An EPOCH Common Infrastructure Tool for Interpretation Management

How to make
Sustainable Visualisations
of the Past

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1. Rationale

Current technology allows us to more and more easily create threedimensional 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 [KUN98], which had been developed for designing and visualising structures that still had to be built, also for visualisation of 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 nearby past, we lack a lot of information to fully reconstruct structures that have disappeared.

We can try to puzzle together all 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 text explains the methodology for doing this in a correct and reproducable way. In fact, archaeological and historical research have been using similar methods already 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 text, we explain and illustrate methods such as *source assessment*, *source correlation* and *hypothesis trees* that 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.

The key goal of this text is to propose a methodology and tool to make open, sustainable 3D visualisations of the past and turn them into an instrument that is accepted in both the research and public presentation domain. This tool is part of the EPOCH Common Infrastructure that provides concrete tools and solutions for common problems in the cultural heritage domain.

2. 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, ...) and is becoming more and more an accepted method for showing interpretation in historical and archaeological research.

3D visualisation however had and partially still has the connotation of lacking crediblity and documentation [RYAN96], which can lead to producing too optimistic and even false conclusions about the past and about the premises and possibilities of archaeology as a discipline [RYAN01].

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 but also for public presentation. This means that we don't want to obtain always 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*.

Most of the technological issues in this field have reached a sufficient level of solution, and a variety of tools is 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.

3. 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 shows that 80 to 90 percent of the work of 3D visualisation of historical structures goes into the assessment and interpretation of the sources, only 10 to 20 percent of the time is spent on building the 3D model. Practice learns 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 simultaneous 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 straight forward, hence having a well defined process how new results alter the interpretation process is necessary to properly manage existing 3D visualisations. 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 coming from those available sources to 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. Even more, 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 it, can have large amount of uncertainty. For public presentations, it is not always useful to expose this uncertainty, hence a certain choice on 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 shows 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 the next 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* that allows all involved disciplines to contribute their part to the project, mainly in an iterative process.

4. Recording methodology

This tool wants to be practical and usable and helps supporting the 3D visualisation process. We need to be aware that this tool needs to be simple, create nearly no overhead and needs to adapt itself to a large range of situations. We need to be aware that not many such tools have been introduced to the 3D visualisation community yet and that only practical use by a large number of experienced people will show how the tool needs to be further developed. Hence, we think that it is wrong to be too prescriptive and too restrictive by forcing people into a rigorous framework. The tool should rather be a container where information can be stored in a flexible way, gently guiding people through the interpretation process following the lines of a certain 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
- list of all potential hypotheses, never "hiding" a discarded hypothesis

- records the interpretation process by making a clear link between the sources, the reasoning and the resulting hypothesis
- structures the potential hypotheses in a tree structure, with sub-hypotheses depending on main hypotheses
- keeps 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 is basically a process with different steps :

1. Creating a source database
2. Source assessment
3. Source correlation
4. Creating hypothesis trees with conclusions
5. Updating

We deal with issues such as the reliability of the hypotheses, multiple hypotheses with the same level of probability, ways to express uncertainties and visualising evolution. We explain the goal and approach of the London Charter, and demonstrate how the EPOCH tool implements these goals.

In the appendix at the end of this text, we provide an example of the methodology and implementation presented in this text, based upon the Saint-Saviour Church in Ename, Belgium.

4.1. 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 shows 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 avoiding 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*. Basically, this does not differ from standard practice in archaeological and historical research (where footnotes are used in most cases) but more technically oriented people making 3D models need to adopt this too.

Each source is referenced on a source sheet (see appendix) that also contains digital images, details of those images or transcriptions of text where necessary. Having such key information copied in the interpretation management system is very useful to avoid physiscal search in documents, which can be available in libraries and archives only.

4.2. Source assessment

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 about 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, source assessment tries to know and understand the process 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 been interpreted already during their creation, hence that mistakes, missing information, incorrect interpretations or deliberate alterations can occur, and that we need to understand the context of the creation of the source to try to get the maximum of correct information out of the source. By applying correlation with 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. 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. 1). The city has preserved very well its Roman and medieval structure, including a well preserved Coliseum, theatre and bridge from Roman times.

To make a 3D visualisation of the city of Verona around the year 1000, we look for all iconography that exists of the city, also of 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 (fig. 2) appears to contain many valid and useful elements, the second source (fig. 3) shows to be useless. Nevertheless, it is useful to record why this source is historically inaccurate, so that other people can assess the arguments why, and not loose any time in reassessing that source (if they agree with the arguments).

Fig. 1: Panorama of Verona from Saint Peters hill (the Roman bridge is visible on the right) (image: Jacopo Prisco)

When analysing the first drawing (fig. 2), we see a clear relationship with the structure of the city and still existing buildings. The castle or church on the hill (marked as Saint Peters hill) next to the river (top middle), the Roman Coliseum (bottom left), the double wall (bottom middle, has been found archaeologically), the Roman theatre (top middle) and Roman bridge (middle of the picture) all proof the authenticity of the drawing.

When analysing the second drawing (fig. 3), we see a castle on a hilltop and a river, but the required structure (the river should be at the foot of the castle and the city should be on he other side of the river) 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 are that Hartmann Schedel during his life 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.

Fig. 2: Iconogaphia Ratheriana, depicting Verona around 1000

Fig. 3: Drawing of the city of Verona by the famous cartographer Hartmann Schedel (1493)

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. 2, 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 rational behind the drawing. Current understanding of fig. 2 shows indeed that most buildings depicted are churches.

In the appendix, we provide two examples of source sheets, one for an iconographical source and one for an archaeological source, with an assessment of both sources.

4.3. Source correlation

The *correlation method* compares the different sources and tries to draw conclusions from the corrspondences, differences and inconsistencies between the sources. Conclusions can 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 basically contain the same information. This can for example happen between different sources of iconography depicting the same scene, or archaeological sources versus iconography. Of course, it is important to keep the context in mind, a drawing from the middle ages for example 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 exists. 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.

Let's illustrate the source correlation method with an example. 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.

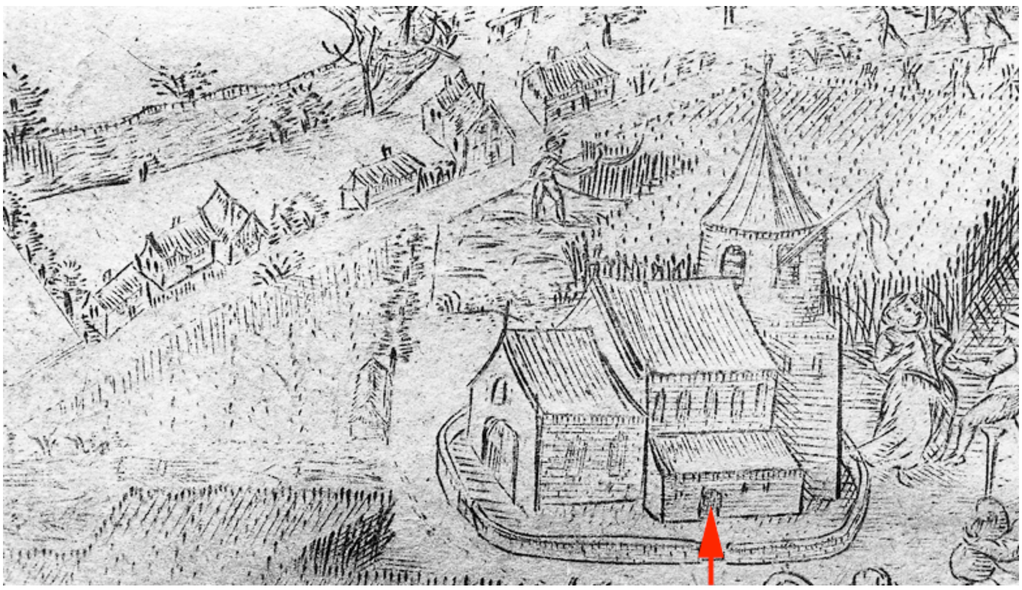

Fig. 4a: Image of the Saint Laurence Church in Ename, dated 1596, from a pilgrims vane

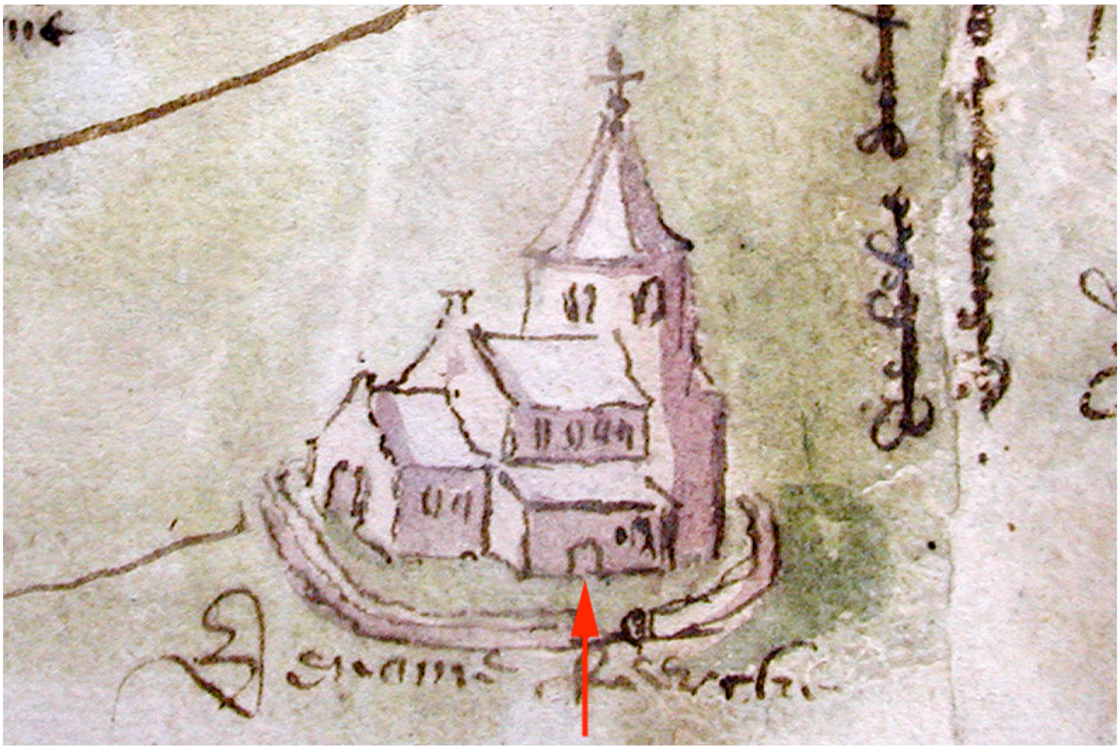

Fig. 4b: Image of the Saint Laurence Church in Ename, dated 1596, from a trial document

The two images above show the Saint Laurence Church in 1596, fig. 4a shows one of the two views on Ename depicted in a pilgrims vane, fig. 4b depicts a detail 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 indepth archaeological survey of the church (but such a door has been found at the north side of the church). So the painter that made the pilgrims vane drawing (which is probably the oldest one of the two) made an error by depicting the door at the wrong 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.

Fig. 5: Image of the Ename village centre, dated 1596, from a recently discovered map

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.

Fig. 6: Source correlation between two drawing of Ename

When performing source correlation (fig. 6) 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) is 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, as both drawings are dated to the same year.

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 left hand side picture probably shows the yearly Saint Laurence celebrations (August 10) before 1596 (but not earlier than 1592), the right hand side picture probably shows the village in 1596. It is possible that this latter drawing has been made in the context of the rebuilding of the abbey, the tent (11) can belong to the stone masons that are rebuilding the abbey. Hence we probably 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, that is well supported by other (text) sources, making these iconographic sources quite reliable. If specialists conclude after study and discussion that there is in fact a few years difference 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 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.

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

In most cases, we don't have the luck to find multiple sources such as drawings or paintings that basically depict the same. 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, record common elements and try to understand why some elements are different or absent. As the major hurdle to take here is understanding the evolution of the structure, we need to correlate all available sources on that structure at once (see chapter "Visualising evolution" below).

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 history of Flanders, and was built at the end of the 11th century. It was destroyed 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.

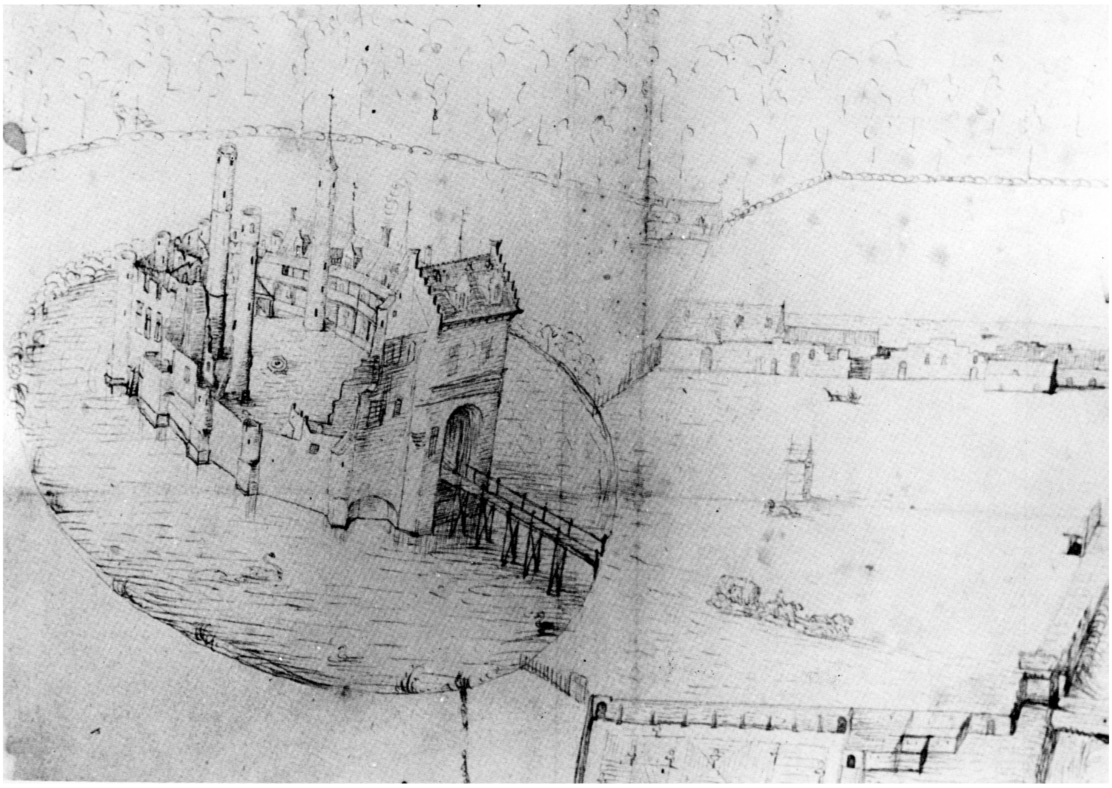

Fig. 8: Drawing dated 1612 showing the Wijnendale castle in ruins

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

The structure of the castle could be determined by correlating this iconography with a major text source, that gives the 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) as being probably very correct as many details perfectly matched with later iconographic sources, cadastrial maps and related text sources. We assumed that the inventory text is correct too, as it is a juridical document.

We have analysed several methodologies to formalise this correlation process, but as this is a very non-linear and complex process, finally it seems 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.

4.4. 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 generates only an additional burden for the person making the visualisation, we need to keep in mind that the methodology needs to support the visualisation process, not making 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 how the sources (indicated through hyperlinks) influence the hypothesis is done in written text, 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 though to stick to the branching hypothesis tree method, to avoid overlooking certain possibilities. Nevertheless, it is common sense that unlikely branches do not need to be expanded as this only creates additional overhead that is not useful, but the unlikely branch needs to be recorded anyway (see updating methodology).

A hypothesis tree implies at first sight that the analysis happens in a top-down fashion. For this, all information needs to be available, so related excavations and historical studies have to finalised. Archaeologists on the other hand want to work in a bottom-up fashion while they excavate and can only merge parts of structures to complete structures when excavations finish. Hence, the tool we will use to document the interpretation needs to be able to deal with this workflow in an elegant way.

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 needs also 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. This example is also used in the case study in the appendix. 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 floor plan is even very similar to a 10th century palace building or "palatium". It contains two phases, the initial phase in red and an extension in yellow.

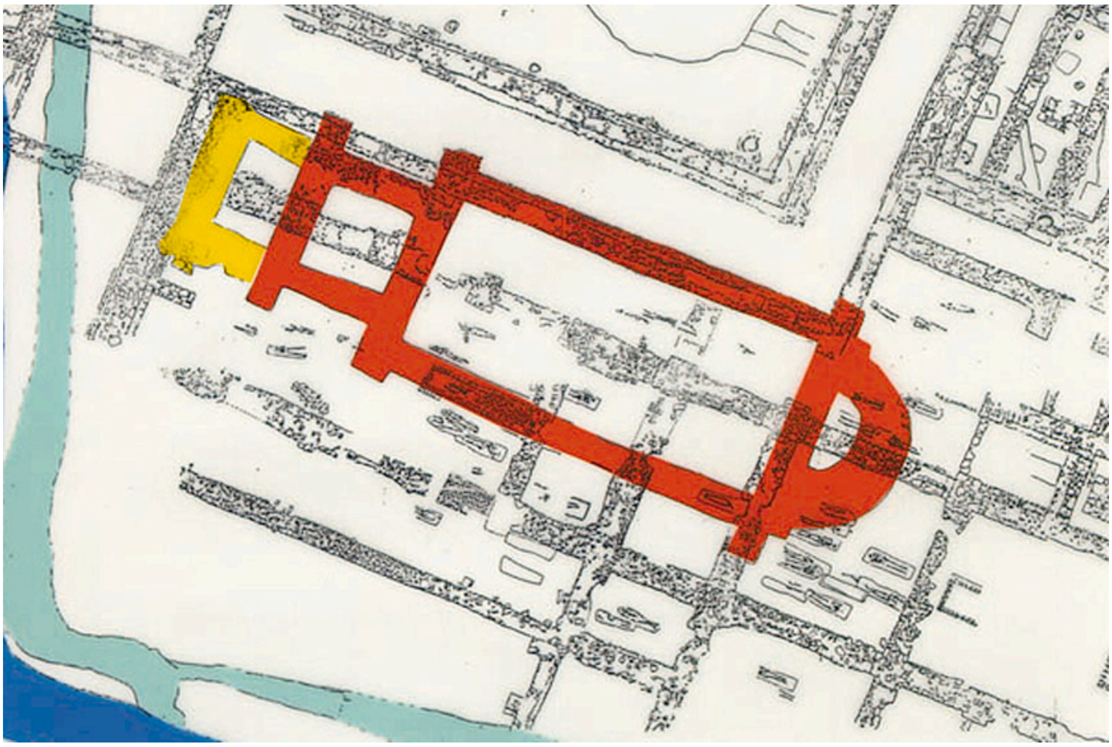

Fig. 10: Excavation plan of the Saint Saviour Church in Ename, Belgium

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

- hypothesis 1 : a church consisting of a nave, east apse and 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 below), 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.

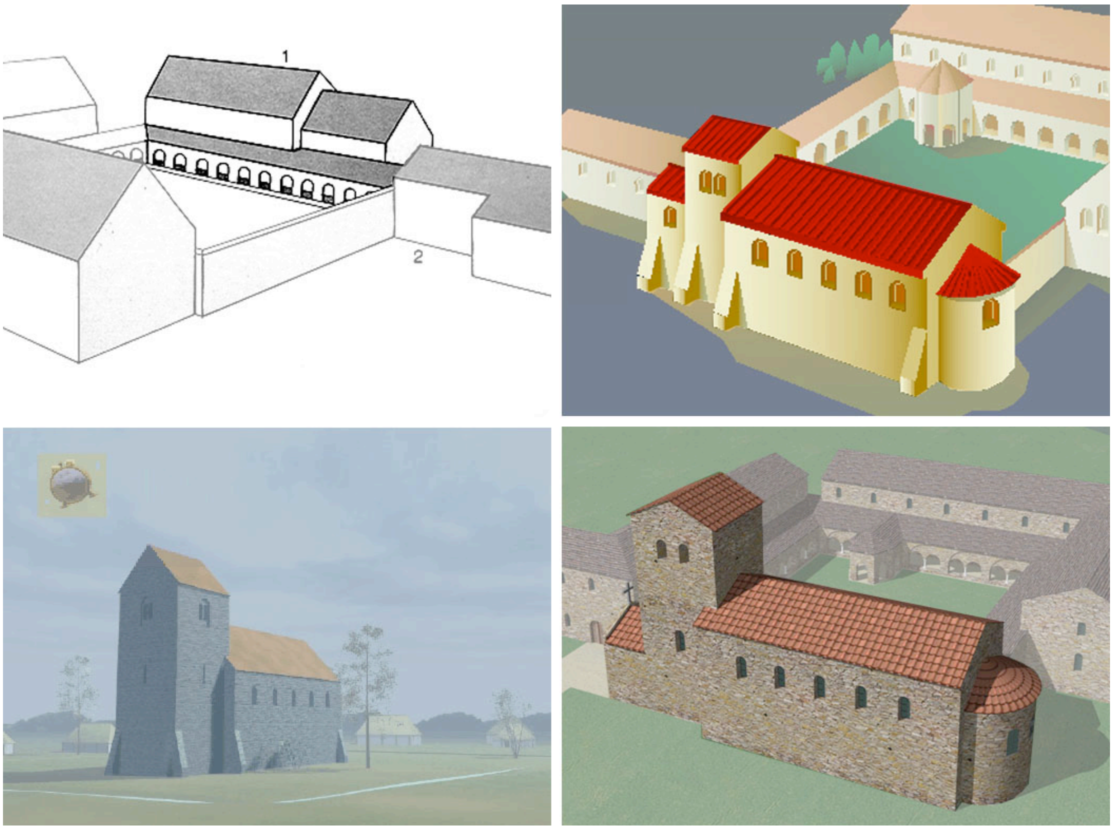

Fig. 11: Different visualisations from 1987 to 1998 of the Saint Saviour Church in Ename

Fig. 11 shows different visualisations that have been made from the excavation of the Saint Saviour Church in 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)

Since 1999, after an extensive source assessment and correlation, 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, is 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 each sub-hypothesis 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.

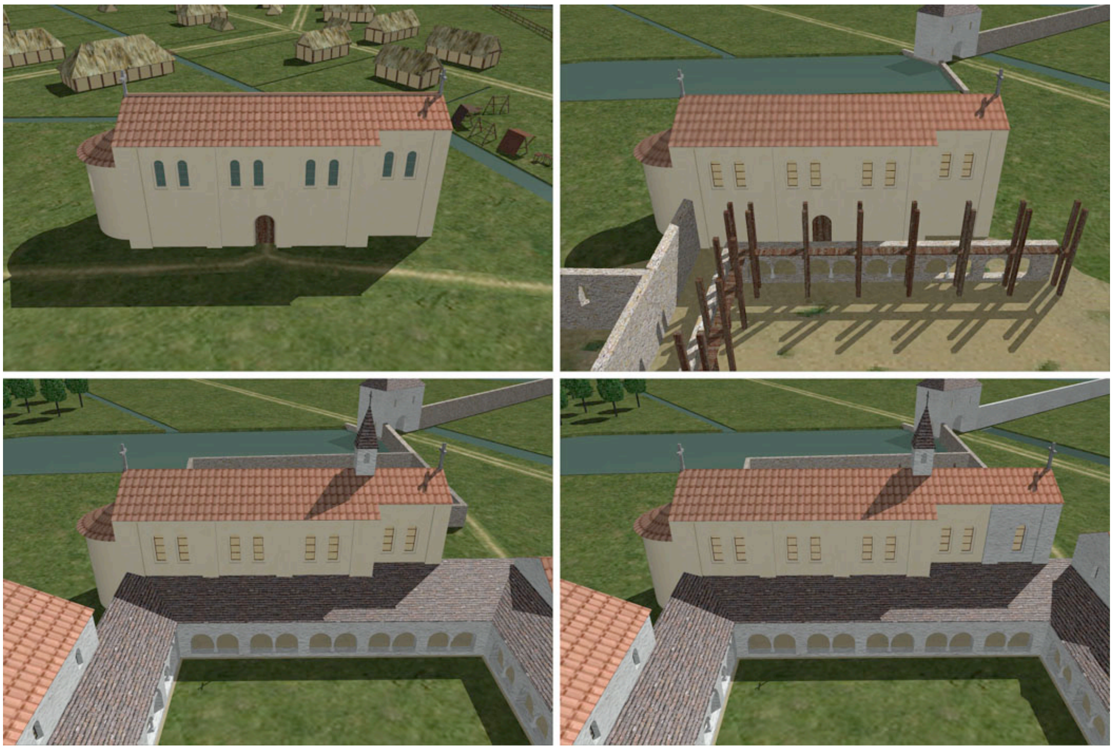

Fig. 12: Different phases of the Saint Saviour Church in Ename (1020, 1065, 1070, 1100)

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.

4.5. Updating

One of the most important reasons to do interpretation management is *updating*. As new sources of information can appear, as new insights or correlations can be found during the study of the source material, we need to be able to record how this new material influences the existing 3D visualisations. 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 yield in another 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 normally is an iterative process, that needs involvement of several specialists, leading 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, 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 no 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 complex tasks that require the appropriate skills. These accredited specialists can be seen as the "scientific committee" of the 3D visualisation programme. We think we can guarantee in this way 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, that should not be longer than two years. The software of the implementation (see below) and its associated data (typically a database with all results) probably will 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").

4.6. The reliability of the hypotheses

Besides what is most probable, we also need to care about 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 source correlation) 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.

In the same way, if a hypothesis matches perfectly with all available sources, the visualisation can be considered as highly reliable, while if a hypothesis matches poorly with the available sources, but no better hypothesis can be found for the moment, the visualisation needs to be considered as unreliable (even if the hypothesis is considered most probable).

Unlike some other specialists in the field of 3D visualisation [HER05], we prefer not to quantify reliability in numbers but assess the reliability as *low, medium or high*. Other authors use a similar methodology. Peter Sterckx [STE07] uses the same system for the visualisation of the evolution of the Horst castle in Belgium (fig. 13), while Han Vandevyvere [VAN06] uses four catergories (low, medium, high and very high) for the Mariemont castle, as does Matt Jones [JON07] in his visualisation of Southampton in 1454.

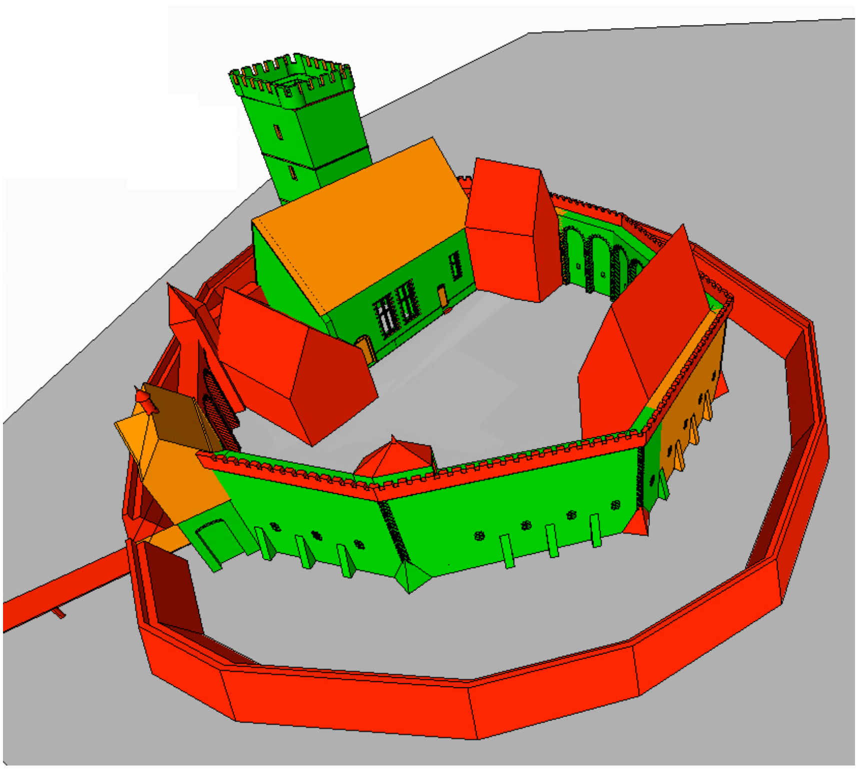

Fig. 13: Reliability of the 16th century phase of the Horst castle, Belgium (red = low, orange = medium, green = high) [STE07]

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 rather will decide to not 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 rather will decide to show also the unreliable parts because they make the structure as a whole more consistent.

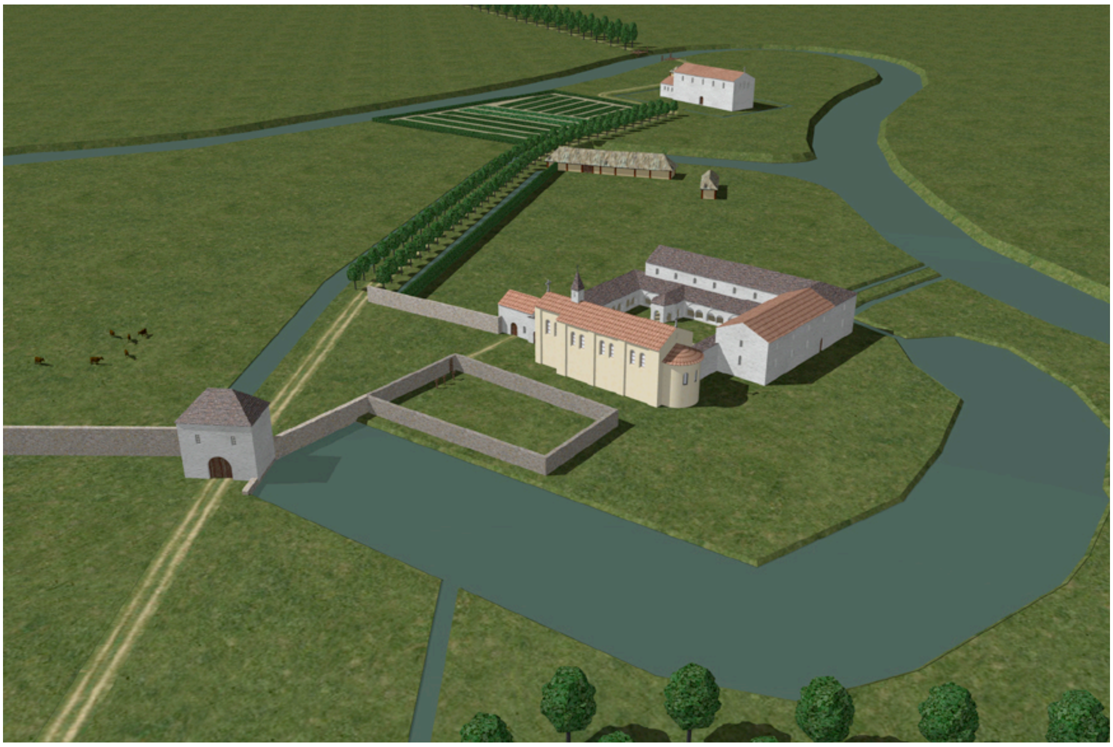

Fig. 14: Scholarly visualisation of the Ename abbey around 1070

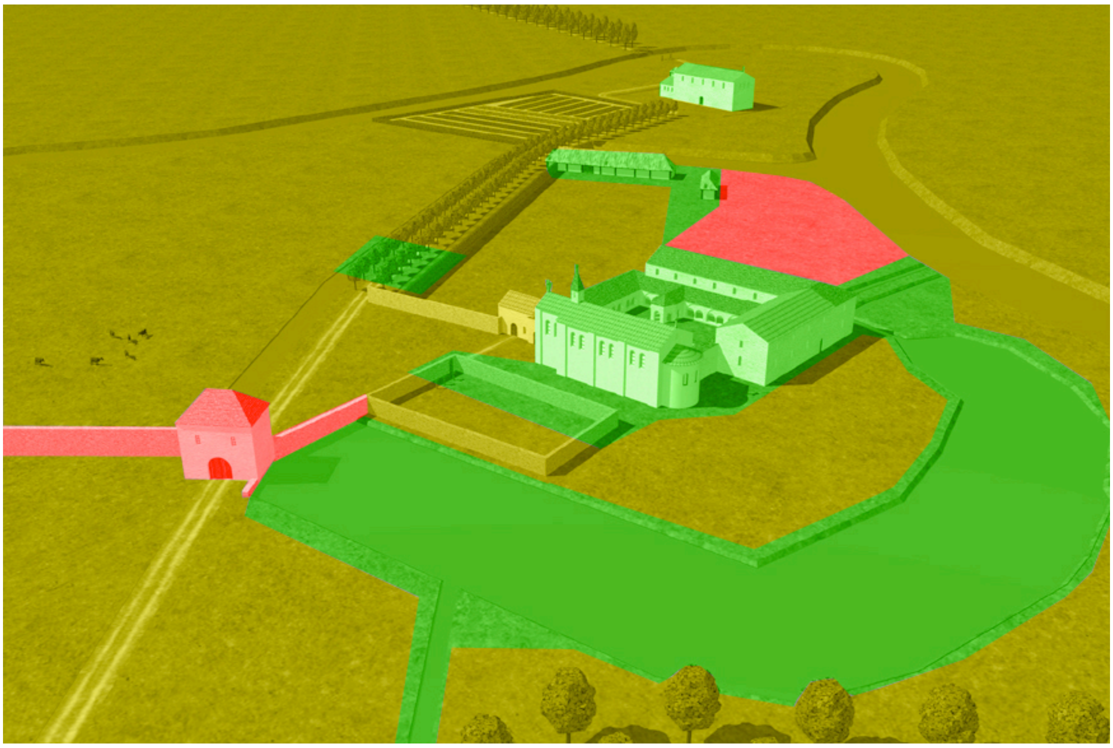

Fig. 15: Reliability of the previous visualisation (red = low, green = high)

Let's illustrate through the same example as above (Ename abbey around 1070, depicted in fig. 14). In fig. 15, we tried to indicate the reliability of fig. 14 through colour coding: green indicates high reliability of the 3D visualisation, yellow is medium reliability, red is low reliability.

Two areas are indicated in red: the abbey entrance at the left hand side of the picture and the empty space next to the abbey farm at 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 right hand side, a lot of archaeology is available, showing many traces of wooden buildings, but all these traces are highly incomplete or disturbed by later 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. 16) 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, ... 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. 16). In a later phase, these buildings are rebuilt in stone, so having some wooden buildings in the earlier phases shows that there is continuity in later phases of the activities that were present in those buildings, even if we have no reliable sources for this particular site to proof this continuity.

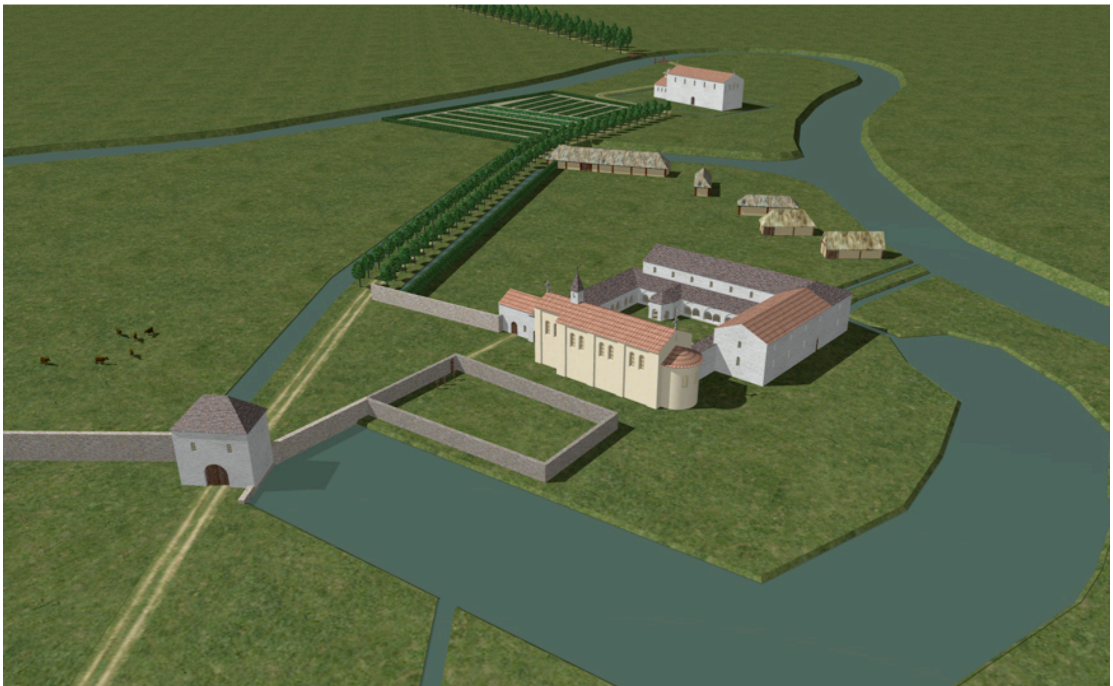

Fig. 16: Public visualisation of the Ename abbey around 1070

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.

4.7. Dealing with multiple hypotheses with the same level of probability

If one hypothesis has clearly 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, regarded 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. 17). As very little iconography is available that depicts such watchtowers, and as there are no standing towers anymore, it is quite unsure how the superstructure of such towers looked like. So from a scholarly point of view, there are several possible superstructures that have equal probability.

Fig. 17: 3D visualisation of Roman watchtower in Valkenburg, Netherlands

But from a presentation point of view, we use one alternative (see fig. 18a) as the representative for the visualisation of this tower (as we do in fig. 17). In the interactive application however 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.

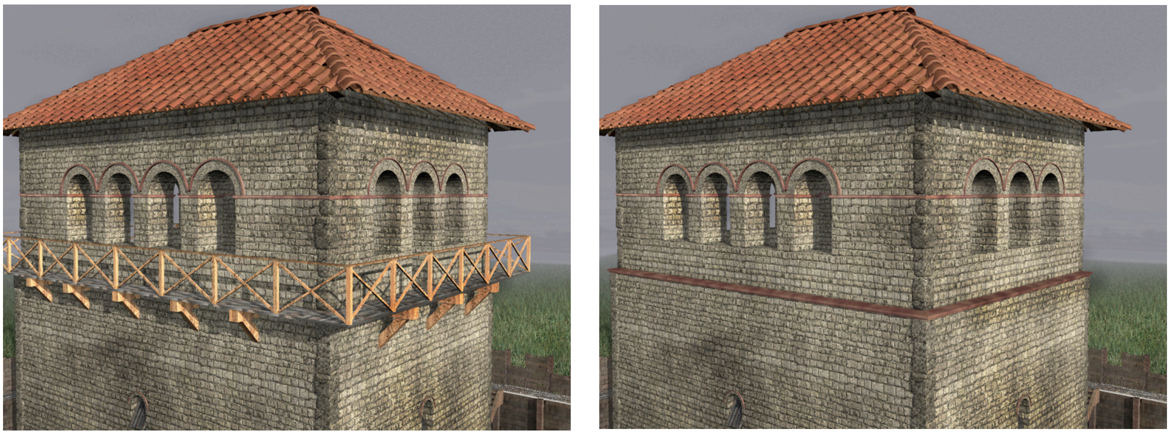

Fig. 18: Two alternatives with equal probability, the left one is chosen as representative visualisation

4.8. Ways to express uncertainties

Let's stick with the Goudsberg as example. Together with the watchtower, we also visualised the landscape around the tower. Although a detailed study was made of the geology and hydrography, yielding a proposal on vegetation and land use, there was very little archaeologcial evidence, so we were looking for a way to *express the uncertainty* of the resulting landscape visualisation [HAL03]. 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 graphical artist draw the Roman landscape in watercolour (fig. 19), based on the scientific study and a panoramic image of today (fig. 20).

Fig. 19: Panoramic 360 degrees visualisation of Roman landscape at the Goudsberg, Valkenburg

Fig. 20: Panoramic 360 degrees photograph of current landscape at the Goudsberg, Valkenburg

The tower was visualised in panoramic mode and "downgraded" from a 3D rendering to a watercolour drawing, which expresses better the uncertainty of the visualisation than sharp, well defined 3D images.

Other ways to express uncertainty [HAL03] 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.

4.9. 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 techique: a QuickTime VR object. QuickTime VR [QTVR] is part of the QuickTime software that is able to visualise panoramical 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.

Fig. 21: Part of a 4D interactive object of the Saint Saviour church in Ename in 1020-1065-1070-1100

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 interactively 3D plus time (evolution). 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 such 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.

4.10. The London Charter

The London Charter [TLC] has been initiated at a meeting of 3D visualisation specialists in 2006 in London 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, in research and communication of cultural heritage, of 3D visualisation upon which the intellectual integrity of such methods and outcomes depend.

The Charter does 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 (version 1.1) 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
- documentation of the 3D visualisation process should allow repeatability of the interpretation process and reuse of the outcomes, and create a scientific dialogue and understanding
- use of standards and ontologies, approved by the community
- sustainability
- improve accessibility of cultural heritage

The London Charter wants to be valid for *all domains* in which 3D visualisation can be applied to cultural heritage. This tool is also very general and has a methodology that can be applied in a wide range of applications and for a wide range of goals. The concept of assessing sources before they are used in the interpretation process, and the method of correlating sources to reveal common thruth are generally applicable. The concept of building a tree of hypotheses allows to work both bottom-up and top-down, which makes it suitable for a wide range of cases. The methodology presented here can be used for research as well as for communication purposes.

The London Charter states that an evaluation of the goals to achieve should prove first of all if 3D visualisation is an *appropriate method*, and if so, which 3D visualisation method is the most adequate to reach the goals. The methodology used here is quite independent of the visualisation method of the results of the interpretation process, which could range from 2D maps over pencil sketches to 3D volume renderings and photorealistic 3D visualisation.

The London Charter states that *sources should be identified and evaluated in a structured way*. This is exactly one of the key elements of this methodology, and is explained and demonstrated in detail in this text.

The London Charter states that the relation between the sources and the 3D visualisation outcomes, the reliability of those outcomes and the interpretation process should be *transparent* and well documented. This again is one of the key elements of this methodology, and is explained and demonstrated in detail in this text.

The London Charter promotes the *scientific rigour of the interpretation process*, based upon documentation, reuse of results and scientific dialogue. These elements are also key elements of this methodology and its implementation through wiki-technology.

The London Charter promotes the development of *standards and ontologies* for documenting the interpretation and 3D visualisation process and enventual approval by the community that develops and uses these 3D visualisations. The proposed methodology in this text and its implementation through a wiki-based tool, together with possibly other implementations, can be considered as a first step and platform for the community to develop these standards and ontologies, as this is still a new and uncharted domain.

The London Charter promotes *long-term archival and sustainability* of the documentation of the interpretation process and its resulting 3D visualisations. This is also a major goal of the methodology proposed in this text. The use of a standard wiki-tool and its inherent mechanisms of archival and versioning will help in realising this goal.

The London Charter states that the documentation of the interpretation process and 3D visualisation outcomes should provide a better *access* to cultural heritage assets in terms of study, interpretation and management. The approach of a wiki-based tool that is accessible for authorised specialists allows a high quality enviroment that can be used for further study, scientific discussion about interpretation and documentation for a wide range of uses.

5. Structure of the tool

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 document, has been created and is freely available.

The tool has five major functionalities: the source database, source assessment, source correlation, 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, ...) can be stored in a data repository and hyperlinked to the 4D visualisation page.

5.1. The source sheet

The *source database* needs to refer to the sources used in the interpretation. Strictly speaking, these sources need only to be traceable. In practice, storing enough data in a digital way makes the sources much more accessible, hence supports the interpretation process. For example, if iconographic sources are available as high resolution images, this is of course more practical when doing interpretation than juggling with a lot of printouts and photographs. In other words, appropriate viewers, tools to find the right sources and good management of multiple windows are important. A functionality that is very powerful is the use of *annotated images*. In this way, text such as transscriptions or remarks can be added to certain areas of the images and appear when the cursor moves over the annotated area.

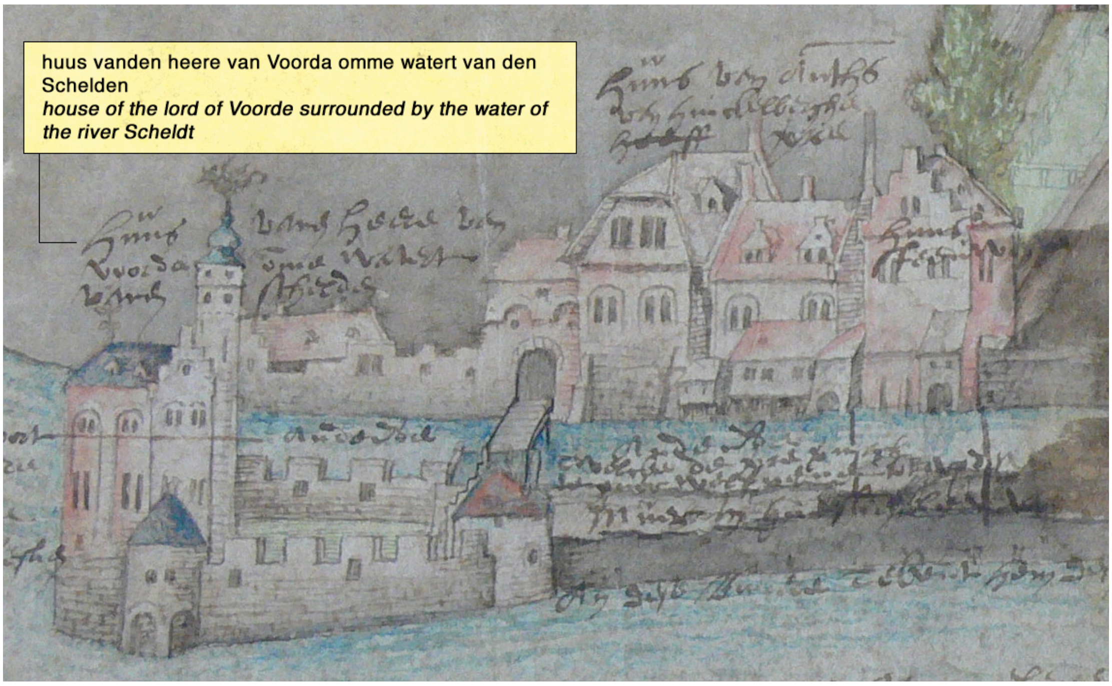

Fig. 22: Annotated image of an iconographic source, providing transcription of the medieval text

In this way, each source is recorded on a *source sheet* that also contains the *source assessment* that records the context, quality and interpretation of the source in itself.

We distinguish *primary and secondary sources*, the former are directly used in the interpretation process, the latter are only used in the source validation and don't need to have images, validation, ... (if there would be an issue with reliability of these secondary sources, a source assessment section can be added).

5.2. The source correlation sheet

On the *source correlation sheet*, we document the correlation process between sources that give us information about a certain topic. By numbering features in iconographic sources that match (see example in fig. 23), we can extract elements with a higher reliability that can be used in the visualisation process. In the case of the Wijnendale castle example in fig. 23 (see another source in fig. 8 and the final visualisation in fig. 9), elements from the historical drawing are not only considered reliable enough to be used in the visualisation process when appearing in multiple sources (such as fig. 8) but also get proper dimensions and georeferencing by correlating them with a cadaster map.

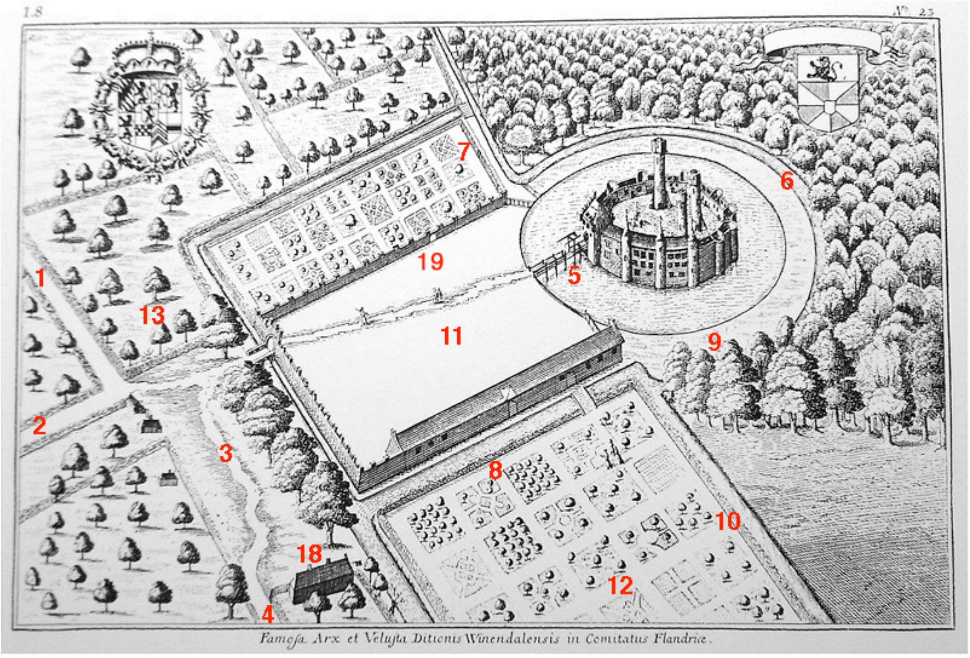

Fig. 23a : Depiction of Wijnendale castle by Sanderus (1641) with indication of matching features with fig. 23b

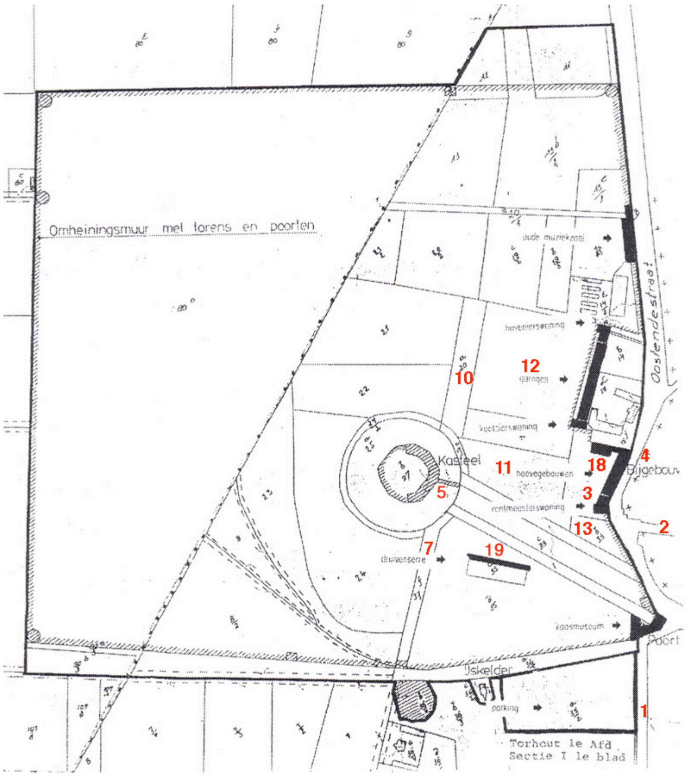

Fig. 23b: Depiction of cadaster map of Wijnendale castle with indication of matching features with fig. 23a

A more elaborate version of this, that is used when there are significant differences between sources, is the technique where matching features are indicated in green while features that do not match are indicated in red (see fig. 6). Features that have an uncertain matching can be indicated in yellow. Based on such an analysis, a detailed description will be recorded in the source correlation sheet that focuses not only on the matching features but also on the differences, and why they are different. For example, further correlation of feature 10 in fig. 6 with other secondary sources concerning the rebuilding of the abbey from 1596 onwards leads to the conclusion that there is probably a time difference between both sources in fig. 6. In this process, the secondary sources, that are referenced to provide the context of the source, simply go into the source database. The source correlation is captured in text with hyperlinks referring to the sources and annotations to the images recording remarks, transcriptions or interpretations.

5.3. The hypothesis sheet

The *hypothesis tree* provides a simple way to decompose the interpretation of a structure (building, landscape, ...) into a tree-like set of possibilities called hypotheses. Each hypothesis can be decomposed in other sub-hypotheses. At each level of the hypothesis tree, conclusions are made, based upon the probability of the possible hypotheses. If a hypothesis has little probability, one can choose not to generate sub-hypotheses for it.

We propose here to build this hypothesis tree as a set of hyperlinked pages called *hypothesis sheets* (see appendix). This approach gives the freedom to change the structure of the tree easily. One common problem in historical interpretation is the assumption of certain conditions or elements. If we want to remove the assumption that is made at a certain level, we need to add an extra level of subhypotheses in the middle of the tree, which is very easy by changing a few hyperlinks.

As archaeologists like to work bottom-up instead of top-down (as they are dependent on what has been excavated already), they can make hypothesis sheets that deal with parts of structures and link them later on with overarching hypotheses once the excavations have progressed or finished. The flexibility of creating and modifying the hypothesis tree through creating or modifying hyperlinks makes the approach described here applicable in many different cases and contexts.

The structure of the hypothesis tree also reflects the logical structure of the object to visualise (see chapter 3.4). As Vatanen [VAT03] points out, only hyperlinked structures can provide the necessary flexibility and interlinking to represent three-dimensional structures (as they can show a complex evolution pattern, they can even be considered as four-dimensional).

If one hypothesis has clearly a higher probability than the others, the *conclusion* will put this hypothesis forward as the most probable interpretation of the available sources. Each conclusion is linked to the *visualisation of the resulting virtual model* and appropriate tools refer to parts of the virtual model, linked to each sub-hypothesis (see appendix).

If two or more hypotheses have more or less equal probabilities, the conclusion will 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, one hypothesis can be chosen as the *representative conclusion* for public presentation, regarded that information is available in that presentation about the other equally probable alternatives.

Each conclusion should also make an estimation of the reliability of the most probable hypothesis. This depends on the number and quality of the involved sources and on the matching between the hypothesis and the sources (see above).

Although parts of a structure can have a low reliability, we can choose to visualise those parts to maintain the consistency of the visualisation. The decision to visualise or not visualise depends very much on the purpose of the visualisation. When used in scientific research, it could better to not visualise unreliable parts.

5.4. The 3D/4D visualisation page

In most cases, the interpretation of a structure (building, landscape, city, ...) deals with the evolution of that structure through a certain period of time. A potential user interface to show this evolution properly can be *4D visualisation* through for example QuickTime VR, where both time and 3D viewpoint can be changed. In this way, links can be made towards the pages of the interpretation, so that the 4D visualisation acts as a user interface to reach the appropriate parts of the interpretation. In other words, clicking on the reconstructed element refers to the exact place in the hypothesis tree, where the structure of that element is discussed.

If the visualisation contains no evolution, this page simply shows the reconstructed element from all sides.

5.5. Advantages of a wiki implementation

As it is important to be able to work on a reconstruction as a full team, with the appropriate discussion and consensus mechanisms, we propose to use *wiki-technology* with predefined templates, revision control and consensus mechanisms to build the three components outlined above (source database, source correlation and hypothesis tree). 4D visualisation tools that can be embedded into a wiki provide the fourth component. User registration, authentication and authorization on different levels (edit, conclusions, 3D model creation and edit) can use the tools that most wikis provide. The update of 3D models is triggered by a change of the conclusions, therefore a change in conclusion and a change of the virtual models can only be decided by accredited people.

Another aspect that we try to realise is data security. We try not only to provide a safe, long term storage of the interpretation process, but also long term storage of the virtual models themselves. As the interpretation process and its updating is linked to a specific 3D model, this model can also be stored (together with all related files, such as textures and animation scripts, and derived files, such as images, animations, interactive applications). In this way, a *central, public storage* is implemented so that the investment of making the virtual model is secured. As 3D model files can have a variety of file types, it is important to provide long term maintenance of those files by translating them into open file formats and provide a further translation of those file if the chosen open file format becomes obsolete in the future.

As nearly all virtual reconstructions are made with public money, it is conceivable to request that 3D models are published and maintained in such a way. In this way, there is not only a much better safeguarding of the financial and intellectual effort that goes into the virtual reconstruction project, but also a public availability of the results (as they have been made with public money). The Network of Expertise, that has been created in the EPOCH project, and that hopes to continue under 7FP, will provide training to have these concepts widely accepted and do lobbying to turn this approach into national policies.

6. Other approaches

The Architectural History and Conservation Research group and the CAAD research group at the University of Leuven have defined a metafile approach for documenting 3D visualisations of historical buildings [VAN06]. This metafile has the form of a spreadsheet and distinguishes the logical structures in the object to visualise (rows) and contains the facts, the written and iconographical sources, the onsite inspection reports, reliability and remarks (columns). This metafile also decomposes the different major elements into a tree structure through a numbering system of the rows.

Practical application to complex structures such as the Horst castle in Belgium [STE07] shows however that this approach has unsufficient flexibility to represent the large amount of links between the elements and the large amount of description and interpretation needed for each of those elements. There is no entry for hypotheses which results in the fact that the interpretation gets scattered over the facts column (where it definitely does not belong) and the remarks column. Especially the interlinking between the different hypotheses get somewhat lost in the limited area that each facts or remarks cell provides. The assessment of the sources is not systematic as it ends up in the remarks column, separated from the different source columns. Most sources don't get any source assessment and there is nearly no source correlation. There is only a text link to the sources, which results in a lot of manual browsing and searching.

Most projects where the metafile approach has been applied are standing buildings for which resolution of interpretation issues at the detail level are the most important. The metafile approach works quite well for this kind of projects but is less optimal for other projects where there are only ruins or archaeological remains left, or when significant rebuilding has take place as in that case, significantly different hypotheses need to be compared to each other.

Another approach has been used by Joyce Wittur [WIT08] in studying the methodology for the Lorsch Abbey Reconstruction and Information System [LARIS]. The Lorsch abbey is a major 8th century abbey and UNESCO World Heritage Site nearby Mannheim in Germany, which has a few standing buildings but also major archaeological remains. This approach uses *argumentation networks* that link sources with interpretations and is very similar to the approach we take in this paper. These networks are built of interlinked primary data, comparisons, observations and interpretations. The major difference however is that there are no phases in the interpretation process such as source assessment, source correlation and hypothesis building, and that the hypothesis building doesn't need to have a tree structure.

If we take the example in fig. 24, we see a clear relation with the text based source correlation process that we described in this paper. The left hand side network in fig. 24 can be described in text as follows :

As the clerestory, which consists of small, roughly hewn stones, has scorch marks while the arcades, which consist of ashlar masonry, have no scorch marks, we conclude that the arcades have been build later than the clerestory.

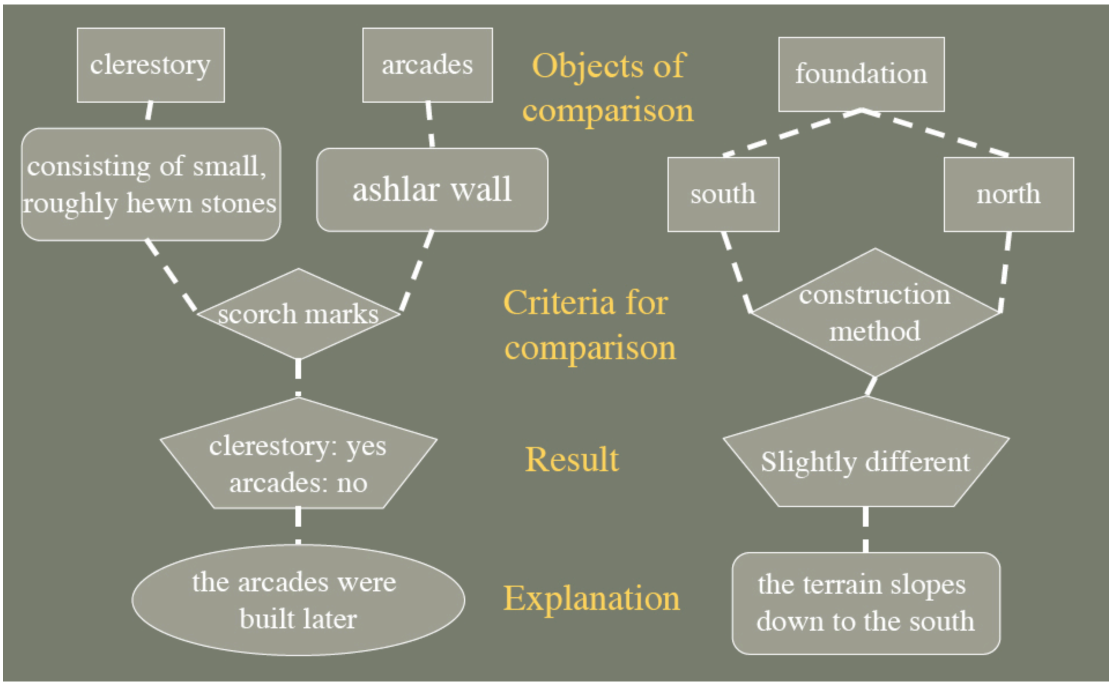

Fig. 24: Argumentation network [WIT08]

Each of the elements in the argumentation network can be linked to data such as images, texts, etc. This is very similar to the hyperlink approach we use in this paper and produces an efficient way to link and structure the data.

Although there are no formal phases of source assessment, source correlation or hypothesis construction, all these elements are present in these argumentation networks. The network approach allows on one hand the flexibility needed to describe all kinds of different interpretation processes, but lacks on the other hand the rigour and guiding of the step by step approach that we promote here.

At this moment, the argumentation networks do not care about reliability of sources, the probability of hypotheses or the update process, although we think that these elements are crucial in good interpretation management.

This argumentation network approach has also been promoted by Vatanen [VAT03], who does take care about the history of the interpretation process and updating.

Argumentation networks do represent very well the way we are thinking, but look somewhat complex and scary at first sight. This could influence negatively the take-up by the 3D visualisation community, so we promote in a first phase the use of plain text to describe the arguments. As Vatanen [VAT03] points out, the first goal of documenting interpretation should be communication within the involved community. Nevertheless, they are a good basis for structured storage of the interpretation process in the near future.

7. Wiki template

This section provides a detailed proposal of the structure of the different types of wiki pages (sources with their assessment, source correlation, hypothesis tree, 4D visualisation, overview).

The source database is implemented as a set of *source pages*, which provide the right reference to the physical source, useful tools such as images that are helpful in the interpretation process and a validation of the source itself.

The goal of source assessment is to define if the source is has a certain degree of reliability and therefore is eligible to be used in the interpretation process, and to reveal the interpretation processes that have already taken place in the creation of the source, so that we can define which elements of the source can be trusted and which elements should be discarded.

A source page contains :

- a short description of the source
- a conclusion (of the validation/assessment process) at the top of the page
- a correct and complete reference to the source, and a URL if online
- images (plus details if necessary) related to the source, for practical reference and for supporting the reconstruction process
- a detailed description of the source
- a detailed description of the context of the source (who made it, why, ...), this can require links to other sources (both primary and secondary sources)
- an validation and assessment of the source itself concerning its context and reliability (both through primary and secondary sources)

A source correlation page groups a number of sources that have something in common, and records the correlation process between all these sources, yielding conclusions that can be made from that group of sources. In this way, archaeological sources are correlated with iconographic sources, or similar iconographic sources are compared amongst themselves.

A source correlation page contains :

- a conclusion at the top of the page
- a list of related sources that document a certain structure, area or period, each source is identified through a hyperlink to its own source page (a source can appear in more than one list)
- a comparison of the listed sources, using correlation techniques and based upon the source assessment, trying to assess similarities (are they really similar?), differences (why is there a difference?), omissions (why is a certain structure missing in a certain source?) or interpretations from other authors in relation to the full set of available sources, each source is hyperlinked for easy reference
- drawing conclusions from the correlation process: if all sources depict the same feature in the same way, the conclusion is that the sources show a reliable feature, if the sources show different and non-consistent depictions of a certain feature, we can conclude that we have little to no evidence for that feature

The *hypothesis tree* is implemented by a set of hyperlinked hypothesis pages and each page covers one branch of the hypothesis tree. All hypothesis pages are linked with each other through hyperlinks to form a tree.

A hypothesis page contains :

- one or more conclusions at the top of the page, linked to the 3D/4D visualisation page if available
- all hypotheses concerning a certain structure or part of a structure, each hypothesis links to its sub-hypotheses
- a written description of the argumetnation, pros and cons of a certain hypothesis, linked to the appropriate source and source correlation pages

A *4D reconstruction* page that shows the resulting virtual reconstruction in an interactive way, with links to the related hypothesis pages. If an evolution in time is available, the model can be 4D. Techniques such as Flash of QuickTime VR can visualise such 4D models. Fig. 21 shows images from such a 4D model, in which for example one can click on the bell tower to arrive at the page that explains why such a bell tower is the most probable interpretation.

Finally, access to all this pages are provided through one or more overview pages that give access to the hypotheses for the object to visualise. An *overview page* can contain multiple objects (for example a list of buildings) and overview pages can be organised in a tree like structure for large and complex sites. As primary and secondary source pages, source correlation pages and 3D/4D visualisation pages are referenced from hypothesis pages, we don't list them explicitly on the overview page.

8. 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 stimulates also *multidisciplinary cooperation* as specialists in certain domains (for example stability analysis or building historians, specialised in a certain era) can be invited easily 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 some 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 transparant 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, a better safeguarding of 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 resuse 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 a list of projects that need update 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 update, so no outdated 3D visualisations will be used or distributed.

9. Conclusion

The focus of 3D visualisation of historical structures is not 3D modelling or creating stunning images but conducting an indepth, systematic study of the sources, correlate and assess them, derive the most probable hypotheses, document this interpretation process in a well structured way and finally visualise them according the requirements of the context in which these visualisation results are used.

This text provides a methodology that is on one hand flexible and capable of dealing with a wide range of subjects and goals, but on the other hand provides a standardised workflow 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, improve their quality and preserve the investments and intellectual effort that has been spent to create them.

A specific EPOCH tool, based on wiki technology, has been realised to support this process and guarantee the safeguarding of the resulting data.

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Appendix : 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 indicated in blue underlined (not all linked pages are shown here in the example).

The *source sheets* use of course a different approach per type of source, for archaeological source sheet, existing excavation reports can be used, where a hyperlink refers 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, some use a two stage reasoning scheme (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 below on this sheet, 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.

The *overview page* lists the hypotheses for the different buildings and structures of the Ename archaeological site (where the abbey buildings were), the hyperlinks of the hypotheses bring the user to the 4D visualisation of each building, to the source correlations that feed the hypotheses and to the primary sources used (secondary sources are referenced in the source assessment of the primary sources). The overview page of the Ename site can be further referenced in an overview page of Ename, where all other elements of the village are listed.

Fig. 24: Excavations at Ename

Source sheet

Short description

Depiction of the Ename abbey in the "Viel Rentier"

Conclusion

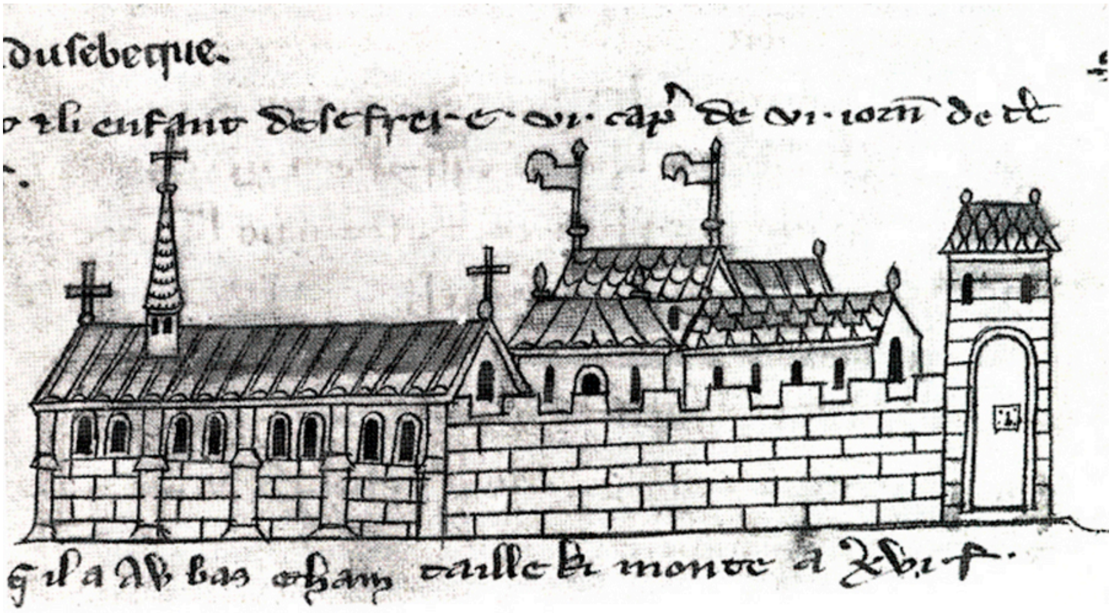
This drawing probably depicts the Ename abbey

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



Ename abbey – Viel Rentier

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 of 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 always has been interpreted (see for example Berings, 1989, p. 147) as the Ename abbey around 1275. We are convinced however that the drawing does not need to be contemporary, but can depict an older phase of the abbey. This is also the case for example for the Pamele Church which is depicted in *le Viel Rentier* in its first phase as chapel (1110-1235), while that phase was replaced already 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.

Source sheet

Short description

Excavation plan of structure S15 in Ename

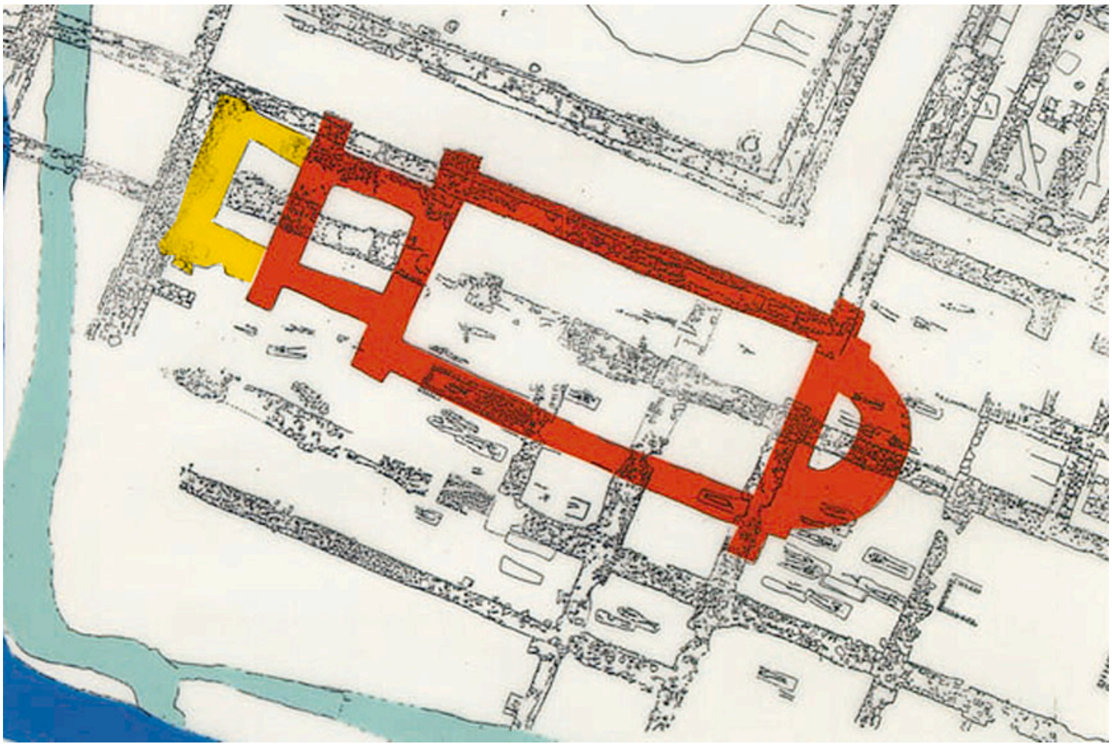
Conclusion

Shows the structure and building phases of S15/Ename

Reference

(reference number to archaeological drawing)

Description



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

Traces of the foundations of S15 church show a building consisting in a first phase (in red) 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 nearly not 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.

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 abbots house (with entrance), the guest rooms, the refectory and the dormitorium
- from the analysis of the foundations of the Saint Laurence church, which is build 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 lenght
- ...

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 probable a church with west and east apse without tower, the Saint Saviour church, build in the same period under the same rulers, has most probable also 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.

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

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)

Ename archaeological site overview

Saint Saviour Church

The first phase of the Saint Saviour church of Ename (about 1005-1139) consists of a double apse church with later extension of the west apse

The second phase of the Saint Saviour church of Ename (about 1149-1578) consists of a Hirschau type of Romanesque church

The Saint Saviour church of Ename has been destroyed and dismantled during the Prothestant revolt (1578-1582) and plundered by the local community until 1596

The Saint Saviour church of Ename has been rebuild from 1596 to 1607

The third phase of the Saint Saviour church of Ename (1607-1795) has the same structure as the second phase with a later addition of an Our Lady chapel

...

Saint Saviour Central Abbey buildings

The Ename abbey has been founded in 1063 in the palace building at the Ename castrum

The first phase of the Saint Saviour abbey buildings (about 1070 – about 1160) have been build with the reused stones and tiles of the Ename keep

...

...