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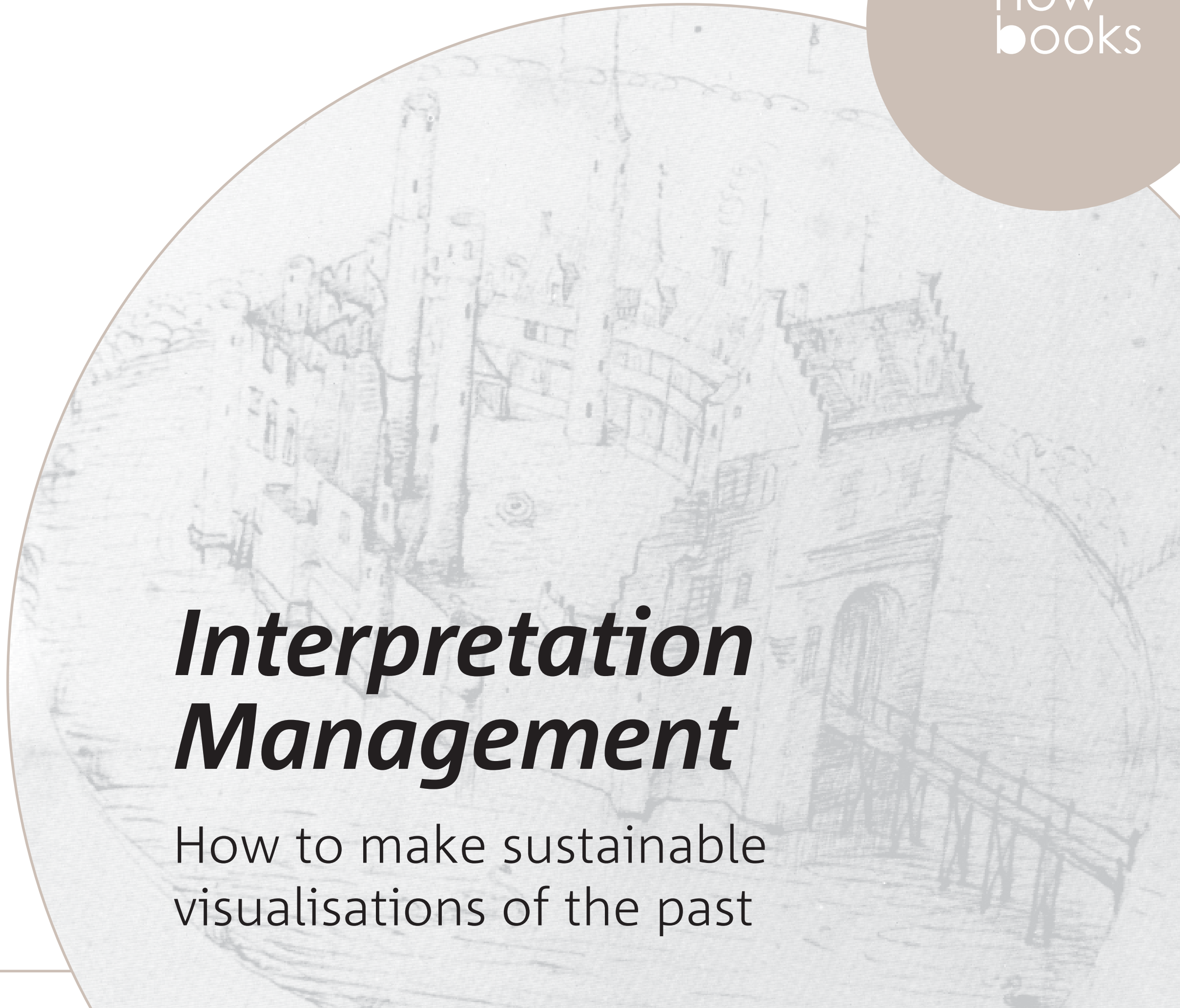

Interpretation Management

How to make sustainable visualisations of the past

Editor: Halina Gottlieb
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Current technology increasingly allows us to easily create three-dimensional models of landscapes and man-made structures and to visualise these models in several interactive and non-interactive ways. In the eighties, the idea arose at IBM to use this technology, which had originally been developed for designing and visualising structures that still had to be built, for also visualising structures that had existed but disappeared for one reason or another.

Although there is no fundamental *technological* difference between visualising structures that still need to be built and structures that have existed, there is a major *conceptual* difference because our knowledge of the past is partial and uncertain. In fact, we are not able to reconstruct the past at all. Even for the recent past, we lack a lot of information to fully reconstruct structures that have disappeared.

We can, however, try to puzzle together all of the information we have about a certain structure in a certain time period, and try to visualise this incomplete and uncertain information in the best possible way. This KNOWHOW booklet explains the methodology for doing this in a correct and reproducible way. In fact, archaeological and historical research have already been using similar methods for a long time, but this methodology hasn't been implemented yet for 3D visualisation, except for some pioneering efforts (see for example [NUME], [ROME]).

In this KNOWHOW booklet, we explain and illustrate methods such as **source assessment**, **source correlation** and **hypothesis trees**, which help to structure and document the transformation process from source material to 3D visualisation. We will also discuss the different approaches of **3D visualisation** in research and in public presentations, and present a tool to manage the interpretation process.

Background

3D visualisation uses our current capabilities to create three-dimensional models of objects, and show them in different ways with varying degrees of realism and interactivity. 3D visualisation has proven to be able to recreate and visualise historical structures (buildings, cities, landscapes, man-made structures, etc.) and is becoming more and more an accepted method for showing interpretation in historical and archaeological research.

Most of the technological issues in this field have reached a sufficient level of solution, and a variety of tools are available for most 3D visualisation tasks. The process of turning available sources into a 3D visualisation on the other hand is far less defined. This interpretation process not only takes most of the time within the visualisation process, it is also a complex, non-linear process that can profit significantly from tools that manage and organise this process. In other words, *interpretation management* is a key element of 3D visualisation of historical structures, as it records and manages how the available sources have led to the 3D visualisation, and supports and smoothes the interpretation process.

Although the term *interpretation* has other meanings and connotations in other domains, we use it here to indicate the intellectual process of turning source material into conclusions. In the context of 3D visualisation, these conclusions are of course focused on all visualisation aspects, but in fact the visualisation process is embedded in most cases in the wider interpretation process, and only helps to support research or transfer knowledge to the wider public.
We don't use the term *virtual reconstruction* because our main goal is not to reconstruct the past – this is something we simply can't do – but to bring together all available sources of information and visualise this with 3D technology. Visualisation can be very useful in a research context and also for public presentation. This means that we don't always want to obtain photorealistic, complete models of landscapes or man-made structures, sometimes we only want schematic or simplified representations. Therefore we use the general term *3D visualisation*.

What purpose does interpretation management serve?

There are several reasons why interpretation management is necessary when visualising 3D models of historical structures.
First of all, it *records* the interpretation process and documents how all elements in the visualisation have been derived from the available sources. This is a necessary step, as practice has shown that 80 to 90 percent of the work of 3D visualisation of historical structures goes into the assessment and interpretation of the sources, while only 10 to 20 percent of the time is spent on

building the 3D model. Practice has also shown that this interpretation process is complex and can extend over a long period, that the amount of source data can be overwhelmingly large, and that in many cases multiple people work simultaneously on the same project. Following well defined procedures, supported by a tool that records and manages this interpretation process, is therefore crucial in safeguarding the majority of the financial and intellectual investment of a visualisation effort.

A second reason for having interpretation management is the ability to *update* 3D visualisations with new results, coming from new excavations or recently discovered historical sources or from new scientific interpretations and insights. The influence of such new data is in most cases far from straightforward, so in order to properly manage existing 3D visualisations, it is necessary to have a well-defined process, which manages how new results alter the interpretation. In other words, 3D visualisations should remain “alive”, even many years after excavations or research efforts have ended.

This brings us to a third element, which is *scholarly transparency*. When visualising historical buildings or landscapes, we need a lot of information to build complete 3D models. In most cases, we have insufficient and indirect sources to construct the 3D model, so using those available sources to create a complete 3D model is a difficult process. We have to understand that the uncertainty of elements in a 3D visualisation can vary largely across the model - some elements are well defined while some elements are totally unclear. The process of how to fill in these uncertainties is undefined, and can yield several good solutions. Furthermore, when basic choices are unclear (e.g. is the excavated structure a small church or a large house?), results can depend to a large extent on small details or even speculations or assumptions. This means that many 3D visualisations, or at least parts of them, can have large amount of uncertainty. For public presentations, it is not always useful to expose this uncertainty, hence a certain choice about what and how to show will be made, but for scientific purposes, a 3D visualisation needs to be transparent, and the uncertainty and choices made need to be well documented, and available for scientific critique and research. In other words, interpretation management is a way to “publish” 3D visualisation.

A fourth element is *data security*. Practice has shown that most visualisation processes yield binders of unstructured documents from which outsiders cannot reconstruct the interpretation process. In other words, the intellectual efforts linked to creating a 3D visualisation cannot be passed onto future generations. By providing a methodology and tool to record and manage the interpretation process of a 3D visualisation in a structured way, we also provide a way to store this data for the long term, giving access to the data and the interpretation process for future use and research.

A final element is *multidisciplinary cooperation*. We need to keep in mind that 3D visualisation brings together a wide range of skills (from history and archaeology to architecture and stability engineering, from pollen analysis and hydrography to 3D modelling and rendering) and that it is impossible that one person can master all the skills needed to do proper interpretation of all available sources. A tool that brings together all sources and all interpretations is in fact also a *collaboration platform,* which allows all involved disciplines to contribute their part to the project, mainly in an iterative process.

A methodology for interpretation management

The methodology and related tool presented in this KNOWHOW booklet are intended to be a practical and usable support for the 3D visualisation process. We want it to be simple and flexible, to create little overhead, and to guide users through the process, so that it can be easily adopted by the 3D visualisation community. In this section, we will explain this approach step-by-step and make the link with the London Charter [TLC] and the EPOCH tool that implements this methodology.

The methodology for interpretation management presented here is based upon many years of experience in 3D visualisation. The main features of the methodology are:

- Clear references to all sources used, no use of implicit knowledge
- In-depth source assessment, making the reliability and potential bias of each source clear
- Correlation of all sources used for a certain visualisation in order to detect common ground as well as inconsistencies, outliers or dependencies
- Structural analysis of the object to be visualised, and division of the object into logical sub-units
- Listing of all potential hypotheses, never “hiding” a discarded hypothesis
- Recording the interpretation process by making a clear link between the sources, the reasoning and the resulting hypothesis
- Structuring the potential hypotheses in a tree structure, with sub-hypotheses depending on main hypotheses
- Keeping the recording process separate from the modelling and visualisation process, as the latter is far from linear

It’s the rigorous implementation of this methodology in general and the use of correlation techniques for iconographic sources and a hypothesis tree in particular that makes it well suited to optimise the process of constructing a virtual model from related sources.

The methodology we propose here can be broken down into five steps:

1. Creating a source database
2. Assessing the sources
3. Correlating the sources
4. Creating hypothesis trees with conclusions
5. Updating

Step 1: Creating a source database

It is a good practice to refer systematically to sources, and document these sources through references, images and text descriptions (many people forget that text is one of the most important sources in a 3D visualisation process). These sources are maintained in a *source database*. Practice has shown that many errors in 3D visualisation are due to incorrect assumptions when using source material. Having a rigorous process to select and document sources helps to avoid this pitfall. There is no standard way to structure the source database, as many different types of sources can be integrated (from iconography to pollen analysis, from unpublished excavation data to well-known historical sources, from historical analysis of existing buildings to oral history). The principle needs to be that *all sources are identified uniquely and can be traced easily when needed* (see appendix). This is basically the standard practice in archaeological and historical research, in most cases as footnotes, but more technically oriented people making 3D models need to adopt this as well.

Step 2. Assessing the sources

A key element in the interpretation process is *source assessment*. This assessment normally yields some understanding of the reliability of the source, and more specifically the reasons why certain elements are not reliable.

This *assessment* can be a detailed study of the context of the source or the way the source depicts the reality. For example, iconography needs to be studied in terms of the creator of the iconography, the reason why the iconography was made or how the iconography needs to be interpreted. In fact, the aim of source assessment is to try to know and understand the process of how reality was represented in the source at hand. We need also to be aware that all sources, from text sources or iconography to archaeological sources or digitised buildings and objects, have already been interpreted during their creation, hence mistakes, missing information, incorrect interpretations or deliberate alterations can occur. Therefore, we need to understand the context of the creation of the source in order to get the maximum of correct information out of the source. By applying the correlation method in relation to other independent sources (see next step), we can try to further remove the veil of error that is present in every source.

Let's illustrate source assessment with an example. To make a 3D visualisation of the city of Verona around the year 1000, we look for all iconography that exists of the city at that time, as well as during later periods, as such iconography can contain useful elements for the period we want to visualise. We show here two examples of well-known iconography, the first source appears to contain many valid and useful elements, and the second source appears to be useless. Nevertheless, it is useful to record why this source is historically inaccurate, so that other people can assess the arguments as to why, and not lose any time in reassessing that source (if they agree with the arguments).

Fig. 1: Iconogaphia Ratheriana, depicting Verona around 1000

Fig. 2: Drawing of the city of Verona by the famous cartographer Hartmann Schedel (1493)

Verona is a city in northern Italy. The old city is situated in a bend of the Adige River and is dominated by the Saint Peters hill on the other side of the river (fig. 3). The city has preserved a great deal of its Roman and medieval structure, including a well-preserved Coliseum, theatre and bridge from Roman times.

When analysing the first drawing (fig.1), we see a clear relationship with the structure of the city and existing buildings. The castle on the hill next to the river (top middle), the Roman Coliseum (bottom left), the Roman theatre (top middle) and Roman bridge (middle of the picture) are all proof of the authenticity of the drawing.
When analysing the second drawing (fig. 2), we see a castle on a hilltop and a river, but the required structure (the

Fig. 3: Panorama of Verona from Saint Peters hill (the Roman bridge is visible on the right)

river should be at the foot of the castle) and the lack of landmark buildings such as the Coliseum make us conclude that this drawing is more fiction than reality, so we classify this source as historically inaccurate. Additional elements to consider are that Hartmann Schedel made two totally different depictions of Verona, and, as far as we know, he has never visited Verona. We need to understand that international travel, or obtaining reliable information from third parties, was far more complicated in the 15th century than today.

Another aspect of source assessment is the understanding of the context and creator of the source and the visual language that is used. If we take for example fig. 1, we know that the creator of the source is Ratherius, bishop of Verona, who lived in the 10th century and was a good friend of emperor Otto I. Therefore, the buildings depicted could be related to activities of Ratherius, which we should study in detail to understand the rationale behind the drawing.

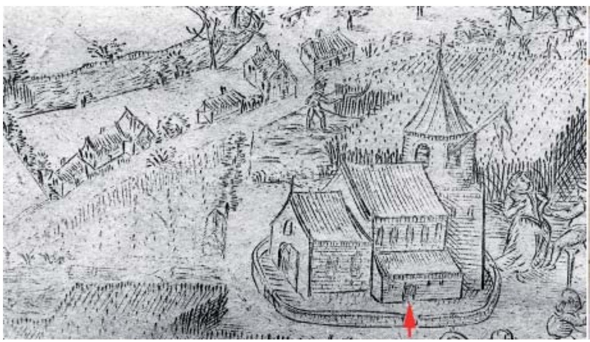
Step 3: Correlating the sources.

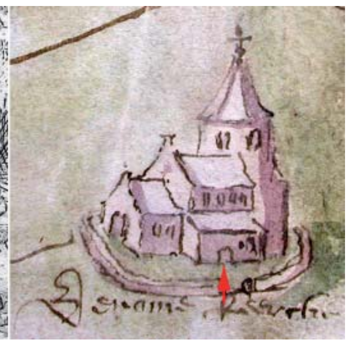
The *correlation method* compares the different sources and tries to draw conclusions from the correspondences, differences and inconsistencies between the sources. Possible conclusions could be that a source is totally unreliable, contains certain deliberate errors or just mistakes, or is a correct and detailed representation of the item it depicts or describes.

The basic correlation method is *consistency checking* between sources that essentially contain the same information. This can for example happen between different sources

The first two images show the Saint Laurence Church in 1596, the drawing on the left is one of the two views on Ename depicted in a pilgrims vane, the drawing on the right comes from a document used in a trial, also dated 1596. Both images show the same point of view, and surprisingly also the same error (indicated by the red arrow). The door depicted in the south aisle has been not been found during the in-depth archaeological survey of the church (but such a door has been found at the north side of the church). In other words, if the same error appears in both drawings, which look similar, chances are high that one drawing was a copy of the other. This has important implications. These drawings are the only ones that show the church with an octagonal tower, there is no other evidence that the church ever had such a tower. If both pictures were uncorrelated, chances would be high that such a tower existed. As both pictures appear to be correlated, chances are much lower.

of iconography depicting the same scene, or archaeological sources versus iconography. Of course, it is important to keep the context in mind, i.e. a drawing of the year 1000 cannot be expected to contain proper perspective. We also need to take the character and limitations of the sources (as recorded in the source assessment) into account.
A special case of this consistency checking is when *several versions* of a certain source exist. By analysing small differences between the different versions, and by historical study, in most cases the most reliable (often the oldest) source can be identified.





The village of Ename, Belgium, is depicted in four drawings that are dated 1596. This gives us the unique opportunity to see multiple views of the same village, hence giving important information towards the 3D visualisation of the village.

Although in-depth historical analysis of this new map is yet to be undertaken, we would like to propose a possible explanation for these differences. We know from the church records that the Saint Laurence Church was unused from 1578 (invasion of the Protestants) until 1592 (archaeological research has confirmed this). We know that monks started rebuilding the abbey in 1596 (in the image on the right, one building (10) seems to be operational again) and reclaimed the village as their rightful property after being expelled in 1578. The cross and pillory in the last image show clearly this re-establishment of the governing rule of the abbey. In other words, there are probably a few years between both images. While the picture on the left probably shows the yearly Saint Laurence

When performing source correlation between the pilgrims vane picture on the left and a recently discovered map on the right, showing the Ename village in 1596, we see similarities in both images (indicated by green numbers), but also important differences (indicated by red numbers). There are more houses depicted in the image on the right (6), and a cross (2), a well (4) and a pillory (5) are present at the central common (3), which is an open square, while that area was still a wheat field in the image on the left. The church (1) is depicted in a sketchy way, but seems to have a square tower. This quick analysis teaches us that we need to understand why there are such differences.

celebrations (August 10) before 1596 (but not earlier than 1592), the picture on the right probably shows the village in 1596. It is possible that this later drawing has been made in the context of the rebuilding of the abbey, with the tent (11) possibly belonging to the stonemasons that are rebuilding the abbey. Hence we likely see the major changes that the village went through in the last decade of the 16th century, recovering from the devastations in 1578-1582, which makes this new source very interesting.

In other words, there is a potential explanation that is logical and plausible (but needs to be confirmed by further research) for the differences between the iconographic sources that are all dated 1596, which is well supported by other (text) sources, making these iconographic sources quite reliable. If specialists conclude after study and discussion that there are in fact a few years between the new and old sources (let's say 1593 and 1596), an update of the virtual models can be made by renaming the existing 1596 visualisation to 1593 (fig. 7) and creating a new 1596 model that shows a further evolution of the village. Once this extra phase has been correlated with

Fig. 7: 3D visualisation of Ename to be dated between 1593 and 1596

the next phase (1640) to obtain a logical evolution, a 3D visualisation of 1596 can be made to show the village and abbey making a new start after the devastations.
In most cases, we don't have the luck to find multiple sources such as drawings or paintings that basically depict the same scene. Normally we have different types of sources that depict the same environment at different points in time, made for different purposes. Correlation in that case consists of a *systematical comparison* of all available elements, recording common elements and trying to understand why some elements are different or absent. As the major hurdle to jump is understanding the evolution of the structure, we need to correlate all available sources on that structure at once (see below on "evolution through time").
To illustrate this correlation between different types of sources, we show here the 3D visualisation of the castle of Wijnendale in Torhout, Belgium (fig. 9). This still-standing castle played a major role in the history of Flanders, and was built at the end of the 11th century. It was destroyed

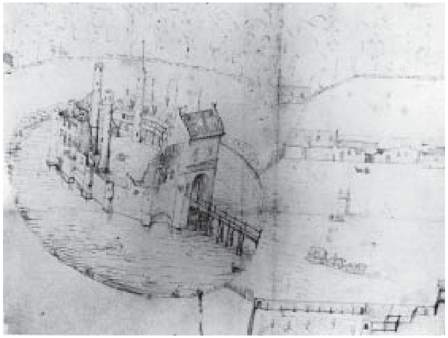


Fig. 8 : a drawing dated 1612 showing the Wijnendale castle in ruins

and rebuilt several times, hence containing several phases. Although no archaeological or structural investigations of the building are available, we have some good historical source material, mostly text sources. The oldest drawing of the castle is shown in fig. 8, when the castle was in ruins in 1612.

The structure of the castle could be determined by correlating this iconography with a major text source, which gives the

Fig. 9: the 3D visualisation of the Wijnendale castle in 1530

detailed inventory of the building in 1530, when the owner died. As the inventory states the floor level and function of each room plus all items present (which also gives an idea about the size of the room), we were able to make a good match between the drawing and the inventory, and complete the 3D model visualising the castle in 1530.
Before doing so, we assessed the drawing (fig. 8) to be highly accurate as many details

perfectly matched with later iconographic sources, cadastrial maps and text sources. We assumed that the inventory text is correct, too, as it is a juridical document. We have analysed several methodologies in order to formalise this correlation process, but as this is a very non-linear and complex process, we have come to the conclusion that only *description through text* can capture all the necessary nuances and be adopted easily. The short description of the tool and the case study below give a good idea how this is done.

Step 4: Making a hypothesis tree with conclusions

When visualising a building, a landscape or a city, we need to impose a certain top-down analysis of the object, decomposing it in *substructures*. These substructures do not always follow the normal, “structural” decomposition of the object but rather the logical decomposition; hence they are closely linked with the hypothesis tree we will introduce. Nevertheless, the object needs to remain well-structured and plausible. Creating too much structure where no information is available only generates an additional burden for the person making the visualisation, and so we need to keep in mind that the methodology needs to support the visualisation process, not make it more complex.

The hypothesis tree is the *formalisation of the interpretation process*. It shows in a top-down fashion the potential alternatives, analyses each of the alternatives in relation to the available sources and draws a *conclusion* about which one of the alternatives has the highest probability, based upon the available sources.

In each hypothesis, *sub-hypotheses* are made, which again are evaluated and the most probable one is selected. The reasoning of how the sources (indicated through hyperlinks) influence the hypothesis is done in written text, therefore we do not believe a formal structure can be devised that is both flexible and user friendly enough to refrain from the normal written word that everybody uses to express interpretation.

It is important to stick to the branching hypothesis tree method in order to avoid overlooking certain possibilities. Although it is common sense that unlikely branches do not need to be expanded as this only creates additional overhead, the unlikely branch does need to be recorded (see updating methodology).

Most historical structures show an *evolution through time*. When interpreting source data and proposing certain hypotheses, we need to think in fact in four dimensions, spatially and chronologically. In other words, every hypothesis also needs to check if it is consistent with the data of the phases before and after a specific 3D visualisation. Arriving at a consistent evolution is a major part of the interpretation to be done, and a major validation step when building or updating the virtual models.

Therefore it is important to entangle the different *phases* of a structure. In other words, interpretations should cover the full evolution of a building, landscape or site. Of course, when there is a discontinuous evolution (for example, a site is demolished

and rebuilt in a totally different way), the interpretation can be divided in those discontinuous phases, and be treated separately.
Let's put this in practice with another example of the site of Ename, Belgium, but now in the 10th to 12th century. The excavation plan (fig. 10) of the Saint Saviour Church in Ename can be interpreted as a church consisting of a nave, east apse and tower, or as a nave with a west and east apse. Its floorplan is also very similar to a 10th century palace building or "palatium". It contains two phases, the initial phase in red and an extension in yellow.

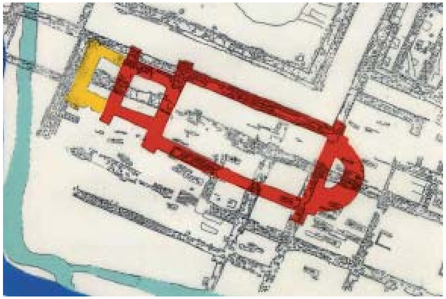


Fig. 10: Excavation plan of the Saint Saviour Church in Ename, Belgium

So we first have to decide on the structure of the building:

- Hypothesis 1: a church consisting of a nave, east apse and west tower
- Hypothesis 2: a church consisting of a nave and west and east apse
- Hypothesis 3: palace building

These hypotheses are documented on one page (see case study in appendix), and each hypothesis is argued with pros and cons, linked (through hyperlinks) to the appropriate sources. At the beginning of the page, a conclusion is drawn on which hypothesis is most probable. There is no need to quantify this probability in a number, but it is certainly useful to express if one hypothesis excels significantly or if two or more hypotheses have similar probability with one hypothesis having a slight preference.

Since 1999, after an extensive source assessment, the most probable model is a church with east and west apse and with later additions of an extension of the west apse and a small bell tower (see fig. 12).
Each hypothesis shows the different structural elements that reside under that hypothesis. In case of hypothesis 2 (double apse church) for example, we have structural elements such as the entrance, windows, nave and roof. For each of those structural elements, we have sub-hypotheses. For example, the main roof can be:

- Sub-hypothesis 2.1: one level (see fig. 12, most probable)
- Sub-hypothesis 2.2: two levels (see fig. 11, top left picture)

Again, through the interpretation of the sources, a certain hypothesis will be promoted as most probable for each of the structural elements. These conclusions are again put at the top of the page. We put the different structural elements together on one page, and do not put them on separate pages, as in most cases, there are dependencies between the different structural elements, so they should be considered all together.

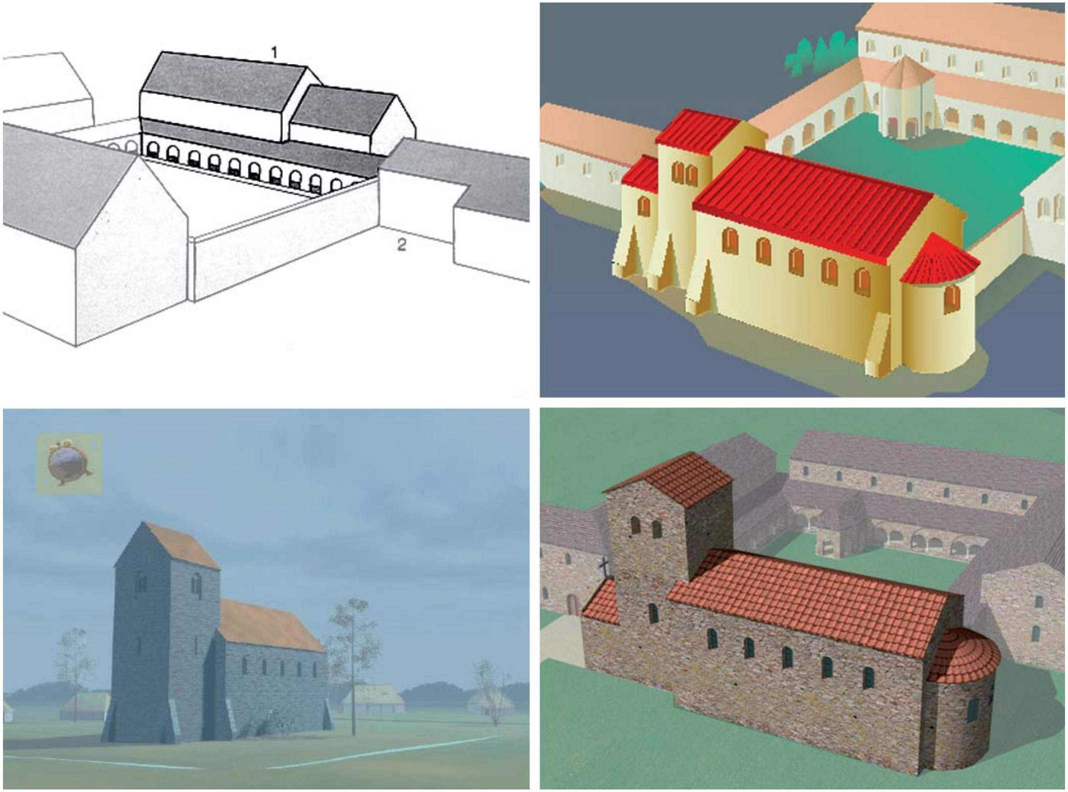


Fig. 11: Different visualisations from 1987 to 1998 of the Saint Saviour Church in Ename

Fig. 11 shows different visualisations that have been made from the excavation of the Saint Saviour Church from 1987 until 1998 (more recent visualisations are shown in fig. 12). From left to right and from top to bottom, we see the following visualisations in chronological order :

- Church with west apse (the east apse hadn't been excavated yet at the time of the publication: Archaeologica Belgica, III, 1987, pg. 216)
- Church consisting of a nave, east apse and two-storey tower with a later extension which is interpreted as a portal (artist impression,1994)
- Church consisting of a nave, east apse and three-storey tower (TimeScope application on the Ename archaeological site, 1997)
- Church consisting of a nave, east apse and reoriented three-storey tower, modelled on examples in Germany, the later extension is interpreted as a portal, (TimeLine application version 1, Archaeological Museum Ename, 1998)

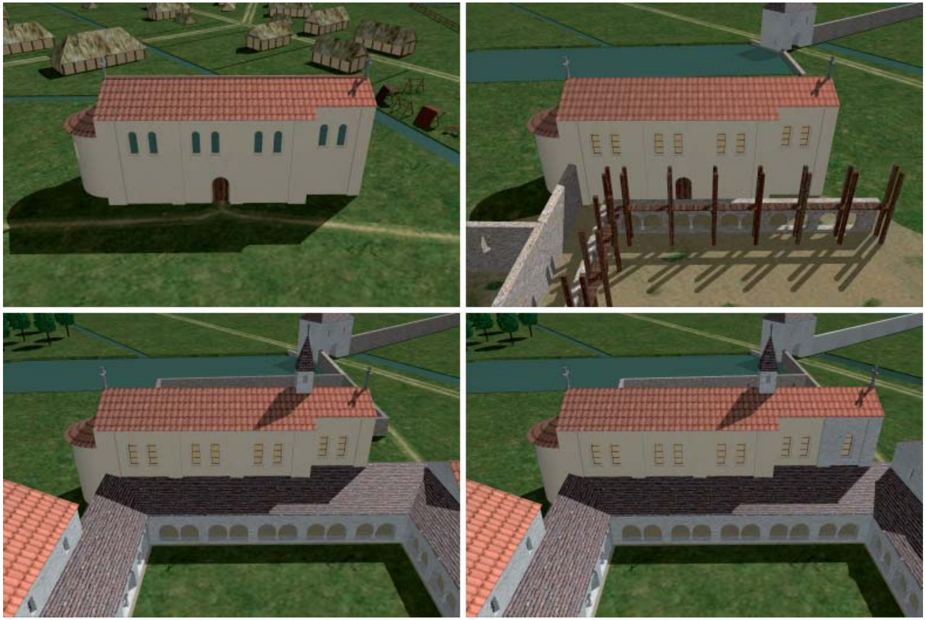


Fig. 12: Different phases of the Saint Saviour Church in Ename (1020, 1065, 1070, 1100)

In the case of the Saint Saviour Church, there are three main phases that have little continuity, and can be treated separately:

- A wooden building, probably a church (950? – 1005)
- A double apse church (1005 – 1139), see the evolution in fig. 12
- An aisled abbey church (1139 – 1795)

Each of these phases can be treated through a separate hypothesis tree, as long as the remaining links to the previous and/or next phase are made clear.

How to deal with the reliability of the hypotheses

Apart from what is most probable, we also need to consider the reliability of the visualisations that result from the most probable hypotheses. Although it is difficult to put a number on the reliability of each structural element of a visualisation, we can derive some estimation from the reliability of the sources (see source assessment) and the number of sources that are available for that specific element (see source correlation). In most cases, an indication of high, medium and low reliability is sufficient. If we have only unreliable sources or if we only have one source, we will attribute the visualisation a low reliability. If we have multiple, reliable sources, we will consider the visualisation as highly reliable.

The issue however is what to do with unreliable parts of the visualisation. Should

we visualise them or not? When we start from a scholarly point of view, we prefer not to visualise unreliable parts. When we start from a presentation point of view, we try to show a consistent image of the visualised structure, so we prefer to also show the unreliable parts because they make the structure as a whole more consistent.
Let's illustrate through the same example as above (Ename abbey around 1070, depicted in fig. 13). In fig. 14, we tried to indicate the reliability of fig. 13 through colour coding: green indicates high reliability of the 3D visualisation, yellow is medium reliability, and red is low reliability.

Two areas are indicated in red: the abbey entrance on the left hand side of the picture and the empty space next to the abbey farm on the right hand side of the picture. The entrance area has a low reliability because that area has not been excavated, and the presence of an entrance at that spot has been derived from one drawing and a structural analysis of the 17th century abbey through a detailed map. For the empty red spot on the other hand, a lot of archaeology is available, showing many traces of wooden buildings, but all these traces are highly incomplete or disturbed by later

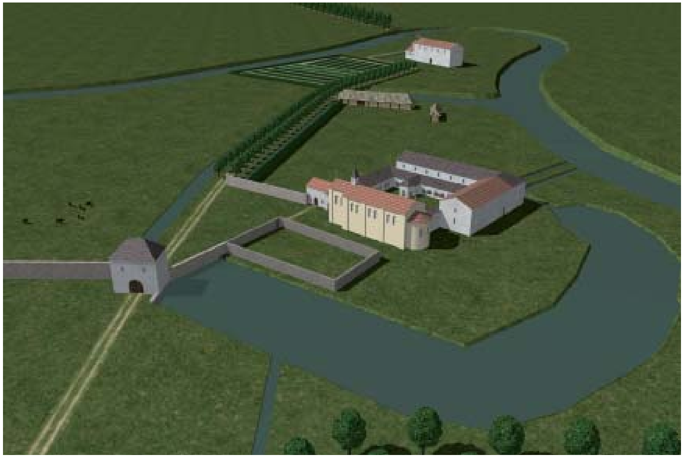


Fig. 13: Scholarly visualisation of the Ename abbey around 1070

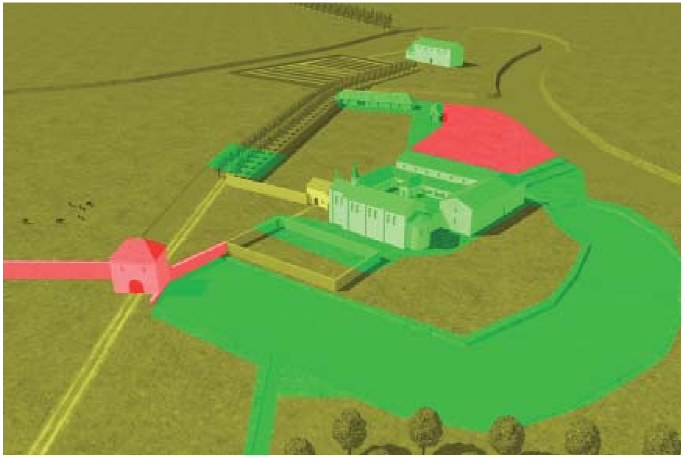


Fig. 14: Reliability of the previous visualisation (red = low, green = high)

phases, so it is nearly impossible to define the size and exact location of the buildings. In the latter case, the *scholarly visualisation* should refrain from showing wooden buildings as no final conclusions can be made from the available archaeology, and no other sources give more information about possible wooden buildings or their function, except for some archaeological traces of iron casting. Also, frequent rebuilding and reshaping of such wooden buildings is considered by the archaeologists as normal.

The *public visualisation* however (fig. 15) should show some wooden buildings, as we know from other sites that an abbey had all kinds of utility buildings such as a forge, a brewery, a bakery, etc. To show a consistent visualisation of that phase of the abbey, we should put some wooden buildings of appropriate size in the area where we have found the corresponding archaeological traces (see fig. 15). In a later phase, these buildings are rebuilt in stone, so having some wooden buildings in the earlier phases shows that there is continuity of the activities that were present in those buildings, even if we have no reliable sources for this particular site to proof this continuity.

We should tell the public that this particular visualisation contains less reliable parts as the archaeological traces are not conclusive, but this works better if some buildings are shown than if the appropriate spot is left empty.

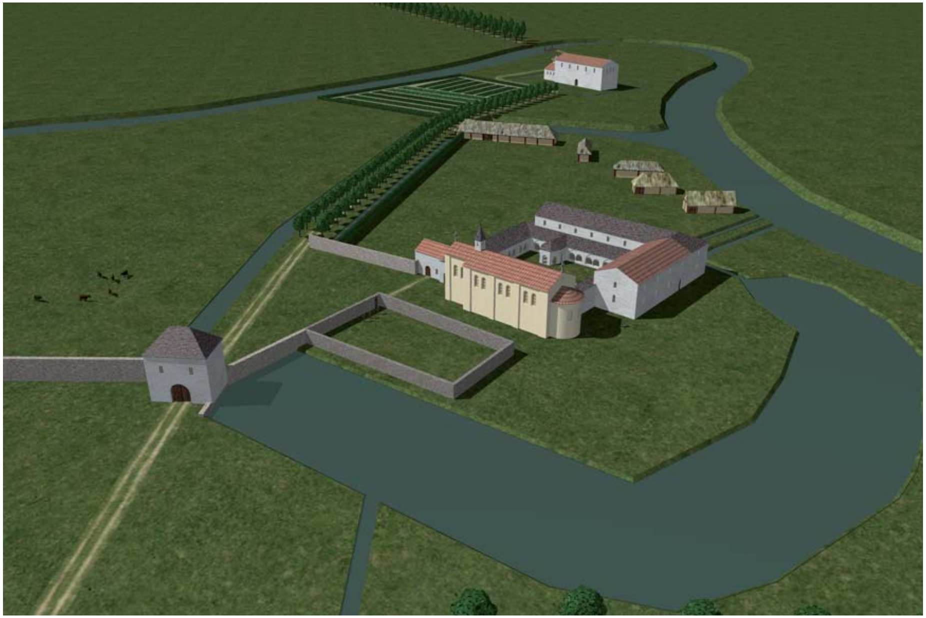


Fig. 15: Public visualisation of the Ename abbey around 1070

Fig. 16: 3D visualisation of Roman watchtower in Valkenburg, Netherlands

Fig. 17: Two alternatives with equal probability, the left one is chosen as a representative visualisation

Dealing with multiple hypotheses with the same level of probability

If one hypothesis clearly has a higher probability than the others, the *conclusion* will put this hypothesis forward as the most probable interpretation of the available sources. However, if two or more hypotheses have more or less equal probabilities, the conclusion needs to reflect the undecided nature of the interpretation. In that case, all probable alternatives will be expanded, i.e. will have sub-hypotheses and developed virtual models.

Nevertheless, if the alternatives are not significantly different, one hypothesis can be chosen as the *representative conclusion* for public presentation, provided that information is available in that presentation about the other equally probable alternatives.

Let's illustrate this with an example. The foundations of a Roman watchtower (built at the end of the 3rd century AD) were found on the summit of the hill Goudsberg in Valkenburg, the Netherlands, and the tower was visualised in the context of a local project (fig. 16). As very little iconography is available that depicts such watchtowers, and as there are no standing towers anymore, it is unclear how the superstructure of such towers looked. So from a scholarly point of view, there are several possible superstructures that have equal probability. But from a presentation point of view, we use one alternative (see fig. 17) as the representative for

Fig. 18: Panoramic 360-degree visualisation of Roman landscape at the Goudsberg, Valkenburg

the visualisation of this tower (as we do in fig. 16). However, in the interactive application that uses these visualisations, we allow the visitors to explore all aspects of the tower and find out that there are multiple possibilities to visualise this tower. In this way, the interested visitor discovers the process and issues of 3D visualisation.

Ways to express uncertainties

Let's stick with the Goudsberg example. Together with the watchtower, we also visualised the landscape around the tower. Although a detailed study was made of

Fig. 19: Panoramic 360-degree photograph of current landscape at the Goudsberg, Valkenburg

the geology and hydrography, yielding a proposal on vegetation and land use, there was very little archaeological evidence, so we were looking for a way to *express the uncertainty* of the resulting landscape visualisation. On the other hand, we were reluctant to create the landscape, vegetation and animals in 3D, as the cost to achieve sufficient visual quality for such elements is high. So we had a graphic artist illustrate the Roman landscape in watercolour (fig. 18), based on the scientific study and a panoramic image of today (fig. 19). The tower was visualised in panoramic mode and "downgraded" from a 3D rendering to a watercolour drawing, which expresses the uncertainty of the visualisation better than sharp, well defined 3D images.

Other ways to express uncertainty are reducing 3D visualisations to line drawings or even sketches, or using black and white or sepia images. For public presentation however, we need to take make sure that the result still has sufficient aesthetic quality.

Visualising evolution

When visualising evolution, we basically want to explore a 3D structure from all sides and see the evolution of (a part of) that structure from the most appropriate angle. Several technical solutions have the potential to do that, but we want to present here a simple but very powerful technique: a **QuickTime VR object**. QuickTime VR [QTVR] is part of the QuickTime software that is able to visualise panoramic and spherical images and interactive objects. Interactive objects basically consist of a matrix of images that can be visualised interactively by dragging horizontally or vertically in the viewer. If we put a 360-degree rotation of the object in the horizontal rows of the matrix, and an evolution through time in the vertical columns of the matrix, then we obtain a 4D visualisation tool that shows 3D plus time (evolution) interactively. Hence, if we drag our cursor horizontally or use the left/right arrow keys, we change our viewpoint, while if we drag vertically or use the up/down arrow keys, we visualise the evolution of the object from a particular point of view.

Simple software packages exist to turn a set of images, structured in such a matrix-like 4D way, into an interactive 4D object. The major advantage is that from the interactive object, hyperlinks can be made so that it can be integrated into hyperlink-based tools.

Step 5: Updating

Fig. 20: 4D interactive object of the Saint Saviour church in Ename in 1020-1065-1070-1100

One of the most important reasons to do interpretation management is *updating*. During the study of the source material, new sources of information can appear and new insights or correlations can be found. We need to be able to record how this new material influences the existing 3D visualisations, so we distinguish four different kinds of updating.

First of all, when a *new source* appears, we need to add this source to the database, find out what other sources it correlates to and assess this new source, both on its own and in comparison to all other related sources. The availability of new source material can influence the assessment of other sources, the reliability of the visualisations or even the hypotheses made (see below).

Another update action is the appearance of a *new assessment of an existing source* where new insights, new sources or new studies (which need to be added to the source list) render the current assessment of a source obsolete or at least incomplete. This new assessment can trigger changes in the hypotheses section and of the reliability of the visualisations.

New sources, changes in source assessment or new interpretations can yield an *additional or updated hypothesis* or can *change the probability of one or more hypotheses* or *the reliability of the visualisations*. This can in turn yield a different conclusion (the hypothesis that has the highest probability) than before.

In this process of updating, there needs to be a detailed *tracking* of the updates. This is not only a technical issue. There needs to be a *consensus* amongst the involved people on any changes to the 3D visualisation, and the changes need to be implemented and validated by 3D specialists. As pointed out before, this is normally an iterative process that involves several specialists, and leads to a change to the virtual model by the 3D specialist. As in most cases these specialists do not share the same working space or meet each other daily, so we need a tool that can act as an internet collaboration platform to allow these interactions to take place efficiently.

It can happen that specialists do not agree on a certain conclusion, or that too little evidence is present to favour one interpretation over another, or that the update is not endorsed by all involved specialists. In that case, there are *two or more solutions* that are treated *as equally probable*. This is in itself not problematic, but needs in-depth consultation and consideration before the decision can be taken that there is no most probable interpretation and 3D visualisation.

It is clear that a certain degree of skills is needed to make or change the interpretation and visualisation of a site. This is the same problem as Wikipedia is facing to maintain the quality of its online encyclopaedia and avoid “vandalism” of the content. Like Wikipedia, everybody needs to be able to contribute to the interpretation of the sources, following the typical discussion methodology and user authentication. Unlike Wikipedia, there should be an authorisation and accreditation process of people who want to change the conclusions and make or change the 3D visualisations, as these are

The London Charter

The London Charter [TLC] was initiated at a meeting of 3D visualisation specialists in London in 2006 and aims to define the basic objectives and principles of the use of 3D visualisation methods in relation to intellectual integrity, reliability, transparency, documentation, standards, sustainability and access. It recognises that the range of available 3D visualisation methods is constantly increasing, and that these methods can be applied to address an equally expanding range of research aims.
The Charter therefore does not seek to prescribe specific aims or methods, but rather seeks to establish those broad principles for the use of 3D visualisation in the research and communication of cultural heritage, upon which the intellectual integrity of such methods and outcomes depend.
The Charter does, however, seek to enhance the rigour with which 3D visualisation methods and outcomes are used and evaluated in the research and communication of cultural heritage, thereby promoting understanding of such methods and outcomes and enabling them to contribute more fully and authoritatively to this domain.
So the London Charter can be seen as the upcoming standard for 3D visualisation.

The methodology we propose here is a way to implement the Charter in practice, which is based on the following principles [TLC]:

- Valid for 3D visualisation in all cultural heritage domains
- Appropriate use of 3D visualisation
- Identification and evaluation of relevant sources
- Transparency of the 3D outcomes in relation to the sources
- Use of standards and ontologies, approved by the community
- Sustainability
- Accessibility

complex tasks that require the appropriate skills. These accredited specialists can be seen as the “scientific committee” of the 3D visualisation programme. In this way, we think we can guarantee the quality of a 3D visualisation while “publishing” this visualisation and creating full transparency about the interpretation.
All data that is stored as result of the creation and update process also needs a maintenance cycle, which should not be longer than two years. The software of the implementation (see next chapter) and its associated data (typically a database with all results) will probably need to be updated.

Files integrated in the database (such as digital images) or in a digital repository (3D virtual models, derived results such as animations, interactive models, ...) need to be transferred to new file formats if the original file formats become obsolete (this is called "data migration").

A tool to record and publish 3D visualisation

EPOCH, as the Network of Excellence for the use of ICT in cultural heritage, has created tools for the cultural heritage community to support specific tasks [EPOCH]. For 3D visualisation, a tool based on the methodology explained in this KNOWHOW booklet has been created and is freely available.

The tool has four major functionalities: the source database, the source assessment, the hypotheses tree with conclusions and the 4D visualisation page. It is based upon wiki technology, that implements not only the hyperlinking, but also the discussion forum and the consensus process that is needed to communicate and discuss research results and update them when necessary.

Resulting 3D models or derived products (still images, animations, etc.) can be stored in a data repository and hyperlinked to the 4D visualisation page.

Benefits

This methodology has several benefits for the different stakeholders involved in a 3D visualisation process.

First of all, as there is very little standardisation in how to conduct and document 3D visualisation research, this methodology helps to *structure and rationalise the interpretation process.*

Currently, the interpretation process behind a 3D visualisation project is in most cases a black box with certain inputs and outputs but very little transparency concerning the process itself. Using some commonly accepted methodology will be beneficial for mastering the process and its quality.

Secondly, by recording the interpretation process through an online tool, other scholars or 3D visualisation specialists can understand the process and contribute their knowledge, through the known wiki mechanisms of discussion and consensus. This creates not only *scientific transparency,* but also stimulates *multidisciplinary cooperation* as specialists in certain domains (for example stability analysis or building historians, specialised in a certain era) can easily be invited to contribute.

In other words, the proposed tool provides a *collaboration platform* to bring together all necessary specialists around the research and/or public presentation through 3D visualisation of historical manmade structures or landscapes.

By hosting this tool on a central server, managed by a central cultural heritage organisation in every country or region, all 3D visualisation processes can be *recorded and stored*, while the organisation itself can take care of all backup and long term storage, including all software updating and data migration in a user transparent way.

As most 3D visualisation projects are funded by public money, a supplementary requirement to record the corresponding interpretation process through such a centralised tool would yield not only a

long term storage of knowledge that would otherwise disappear (safeguarding the financial and intellectual effort that went into 3D visualisation projects), but also *general availability of 3D visualisation results* for the related community and for reuse in other projects.
Whenever new or updated information becomes available, the underlining database of the tool can be searched and all projects that use that specific information can be earmarked for update. Specialists can be invited to work on such an update, or simply providing a list of projects that need updating could invite specialists to donate time to integrate these new or updated results into the 3D visualisations. In the same way, results that would be reused will be earmarked for updating, so no outdated 3D visualisations will be used or distributed.

Conclusion

The focus of 3D visualisation of historical structures is not 3D modelling or creating stunning images but conducting an in-depth, systematic study of the sources, correlating and assessing them, deriving the most probable hypotheses, documenting this interpretation process in a well structured way and finally visualising them according the requirements of the context in which these visualisation results are used.
This KNOWHOW booklet provides a methodology that is on one hand flexible and capable of dealing with a wide range of subjects and goals, and on the other hand a form of standardisation which tries to turn 3D visualisation of historical structures into a repeatable, documented process that is transparent and publicly available.
In other words, this methodology for interpretation management establishes a sound framework for creating and publishing 3D visualisation results, improving their quality and preserving the investments and intellectual effort that has been spent to create them. A specific EPOCH tool has been realised to support this process and guarantee the safeguarding the resulting data.

References

[EPOCH] EPOCH Network of Excellence (http://www.epoch.eu/)

[TLC] The London Charter (http://www.londoncharter.org/)

[NUME] Nuovo Museo Elettronico (NuME) - 4D visualisation of Bologna (http://www.storiaeinformatica.it/nume/english/ntitolo_eng.html)

[QTVR] QuickTime VR (http://www.apple.com/quicktime/technologies/qtvr/)

[ROME]Rome Reborn 1.0 (http://www.romereborn.virginia.edu/)

Panorama of Verona from Saint Peters hill by Jacopo Prisco

Case study Saint Saviour Church Ename

In the case study below, we show how the tool turns the examples on the Saint Saviour church into practice. We show two source sheets (one for iconography and one for archaeological results), one source correlation sheet, one hypothesis sheet and one 4D visualisation sheet. The hyperlinks to the corresponding pages are underlined and in blue (not all linked pages are shown here in the example).

The source sheets use a different approach according to the type of source. For an archaeological source sheet, existing excavation reports can be used. A hyperlink can refer to the appropriate paragraph in that excavation report so that it is not necessary to cut the excavation report into different source sheets.

On the correlation sheet, we have listed several correlations between sources. Most correlations are just between two sources, whereas some use a two-stage reasoning (bullets 6, 7 and 8) that first correlates two sources and then correlates the result with a third source.

Clicking a hypothesis on the hypothesis sheet gives the subsequent sub-hypothesis in the hypothesis tree. As you can see on the sheet below, hypothesis 3 has no further branches, as it has no hyperlink (because it has a low probability).

The hyperlinks in the conclusion of the hypothesis tree link to the 4D visualisation sheet, where the 3D visualisation is shown in a 4D way. The appropriate phase and structure is highlighted, but the user can explore that structure from all sides and check phases before and after.

The hyperlink in the “Description” part of the 4D visualisation sheet links back to the corresponding hypothesis. On this page, there are also hyperlinks to the 3D model files and to derived results such as images and movies.

Source sheet

Short description

Depiction of the Ename abbey in the "Viel Rentier"

Conclusion

This drawing probably depicts the Ename abbey

Reference

Viel Rentier, Royal Library Brussels, manuscript dept. 1175, f°8r°
Published in L. Verriest, Le polyptique illustré dit "Viel Rentier" de Messire Jehan de Pamele-Audenarde, Brussels

Description

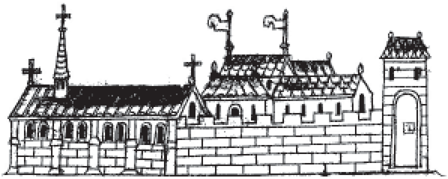
This seems to be the oldest depiction of the abbey of Ename. It shows – from left to right – the abbey church (Saint Saviour), the abbey buildings, a wall of the enclosure and a gate. The document is dated around 1275.

Context

This book lists all the properties owned by knight Jehan de Pamele-Audenarde, and all the benefits he received for renting these properties to third parties. The text is illustrated by two different illustrators who have added drawings that were related to the text. In the case above, the text talks about the rent to be payed by the abbot of Ename ("abbas eham", see lower left in the picture above). It is commonly accepted that the depicted buildings belong to the abbey of Ename.

Analysis

The drawing has always been interpreted (see for example Berings, 1989, p. 147) as the Ename abbey around 1275. We are convinced however that the drawing is not necessarily contemporary, but can depict an older phase of the abbey. This is also the case for the Pamele Church, for example, which is depicted in le Viel Rentier in its first phase as chapel (1110-1235), while that phase was replaced by the current Gothic church in 1235 (finalised in 1300), which is of substantial size. As the illustrators had to make many drawings, it is possible that they did not go on site but copied older iconography, that is unknown today.



Ename abbey – Viel Rentier

Source sheet

Short description

Excavation plan of structure S15 in Ename

Conclusion

Shows the structure and building phases of S15/Ename

Reference

(reference number to archaeological drawing)

Description

Traces of the foundations of S15 church show a building in a first phase (in red) consisting of a round east apse, a nave and a square structure on the westside, which was extended in a second phase (yellow), which is younger than the abbey buildings, based on stratigraphic analysis.

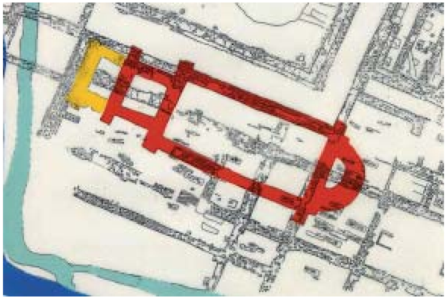
Context

Excavations seasons 1986-1988

Analysis

The structure of the building and its later extension is quite well defined although most of the foundations only left a negative groundtrace. The foundations of the first phase show typical extensions at the west side, at the connection of the west apse to the nave, and at the connection of the nave to the east apse. These extensions are barely present in the second phase.

All foundations of the first phase have about the same width, except for the foundations of the east apse which are significantly wider. The foundations of the second phase are wider and more irregular, except for the northern part.



Structure S15 – first phase (red) with extension (yellow)

Source correlation sheet

Conclusion correlation analysis

The abbey depicted in the Viel Rentier is the first phase of the Ename abbey (about 1070 – about 1160) and the church depicted is the first phase (about 1005 - 1139) of the Saint Saviour church of Ename.

Correlated sources

– Depiction of the Ename abbey in the "Viel Rentier"
– Excavaton plan of structure S15 in Ename
– Excavation plan of the Saint Laurence church in Ename
– Roof structure analysis and dating of the Saint Laurence church in Ename
– Excavation report A. Vande Walle of the Saint Saviour church
– Excavation report on the palace building in Ename
– Excavation report on the first abbey in Ename

Correlation analysis

– In the Viel Rentier drawing, the roofing consists of roman *tegulae* and wooden tiles, both have been found in layers of the first abbey (1070-1160) during the excavation, while other types of roof tiles where found in the layers that can be associated with the period around 1275.

– In the excavation plan, we see that the ratio of the length of the archaeological remains of the west structure against the nave of the building of the first phase is 1:3, which fits perfectly with the structure (4 equal parts) of the church depicted in the Viel Rentier drawing, while the remains of the second abbey church cannot be correlated with this drawing.

– The west extension (phase 2 of S15, build before the second abbey church in 1139) does not fit with the Viel Rentier drawing - the drawing could precede the extension.

– The abbey buildings depicted on the Viel Rentier drawing fit with the excavation results of the fist abbey. From left to right we see the abbot's house (with entrance), the guest rooms, the refectory and the dormitorium.

- From the analysis of the foundations of the Saint Laurence church, which was built around the same time, we see that there is a strong correlation between the foundation structure of S15 and the Saint Laurence church. One of the typical features is the presence of underground extensions of the foundations where arch structures are present.

- Having the same foundation structure, and as the Saint Laurence church has no visible buttresses, we can deduce that S15 had no visible buttresses too, which fits with the absence of buttresses in the Viel Rentier drawing.

- From the analysis of the foundation structure, we deduce that there is a wall (probably with an arch) between the west structure and the nave, and that such a wall extends to the roof (see roof structure of the Saint Laurence church). This fits very well with place of the small bell tower in the Viel Rentier drawing.

- When analysing the foundation structure of S15, and taking into account that there is a clear relationship between foundation width and the height of the walls on that foundation (see the analysis of the foundation structure of both the Saint Laurence church and the palace building in Ename), we have to conclude that the west structure should be of similar height as the nave, as both structures have a similar foundation width. This fits with the depiction of the Saint Saviour church in the Viel Rentier drawing as a building of constant height over its entire length.

Hypothesis sheet

Conclusions

The excavated structure S15 can be identified most probably as the first phase (about 1005 - 1139) of the Saint Saviour church of Ename, consisting of a nave, a west apse and an east apse. The extension (phase 2) of structure S15 can be identified as an extension of the west apse of the church, while being abbey church.

Hypotheses

- 1. The excavated structure S15 is the Saint Saviour church of Ename, consisting of a nave, east apse and tower.

- 2. The excavated structure S15 is the Saint Saviour church of Ename, consisting of a nave, east apse and west apse (most probable).

- 3. The excavated structure S15 is a palace building that has been transfomed into a church (least probable).

Analysis

- From the similar foundation width of the west structure and the nave of the building, hypothesis 2 is most probable, as a tower (hypothesis 1) would need a wider foundation on the west side, while a palace building (hypothesis 3) would need a smaller foundation on the west side (as a camera on the west side in palace buildings is typically one floor while the nave is typically two floors, see for example foundation structure of the Ename palace building).

- The structure S15 was surrounded by a ditch, which is typical for a church, demarcating the holy ground and cemetry – such a ditch is unusual for a palace building.

- The phase preceding S15 was also surrounded by a similar ditch, so it is much more probable that S15, and its predecessor, have been churches, with no relation to a palace building (the palace building has been found archaeologically 200 m north of S15).

– A text source states clearly that Ename had two churches – Saint Saviour at the portus (that becomes abbey site) and Saint Laurence at the village. With Saint Laurence still standing, no other potential site than S15 is known to be Saint Saviour.

– The Saint Laurence church is most probably a church with west and east apse without tower. The Saint Saviour church, built in the same period under the same rulers, most probably has the same structure.

– The correlation between the Viel Rentier drawing and all archaeological related sources is high, so we accept this drawing as a depiction of S15 as the Saint Saviour church with a nave, west apse and east apse.

4D visualisation sheet

Description

4D visualisation of the Saint Saviour church of Ename, consisting of a nave, a west apse and an east apse, for the approximate dates 1020, 1065, 1070 and 1100. The church has been found probably in 1005 and replaced by a much larger abbey church in 1039.

3D models

saint_saviour_church_Ename_1020.3ds (3D model representing the 1020 phase)
saint_saviour_church_Ename_1065.3ds (3D model representing the 1065 phase)
saint_saviour_church_Ename_1070.3ds (3D model representing the 1070 phase)
saint_saviour_church_Ename_1100.3ds (3D model representing the 1100 phase)

Derived results

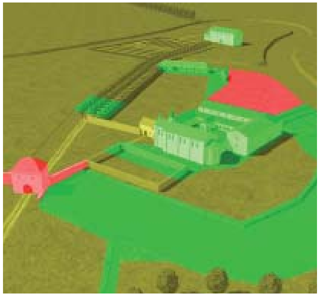
saint_saviour_church_Ename_QTVR.mov (4D interactive object)
saint_saviour_church_Ename_QTVR.mov (animation)
saint_saviour_church_Ename_1020.jpg (high resolution still image)

Saint Saviour church Ename : 1020-1065-1070-1100

Interpretation Management

Technology/Interaction

The tool is a wiki and can be used as a collaboration platform for multidisciplinary groups of experts.



Ideas for implementation

This methodology is recommended in every case of historical 3D visualisation, to provide scholarly transparency and debate, to raise the quality and consistency of the results, to allow efficient and correct updating and to create the potential for long term storage and public accessibility.

Summary

Methodology and tool to record and manage the process of analysing and interpreting sources to create 3D visualisations of historical landscapes and manmade structures.

Required competencies

Analysis and interpretation of historical, archaeological and other sources to yield 3D visualisations. Knowledge of 3D visualisation itself is useful, but not required.

Resources

Man hours: depends largely on the size and complexity of the project
Technology: 2000 euro for appropriate PC with sufficient data storage, 2000 euro for good 3D visualisation software
Production cost: none (except for small cost for central data storage)
Maintenance cost : cost for data migration to updated or new file formats

Interpretation Management
Project team

Involved Partners :
- [1]Visual Dimension bvba, Ename, Belgium
- [2]pam (Provincial Archaeological Museum) Ename, Belgium
- [3]Flemish Heritage Institute, Brussels, Belgium
- [4]KF Productions, Maastricht, Netherlands
- [5]ROB (currently RACM), Amersfoort, Netherlands
- [6]pam (Provincial Archaeological Museum) Velzeke, Belgium
- [7]Thermenmuseum, Heerlen, Netherlands
- [8]BIAX Consult, Zaandam, Netherlands
- [9]Hoaxland, Oudenaarde, Belgium
- [10]Crossmedia, Heerlen, Netherlands

Ename 3D visualisation:
- curator: Marie-Claire Van der Donckt[2]
- digitalisation iconography: pam Ename
- excavations: Flemish Heritage Institute, directed by Dirk Callebaut[3]
- historical research: Geert Berings, Dirk Callebaut[3]
- 3D visualisation: Daniel Pletinckx[1]

Wijnendale 3D visualisation:
- historical research: Guy Dupont, Michiel Mestdagh
- 3D visualisation: Daniel Pletinckx[1]

Valkenburg 3D visualisation:
- excavations: ROB, directed by Marc Kocken[5]
- archaeological research: Marc Rogge[6], Sjef Born[7], Arne Haytsma[5]
- historical landscape research: Laura Kooistra[8]
- 3D visualisation: Maarten Welzen[10], Daniel Pletinckx[1]
- landscape visualisation: Geert Reynaert[9]
- interactive application: Kris Förster[4], Daniel Pletinckx[1]

Proof-reading for booklet:

Kristi Wilson Lindroth

Publisher: The Interactive Institute AB, Stockholm, Sweden
Editor: Halina Gottlieb
Graphical design: Rafał Sosin

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"Current technology allows us to easily create three-dimensional models of landscapes and man-made structures and to visualise these models in several interactive and non-interactive ways. However, our knowledge of the past is partial and uncertain. In fact, we are not able to reconstruct the past at all, but we can try to puzzle together all of the information we have about a certain structure in a certain time period, and try to visualise this information in the best possible way.

This KNOWHOW booklet explains the methodology for doing this in a correct and reproducible way. We explain and illustrate methods such as source assessment, source correlation and hypothesis trees, which help to structure and document the transformation process from source material to 3D visualisation. We also discuss the different approaches of 3D visualisation in research and in public presentations, and present a tool to manage the interpretation process."

The KNOWHOW booklets are an inspirational series cataloguing existing examples of a variety of projects which use ICT for the recording, display and interpretation of cultural heritage. These booklets highlight functional information covering the design, development and implementation of ideas and their solutions, and give thoughtful suggestions for alternative applications within the cultural heritage sector. The KNOWHOW booklets aim to support people working in the area of museums, heritage sites and monuments. The information covered within the booklets benefits managers, exhibition producers/curators, pedagogues and professionals working with digital restoration, as well as those working with communication and audiences. These booklets cover projects developed by the partners of EPOCH, and are divided into the following categories: MUSEUMS, HERITAGE SITES and MONUMENTS.

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