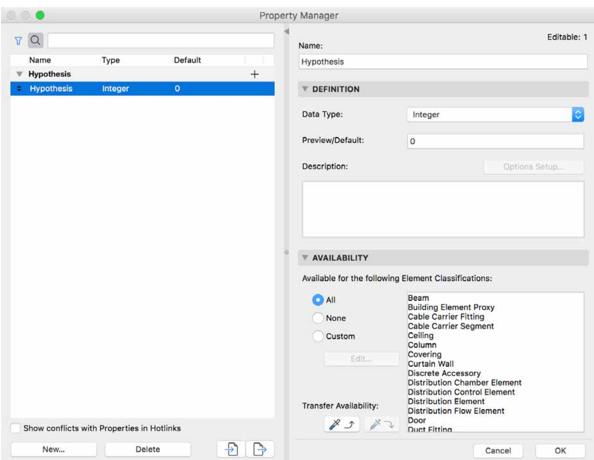


Figure 6: Hypothetical model of the Palais Rihour at Lille, made using Graphic Overrides.





In earlier KU Leuven reconstructions, several techniques were attempted, including creating separate variants of the model manually, using fake materials or using image-editing in Photoshop. While the results were visually satisfying, none were data-driven, nor could the color-coded representations be derived automatically from the reconstruction model. It was thus impossible to embed information and sources that led to the reconstruction in the model. With the adoption of BIM techniques, however, it has become possible to actually embed parts of these meta-data into the model and having them steer the representation. This helps to integrate conclusions more deeply with the model, and reduces the workload and chances of errors creeping in.

In BIM software, a custom parameter can be attached to model elements and filled with the hypothesis value from the meta-file. This can be done directly with the element properties, or in a derived schedule, which facilitates entering the information for a large quantity of elements and helps to discover errors or missing fields more easily. For instance, within ARCHICAD 20 two new features were introduced in 2016 which greatly improve the workflow to embed this information in a custom representation: property tables allow easy creation of custom parameters, which can even be exchanged with MS Excel, so the tables can be entered in a more familiar spreadsheet environment. The results can be re-imported into the model. Additionally, Graphic Overrides allow the visual representation to be derived from element properties. By creating a custom Hypothesis property, with possible values ranging from one to five, a data-driven visualization of the degree of hypothesis is possible by assigning a color code to the different values (1- green to 5 – red). This has been applied in the Palais Rihour reconstruction (fig. 6).[14]

These techniques facilitate integration and automation: the same model can still be represented with regular materials, alongside additional thematic views, driven by model data. This color-coded model represents the conclusion of the historic research, showing the amount of available source material and the plausibility of the reconstruction. For now, the decision-making process leading to this conclusion is not inherently part of the BIM reconstruction, although it could be implemented in custom text fields. This way, the meta-file becomes even more valuable in the context of HBIM.

The snags of HBIM

Modeling a building within a BIM environment essentially implies breaking it down into its constituent elements and assembling it up from there. The model becomes a hierarchic aggregate of elements, their components, and the relations between elements. The current generation of BIM software, while fairly mature and increasingly widespread, focuses mostly on contemporary building practice, especially on the documentation of recent residential and commercial buildings. Likewise, the included material libraries only cover contemporary machine-produced brick masonry and industrial wood construction. When transposed to the historical domain, the available BIM libraries naturally do not fully cover the wide gamut of architectural styles and construction techniques needed to 're-compose' historical buildings. Their application in the context of historical reconstruction thus presents severe limitations.

Moreover, BIM tools are inherently constrained: walls are commonly vertical, with a constant thickness; floors are horizontal and windows are rectangular; stairs are straight and obey building code rules. Even though there is some flexibility in the native element tools (e.g. slanted wall, sloped roof), they are meant for an idealized description of a building. For heritage documentation and especially in the restoration context, it is very difficult to properly describe the actual situation with its irregularities and finer detail. Modeling a profiled vault, timber construction or dormer window thus becomes very complex rather quickly.

A solution to this would be a custom library of historic elements, a concept which is not new. Chévrier and Perrin[15] described the use of 3D animation software (Autodesk Maya) to develop a parametric collection of building elements for the research of a particular corpus of elements for Montréal (Canada) and Nancy (France). A first possibility, which most systems provide, is the direct modeling of these elements as static geometry. Murphy et al.[16] focused on Laser Scanning and using these scans as a reference context for reverse engineering, thus obtaining an 'as-built' BIM component. This method is only applicable when actual artefacts are available and accessible. When there are no physical artifacts left of a particular site, comparative reconstructions can be based on descriptions, excavations, and analogies with other still existing buildings of the same period and style.

In this context, it is tempting to use building or construction guides, and the treatises of the early modern age on the column orders. Most of these were conceived as an elaborated catalogue of architectural forms, often supplemented with reality-based measurements and geometric instructions on how to achieve the discussed shape. Following the same rules, it thus seems possible to construct these elements without too much difficulty, transforming them into digital BIM objects, which could then be developed into a library of elements. But this is not feasible everywhere. In the sixteenth-century Low Countries, for instance, practice-based treatises are lacking and many of the built examples have partially or even completely disappeared. By adding the necessary attributes, it is possible to integrate such objects with reasonable results into the model. It is even possible to add a custom but static 2D symbol for plan representation. While by far the easiest way to add custom elements, this approach nevertheless does not profit by the added value of BIM: these objects are not flexible to adapt and do not react to the expected representation settings found in regular BIM objects, such as scale-sensitive display or adapting to changes in dimensions and properties.

In order to use the full potential of the BIM approach in historic reconstruction, a custom library is seen as the better solution. Here the forms and architectural elements that constitute the basis of the reconstruction are defined. It is most efficient to define generic, parametric elements according to a particular "style" or period, so they can be used for different projects, thus creating a re-usable library. If a true HBIM library could be applied, reconstructions would embed more reusable information. It would become possible to extract lists and counts (e.g. the list of all windows, grouped per size and type), or to derive estimated material quantities from the model, provided that reasonable information is available regarding elements' composition and dimensions. More structured models will also facilitate data mining on models: numerical analysis of model aspects can be used to support project comparisons beyond mere visual aspects. A relatively accurate reconstruction can be used as the basis for deeper analysis, with information that has become more accessible. However, care has to be taken with the development of such objects, in order to maintain full control and usability in the reconstruction process.

The following example displays an arched opening, where the dimensions but also the form of the arch can be parametrically controlled (fig. 7). They are derived from mathematical rules, drawn and parameterized directly in the BIM software. This way, the window element not only contains the geometry, but also actual information, such as dimensions or type. As such, the geometric model becomes richer in embedded information. By allowing parametric control, with graphical hot-

Figure 7: Arched opening with parametrically controlled dimensions and arch type.

spot editing directly in the 3D window, the user can position and reshape elements interactively and still retain full controllability at all times.

However, this approach with a custom library of re-usable elements is also potentially flawed. The building archaeologist's point of view would be diametrically opposed to this, stating that each object (column, window, roof truss) is one of a kind and that the reduction to standard elements means losing the individuality of a building. The method would nevertheless still make sense in certain historical contexts, e.g. for reconstructions post-1860 when industrial fabrication made it possible to produce increasingly standardized elements. Generally, the development of real parametric library objects is justified for re-usable elements, whereas the creation of particular, singular elements may be executed using direct modeling.

Exploring new avenues in Historical Building Information Modeling (HBIM)

Part of the model for La Maison du Peuple by Victor Horta, developed ten years ago, used BIM software for reconstruction purposes.[17] In fact, the student chose to split the model into an abstract interior model, using ArchiCAD BIM software, and a more detailed ornamental façade model, using 3D animation software (3ds Max). This way, plans and main schematics to explain the building were based on the HBIM model, but the intricate organic detail of the façade was deemed too complex at the time for this environment. To that purpose, animation software was

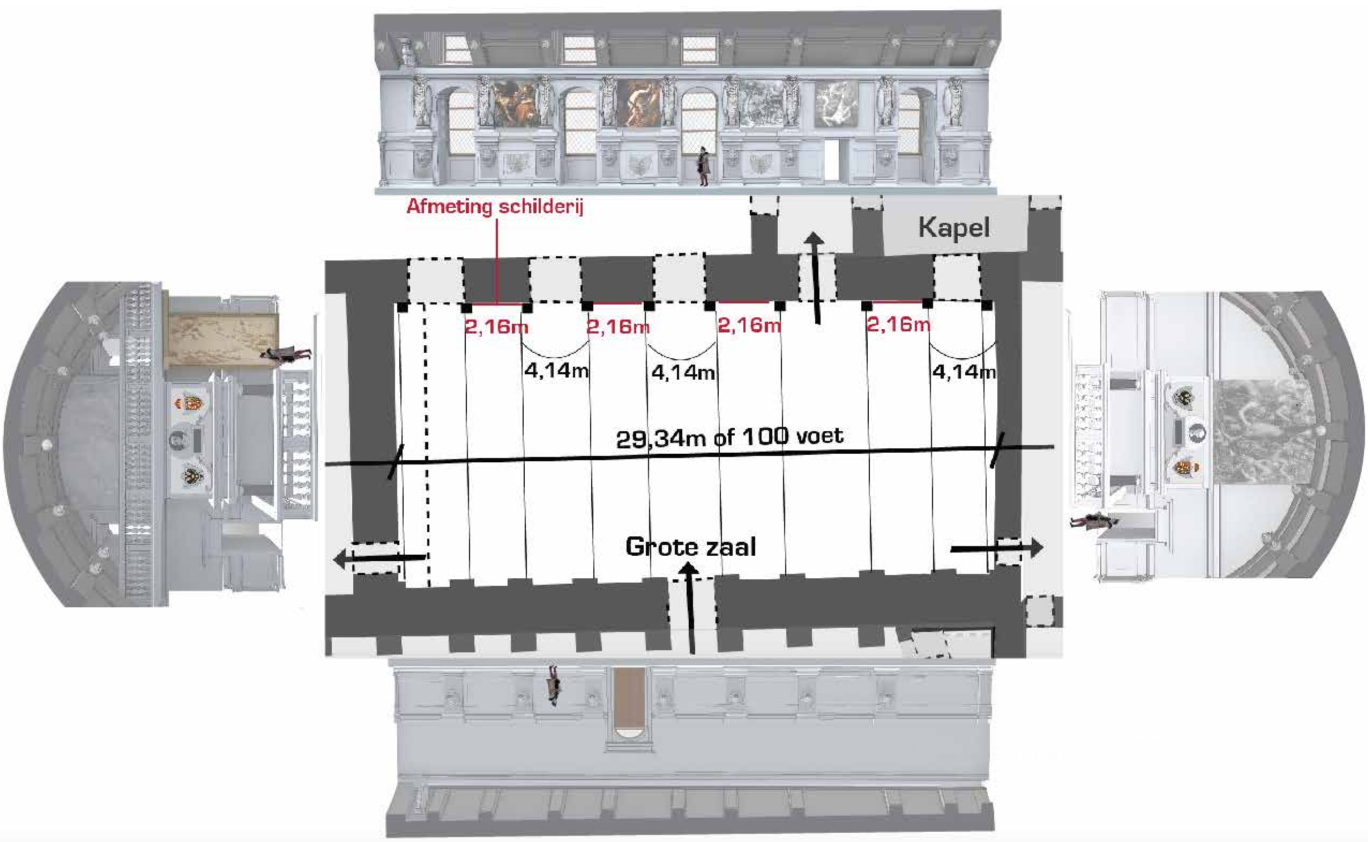
Figure 8: Model for La Maison du Peuple (left: detailed façade model in 3ds Max, right: abstract interior model in ArchiCAD BIM).

Figure 9: Reconstruction of the Rubens House in Antwerp.

Figure 10: Comparison of the reconstruction with a historic photograph of the reconstruction site.

Figure 11: Reconstruction of the great hall of the palace of Mary of Hungary at Binche.

Figure 12: Visual description of the dimensions and wall composition of the great hall at Binche.



used with parametrically driven splines and sweeps. The end result was quite detailed, and pushed the capacity of the lab computers available at that time to the limit (fig. 8). Today, computer power presents fewer limitations, but the complex organic forms of the façade are still not offered by the BIM library, a problem that will be treated in detail later in this paper.

The reconstruction of the Rubens House in Antwerp used a combination of a HBIM Model (fig. 9), an integrated visualization system and an interactive application.[18] As part of the presentation an interactive application was developed, with model geometry extracted directly from the HBIM model. The application used the reconstructed house, which is currently a museum, as a virtual environment with a guided tour of the iconographic source material and explanatory descriptions. The concept could be extended to accompany a physical visit, as the house is open to the public, but the option of a fully controllable walk-through was rejected in favor of focusing on the narrative and educational aspects. The added value thus lies not in the virtual visit, but in the opportunity to present additional information in the context of the project. The visitor is guided and directly embedded in the 3D model, with the possibility to choose between a few key locations. The following image (fig. 10) illustrates how the model compares with a photograph of the 1930s reconstruction, when two possible variants were created on-site to assist decision makers.

An example of a more hybrid use of HBIM can be found in the reconstruction of the palace of Mary of Hungary.[19] The study focused on the circulation route through the palace; because of time limitations only part of the main apartment was recreated in 3D (fig. 11). While HBIM was used for the reconstruction, other tools were explored to evoke the interior of the larger rooms. Where relevant, statues and ornamental elements have been created, but in other places, images have been inserted. A more time-consuming, and indeed more complete way, would have been to model every part: in theory, this is possible thanks to archival material and data from excavations. However, the actual reconstruction into 3D fragments was mostly used to assist the communication of the process and the reasoning behind the reconstruction. It was reshaped and graphically edited with DTP software, to arrive at a more conceptualized visual description (fig. 12). Yet, even then, sizes and volumetric detail of the HBIM model were retained.

In the reconstruction of the lost Aarschot residence of the Croÿ-family,[20] HBIM made it possible to achieve a more realistic result. At any given time, sections could be made through the model, allowing to adapt floor levels, heights and roof slopes, and correct inconsistencies. Certain assumptions and possible reconstruction variants could thus be assessed more easily. The presentation also systematically used color-coding to indicate perceived accuracy of the reconstruction (fig. 13).

In the reconstruction of the Graethem Chapel,[21] two issues were explored: archeological exploration and presentation to the public. The reconstruction thus included different construction phases, to assist a timeline visualization. However, the BIM software had no explicit support for the complex phasing required here. Typically, it can tackle a renovation project, with new/existing and demolished states for model elements, but nothing more extensive. The model was thus split into a large series of more than 60 complementary partial models (hotlinked modules in ArchiCAD terms), with a customized layer structure to assemble the different phases, while at the same time avoiding redundancy. Each element was only modeled once and embedded in the most suitable model component. The assembly models could then recreate the different phases. In addition, a set of customized library objects had to be developed for the elements, such

Figure 13: Schematic section of the Croÿ ducal palace at Aarschot with indication of hypothesis through color-coding.

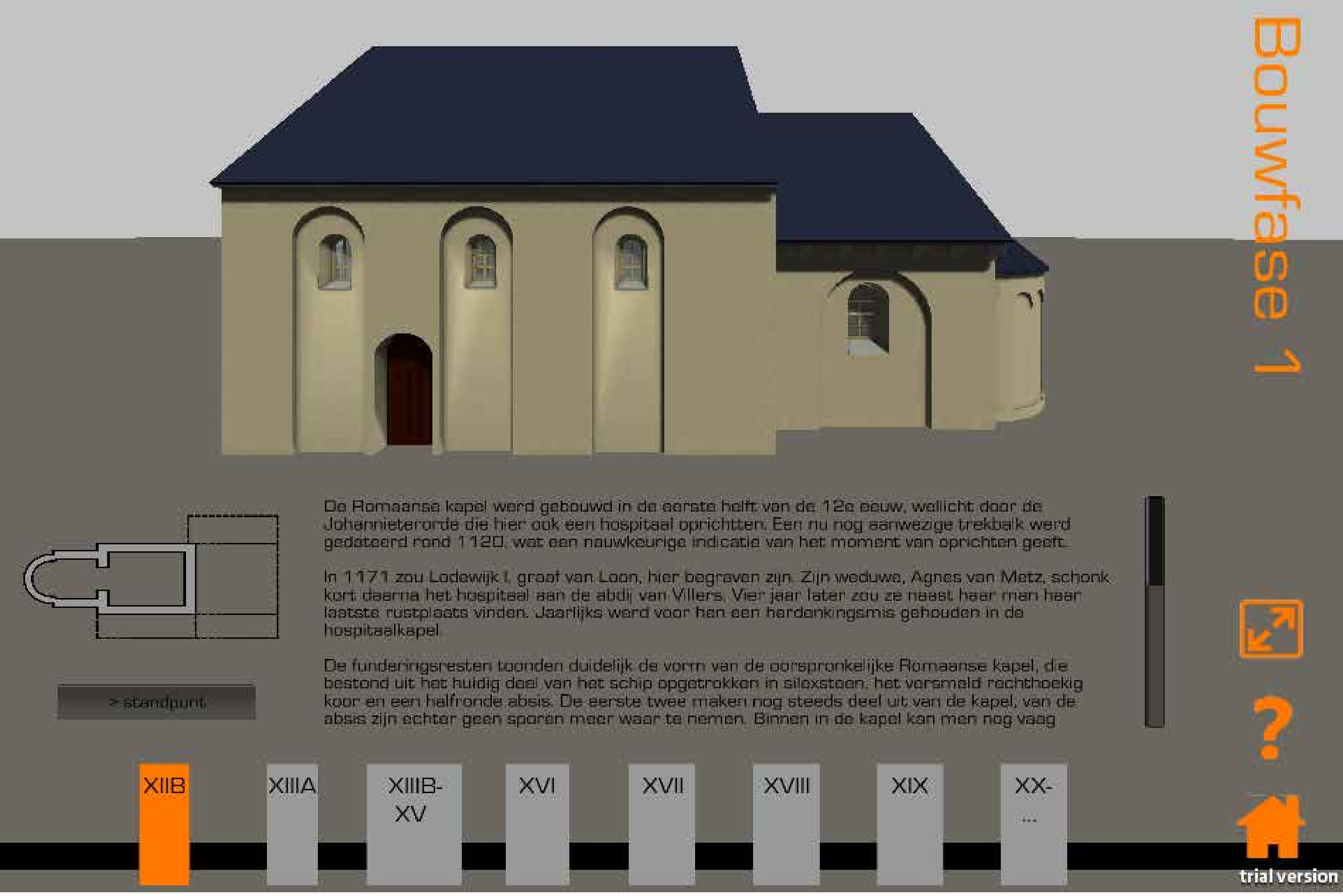
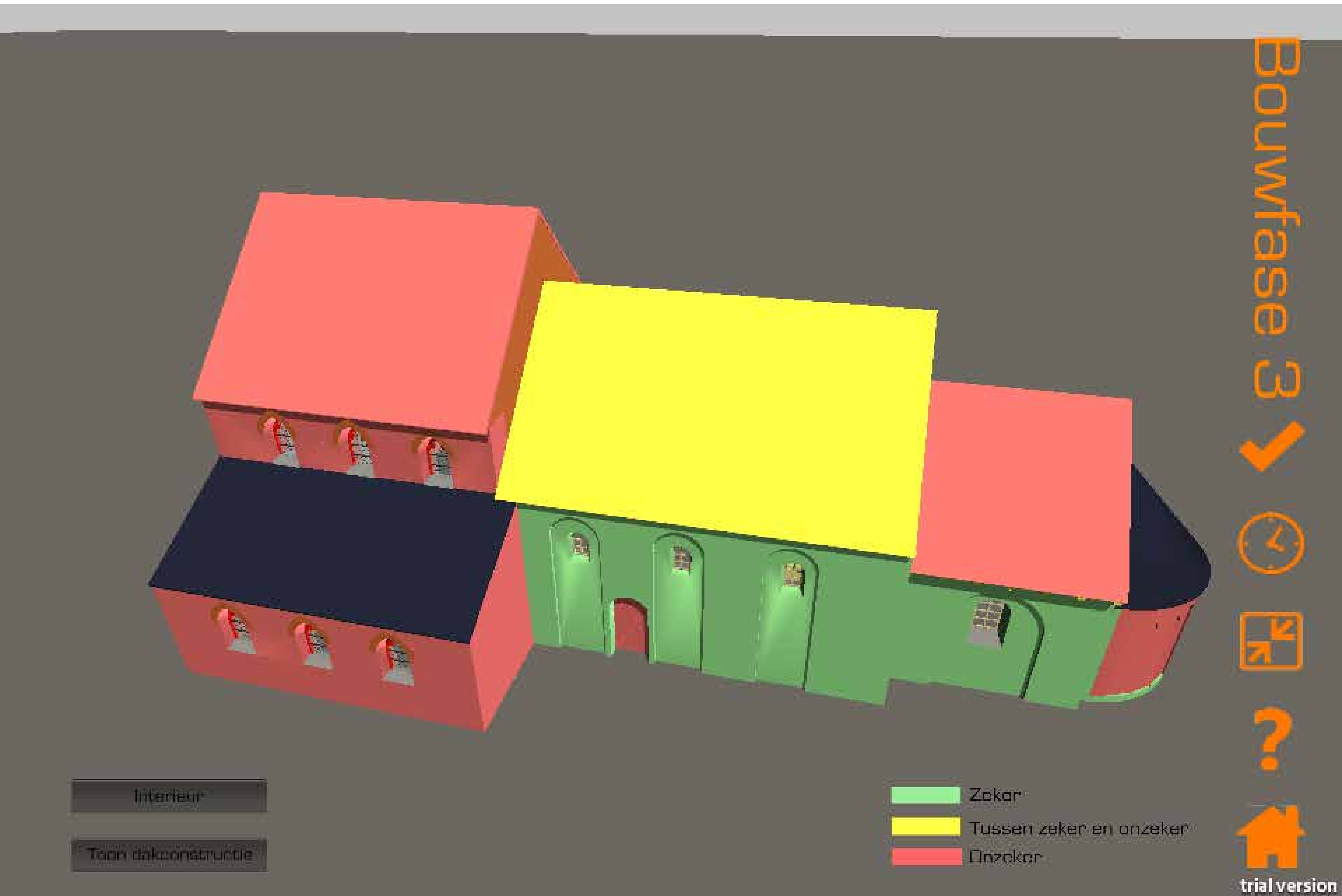


Figure 14: iPad application exploring the building history of the Graethem chapel.

Figure 15: Hypothesis representation of the building history of the Graethem chapel.



as trusses and openings. The end result was also embedded in an interactive iPad application using, again, the Unity game engine, where the re-assembly of partial models could be performed dynamically, using a timeline as graphical user interface for the visitor of the chapel (fig. 14). Each step in the timeline displayed a small explanatory text, the current situation of the model, and allowed the user to toggle different viewpoints.

Additionally, the different parts were also dynamically colored when a hypothetical representation was chosen, without requiring separate models (fig. 15). In this case, the game engine allowed for dynamic colorization, based on model information. Materials are switched dynamically, depending on the dissemination context, to not only represent approximate materialization, but also to represent color-coding to indicate a "Level of Certainty" about the reconstruction of that particular part.

In a series of tests we have also been able to embed information from the model as additional metadata and use the Graphical User Interface (GUI) methods of the game engine to display them in a popup view when the visitor clicks on an element or interface button. That way, we can move beyond merely showing the geometry, but also give access to the underlying information, such as material properties, historical notes or the results from the hypothetical reconstruction embedded in the model. While current examples often rely on splitting the transfer of geometry and information, the use of Industry Foundation Classes (IFC) will present a better integration with a single transfer, allowing "information" to remain connected to the geometric representation. This is a subject to be elaborated in further detail with future reconstructions.

The reconstruction of the fifteenth-century Palais Rihour at Lille[22] also addresses the split-up of the project into separate modules or sub-models. Done properly, it allows the different buildings on a site to be managed more easily, in spite of the increased complexity. As the approach is completely data-driven, all geometry and attached attributes remain fully accessible in the aggregate model. Within general BIM practice, working with multiple sub-models has become a necessity in complex projects, as different disciplines and responsibilities can be separated with greater ease. In addition, as projects demand ever larger BIM model files, performance can still be reasonable when sub-dividing projects in multiple models.

Conclusion

Although CAD has been applied in historical research ever since the early 1990s, the real methodological turning point has come with the implementation of BIM in historical reconstructions. The BIM approach sheds a new light on the methodology of historical reconstruction, enabling deeper insight and opening up new ways of analysis. Best practice for HBIM has become an important issue. With the constant evolution of BIM software packages it becomes increasingly important to go for a holistic approach, where not only plans, sections and 3D visualizations but also the underlying decision-making process leading to the reconstruction is part of the same project file. Thus fully documented, the model not only becomes verifiable but also 'reusable': it can later be adapted by third parties as new information becomes available. With the necessary data management system it would even be possible to customize libraries of parametric elements to reuse over different projects. Apart from economic hindrances, however, all the problems faced by the authors of architectural repertoria must also be faced by the creators of such a library.

In historical reconstruction, modeling *an sich* is not the chief objective. The aim is to achieve a different interaction with the built environment (lost or extant) through a methodology that allows a deeper reading of that environment.

Notes

[1] Alkhoven, 'The Reconstruction of the Past: The Application of New Techniques for Visualization and Research in Architectural History'.
[2] Boeykens, Santana Quintero, and Neuckermans, 'Improving Architectural Design Analysis Using 3D Modeling and Visualization Techniques'.
[3] Lesaffre, 'Digitale Architectuuranalyse: Gevallenstudie Stockletpaleis - Joseph Hoffmann (MSc Thesis)'.
[4] Boeykens, 'Using 3D Design Software, BIM and Game Engines for Architectural Historical Reconstruction'.
[5] Galiana et al., 'Methodology of the Virtual Reconstruction of Arquitectonic Heritage: Ambassador Vich's Palace in Valencia'.
[6] Kepczynska-walczak, 'Performing the Past and the Present for the Knowledge of the Future'.
[7] Garagnani, Mingucci, and Cinti Luciani, 'Collaborative Design for Existing Architecture : The Building Information Modeling as a Frontier for Coordinated Process'.
[8] Boeykens, 'Reflections on the Digital Reconstruction of the Portico and Garden Pavilion of the Rubens House'.
[9] Himpe, 'The Vinohrady Synagogue in Prague - A Virtual Reconstruction (MSc Thesis)'.
[10] Hoppe, 'Northern Gothic, Italian Renaissance and beyond. Toward a 'thick' description of style'. After Clifford Geertz.
[11] Martens and Peter, 'A Long-Term Scope of Actions for Reconstructed Cultural Heritage : Maintaining a Virtual Archive of Non- Existing Synagogues'.
[12] Vandevyvere, Neuckermans, and De Jonge, 'Digital Historical Reconstruction: Case Studies of an Interdisciplinary Task'.
[13] De Voght, 'Reconstructie van de Verdwenen Sint-Walburgiskerk van Antwerpen (MSc Thesis)'.
[14] Bosmans, 'Digitale Reconstructie Palais Rihour (MSc Thesis)'.
[15] Chévrier and Perrin, 'Generation of Architectural Parametric Components'.
[16] Murphy, McGovern, and Pavia, 'Historic Building Information Modelling (HBIM)'; Murphy, McGovern, and Pavia, 'Historic Building Information Modelling—Adding Intelligence to Laser and Image Based Surveys of European Classical Architecture'.creating full 2D and

3D models including detail behind the object's surface concerning its methods of construction and material makeup, this new process is described as HBIM. <B>Originality/value</B> - The future research within this area will concentrate on three main stands. The initial strand is to attempt improve the application of geometric descriptive language to build complex parametric objects. The second stand is the development of a library of parametric based on historic data (from Vitruvius to 18th century architectural pattern books

[17] Vaeck, 'Digitale Architectuuranalyse. Horta's Volkshuis Gereconstrueerd (MSc Thesis)'.

[18] Veelaert, 'Het Rubenshuis. Een Digitaal En Interactief Model van de Reconstructie Door Emiel Van Averbeke (MSc Thesis)'.

[19] Pieters, 'Digitale Reconstructie: Het Paleis van Maria van Hongarije (1545-1554) (MSc Thesis)'.

[20] Ali Salam, 'Digitale Reconstructie van Het Hertogelijk Huis van de Croÿ-Familie Te Aarschot (MSc Thesis)'.

[21] Massart, 'Digitale Reconstructie van de Bouwfase van de Graethemkapel Te Borgloon (MSc Thesis)'.

[22] Bosmans, 'Digitale Reconstructie Palais Rihour (MSc Thesis - in Preparation)'.

Bibliography

Ali Salam, Van. 'Digitale Reconstructie van Het Hertogelijk Huis van de Croÿ-Familie Te Aarschot (MSc Thesis)'. KU Leuven, 2015.

Alkhoven, Patricia. 'The Reconstruction of the Past: The Application of New Techniques for Visualization and Research in Architectural History'. In *CAAD Futures*, 549–566, 1991.

Boeykens, Stefan. 'Reflections on the Digital Reconstruction of the Portico and Garden Pavilion of the Rubens House'. In *Architectura Moderna 11: The Notion of the Painter-Architect in Italy and the Southern Low Countries*, edited by Piet Lombaerde, 1st ed., 1–15. Turnhout (Belgium): Brepols, 2014.

———. 'Using 3D Design Software, BIM and Game Engines for Architectural Historical Reconstruction'. In *Designing Together - Proceedings of the 14th International Conference on Computer Aided Architectural Design Futures*, edited by Pierre Leclerq, Ann Heylighen, and Geneviève Martin, 493–509. Liège (Belgium): Université de Liège Press, 2011.

Boeykens, Stefan, Mario Santana Quintero, and Herman Neuckermans. 'Improving Architectural Design Analysis Using 3D Modeling and Visualization Techniques'. In *Digital Heritage : Proceedings of the 14th International Conference on Virtual Systems and Multimedia*, edited by Marinos Ioannides, Alonso Addison, Andreas Georgopoulos, and Loukas Kalisperis, 67–73. Limassol (Cyprus): Archeolingua, 2008.

Bosmans, Charlotte. 'Digitale Reconstructie Palais Rihour (MSc Thesis - in Preparation)'. KU Leuven, 2016.

Chévrier, Christine, and Jean-Pierre Perrin. 'Generation of Architectural Parametric Components'. In *Joining Languages, Cultures and Visions : CAAD Futures*, edited by Temy Tidafi and Tomas Dorta, 105–18. Montréal (Canada): Les Presses de l'Université de Montréal, 2009.

De Voght, Maud. ‘Reconstructie van de Verdwenen Sint-Walburgiskerk van Antwerpen (MSc Thesis)’. KU Leuven, 2009.

Galiana, Mercedes, Ángeles Más, Vicente Galvañ, Carlos Lerma, and Salvador Conesa. ‘Methodology of the Virtual Reconstruction of Arquitectonic Heritage: Ambassador Vich’s Palace in Valencia’. *International Journal of Architectural Heritage: Conservation, Analysis, and Restoration*, 2012, 1–14. doi:10.1080/15583058.2012.672623.

Garagnani, Simone, Roberto Mingucci, and Stefano Cinti Luciani. ‘Collaborative Design for Existing Architecture : The Building Information Modeling as a Frontier for Coordinated Process’. In *Proceedings of SIGRADI 2012 | Forma (in) Formação*, 96–100. Fortaleza (Brazil), 2012.

Himpe, Caroline. ‘The Vinohrady Synagogue in Prague - A Virtual Reconstruction (MSc Thesis)’. KU Leuven, 2012.

Hoppe, Stephan. Northern Gothic, Italian Renaissance and beyond. In *Toward a ‘thick’ description of style. Le Gothique de la Renaissance. Actes des quatrième Rencontres d’architecture européenne*, edited by Monique Chatenet, 47-64. Paris 12-16 june, 2011.

Kepczynska-walczak, Anetta. ‘Performing the Past and the Present for the Knowledge of the Future’. In *Computation and Performance—Proceedings of the 31st eCAADe Conference – Volume 2*, edited by Rudi Stouffs and Sevil Sariyildiz, 453–62. Delft (The Netherlands): eCAADe and Faculty of Architecture, Delft University of Technology, 2012.

Lesaffre, Kristof. ‘Digitale Architectuuranalyse: Gevallenstudie Stockletpaleis - Joseph Hoffmann (MSc Thesis)’. KU Leuven, 2007.

Martens, Bob, and Herbert Peter. ‘A Long-Term Scope of Actions for Reconstructed Cultural Heritage : Maintaining a Virtual Archive of Non- Existing Synagogues’. *International Journal of Architectural Computing* 9, no. 3 (2012): 285–302. doi:10.1260/1478-0771.9.3.285.

Massart, Claudia. ‘Digitale Reconstructie van de Bouwfase van de Graethemkapel Te Borgloon (MSc Thesis)’. KU Leuven, 2014.

Murphy, Maurice, Eugene McGovern, and Sara Pavia. ‘Historic Building Information Modelling—Adding Intelligence to Laser and Image Based Surveys of European Classical Architecture’. *ISPRS Journal of Photogrammetry and Remote Sensing* 76 (February 2013): 89–102. doi:10.1016/j.isprsjprs.2012.11.006.

———. ‘Historic Building Information Modelling (HBIM)’. *Structural Survey* 27, no. 4 (2009): 311–27. doi:10.1108/02630800910985108.

Pieters, Els. ‘Digitale Reconstructie: Het Paleis van Maria van Hongarije (1545-1554) (MSc Thesis)’. KU Leuven, 2015.

Vaeck, Kirsten. ‘Digitale Architectuuranalyse. Horta’s Volkshuis Gereconstrueerd (MSc Thesis)’. KU Leuven, 2006.

Vandevyvere, Han, Herman Neuckermans, and Krista De Jonge. ‘Digital Historical Reconstruction: Case Studies of an Interdisciplinary Task’. *International Journal of Design Sciences & Technology* 13, no. 1 (2006): 51–65. doi:10.1.1.119.1382.

Veelaert, Isabeau. ‘Het Rubenshuis. Een Digitaal En Interactief Model van de Reconstructie Door Emiel Van Averbeke (MSc Thesis)’. KU Leuven, 2015.

Stefan Boeykens is an architect-engineer from Belgium, who worked as an independent architect, before joining the KU Leuven as a Guest Professor for BIM. In 2014 he joined D-Studio, a Belgian BIM development and consulting company, guiding technology implementation, analysis, project management and long-term innovation around BIM.

Correspondence e-mail: stefan.boeykens@kuleuven.be

Sanne Maekelberg has a masters in civil engineering and architecture from the University of Leuven (June 2014). She is currently working on a PhD project 'The residential system of the high nobility in the Habsburg Low Countries: the Croÿ case', where she combines approaches from architectural history with an interest in digital visualization techniques.

Correspondence e-mail: sanne.maekelberg@kuleuven.be

Krista De Jonge is Full Professor of History of Architecture at the Department of Architecture of the University of Leuven. Her personal research concerns early modern architecture in the Low Countries in its relationship to France, Italy, Spain, Germany, Denmark and Portugal, and especially the architecture of the Burgundian and Habsburg Courts, and has chaired the European Science Foundation Research Networking Program 'PALATIUM. Court residences as places of exchange in late medieval and early modern Europe (1400-1700)'

Correspondence e-mail: krista.dejonge@kuleuven.be