Building the Past

Virtual Reconstruction in art historical context.
Two studies of Finnish wooden churches

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Content

A great deal of art history works with the question: "How things looked in the past." Reconstructing earlier ages and their art entails not only visualization but also serious scientific investigation. This is a long established tradition in the study of art history. Yet, new technology can greatly assist in enhancing this tradition.

Three-dimensional, virtual reconstruction models are today visually helping us interpret the past. For example, destroyed or altered buildings can be brought back digitally. As a result, not only scholars, but also the general public benefits from recent technological development in this area. Providing access to cultural heritage via digital techniques can turn our interest from virtual to real.

One of the primary goals of the Department of Art and Culture Studies at the University of Jyväskylä is to make art and its history meaningful in our own time. Information technology is widely used in various sectors, and experiments in virtual reality have raised cooperation between different educational institutions and scholars. For instance, a very promising endeavor is our department's The 3D Interfacing of Cultural Heritage and New Technology, a project which brings together virtual modelling research from various countries including Finland, the United Kingdom, and Germany.

Another example is a special Master's program in Art, Science and Technology (2001-2004), under whose auspices this publication is produced. These endeavors will be continued under newly the established discipline of Digital culture. It is our view that standing firmly in the present offers one the best view of both history and future.

Heikki Hanka
Professor in Art History

Attempts to reconstruct important buildings are not new. The results of a reconstruction are traditionally presented with plans and sections, perspective drawings or scale models which all have their own pros and cons. Plans and sections are widely used among experts. Creating them does not require expensive equipment but it is difficult to present all aspects of a complex building just with plans or sections. However, drawings with perspective are difficult to prepare and they must be re-drawn for every viewing angle. It is possible to ignore problematic ranges.[1] Scale models are difficult to construct, modify and move and the viewing angles are often very limited. Nevertheless, with a scale model the whole building can be presented at once and it is also easy to depict for non-experts. Yet, with all of these possibilities still the impression of a high Gothic church room cannot be achieved with traditional presentation methods.

This study discusses computer-based, three-dimensional virtual reconstruction and its methodology in the field of art history. The study is based on the cases of virtual reconstructions made of two Finnish wooden churches, both built in the 18th century. The primary aim of this article is to briefly describe these two virtual reconstruction processes, and to discuss the methodology needed when working with virtual models. A secondary aim is to provide a brief introduction to the virtual reconstruction techniques.

The Old Church of Petäjävesi, which is one of UNESCO's World Heritage sites, was built in 1764 by Jaakko Klemetinpoika Leppänen. The Old Church of Petäjävesi was virtually reconstructed to its former condition before major changes were made in the beginning of the 19th century. Professor Heikki Hanka of the University of Jyväskylä was chiefly responsible for the research data and photographing. Part of the photograph and all of the 3D-modelling was done by Ari Häyrinen

The church of Oulainen was built in 1754 and has had three different appearances over the years. There has been a unique set of paintings in the church, which had been covered and was later revealed. The first two phases of the church of Oulai-nen were virtually reconstructed during this study. Marja-Liisa Rajaniemi, an expert of ecclesiastical art of the 18th century, was chiefly responsible of the research data. The photographing was done by Heikki Hanka and Ari Häyrinen; the latter was also responsible of the 3D-models, image manipulations and www-programming.

The purpose of actual reconstruction or restoration is often to rebuild an object as it was "meant to be". Therefore the very act of reconstruction has a very strong value statement; it prioritizes certain architectural styles or decades[2]. The purpose of reconstruction in research situations is to produce new information about subject. Yet there is no need to make any compromises due aesthetic or cultural-historical reasons.

Reconstruction made with computer based virtual models is usually called virtual reconstruction. Virtual reconstruction has been used in the field of archaeology since the early 1990 and also widely discussed there.[3] Much of what has been said about virtual reconstruction in archaeology can apply to art historical reconstruction. Masuch presents four categories for the sources of archaeological data:

findings: artifacts that actually have been excavated,
deductions: facts that can derived directly from the excavation,
analogies: facts that have no excavation equivalent, but can be deduced from similar buildings of the same architectural period,
assumptions: details that are assumed because "something had to be there", but which have no excavation basis. [4]

By replacing the word excavation with historical source we can use the Masuchs classification in architectural reconstruction. In art history, findings include all historical evidence such as drawings, old account books and notices in parish registers. Therefore the concept findings are less precise in art history; literal sources need to be interpreted first. In literal findings we can have deductive arguments. In a valid deductive argument, the truth of the premises guarantees the truth of the conclusion. For example, in the case of Petäjävesi there was a note in the account books that fees were paid to construction men for pulling down the choir rail. If it was pulled down, then it had to exist at one time. So it can be deduced that there was a choir rail. However the design of the choir rail cannot be deduced from this entry and other methods must be used to find out the design.

When it is not possible to deduce a structure from the findings, analogies must be sought from other objects from the same time period. The use of analogies is based on an inductive argument. In a valid inductive argument, the truth of the premises only makes the conclusion probable. If there has been an X in Y in all previous cases of Y, then it is probable that in this case of Y there also is X. The challenge is to find valid analogies for the premises. For example, in the case of the Oulainen we considered as valid analogies other similar churches that Matti Honka had built. However, finding valid analogies can be problematic since there often have been modifications in buildings that has not been necessarily documented.

It is possible that structure cannot be deduced from the findings and analogies cannot be found. Then the structure must be assumed, a process that involves intuition. The scientific status of intuition is hard to define. Experts who handle images, drawings and notes about certain time periods on a daily basis, possess "silent knowledge" about their subjects. Silent knowledge is information that cannot be explicitly articulated. This knowledge is in use when one sees that there is "something missing" or "something wrong", for example, in the reconstruction image. In these circumstances, it appears that there is something in the picture that conflicts with the mental image the image has about the subject. So assuming does not mean randomizing, but rather making educated guesses.

These four categories - findings, deduction, analogies and assumptions - overlap during a reconstruction process. All of the stages require reasoning and most stages require some assuming. The level of certainty of the decisions made depends on the amount and the nature of available data about the subject.

The difference between computer-based 3D model presentations and traditional presentations is that once the model is completed, it is possible to produce a visual presentation of an object from any perspective. As a result, the selection of a view can be based on the purposes of the presentation without technical limitations. Traditional scale models can usually be seen from an aerial view only and they are built to be seen from that perspective.

A virtual reconstruction can be regarded as a continuous (evolutionary) process in which the 3D model experiences constant refinement.[5]

The 3D model consists of individual objects, and this modularity allows for easy changes in a model. The 3D model offers immediate visual feedback when testing various solutions, and therefore the model works like a virtual construction yard. The detail level of the 3D model depends on the purpose of the model and the available data. It is possible to make very plain models which are suitable to illustrate, for example, city plans or to produce highly detailed and realistic models of individual objects, such as buildings or choir rails. The difference between the largest and the smallest object in the 3D model can be enormous. In the scale model this difference is limited because very small objects are difficult to handle and they are practically invisible in a large model because the model limits the person's viewing angle. This is not a concern with a computer model, which is also very accurate, because measurements can be given directly in a numerical format, if they are known. The major drawbacks in the use of 3D models is that they require a familiarity with the software used and that the programs are rather expensive.

The construction of a 3D model has usually four stages: modelling, the making textures and applying them, lighting and rendering. In practise, these four phases overlap. The 3D model can be created in several ways. The most common way is to use tools provided by the modelling software and build the model with them. In some cases photogrammetry[6] or 3D scanning[7] can be used. Photogrammetry is a method that can be used to construct a model directly from photographs that presents object from different perspectives. In 3D scanning model can be built by scanning the original object with 3D-scanner. Despite the creation method used, construction of a 3D model is a rapid process as compared it to other reconstruction methods when presenting the same level of details.

In order to create a convincing effect of the finished model, textures must be prepared from photographs in such a manner as to make texturing possible. The first step in this stage is the actual taking of the photographs. This is critical, because without consistent, photos without perspective, materials cannot be made convincing. A problem arises when the photographic material is old, which usually means that it is presented in shades of grey. Options are to colour the photographs, which could be a very difficult task, or to use the photographs as they are. For example, the case of Oulainen the paintings, which no longer exist, had been photographed with b/w-film. The b/w-textures used in a model can offer information of location and subject of the original paintings, even if the rendered picture is in colour.

The last stage in the construction process before rendering is lighting, which is a sizeable challenge when aiming for realistic pictures. The reconstruction of the light conditions in virtual reconstruction is very problematic[8]. Even if a perfect algorithm for light calculations existed, good results cannot be achieved without perfect knowledge about the materials used in the original subject. Various materials reflect light in different ways and therefore light solutions are always estimations. As a result it is very difficult to restore light conditions in interiors when the amount of incoming natural light has changed, for example due to changes in window locations and sizes. But this does not mean that the estimations would be useless. Although with light calculations we cannot have absolute light conditions, we can have a good estimation of how light is scattered in space and we can have good alternative estimations for a variety of materials. So we can present answers questions such as: How is light scattered in the space if the floor is dark? What if it is white?

Rendering is a process in which the final images or animations are produced from a model. The final image is a combination of point of view, visible objects, textures, lighting and the rendering method. Three dimensional computer models offer a great variety of presentation techniques. It is possible to produce illustrations, perspective drawings, photo-realistic images, pictures of specific parts of the model, animations, and real-time applications.

There are several different options in rendering affecting the quality of the final image. The first choice to be made is a selection between an orthographic view and a perspective view. The orthographic view represents the model without perspective from the angle perpendicular to the one of the main axes: top, front or side. In the perspective view it is possible to adjust the field of view, which is the same as changing lenses in a real camera. By using different rendering methods, one can have images for different purposes from the same model. For example, plane drawings are a widely used presentation method for architecture and, as Masuch states:

> ***[...] experts feel more comfortable with non-photorealistic visualizations in a discussion among fellow researchers.*** [9]

Illustrations that are very similar to traditional architectural drawings can be produced with appropriate rendering software (see Fig. 1). It is also possible to render a modelled building in its natural environment by placing a photograph or a video sequence taken from the actual setting in the model's background. Camera matching[10] allows the perspective of the model and the perspective of the environment can be aligned, so the model is seamlessly fitted in the environment. Convincing overlays can be produced this way.

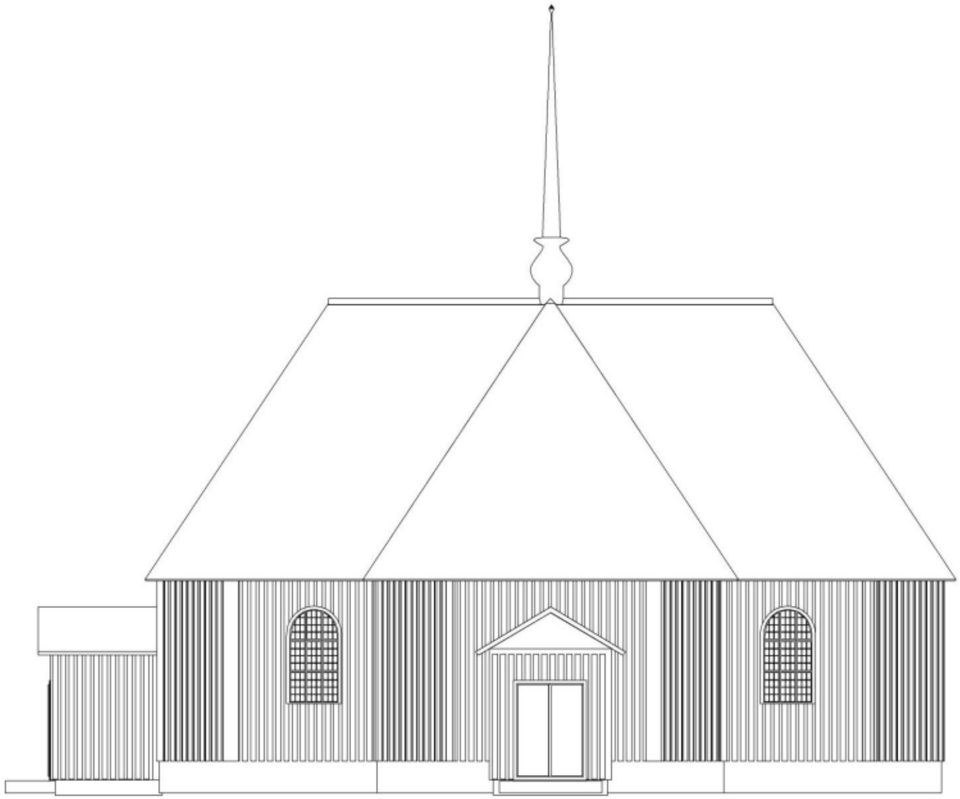


Figure 1. A line rendering.

The primary idea of the virtual reconstruction of the Old Church of Petäjävesi, which was built in 1763-65, was to examine the use of 3D modelling in architectural reconstruction. Therefore the case of Petäjävesi can be considered as having a more technical approach than a typical art historical approach.

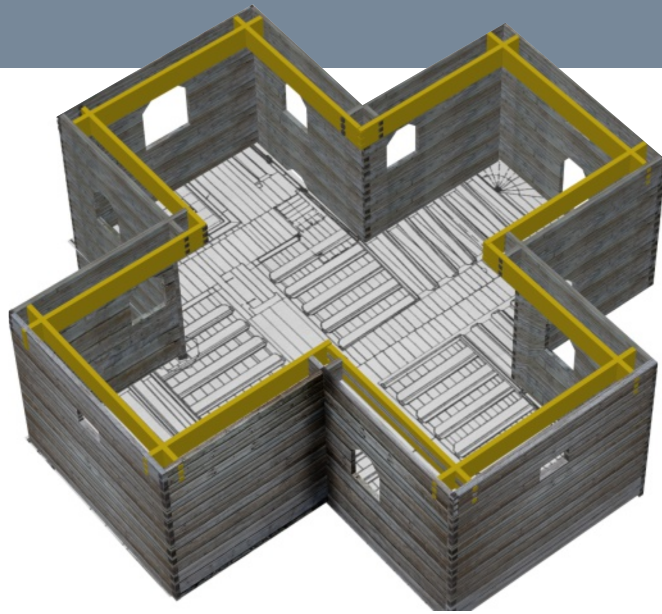


Figure 2. The plane drawing of the church is located as a texture to the floor surface.

Reconstruction

Only minor changes had been made in the church during its history. In the beginning of the 19th century the windows were enlarged and the shape of the windows changed from three-folded to square, the choir screen was pulled down, the pulpit was moved to the opposite wall and the vestry was relocated in the eastern cross-arm.[11] The main part of the virtual reconstruction of the Old Church of Petäjävesi was made in summer 2000. The first step in the creation of a completed model was the careful documentation of the church. Hundreds of digital photographs were taken and some video material was recorded. Fortunately, documentation drawings of the church were available[12]. The final virtual model is based on several traces and fragments found. It is one possible interpretation of the interior of the church before 1830.

A small square piece of painted and decorated timber is preserved in one of the storage rooms of the bell-tower. Another piece of the same kind of square timber can be found in the rail of the northern gallery, where it has been used repair the gap left by the earlier stairs of the gallery. In the wall near the pulpit there are three notches which have probably been for the choir screen. The size of the timbers fits the uppermost notch and thus they were probably part of the choral screen. The only remaining three-folded window is behind the current altar painting. Other windows were construed from this window by scaling down the size, so that the width of the construed window could fit to the current window width.

The church was first modelled in its current state, so we had a complete model to work with in the reconstruction process. The documentation drawings were used to assist modelling by importing them in the modelling program. By placing the plane drawing on the floor of the church, it was easy to find correct locations to objects currently inside the church (Fig. 2).

Results

Figure 3 presents the full 3D model from a perspective view. This kind of illustration simplifies an object's visual shape by fading out the surfaces and thereby making it comparable to drawn illustrations. The illustration was rendered with the Vecta[13] renderer from a 3D model. The individual timbers can not be seen in the log wall, because the walls are one solid object in this model and the look of the log wall is achieved by using log textures. For the same reason, the carvings of the pulpit are not visible in this rendered drawing. It would be possible to model individual timbers and carvings, but in this case the benefits would have been minimal. In particularly carvings are very difficult to model and they usually can be left to the capabilities of the texture mapping without affecting the usability of the model.

Figure 3. Reconstruction seen from the western cross-arm. Computer rendering with perspective.

Figure 4. The drawing on the wall shows the size of the current window as compared to the original window.

With a computer model, the changes in structures can be shown by using elevation drawings as textures (Fig. 4). The elevation drawing which presents the current state of the northern wall in the eastern cross-arm, is used to cover the same wall in the reconstruction model. The changes in the windows size and shape are clearly visible.

Figure 5. The church rendered without vaults, roof trusses and roof.

Figure 6. The roof structure of the church.

Figure 7. (next page) Interior rendering of the church.

The virtual reconstruction of the Church of Oulainen was made during spring and summer 2003. Results and references are published in the book Oulaisten kuvakirkko[14] and on the research website. Therefore only a brief description is presented here.

The church was built in 1753 by Matti Honka and its interior was finished 26 years later. Paintings had an important role in the church's interior. All six wall paintings still exist in the church but the one located in the church's opaion is destroyed. The altar painting is still in the church while the paintings that had been located above the doors are now preserved in the Finnish National Board of Antiquities. The original pulpit with its paintings is now located in the church of Vihanti[15]. It has remain only partly unchanged.

The first phase of the church ended in 1882, when major changes were then made in the church: The Neo-Gothic style was used and the church's interior and exterior were totally re-designed. This second phase is very well documented since there are photographs of both the interior and exterior; building drawings also exist. Although the second phase was well documented, we wanted to reconstruct the colours and the rich wooden decorations which were no longer visible and could be only seen in the colour analysis.

Web-based workgroup

At the start of the reconstruction of the Church of Oulainen, it was decided to construct a very simple workgroup tool that could be used during the process. A web-based workgroup is a tool that assists research by providing a structure to the research data, facilitating communication between content providers, and enabling documentation. The workgroup offers some basic functions such as adding pictures with commentary, user authentication, and a structure that can be easily modified. The result of that effort was a website called Inspektori.

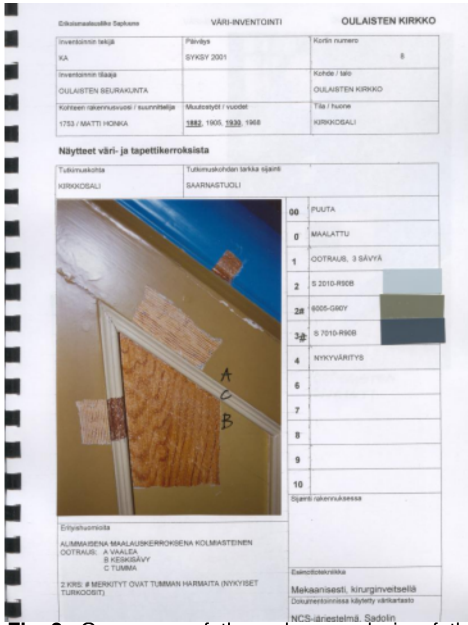
The workgroup was designed for use through a normal web browser and its navigation was made as easy as possible for anyone familiar with basic Internet practices. After negotiating the login window the user arrives to the first page in which there are the navigation links on the left. In the first page user sees the most recently added images in chronological order. Every image has a link to the page including comments of that image and every thumbnail image is a link to an larger image. Therefore the user immediately sees the recent images when entering to the site, and by following the links he can see the actual context of the image.

The visual research material in the website is organized in various categories. The main categories are two different stages which were used in the reconstruction: the original design in the 18th century and the Neo-Gothic phase in the 19th century. These two main categories are divided into more detailed categories according the architectural parts of the church: floor, ceiling, pulpit, benches, doors, windows, altar, choir, paintings, exterior in general, and interior in general. All gathered material is placed under one of these sections, providing an easy way to navigate between the different materials.

While users navigates around the site, they can see thumbnail pictures and corresponding comments in chronological order. Every picture has its own comments and an authorized user can add a new comment by clicking the link below the picture. The idea was that this organizational structure would offer documentation of the argumentation used in the reconstruction by showing findings, analogies, and the overall development of the reconstruction.

The navigation links are created dynamically from a text file, that can be edited through a web browser. There is also a link to a page showing the most recent comments, thus enabling fast access to a new material.

The site was developed on a very rapid schedule which left no room for improved planning of the data structure. The database in the site is text-file based, which meant considerable extra work comparing to usage of some existing database structure like MySQL. Unfortunately, the web server used did not offer such functions. However, even this kind of very simple web-based workgroup turned out be a very useful tool during the process. It offered a quick way to publish pictures and commentary and - most important - this provided full documentation in one easily-accessed place.



Erikoismaalausliike Sapluuna — VÄRI-INVENTOINTI — **OULAISTEN KIRKKO**

Inventoinnin tekijä	Päiväys	Kortin numero
KA	SYKSY 2001	8
Inventoinnin tilaaja		Kohde / talo
OULAISTEN SEURAKUNTA		OULAISTEN KIRKKO
Kohteen rakennusvuosi / suunnittelija	Muutostyöt / vuodet	Tila / huone
1753 / MATTI HONKA	1882, 1905, 1930, 1968	KIRKKOSALI

Näytteet väri- ja tapettikerroksista

Tutkimuskohta	Tutkimuskohdan tarkka sijainti
KIRKKOSALI	SAARNASTUOLI

00	PUUTA
0	MAALATTU
1	OOTRAUS, 3 SÄVYÄ
2	S 2010-R90B
2#	6005-G90Y
3#	S 7010-R90B
4	NYKYVÄRITYS
6	
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9	
10	

Sijainti rakennuksessa

Erityishuomioita

ALIMMAISENA MAALAUSKERROKSENA KOLMIASTEINEN OOTRAUS: A VAALEA B KESKISÄVY C TUMMA

2 KRS: # MERKITYT OVAT TUMMAN HARMAITA (NYKYISET TURKOOSIT)

Esiintotekniikka: Mekaanisesti, kirurginveitsellä

Dokumentoinnissa käytetty värikartasto: NCS-järjestelmä, Sadolin

Fig 8. One page of the colour analysis of the pulpit.

Reconstruction

After photographing the church, virtual reconstruction was started from the church's Neo-Gothic phase because it was well documented. The church was modelled according to available drawings and photographs. The chief differences between this second phase of the church and the current structure of the church are the windows, the vault and the colours.

The most challenging part of the second phase was the reconstruction of the colours. The second phase of the church had very richly painted wooden grain surfaces. From the colour analysis (Fig. 8) we could reconstruct the main colours and the grain patterns[16]. However, the colour analysis only revealed small regions of patterns, so the rest had to be somehow construed. The colour analysis was first scanned to a digital format and then the patterns were construed with an image manipulation program. Then the images were applied to the model as textures.

The reconstruction of the first phase of the church was very challenging since there was very little reference material available. The church was elevated during the changes in 1882, so construction of the model was started by lowering the church and placing the bench blocks. Most of the reconstruction decisions had to be made by finding analogies from other churches. The size and the shape of the church were known, as were the positions of the pulpit and the altar[17]. The location of the windows could be estimated based on the current window positions. The windows were construed based on the fragment of the window of the Merijärvi church. There were no description of the altar and it was construed based on the altar of Teerijärvi church[18].

In the reconstruction of the Oulainen radiosity calculations were used to achieve the look of natural lighting in the interior scenes. The radiosity is an algorithm that simulates natural light behaviour, such as the bouncing of light and colour bleeding. There were two light sources for the model: the direct sunlight and scattered light. The direct sun light was simulated by placing a direct light outside the church. The light was controlled by sun light system, which controls light positions according to the time of the year. Scattered light was produced with self-illumination window glass.

Figure 9 shows a radiosity test rendition of an empty interior of the first phase of the Church of Oulainen. It is noticeable that the material of the walls and the roof are almost pure white while the floor's brown material is reflected very strongly onto the walls and the roof making them appear light brown in the rendition. This is called colour bleeding, and it can be adjusted for in material basis with the rendering software. However, as this shows, light calculation cannot be accurate if colour bleedings values are not accurate. In the case of Oulainen, the default values were found too high and they were reduced based on the test renditions.

Figure 9. A radiosity test.

Results

In its original state (Fig. 10) the church of Oulainen had a lower stone base and also the walls of the church itself were lower than in the current state. There were no entry in the northern cross-arm and there was a simple pole in the cross-centre.

The entry to the northern cross-arm and the vestry to the eastern cross-arm were added in 1882 (Fig. 11) and a new stone base was built. A tower was built in the cross-centre instead of the pole. The shape of the windows was changed and the thick shingle roof was replaced with a roof made with thin wooden shingles.

The most remarkable changes in the church takes place in the interior. The wall paintings were dominant part of the church's interior after it was finished. It is uncertain if doors of the bench blocks were painted or not. It is possible that only a part of them was painted while rest had only a plain wooden surface.

The altarpieces of the first two phases does not exist any more. The colour tones of the second phase's altar were estimated based on the b/w photographs of the original altarpiece.

Figure 10. Overlay of the first phase. The yellow area presents the current size of the church.

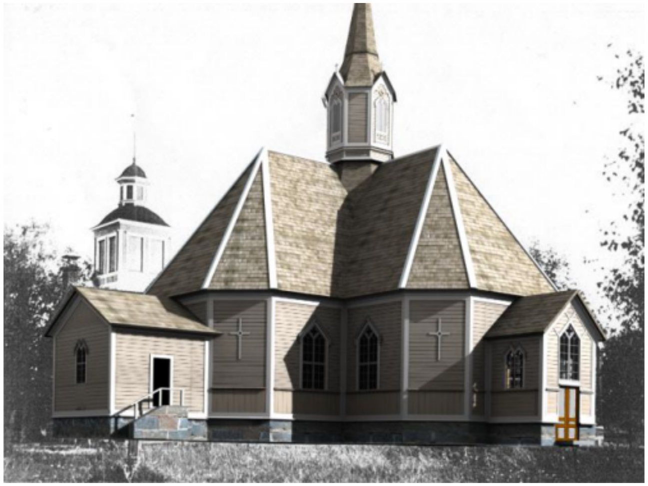

Figure 11. Overlay of the second phase. Model is rendered over photograph presenting the current state without any extra manipulation.

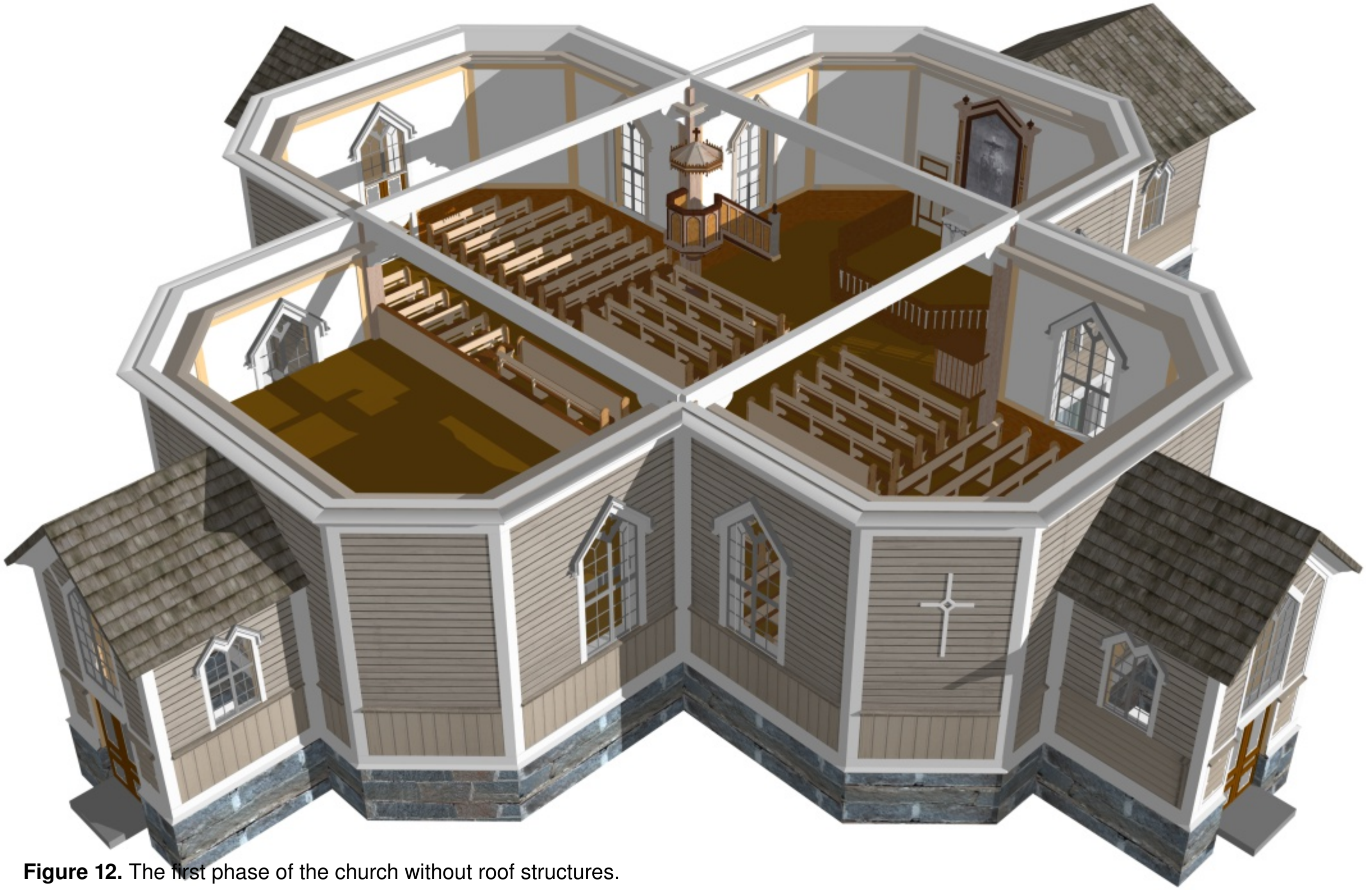

Figure 12. The first phase of the church without roof structures.

Figure 13 and 14. (Next spread) Interior reconstruction of the first phase on the left and interior reconstruction of the Neo-Gothic phase on the right. A view toward to eastern crossarm.

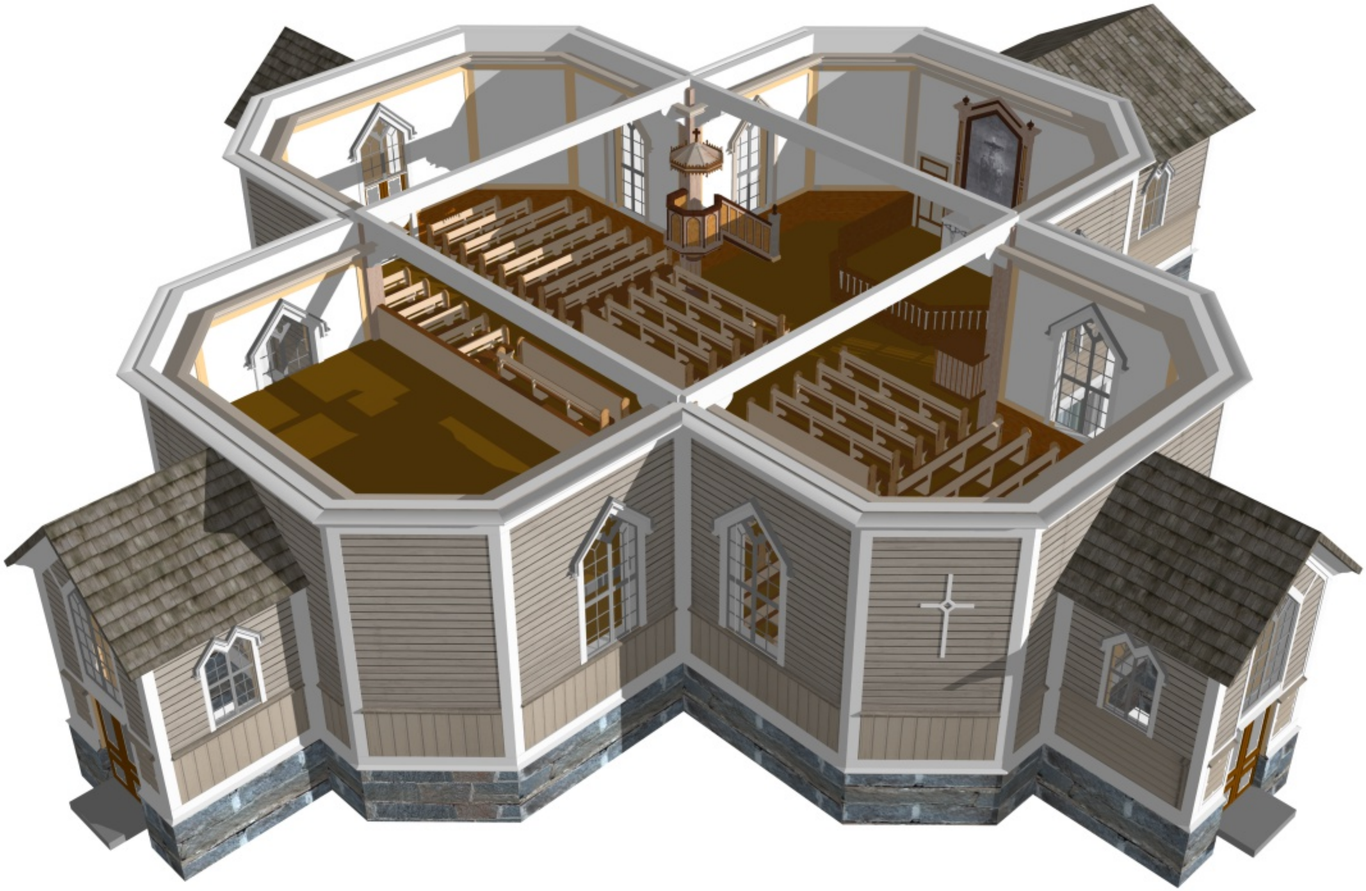

Figure 15. Neo-Gothic phase of the church without roof structures.

It is important to separate the two aspects of a virtual reconstruction method: On the one hand it is a tool for research and on the other hand it is a method of presentation. Most problems in the virtual reconstruction are connected to the presentational role of the virtual reconstruction.

Highly realistic pictures can be produced from virtual models. However, realistic impression can be only achieved with a high level of detail. There can not be any visible gaps or blank areas in the image. Because every detail in a reconstruction requires decisions, the number of decisions increases as the detail level of the model increases. This means that there are more guesses in a fully detailed model because the amount of the initial data remains the same. Nevertheless, the end result - the photographic image - is very convincing. So although less accurate, a fully detailed reconstruction looks more convincing than a more accurate, but less detailed, reconstruction. However, by choosing a different rendering method, it possible to create less detailed images from the fully detailed model. For example, in a line drawing (Fig. 16) there is no need to make decisions about surface materials, colours, possible decorations or lighting and its behaviour. After all, the atmosphere of the place is missing in the line drawing but the structure, or at least the main part of it, is presented.

So is there any reason to use fully detailed, photographic reconstruction images when there is not enough initial data? The answer to this can be put to a form of another query: What question is the reconstruction image suppose to answer? A line drawing shows a structure so it answers the questions "What was it like?" or "What kind of structure did it have?". But if there is a need to answer questions like "What did it looked like?" or "What was the atmosphere of the space?" or even "What feelings were raised by this space?", then the photographic renderings must be used. The key to the atmosphere and to the "being there" feeling is

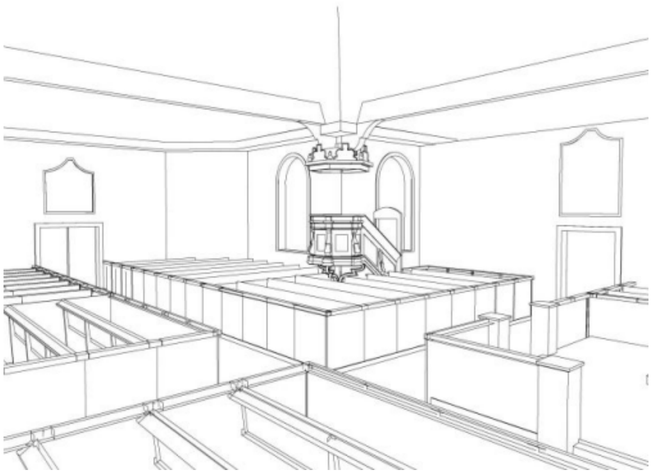

Figure 16. The reconstruction of Oulainen. A less detailed rendering.

Figure 17. The reconstruction of Oulainen. A fully detailed rendering.

light. The presence of light is essential to architecture since it is used to create atmosphere and even a religious experience. In a way, photographic renderings can be seen as reconstructions of the atmosphere where details are less important. There might be errors in the picture but there is also information that cannot be presented any other way. Justification for the use of photographic renderings and the use of virtual reconstruction in general can be underscored by following statement:

> ***Nevertheless, there is still information that cannot be found without visualisation, and that is the case with human visual perception of architectural space[19].***

One way to understand the validity of a photographic reconstruction image is to compare it to a photograph. A photograph claims that one certain moment has taken place in the history and that moment has had certain visual appearance when looked at through the camera's lens. The certain light at a certain time has affected a light-sensitive surface resulting in a visible image and this gives the photograph its evidentiary nature. A photograph, therefore has a link to reality which is, in its nature very different from that of (photo-realistic) reconstruction images. It can be said that a photorealistic computer rendering borrows its evidentiary value from a photograph. The danger is that at some point the reconstruction image is no longer seen as such but as an image of the actual object. This could happen when the context of the image is lost for some reason. Traditional presentation techniques show themselves more clearly as artefacts.

With a photographic rendering it is possible to make more refinements by adding noise, blur and adjusting colour balance in order to achieve the grainy look of a old photograph. However, this kind of image can be considered a forgery. While this method produces images that are comparable to the old photographs, and thus illustrates the differences between reconstruction and the actual photographs, it can also accidentally mislead the viewer. In overlays, where the rendering is done over an existing photograph, this problem can be solved by leaving a mark that separates the photograph from the rendering. With b/w photographs this mark can be done by leaving the colours of the rendered object unchanged. That way the amount of information remains the same, but image provides a clue regarding the image's artificial origin. Colours can be also used with photographic renderings to mark out reconstructed objects.

Argumentation is the missing link between reality and the reconstruction image.

> ***Noticeable gaps are represented by the fact that the models are not transparent in respect to the initial information (what were the initial data?) and by the use of the peremptory single reconstruction without offering alternatives (it could have been like this but we can also offer other models...).[20]***

This transparency is not an easy task to accomplish. As stated earlier, the argumentation of decisions made is essential to a virtual reconstruction. This of course applies to all presentation methods used. The careful documentation of the reconstruction process is the key when striving for transparency to the initial information and the web-based workgroup turned out be one viable solution for this task.

We experienced that the best practise for the refinements of the model was to work in a small group with the model. The computer output can be projected onto a large screen so that everyone can see the model. This arrangement provides for a very useful collaborative environment without extra cost. However, in order to make refinements "on the fly", a person with a good 3D-software experience is required.

One problem with models in virtual reconstruction is that a virtual model disconnects the relationship between the amount of work done and the result, due the cloning system. For example, carvings in the older buildings are hand-made and the time required to make them has a strict relation to the number of carvings, even if they appear to be identical. Similarly, with drawings or scale models, every carving has to made or drawn for every instance. On the contrary, in a 3D model the carving can be duplicated without any extra work. This may lead to a tendency to re-construct more rich decorations than there has been in the original building. At least, this is something that should be kept in mind during virtual reconstruction process.

In general virtual reconstructions and reconstruction images could be seen as a scientific theory that makes claims about the real world at a certain time. With that point of view reconstruction can be studied with tools provided by the philosophy of science. Popper states that a good scientific hypothesis should be falsifiable[21]. This means that there must be way to present an argument or test that could falsify the hypothesis. Although Popper's theory has its limitations and could be criticized as being too strict, Popper's idea about falsifiability can be applied to reconstruction. When we consider the truth of a reconstruction, there is usually no possible way to prove that the interpretative leaps required to complete a reconstruction are true. On the contrary, it is only possible to prove that a reconstruction is false or that some part of it has an error. As a result, it is very important that the reconstruction method allows modifications so that discussion among experts could lead to refinements. Virtual reconstruction has a propositional nature due to its dynamics; it does not tell how things are but presents some suggestions. By being forced to make decisions about every element of the structure, virtual model helps experts to see the subject in a wider sense. Scale models, for example, lack of this kind of flexibility[22].

Computer-based reconstruction can be understood both as a new presentation technique and as a new method for research. During the reconstruction process, virtual reality and virtual models can be used as a construction site, offering new tools to resolve scientific problems[23]. Virtual reality allows rapid changes to a model and therefore it offers a new way to work collaboratively for example, through a web-based workgroup. Images produced by sophisticated 3D programs can have a photographic look leading to some epistemological and ontological problems concerning the nature and the scientific status of these reconstruction images. On the contrary, traditional reconstruction presentation techniques, such as line drawings or scale models, show themselves clearly as an abstract construction.

Virtual reconstruction technologies offer almost endless possibilities to visualize past events - much like, for example in the TV series Walking with Dinosaurs - in ways that are easy to understand by both experts and non-experts. At the same time they offer endless possibilities to mislead a viewer.

> ***It is not the models themselves, which are deceptive, but rather their visual attractiveness, which allows the uncritical spectator to all too easily accept them as reality. Reconstruction such as these are convincing even when wrong and may perpetuate errors for generations.*** [24]

We experienced that 3D modelling is a valuable tool in art historical reconstruction. And like any new method in any discipline, it raises new challenges and issues. It requires a new way to work with constant refinements and it forces one to make more detailed decisions about structures. The making of fully detailed virtual models is not a problem, the problem is how to document the process and what to present to the viewer.

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