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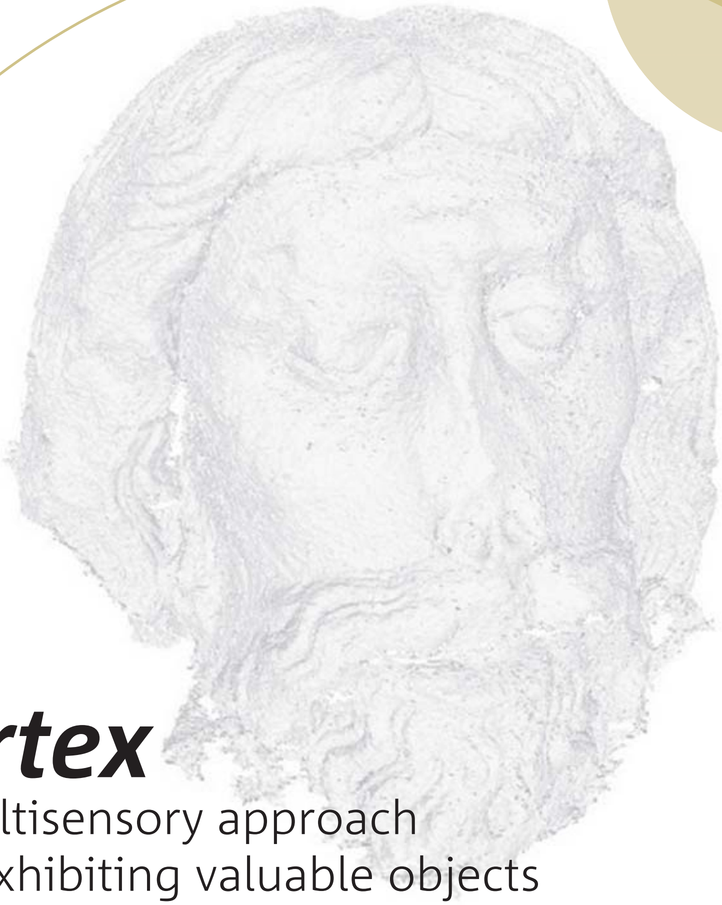
Virtex

a multisensory approach for exhibiting valuable objects

This book is dedicated to Prof. em. A.L.J. Vande Walle (1922-2006), a dedicated and passionate art historian, who did most of the research concerning the meaning and importance of the ivory object we used as a test case in this know-how book.

Daniel Pletinckx
Visual Dimension bvba



Virtex

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Exhibiting valuable objects

Valuable art objects are a challenge for museum curators to exhibit. On one hand, they require the highest protection against damage and theft; on the other hand they have a rich, complex story to tell. This know-how book presents a new methodology to exhibit such valuable objects by turning them into an interactive, explorable world that unfolds for the visitor by manipulating a replica of the object. In this way, a multisensory experience is created where the visitor not only holds the untouchable object (as a replica) and feels all details of the object but also explores at their own pace the meaning of the object through sound and image. Above all, the visitor sees the object from all sides in unprecedented detail in a three-dimensional way.

We call this presentation method VIRTEX (VIRTual EXhibition), although the key idea is to use it side by side with the real object where possible. Through VIRTEX, the replica is turned into a storytelling device, giving access to art objects. VIRTEX opens a wide variety of opportunities to deal with valuable objects in a different way, with improved protection of the object, an engaging storytelling methodology, an exceptional multisensory experience and an innovative approach for making the object accessible and enjoyable.

Background

Many art objects are *exceptionally valuable*, due to the uniqueness of the object, the exceptional craftsmanship that produced them, the historical facts they are related to, or to the precious materials of which they are made. In most cases this is due to a combination of these factors.

Exhibiting such objects is always a challenge. On one hand, the museum wants to make the object as *visible and accessible* as possible to the public, on the other hand, a lot of factors jeopardise this accessibility.

First of all, light can damage certain objects or parts of them, so that only very dimmed light with special UV filtering is allowed. Such *lighting conditions* are not compatible with object information in the form of illustrations and written text, which explain the importance, history or value of the object, so that these objects lack context and the goal of exhibiting them is more or less lost. Reading the exhibition catalogue afterwards is a solution, but practice shows that only hardcore cultural tourists are willing to do so.

Secondly, the object needs to be protected from all other factors which can cause *damage*: changes of humidity and temperature, vibrations, ... This requires sturdy custom made showcases, expensive air conditioning equipment and expensive logging equipment to measure the temperature and humidity.
Thirdly, the museum has to protect the objects against *theft* or *intentional damage*, which requires guards, protected showcases and expensive surveillance equipment. Most museums have problems combining public access with their safekeeping role, resulting in important objects remaining in stock, invisible for the visitor. Some museums solve this problem by keeping their most valuable objects in a specific secure environment, prohibiting the object to ever leave the museum. This means that many of those *valuable objects don't travel any more*, rather they require the visitor to travel to see them.

Other objects are only *visible at major exhibitions*, which consequently draw a lot of visitors. This means in practice that these objects can turn into bottlenecks, so that you only can have a glimpse of the objects. In most cases, the only good way that remains to have access to the object is the catalogue. Unfortunately, such (expensive) catalogues are often not written for the general public, but for the highly educated, even specialised cultural tourist.

Additionally, most of these objects *contain complex and rich symbolism*, and tell *interesting stories* about their historical context. When compared to the costs that are involved in displaying, safeguarding and maintaining the object, the number of people that finally receive this interesting cultural and historical information is small, while the potential audience is much wider. This know-how book proposes a new and secure way to exhibit such valuable objects while using a new paradigm for learning about the object through interactive exploration of a physical replica.

How it works

VIRTEX is based upon a *replica* of the object that serves as the *interface to explore the object*. We will illustrate the method based upon a valuable ivory object in the Provincial Archaeological Museum in Ename, Belgium.

Several of the concepts presented in this text have been applied in practice in the Ename museum in Belgium for more than 4 years, available to both individual visitors and groups with a guide.

Ivory object, 11th century, Archaeological Museum Ename, Belgium

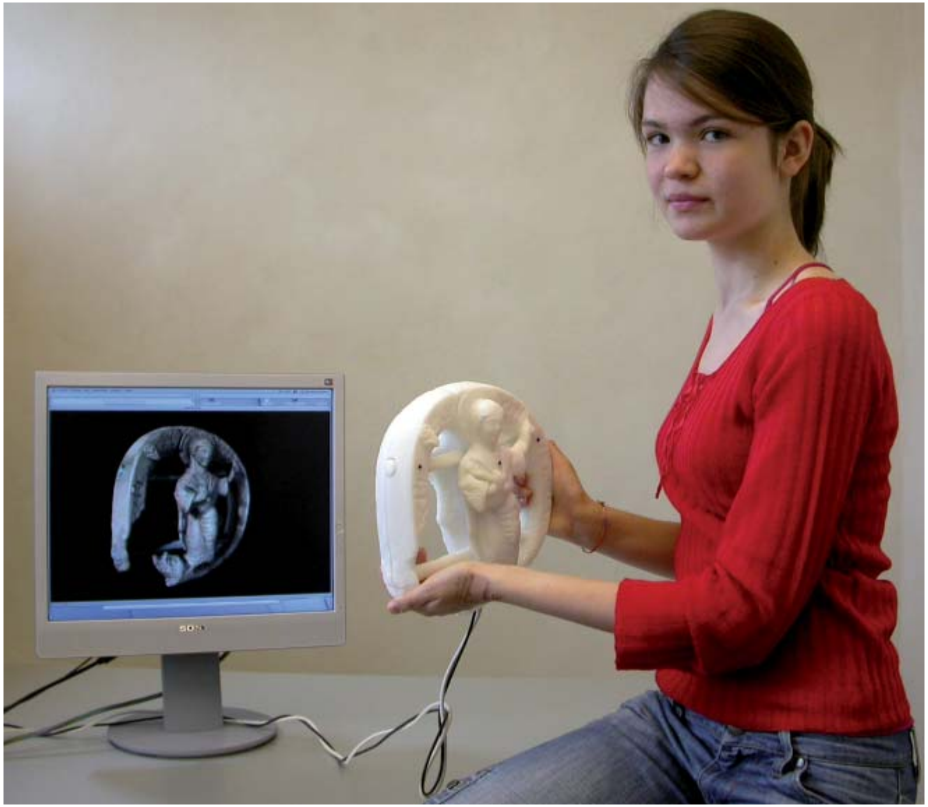
Display context of the test object in the Ename museum

In the TimeLine part of the museum, where this ivory object is on display, the real object is complemented by an interactive application with a touch screen. A large screen projection makes the application also available for groups up to 50 people. Most of the presentation of the 6 cm wide object is done through this interactive application that reveals even the smallest detail on the large screen. This text describes a further development of this presentation technique, called VIRTEX, through the addition of an interactive replica, connected to a normal PC and a screen or projection system.

TimeLine application in the Ename museum

First of all, a laser scan is made of the object, yielding a *detailed 3D model of the object*. This virtual model is then used to make a *replica* of the object in a plastic-like material by a technique called **stereo lithography**. In this case, the original object is quite small (6 cm) so the replica is bigger than the original object making the minute details of the object stand out and the object large enough to handle properly.
To make it interactive, an *orientation sensor* is integrated in the replica, so that the object can be visualised on a computer screen by following precisely all orientation changes of the replica. In this way, the user feels the shape and details of the object and sees the virtual representation of the object, behaving in exactly the same way as the replica.

By adding *touch sensors* to the surface of the replica in areas of interest, the user can explore the meaning of the object. By touching an area, a story develops that explains the deeper meaning and history of the object. These stories are


Interactive use of the replica

small video or animation sequences with narration that play on the same screen and explain the feature that has been touched. For example, if the object contains an inscription, the user can learn what the text means and what the message is behind the text by simply touching the text. Below are two frames from such a story (also made in 3D) that shows the probable meaning and use of the object, and gives an impression of the abbey and its inhabitants where the object was commissioned, used and disposed.

Two frames from the animation showing the probable use of the object

This “multimodal” interface allows the visitor to experience and explore the object in an exciting and innovative way, as it uses vision, sound (of the stories) and touch. In other words, the replica acts as a “3D mouse” with the user looking at the screen while manipulating, exploring and feeling the object.

The resulting system can be used by individual users, families or by guided groups (where the guide interacts with the object). In other words, at an exhibition, multiple workstations can be provided to allow individual users and families to interact with the same object, while one central setup with large screen projection can be made for groups. The display case with the real object can be integrated in this setup, allowing the visitors to enjoy the real object, but they explore it and learn about it through the interactive setup. This approach allows many people at the same time to enjoy a valuable object in depth without creating bottlenecks or poor presentations.

If for some reason, the real object is not available for a certain exhibition, there is still a way to show the object at that exhibition. In this way, very valuable objects that don’t travel at all (such as the German Reichskrone shown on next page, which hasn’t left Vienna for the last 200 years) can be made accessible to the public in all its splendour and richness, accompanied with the many stories that go with this object.

German Reichskrone – Schatzkammer der Wiener Hofburg

In other words, we create a new and appealing way to interpret valuable objects, while providing a cost effective way to give in depth access to such objects without creating bottlenecks.

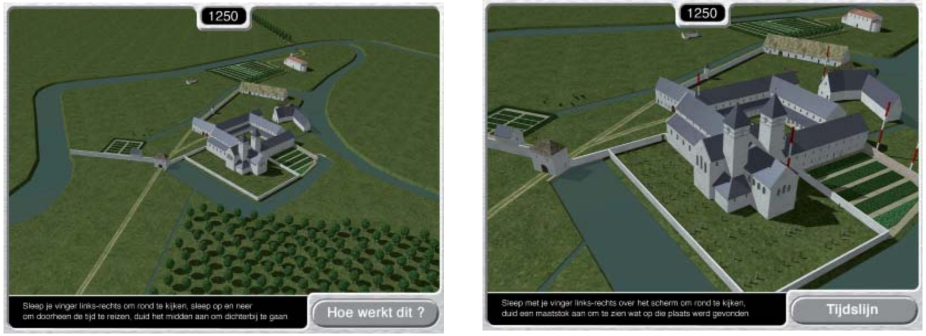
Implementation

Previous experiences

Since the opening of the Ename museum in 1998, real objects have been on display in the TimeLine room (see above) with complementary information on a touch screen and large screen projection. Virtual reconstructions of the village through more than 1000 years of history are shown, and the place of each object on display is shown in the appropriate period.

It is unclear how the ivory object got buried under the floor of the abbey church choir, but archaeologists think this happened between 1150 and 1250, when most of the abbey buildings were significantly extended. The object is indicated in the 1250 reconstruction as a yardstick in the church choir (see images below).

The object is shown interactively as a QuickTime object, dragging your finger horizontally over the touch screen makes the object turn, so that you can see it from all sides.



Sleep je vinger links-rechts om rond te kijken, sleep op en neer
om doorheen de tijd te reizen, duid het midden aan om dichterbij te gaan

Sleep met je vinger links-rechts over het scherm om rond te kijken,
duid een maatstok aan om te zien wat op die plaats werd gevonden

Two images from the TimeLine application in the Ename museum showing the abbey of Ename around 1250

Sleep met de vinger van links naar rechts over het scherm om de kromstaf rond te draaien. Druk op een deel van de kromstaf om meer informatie te krijgen.

Timeline user interface to explore the ivory object

Sint-Salvator houdt in zijn linkerhand een rijksappel vast, wat een symbool is voor zijn macht. Het kruis daarop betekent dat Christus over de wereld heerst.

Invisible hotspot zones allow visitors to explore every part of the object, for example the globe that Christ holds in his left hand

The object is completely interactive: clicking anywhere on the object gives you the information about that part of the object. This is implemented through hot spot zones (see image below) for every orientation of the object. When clicking for example on the globe that Christ is holding in his left hand, the symbolism of the globe is explained and related art objects are shown (see below).

This setup has proven to be very successful, both for guides and individual visitors.

Guides like the system very much as they can easily select the appropriate part of the object and show the related information that supports their story. Individual visitors show a lot of interest in exploring the object and the other parts of the TimeLine application.

These experiences have stimulated the development of a further development of the method, based upon an interactive replica of the object.

Stakeholders

In the implementation of this project, seven distinct stakeholder groups are involved. Firstly, there are the *museum curators* who want to provide a better and more *appealing way of telling the story of a valuable object*. Most of these objects are well studied and have a lot of content and historical background related to them. Museum curators also like the *improved visitor flow* that can be generated, by having multiple systems to show the object, with separate handling of individual visitors and group visitors (which avoids blocking the visitor flow). As explorative presentation methods are quite new in the museum world, it will take some time, effort and concrete case studies for curators to find ways to exploit and integrate this methodology in an optimal way.

Secondly, VIRTEX provides *creative people* with an innovative storytelling device that can handle different types of stories: ranging from illustrated text based pages to full blown video animations. As even 3D visualisation is possible (see below), VIRTEX becomes quite a challenge to graphic designers to create a 3D storytelling booth. Also sculptors can contribute significantly by providing good, handmade replicas (see below). Pilot projects are necessary to fine-tune these creative workflows.

Thirdly, *museum management* will like the *improved availability* of the object (as it can be provided to other museums without transporting the object). In other words, the digital, explorative presentation of the object, linked to appealing, visual stories, a very realistic visualisation of the object and a replica of the object that can be handled and touched by the visitor is a *new digital product* that the museum can provide to other museums *without the costs and burden of physical transport of the object*. If the physical object is on display, it can be *integrated into the exhibition in a more secure and protected way*, as the time that visitors will need to spend with the real object is shorter. For example, the object can be integrated in a side wall, which is safer than being shown in a standalone display case. It is clear that it will take some time and effort for most museum managers to deal with the new business models that are behind this new presentation methodology.

A fourth stakeholder group in the museum is the *educational department*, for which VIRTEX can provide new opportunities. As the content can be adapted to the audience easily and cost effectively, *separate setups can be made and integrated into the educational activities of the museum*. This group will need to learn how to use this new presentation paradigm as an educational asset and how to integrate it into the rest of the educational activity.

A fifth stakeholder group are the *museum designers*. Whilst VIRTEX offers *new design possibilities* for this group it also requires a solid understanding of the design requirements. Designers will need to take into account visitor flow and experience when integrating VIRTEX into their displays (for example how to separate the sound channels of each display unit). Also, best practices on how to create the replica and how to make it interactive will need to guide the museum designers when conceiving museum spaces that use VIRTEX (for example, do you make the replica of the earlier depicted crown in metal or in plastic).

A sixth stakeholder group are the *technology providers* that take care of the object scanning and creation of the interactive replica, the interactive application and the audiovisual stories that are triggered by the interactive zones on the replica. This group will benefit from the *business opportunities* that this method offers, as more budget can be spent on presentation instead of insurance and protection. This will require a detailed decision scheme on which technologies to use. Pilot projects can be very helpful in realising such a decision scheme.

Finally, the *visitors of the museum* are the last stakeholder group. Although VIRTEX offers very exciting new ways to enjoy cultural heritage, we need to be aware that this is something completely new. In other words, the learning curve to use this kind of new technology needs to be very short, and the usability of this technology needs to be optimal. A recent study [PET06] done by the University of Sussex proves that this is indeed the case, but more usability studies should be conducted to provide more detailed evidence.

Although VIRTEX is designed for valuable archaeological objects and art objects that have a large and rich content, it can be used in other domains too. Generally, it can be used in *science museums* (to explain body parts or mechanical devices), *monuments and landscapes* (where an interactive scale model can be handled to trigger stories) and *interactive art installations*.

Institutional framework

This new presentation methodology is basically intended to be used in medium and large museums that have valuable objects. As there is still limited experience with this new method, it is advisable to concentrate on museums that have the capacity to set up and assess *pilot projects* based upon this methodology.

The big advantage of this methodology is that it makes exceptional art objects available in a compelling, digital form, therefore giving access to a much wider audience, as the object can be distributed in multiple copies. Nevertheless, there is much resistance in the museum world towards replica-based exhibitions as opposed to having the real object present, and there is not yet a *business model* or *copyright agreement* that supports this kind of “object loan”.

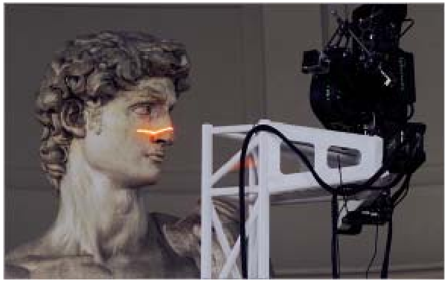
Workflow

In this paragraph, we analyse in much greater detail the VIRTEX workflow and the options one has when creating such a setup. This workflow consists of seven steps:

- digitalisation of the object
- creation of the replica
- making the replica interactive
- visualisation of the object
- creation of the stories
- integration of the interactive application
- display of the resulting application

The **first step** is the *digitalisation* of the object, in order to make the replica object, which is a key element in the methodology. This step can be skipped if the replica has been made by hand (see second step) and the visualisation is done photographically (see fourth step).

One way to realise this object scanning is by *laser scanning*. For museum objects, triangulation scanning is nearly always used, where a laser beam is projected onto the object and a camera looks at this projection from a certain angle. When knowing the geometry of this setup and the movement of the laser beam over the object, a computer can calculate the surface model of the object.


Triangulation laser scanning of the David statue

As the camera and laser need to remain exactly in the same position while scanning, it is impossible to scan the full object in one scan. Therefore, several scans are made, and the resulting model parts are merged through specialised software into one virtual model (see below).

Laser scanning can only happen if the surface characteristics are suited for this method. The ivory of the test object did not pose any problem, but the crown depicted on page 8 would definitely be a no go. Unsuitable surfaces can be made ready for scanning by applying powder. However, most valuable museum objects that are too glossy or transparent, will not get permission to be powdered to improve the surface characteristics for scanning, as intensive cleaning can damage the object. The limiting factor for the resolution of the virtual model is in most cases not the precision of the scanner profiles derived by the camera, but the size of the laser spot and the lateral spacing of the laser tracks. Surface details smaller than the laser spot or the track spacing cannot be resolved by this type of laser scanner. As a result, very small details or sharp edges can be absent in the virtual model. In specialised scanners, spot sizes and spacing can be as small as 0.01 mm. The test object was scanned with a spacing of 0.02 mm; about 70 scans were made to cover the full object, which took two full days.

If a museum wants to digitise large collections of objects, laser scanning is a job for external specialists as the investment is quite high: there are quite a number of different types and brands of laser scanners, the correct scanning setup and object handling requires a lot of expertise and the postprocessing of the scan data is highly technical requiring appropriate computer equipment. For example, to decide which parts of the object can be scanned in one pass, one has to make a trade off between the depth of field of the laser scanner (as the laser beam needs to stay focused on the surface of the object) and the size of the region to be scanned.

The whole process for creating a finished 3D model from laser scanning an object such as our test object can take 3 to 5 days, and can cost in the order of 5000 to 10000 euros. On top of that come extra costs of insurance to transport the object to the scanning lab.

Virtual model of the test object through laser scanning

A second way to realise a 3D model is through *photography*, which needs to cover the complete object from all sides. These photographs are fed into the state-of-the-art **ARC3D software** [ARC] to generate a 3D model. ARC stands for Automatic Reconstruction Conduit, has been developed by the University of Leuven and has been made available to the cultural heritage community through the EPOCH network. The reconstruction is made by automatically recognising object features from which the 3D position is calculated from the different photographs.

An important advantage is that the object does not need to be touched or treated to take these photographs. Normal light conditions work fine, but appropriate lighting, similar to what is used for professional object photography, does help the reconstruction software to create a good model. Similar to laser scanning, the model is generated by the software in separate parts, which are then merged by specialised software (see image on next page).

The disadvantages of this software is that the reconstruction is poor where insufficient surface features are present, and the model contains more noise than laser scans (which translates in more surface roughness of the replica than present in the real object – see image on next page). This surface noise can be removed with specific software, but it is difficult to maintain the right balance between removing noise while leaving the real surface details.

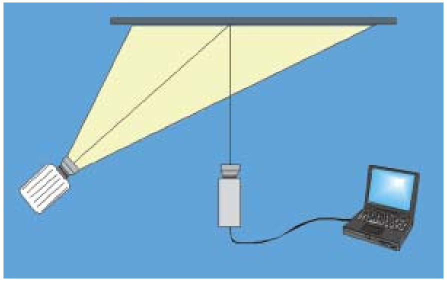
This method requires a normal digital camera and the ARC3D software is provided as a simple webservice returning the reconstructed 3D model in 15 minutes to 2 hours. Examples such as the head below are very easy to make. However, making a fully finished object within specified requirements needs extensive skills in photography, 3D model processing (see below) and modelling, and should be left to the professional. Making 3D models with this method takes about the same time as with laser scanning, but costs are lower as no special scanner equipment is needed. The first part of the processing can be done on the spot in the museum (if there is a broadband internet connection available). This avoids transporting the object out of the museum, lowering the insurance cost significantly.

Photograph, textured and untextured museum object made with ARC3D software.
Head of a statue at the Lleida Cathedral, Spain

A third method is structured *light scanning,* which is similar to triangulation laser scanning, but the laser beam is replaced by a light pattern (such as lines or a checkerboard pattern) that is projected onto the object. The deformation of the pattern, when seen under a certain angle by a camera, allows the computer to reconstruct the surface.

The method works fine if certain surface characteristics are suitable (similar to laser scanning) and if surface details are not smaller than the pattern resolution (the pattern is made by projecting light through a LCD screen, on which the pattern is generated by the computer).
In practice, the maximum resolution obtained can be about 0.2 mm. There is a trade-off between the area covered by the scan and the resulting resolution.

As pointed out above, all methods have problems with (parts of) objects, or parts of the objects that are *reflective, glossy or*



Structured light scanning

transparent. Sometimes, these problems are small and localised in only a few places (glossy parts for example tend to create a few ‘spikes’ or local deformations of the surface), or it is simply unfeasible to digitise such objects with these commonly used methods, so that one has to resort to special techniques. It is beyond the scope of this know-how book to explain all these digitalisation issues.

Whatever method is used to create the model, the resulting parts of the virtual object are *cleared* of any abnormal parts through software filters or manual correction of the model parts. These parts are then *merged* into one model through specific, semi-automatic software. The resulting model needs to be a completely *closed surface*; all remaining holes after the merging process need to be removed, which is done automatically for small holes, or manually for larger holes and in specific, complex regions. Creases and cavities for example are areas where holes appear frequently (see the model of the statue head above) as the scanner has little access to those areas.

In some cases, the resulting model will be further *simplified* to reduce the number of “polygons”. For example, nearly flat surfaces can be represented easily with fewer polygons without affecting the precision or quality of the model.
The EPOCH project has made a set of tools available for the cultural heritage community, developed by the Visual Computing Lab of CNR (the National Research Council of Italy), to do surface cleaning and noise removal, merging, hole filling and model simplification. These VIHAP3D-tools [CNR] can handle very large models (millions of polygons) and are suitable for the three methods that we explained above. Museums that want to create an internal scanning team will have the opportunity to learn the tools.

The pitfall however is that it requires extensive experience to use these tools correctly and end up with a 3D model with known precision and without artefacts. For example, as VIRTEX makes the user feel the surface characteristics of the object, it is important to have a 3D model that represents the surface of the object faithfully. Unless a museum dedicates one or more people to this task, it is better to commission these digitalisation jobs to specialists who can produce results within specifications, time and budget.

The **second step** is the *creation of the replica*. This can be done in several ways. Before we explain the creation process of the replica, we first have to expand on an important pitfall: the size of the object. In the case of this test object, the object is basically too small to have its fine detail reproduced or to have the necessary electronics integrated into the interior of a real size replica. Therefore, it was decided to enlarge the object by 400 % to accommodate the orientation sensor (see step 3). As we see the replica as a storytelling device, we think this is acceptable, but we understand that a real size replica is to be preferred whenever possible.

Another pitfall is the reproduction capability of the detail of the object as most reproduction methods have a lower resolution than the scanning data. We will expand on this further on.

If we have a 3D model of sufficient quality, *stereo lithography* allows generating the replica easily from the 3D model obtained. The model though needs *pre-processing* before it can go to the stereo lithography facility. First of all, one needs to decide how the interior of the replica should look to provide sufficient space for the sensors and electronics (see step 3), how the replica will be assembled from two or more parts and which holes (for sensors or wires) or supports and screw holes (for assembly) need to be created.

A related issue is *optimal use of the model material*. Basically, we don't want the model to contain more model material than necessary (because of cost) and for some materials, we want to avoid large, solid volumes as some materials tend to shrink during production and create cracks. So we need to decide which parts of the model have to be solid. In our test object, protruding elements, the arms of the figures and the horizontal bars are solid to be strong enough (see image below).

A third**,** production related step is adding *support structures*, as every layer needs to rest on the layer before.

If we want the replica to have the *correct weight* (as much as the original object), we can foresee compartments that need to be filled with other material such as little sand bags or alike. In this process, close cooperation and advice from the stereo lithography production team is essential. In fact, these editing operations should be done preferably by this team to avoid any production or assembly issue.

The replica was created as a pair of two 3mm thick shells

The replica of the test object was created by the company Materialise (Leuven, Belgium) as two hollow shells with a thickness of 3 mm. In this way, all shrinking issues where avoided, while providing enough space for the electronics to be integrated. Both shells were glued together after assembly of the electronics. The material chosen was white, impact resistant ABS plastic that can withstand object handling by children. The production ready virtual model was translated in STL (stereo lithography

language) format before production.
The technique used for the production of the test object replica is *Fused Deposition Modelling* (FDM). It is a solid-based rapid prototyping method that extrudes material, layer-by-layer, to build a model. The build material, production quality thermoplastic, is melted and then extruded through a specially designed head onto a platform to create a two-dimensional cross section of the model. The cross section quickly solidifies, and the platform descends allowing the next layer to be extruded onto the previous layer. This continues until the model is complete. It is then removed from the build chamber and cleaned for shipping.


FDM machine in operation (notice the vertical support structures)

The step size (hence the resolution) of FDM ranges from 0.13 to 0.35 mm. In practice, this means that the 3D model of an object (for example obtained through laser scanning with a lateral spacing of 0.02 mm) can contain much more detail than a FDM machine can reproduce. This was the case with our test object. By enlarging the replica, we were able to reproduce more of the detail that was present in laser scan data.

The pre-processing and creation of the replica in two parts (as explained above) costs around 1500 Euro. Typically, it takes a few days from sending the data to receiving the replica.

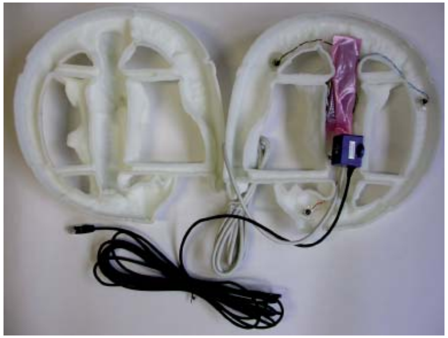
When not using stereo lithography, we can have an *artist* build the replica, for example if the object is made of metal, so that a metal replica gives the right tactile feeling.

Touching the object is an important part of the VIRTEX concept, so the touch and feel of the object should be taken into account.

The **third step** is to make the replica *interactive*. The approach we use here is to provide only the orientation of the replica to the computer system, which in turn visualises the same orientation (from the users point of view) on the display


Final interactive replica

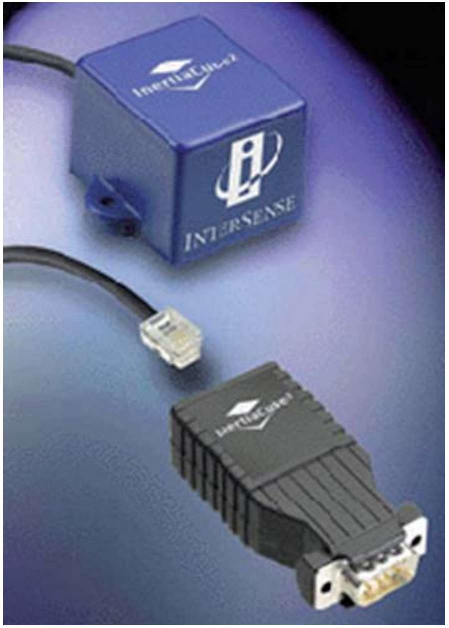
system. We also make parts of the object touch sensitive, so that more information is displayed about the part that is touched. Therefore, the replica basically contains three pieces of electronics: an orientation sensor, touch sensors and the interface electronics.



Inside of the interactive replica

An *orientation sensor* is integrated into the replica, and provides the orientation data for the visualisation software (see step 4). While the user is manipulating the replica, the visualisation on the screen follows exactly all orientation changes of the object. For this test object, we have used an **InertiaCube2** sensor from InterSense. This device continuously tracks how the sensor is oriented in space, but doesn't give any information on where it is. Basically it works by measuring the direction of the gravitational pull of the earth's magnetic field. This means that a displacement of the replica is not registered by the sensor, and will not give any change in visualisation. The device gives 180 orientation values per second through a serial interface.

At the time of realisation of the test object, only the InertiaCube2 was available. Currently, both a smaller InertiaCube3 and a wireless InertiaCube3 are available. This means for example that an interactive replica of the test object needs a scale factor of 250 % only (instead of 400 %).



InertiaCube2 sensor with serial interface

The *touch sensors* implement the interrogation mode of the device. Touching one of the sensors triggers a story to be told, connected to the spot that has been touched. Several types of touch sensors can be used, such as proximity switches and resistivity based electronic switches, … For ease of implementation and integration, the replica of the test object has been equipped with simple micro push buttons. These buttons, although small, stand out clearly and indicate which items can be pushed. Because they are small, the user will rarely press them by accident.

The microswitches are glued onto the inside of the replica

Other types of switches, such as proximity switches, can be completely hidden within the replica but could need some indication by means of colour or marking. Software processing of the signal from the proximity switch can distinguish between accidental touching, holding and deliberate touching. Touch sensors are the link to stories that are triggered by the user, so their signal needs to be available to the computer in a digital form. For the test replica, we have chosen a simple digital input/out controller that transforms a maximum of 16 push button signals into a 16 bit number that is sent continuously to the computer through a USB interface. This number is interpreted by the user interface software (for example, a story on display is interrupted when the same button is pushed again). It is important to properly define the behaviour of the system for all possible touch interactions, as this influences the quality of the user interface. At the moment of implementation, no wireless orientation sensor was available, so a double cable from the orientation sensor and the microcontroller to the computer was necessary. This cable was nevertheless seen as an advantage. First of all, the cable tied the replica to the display environment in the museum, so that no measures had to be taken to prevent theft or just displacement of the replica in the museum. Secondly, the cable is intended to be shorter than the distance to the floor, preventing the replica from falling to the ground, possibly damaging the plastic casing or the electronics.

The **fourth step** in the creation of a VIRTEX system is the *visualisation of the object*. Basically, three methods can be used here. A first method uses the *digital model* that has been used to make the replica. If the model has been generated from photographs through the ARC3D software or through structured light, it already contains the texture (colour information) of the object. If the model has been acquired through laser scanning, it is possible that the texture information still needs to be acquired separately, as only some laser scanners acquire both colour and shape information at the same time. In this case, photographs of the object need to be mapped exactly onto the 3D model. This is referred to as texture mapping and a detailed description of this is beyond the scope of this know-how book. This also has to be carried out by the above mentioned digitalisation specialists.

Once a textured model is available, we can visualise this virtual model through a powerful graphics card that can be added to the computer. Coupled with appropriate visualisation software, this allows for an interactive visualisation from the continuous stream of orientation information that comes back from the replica.

There are however *three serious pitfalls*.

First of all, we need to assess if we are *able to visualise accurately enough* the object. For most museum objects, the answer could be simply no. Objects that contain transparent and reflective parts are not only difficult to digitise, but also difficult to visualise (see the image of the Reichskrone on page 8 as a typical example). The problem here is not to visualise reflective objects (as real time reflection mapping can be done) but to acquire the correct surface and material characteristics from the object. We will discuss this in the chapter “Future developments”.

Secondly, as we want to give the impression that the virtual object rotates while we rotate the replica, we need to create a visualisation in which the virtual light sources stand still while the virtual object moves. This means that we need to be able to dynamically show the changing illumination of the object. This is not an easy task. A virtual object can easily contain over one million polygons. Even the most powerful graphics cards can barely handle this complexity. In other words, we need to *simplify the model significantly* so that the graphics card is capable of creating a real-time visualisation of the object. Simplifying objects without losing visual quality is an art and should be left to the digitalisation

Photograph of the object with ambient light

Virtual model of the object with synthetic lighting

specialists that make the virtual object.
In other words, these specialists need to provide two digital models: one very detailed one to make the replica, and another very optimised one to be used in the VIRTEX visualisation.
Thirdly, as we want to use virtual lighting on the virtual object, the texture of the object should contain no shadow, otherwise we have a double shadow effect (one from the virtual illumination, and one from the real illumination while photographing or scanning the texture). The image below shows the result by surrounding the test object from all sides with large floodlights, to approximate the illumination without shadowing (which is called the *ambient component* in technical terms).

As we use virtual lighting with this virtual object, we have the freedom to choose the type of lighting we want. For the test object, we have chosen *dramatic lighting* that makes the details and forms stand out very well (see image above).
A second visualisation method uses *photographic recording of the object from all directions*, by rotating the object in an equally spaced manner. The added value of this approach is that the object is visualised whilst preserving all of its fine surface characteristics and reflections, without having to model the object in 3D. The drawback of this approach is that the object can only been visualised from discrete directions, but practice shows that this is perceived by the user as continuous if the spacing of photographs is fine enough (typically 3 to 5 degrees).
Photographing an object in this way is done on an *object rig*, which is provided by specialised companies such as Kaidan.

Two types of object rigs that allow objects to be photographed from all sides

The rotation of the object in equal steps, combined with the rotation of the camera and the automatic capture of the object is done automatically. There are specialised companies that have this equipment plus the skills to create such photographic recording in a professional way with no danger of damaging the object. One of the issues they can solve easily is that this type of equipment does not allow to photograph the bottom side of the object, so they need two recording sessions (one with the object in the normal position and one with the object upside down) that need to be merged seamlessly.

Basically, the result of this image capture is a matrix of images, in which the selected image approaches the orientation that is detected by the orientation sensor. Suppose that we have captured the object in steps of 5 degrees, and suppose that the orientation sensor tells us that the replica is rotated over 32 degrees along the vertical axis and 21 degrees above the horizontal plane, then the software visualises the image of the object that was taken at 30 degrees (turntable rotation) and 20 degrees (rig rotation).

The third method is a kind of mix between the first two methods and uses *image based rendering*. A photographic capture of the object is used to make a simple 3D model of the object. This simple model is used when blending between recorded photographs. To use our example again, we can calculate the image for rotations of 32 and 21 degrees by blending between the four images corresponding with 30 and 20 degrees, 30 and 25 degrees, 35 and 20 degrees and finally 35 and 25 degrees. Explaining this technique would take too long, the software is still somewhat experimental (especially for visualisation of all orientations of the object at once) and needs to be optimised to calculate this kind of visualisation in real time (which means at least 15 images per second to have the impression of a fluid movement of the object). We do not recommend using this *best of both worlds* method at this time, but we can expect a working solution quite soon.

While all these technical components are being assembled, we need to focus on the **fifth step**, which is the *creation of the stories*. Basically this phase of the process runs in parallel with the previous steps as the definition of the interactive zones, linked to stories, is already needed in steps 2 (where the replica is made) and 3 (where the object is made interactive).

From the available research and information on the object, information needs to be selected that can be grouped together in appealing stories that are related, or can be attributed, to parts of the object. This is a creative process that in most cases needs several iterations. One of the criteria is the form of the story (pages with text, voice over with still images, video), another is the display medium (if the visualisation can handle 3D images, the story could be produced in 3D, see step 7).

As the stories are accessed in a random order, they can't rely on information in other stories. In practice, this means that an introductory story needs to give the global context of the object, inviting the user to explore the object.

Once decisions have been made on the story content and form, a storybook needs to be made and the story needs to be produced.

If video content is linked to the replica, VIRTEX becomes an engaging storytelling device as the visualisation of the object is mixed with stories that seem to appear from the object. Let's have a closer look at two stories that were realised as 3D animations for the test object.

The first story is about the object itself, what it means and what it was used for. As specialists think our test object was an abbot's ceremonial crook, a story has been designed to show the use of the object in the life of the monks in the abbey. We hear the bells tolling and see all the monks and the abbot gathering in the abbey church to celebrate the mass (see images on page 7). In this way, we get a glimpse of how the abbey and the life in the abbey looked. In the animation, a digital restoration of the ivory object is shown. Applying digital restoration as part of the information on the potential use of the object is one of the major advantages of VIRTEX.


Two frames from the "Symbolism Story", showing the abbey in 1065 (left) and 1080 (right)

The other story tells us about the symbolism of this object, as it consists of a depiction of Our Lord on one side, and Our Lady on the other side. This configuration is very special, and only one other similar object is known (most probably also coming from the Ename abbey), so specialists are convinced that it is linked to the origins of the Ename abbey. In fact, the abbey was dedicated to Our Lady by the daughter of the French King when founded in 1063 in the former palace building of Ename. As this building was probably too small to accommodate a community of 13 monks, the decision was taken shortly after to build a new abbey next to the Saint-Salvator church of the former city, 200 m south from the original abbey building. In 1070, this new abbey was founded as a Saint-Salvator abbey and the old abbey building was transformed into the Our Lady chapel. The ivory object most likely depicts this double origin of the abbey, dedicated both to Our Lady and Our Lord (Saint Salvator).

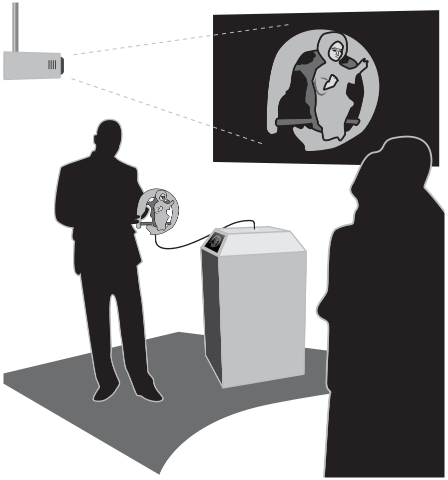
Six other stories are linked to the test object, explaining the inscriptions on both sides of the object, the symbolism of the lily, the globe and the monster and the creation of the object from ivory (with comparison to similar objects and new conclusions about the dating of the test object).

The depiction of both Our Lady and Our Lord refers to the origins of the Ename abbey

All the results of the previous steps come together in the **sixth step** where the *integration of the interactive application* is taking place. We have chosen to integrate VIRTEX into the **ARCO** platform, where some extra modules were added to handle the data from the microcontroller and orientation sensor. This platform provides a methodology to have interactive museum setups created by non-technical museum staff linked to collection information, by providing tools that build the object database and interactive pages with text, animations and 3D visualisation. Integrating VIRTEX in ARCO yields an innovative presentation system, embedded into a collection management system. Additionally, VIRTEX can be a stand-alone application, written from scratch, as its functionality is quite simple. It needs an introductory film, that is triggered by picking up the replica, an interactive mode where the object visualisation is steered by the orientation of the replica and a module that handles the touching of the interactive zones and triggers the display of stories in the form of static pages or animations. Orientation sensors such as the InertiaCube come with a library to interface the sensor for PC, Mac OS X and Linux.

VIRTEX runs on normal PC, Mac OS X or Linux system if created as a stand-alone system. When integrated with ARCO, it runs on PC only. When using a virtual model for the visualisation of the object, a high-end graphics card is useful to provide the necessary visualisation power.

Finally, the **seventh step** is the *creation of the resulting museum setup*. When making a setup for groups, this should consist of a *large screen projection*, so that the guide and the whole group can see the object visualisation. To allow the guide to have eye contact with the group (hence looking away from the large screen), it is useful to provide a small screen for the guide only, to see the object and story visualisation. For individual visitors, families and small groups, a visualisation on a large LCD or plasma screen is the best choice. In both cases, a surface should be provided to leave the replica. The wire should be short enough to both prevent it from dropping onto the floor and to ensure that the surface is the only one where the replica can be put. Since mid 2006, a new generation of excellent 3D visualisation on large LCD screens is available without having to wear special 3D glasses. These *autostereoscopic 3D displays* typically use an image plus a depthmap to create the 3D effect. A depthmap is a black-and-white image where the grey value indicates how far that part of the image is from the viewer. Black (typically represented by 0) means far away into the screen, white (typically represented by 255) means closer to the user in front of the screen, middle grey (typically represented by 128) means in the plane of the screen. Depthmaps are generated by 3D modelling programmes, or can be calculated from stereo images, or generated semi-automatically from 2D images. In other words, when we create 3D images, this information is readily available and when we record the object photographically, we should do this in stereo.



Sketch group setup

Such screens typically have 7 or 9 sweet spots (places where the 3D effect is optimal) that

Image plus its corresponding depthmap

are about 30 cm apart. This works fine for a small group, while large screen projection is to be preferred for larger groups. In the latter case, 3D visualisation can be provided at the cost of wearing passive stereo glasses (which look like normal sun glasses and exist in cheap paper versions).

Visualisation of the object on a 3D plasma screen

The visualisation for individuals and small groups can be done on a normal screen too, but 3D visualisation helps significantly in creating the right experience (but it comes at a certain cost, for example a 42 inch 3D LCD screen costs 10.000 euros more than its non-3D version, this price difference is expected to shrink substantially when market penetration is realised).

The test object was visualised on a number of display mediums, an implementation in the Ename Museum is expected to be realised soon.

Notes and possible future developments

This paragraph adds some notes about VIRTEX and discusses some developments that are still in the research phase that can improve VIRTEX in the coming years.

A first note is that, when providing a virtual object for visualisation of the real object, the virtual object should be a very accurate representation of the real object. Most museums objects have complex surface characteristics, so there is a definite need to characterise surface details of objects automatically. A lot of research is being done on this. Nevertheless, we still lack robust techniques for deriving them from for example a set of photographs. When analysing our test object we see that the glossiness varies considerably over the object, due to partial deterioration of the surface (see below). This was not visualised in the test project we have set up.

Delicate surface characteristics due to surface deterioration

As noted above, proper use in a virtual environment also requires that the object can be relit, in other words the lighting needs to be removed from the recorded object texture. In this test project, we have tried to photograph the object with ambient lighting by putting surface light sources around the object (see above). This works well but is not perfect. Good and robust software techniques are being developed to derive this “unlit” texture from photographs of the object.

Several researchers have tried to measure the orientation of an object from several real time camera images, instead of using an orientation sensor. This has the advantage that VIRTEX could be used for small objects or objects that lack the space to integrate the sensor (basically, our test object is like that), but designing the setup becomes much harder to ensure uninterrupted line of sight for all cameras. As we believe that incorrect orientation representation (for example when some line of sights are interrupted) breaks the magic of the setup, we do not recommend this approach. Orientation sensors are becoming smaller and smaller, and even wireless, as the medical world has a lot of interest in using them.

A study by the University of Sussex [PET06] proves through experimental research that the VIRTEX user interface is superior to other ways of presenting the object, in terms of memorising content, ease of use, object orientation and overall performance. Nevertheless, pilot projects and more studies need to be done to assess the overall performance and user experience in a museum context.

Extended tests with museum visitors are also needed to determine the added value of VIRTEX when used in combination with the real object or alone.

A very interesting study to be done is determining the added value of the replica. If this added value, compared to a dummy object, is small, then a setup with a dummy object could be used to visualise multiple objects (in the study [PET06] mentioned above, a rectangular box with push buttons and orientation sensor was used). We expect that the added value of the replica is high enough for this not to be the case, but user studies need to prove this.

VIRTEX should not be used on the Internet as it is based on the one hand, on the presence of the real object, and on the other hand on interaction with a physical object. Interfaces such as the **Nintendo Wii** however could provide a dummy object approach that could be useful to test out. Only detailed user studies will show if such an approach appeals to the public and provides a better way to deal with virtual museums.

Benefits

VIRTEX has several economical benefits, by lowering costs and creating new income. First of all, the need to exhibit the real art object can be avoided. This saves a lot of insurance money and transport costs for museums. A typical insurance fee is 1-2 % of the estimated value for the duration of an exhibit. Although most valuable objects are accompanied by a person from the museum where the object resides, it is nevertheless inevitable that sometimes damage occurs when transporting fragile and priceless art objects. Yearly, European museums spend a significant amount repairing damage to objects on loan. Also the costs of secure display cases, air conditioning and surveillance are high.

If the real object is displayed, safer display conditions can be created, in most cases at a lower cost, as people need to spend less time to see the object.

On the other hand, as this methodology allows ‘cloning’ of the art object, the object can be seen and explored by many people in the same exhibition, as well as being distributed over several exhibitions at the same time. This will allow for far better access to our cultural treasures for a much wider public, which should result in higher

visitor numbers, higher visitor satisfaction rates and more income for museums. This is based upon the current trend of cultural tourism, and the interest for innovative ways to add context to museum objects (see for example the TimeLine in the archaeological museum in Ename).
As the object on loan is not a physical object any more but a technology to show, experience and explore the object, the museum can licence this technology, and receive income. It is not common to pay a loan fee to the museum that provides the object.

VIRTEX has other non-economic advantages.

First of all, the proposed presentation method allows for greater access and understanding of the object for a wide range of visitors. They can explore the object, see and feel the details, and get an appealing set of stories telling the background and meaning of the object, without creating bottlenecks or other drawbacks while showing and respecting the real object. VIRTEX creates a much closer bond between the object and the visitor, who will feel that this heritage belongs to him or her by having such a close and personal interaction with it.
Secondly, VIRTEX allows for completion of the object when there are parts missing (digital restoration), removal of parts that have been added later on, or showing the functionality of the object (for example, the crown shown on page 8 had a clever mechanism to fit on all head sizes, which was not present in the original crown). This added value is difficult to create with other than digital means.

Thirdly, using a virtual counterpart of the object also means safeguarding the object from damage, destruction and theft, as the original can be stored in secure conditions.

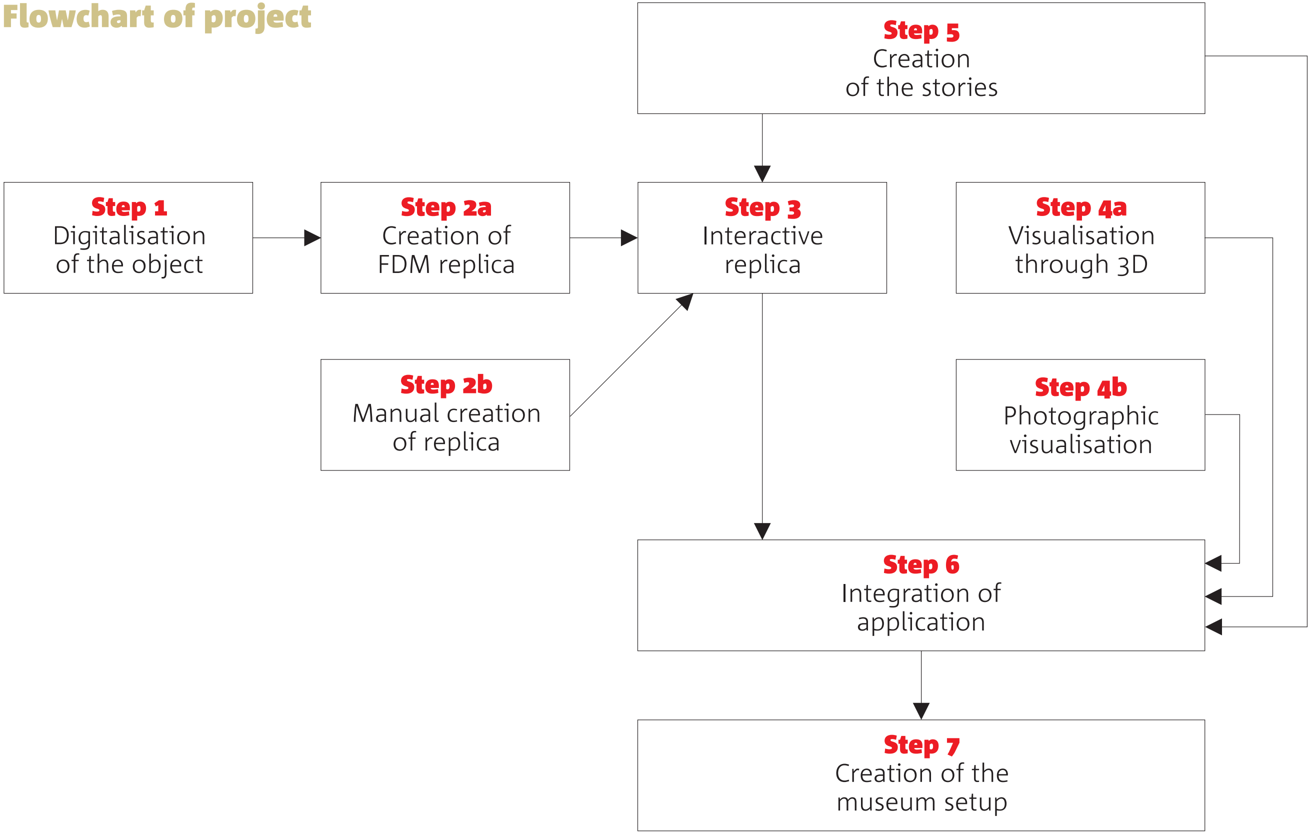
Summary

VIRTEX is a presentation methodology that allows a radical change in dealing with valuable museum objects. On one hand it allows the object's story to be told in a much better and more appealing way, on the other hand it allows the objects to be better protected and make them more accessible to a large audience.

The multimodal interface creates an unprecedented way to enjoy and explore such major pieces of art, as the museum visitor can feel and hold the object, see it in all its beauty and splendor from all sides and experience the stories that are embedded in it.

The combination of exhibiting the real object, complemented by an interactive storytelling device in the form of the object, will create an exceptional visitor attraction that can be integrated smoothly in any permanent or temporary exhibition.

Flowchart of project



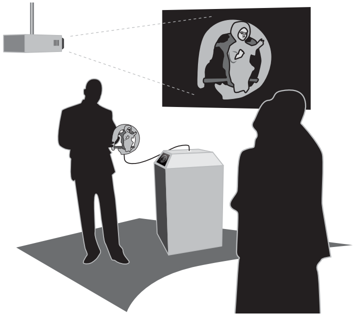
VIRTEX

Technology/Interaction

Interactive presentation technology for valuable museum objects that complements the physical exhibition of such an object. Uses a replica of the object that drives a 3D visualisation of the object and allows to trigger stories. Provides a multimodal (vision, sound, touch), explorative storytelling interface.

Ideas for implementation

VIRTEX is recommended to be used in:
- Permanent exhibitions where valuable objects lack an appropriate way to bring their rich content
- Museums with a fixed collection, where it can augment that collection and create a new drive to attract visitors
- Temporary exhibitions where certain top pieces of art would create a bottleneck, because of their importance or rich content
- Permanent or temporary exhibitions where certain top pieces of art are not present, although they should be present to complete the exhibition in a thematic or conceptual way, so that an appealing stoytelling device can replace the object and create an experience of presence of the object



Required competencies

Laser scanning or photographic object recording
Mechanical design
Electronics design
Stereolithography
Exhibition design
3D modelling
Application development
Storytelling
Multimedia & graphics design
Project managment

Summary

VIRTEX is an interactive storytelling methodology where a replica is used by museum visitors to explore a valuable museum object and the stories and information related to it through vision, sound and touch.

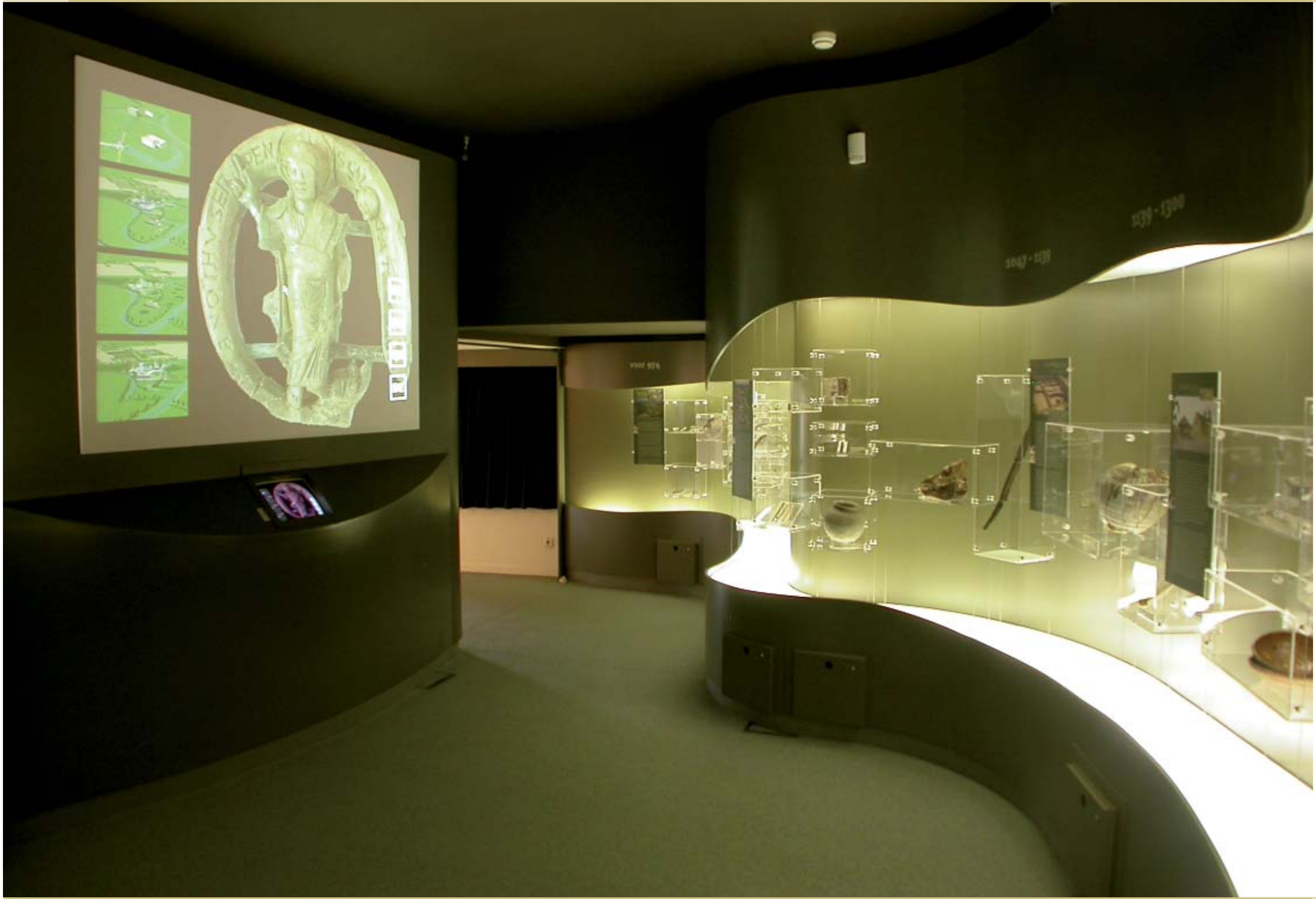
Resources

Manhours:
200–800 hours

Technology:
5,000–10,000€

Production costs:
10,000– 50,000€

Optional 3D visualisation (without glasses): 10,000 €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Virtex

Project team

Involved Partners:
- [1]Visual Dimension bvba, Ename, Belgium
- [2]pam (Provincial Archaeological Museum) Ename, Belgium
- [3]Flemish Heritage Institute, Brussels, Belgium
- [4]Ename Center for Public Archaeology and Heritage Presentation, Belgium
- [5]Techniphoto, Oudenaarde, Belgium
- [6]3D Solutions, Temse, Belgium
- [7]Ecole Polytechnique Fédérale de Lausanne, Switserland
- [8]University of Sussex, Brighton, UK
- [9]University of Ghent, Belgium

Concept: Daniel Pletinckx[1]

Test object:
- Curator: Marie–Claire van der Donckt[2]
- Excavations: Flemish Heritage Institute, directed by Dirk Callebaut[3]
- Restoration: Natalie Cleeren, Flemish Heritage Institute

Test project coordination: Dirk Oosterlynck[4]

Photographs test object: Pieter Van Wambeke[5], Paul Maeyaert

TimeLine application: Daniel Pletinckx[1], Lars De Jaegher[1]

Laser scanning: Pieter Temmerman[6]

Replica preprocessing and production: Materialise nv, Leuven, Belgium

Interactive replica: Dirk Oosterlynck[4]
3D virtual object: Tom Nevejan[4]

Abbey story:
- Historical research: Iris Langen[4], Truus Helsen[4], Prof. em. A. Vande Walle[9]
- Scenario: Daniel Pletinckx[1], Tom Nevejan[4]
- Abbey model: Daniel Pletinckx[1]
- Design virtual monks, animation and rendering: Ronan Boulic[7], Branislav Ulicny[7], Pablo de Heras Ciechomski[7], Mireille Clavien[7]
- Director: Daniel Thalmann[7]

Symbolism story:
- Historical research: Dirk Callebaut[3], Prof. Ludo Milis[9], Prof. em. A. Vande Walle[9]
- Archaeological research: Flemish Heritage Institute, directed by Dirk Callebaut[3]
- Virtual reconstruction Ename site: Daniel Pletinckx[1]
- Scenario and rendering: Daniel Pletinckx[1]

Other stories (2D): Lars De Jaegher[1], Martin White[8]

Interactive application: Martin White[8], Panagiotis Petridis[8], Maria Sifniotis[8]

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At a time when museums are under increasing pressure to both show their valuable artifacts more widely, as well as safeguarding them, with the associated high costs, VIRTEX offers an ideal solution.

By creating digitally enhanced replicas of their precious art objects, museums can allow visitors to have a truly hands on experience, increasing access to the objects and adding virtual information feeds to the user experience. VIRTEX allows museums to transform their artifacts into accessible, distributable and reproduceable exhibits.

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

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