Etruscanning

Digital Encounters with the
Regolini-Galassi Tomb
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- Museo dell’Agro Veientano, Formello
- LVR-LandesMuseum, Bonn

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Contents

Etruscanning — Introduction 7

The Regolini-Galassi Tomb Revisited — 3D Reconstruction as a Research Instrument 17

The online blog on the 3D visualization of the Regolini-Galassi Tomb 27

Virtual Reconstructions in the Museum — Evaluating User Experiences of a Virtual Museum Application Embedded in an Exhibition 97

Facts & Figures 111

About the Authors 115
Etruscanning

Introduction

WIM HUPPERETZ

Etruscanning started from a basic idea of bringing objects from an Etruscan tomb together with the original space. Since this could not be done with the original objects in the original space, this had to be done in a virtual way.

The main goal of the Culture Program is to celebrate Europe’s cultural diversity and enhance our shared cultural heritage through the development of cross-border co-operation between cultural operators and institutions. Etruscanning was aimed at exploring new visualization techniques through the virtual re-creation and restoration of Etruscan tombs. For this reason, we selected two test-beds; the Regolini-Galassi Tomb and the Monte Michele Tomb 5. The main focus of the project and this publication was the Regolini-Galassi Tomb, since the application that resulted from our collective efforts was integrated into an exhibition and since we were able to conduct several evaluation studies. The Monte Michele Tomb 5 test-bed will be described very briefly below.

Etruscanning in Short

Etruscanning was a close collaboration between museum curators, archaeologists, software developers, interactive designers, exhibition designers, specialists in storytelling, consultants in digitization and digital restoration, evaluation specialists and many others who contributed their knowledge and expertise to the project. This list of collaborators shows how this innovative project went beyond many traditional borders and domains. Within the project, we were able to establish an international cooperation in digital acquisition, digital restoration, and 3D representation. Through exhibitions, blogs, videos, and publications, we were able
to realize a new approach to the communication of Etruscan tombs and collections in exhibitions in the Netherlands and Belgium. At the end of the project, the final resulting applications will be installed for permanent use in the Vatican Museums, Villa Giulia (Rome, IT) and Museum Formello (Veio, IT). Furthermore, this project proved that it is possible to enable and support cultural heritage institutions to create, run and exchange digital 3D reconstructions.

In this project, we focus on two important Etruscan tombs: Regolini-Galassi Tomb, the grave of a princess in the Sorbo necropolis of Cerveteri, and Monte Michele Tomb 5, the grave of a warrior, in Veio. The finds from these tombs are mostly in museum collections and the existing (empty) tombs are not always open to public. By making 3D reconstructions of the tombs and of the objects which originally were found inside, we can re-create the archaeological context of these Etruscan tombs.
3D reconstruction as a research tool

The 3D visualisation of the Regolini-Galassi Tomb has not only proven to be an essential tool for obtaining greater knowledge about the tomb and Etruscan funerary customs, it also provides an attractive way to present research results. In our multidisciplinary approach to the realization of this 3D visualization, we re-examined and re-interpreted earlier publications on the archaeological context of the finds, and reached new conclusions regarding the location of the objects within the tomb. Through the virtual reconstruction, we were able to place the objects virtually in the tomb, allowing us to identify inconsistencies in the source material and to determine the most plausible configuration for the objects. Using 3D visualization as our research instrument, we were able to study the tomb on another level.

Digitization and digital restoration

During the first phase of the Etruscanning project, the famous Regolini-Galassi Tomb from the Sorbo necropolis in Cerveteri was selected to be virtually restored. Using advanced techniques for digital acquisition, including laser scanning and photogrammetry, the tomb and most of its objects were rendered and restored, and subsequently placed in their original locations within the virtual tomb.

The project has been developing through a complex methodological approach; from the collection of existing data, to new topographical digital acquisition. Several ontologies of data have been acquired and elaborated upon, according to the typology and topology of the artefacts; including point clouds from laser scanner, photogrammetric data (dense stereo matching), and computer graphics.

The application

The Virtual Reconstruction of the Regolini-Galassi Tomb was first installed for public use in both the Allard Pierson Museum (Amsterdam, NL) and the Rijksmuseum van Oudheden (Leiden, NL), as part of a joint
exhibition on the Etruscan civilization, entitled *Etruscans. Eminent Women, Powerful Men*. The most innovative element of the Virtual Reality application developed for Regolini-Galassi Tomb is the paradigm of interaction based on the use of natural interfaces. This means that the user moves inside the 3D space through just his body movements alone.

The public now had the possibility to explore the virtual tomb, to get near the artefacts, and to listen to the narrative contents directly from the voices of the prestigious Etruscan personages buried inside; the princess and the warrior, to which the precious objects were dedicated. All of this is possible by moving in the space in front of the projection of the virtual tomb, in a very simple and natural way, without a mouse, keyboard, joystick or console.

**Evaluation**

The presentation of the tomb employed a natural interaction interface which allowed users to enter and explore the virtual tomb using a map

Members of the *Etruscanning* project visiting the Regolini-Galassi Tomb during the kick-off meeting in May, 2011 (photo: Christie Ray)
on the floor with certain ‘hot spots’ indicated where short stories about the objects in the tomb could be heard. Throughout the exhibition period, the virtual reconstruction was evaluated to determine the added value of incorporating such an application into a museum exhibition and how users responded when confronted with a technological application in a traditional museum environment.

The results of the evaluation study presented in this publication offered a great deal of insight into the user experience of the presented case study, the Virtual Reconstruction of the Regolini-Galassi Tomb. Reflecting upon the results of this evaluation study, the added value of embedding the installation into the exhibition was threefold; contextual, educational, and museological.

**Contextualization**

The participants recognized the importance of the installation for providing a clearer understanding of the original placement and purpose of the objects from the Regolini-Galassi Tomb. Providing contextualization virtually, as it was done in the Virtual Reconstruction of the Regolini-Galassi Tomb, gives museum visitors an opportunity to better understand the objects, their use and origins, while protecting the original objects from the potential harm that can come from physically handling and moving objects to prepare for a traditional, object-based exhibition. Furthermore, the installation provided a unique opportunity to experience virtual objects in a virtually reconstructed environment, which is something that would not be possible using the original objects. Generally, the participants in the study were able to identify and praise the improved contextualization of the objects that the installation offered. Although their expressed attitude was that such virtual representations of objects and environments should not attempt to replace the presence of authentic objects, rather they should complement and supplement the more traditional style of object-based exhibition presentations.
Educational value

The Virtual Reconstruction of the Regolini-Galassi Tomb offered additional education value, to supplement the content provided in the exhibition. When participants evaluated their experience after the installation and the exhibition, the results showed greater confidence in participant responses when they had experienced both the installation and the exhibition. When examined separately, users were able to provide correct responses to the questions asked after each the installation and the exhibition, but once both parts of the study had been completed, the results show that the participants were more certain of their answers than they were after completing only the installation or the exhibition. The content presented in both the installation and the exhibition served to reinforce each other, creating a more enriching experience for the museum visitor.

Museological value

The museological value of embedding the Virtual Reconstruction of the Regolini-Galassi Tomb into the Etruscan exhibition is reflected in both
the enhanced contextualization of the presented collections and the reinforcement of educational content shared between the installation and the exhibition. More than this, however, the results show that the way museum experiences are being defined by visitors is evolving to include a broader range of content dissemination styles, including a more generally accepted presence of technology integrated into museum presentations. The acceptance of technology and Virtual Museum applications in museums by visitors will undoubtedly impact the future study of museology, especially as more museum directors are starting to recognize the value of incorporating technology in museums.

**Dissemination**

The methods applied in *Etruscanning* are not only multidisciplinary but also present a new approach to cross-media dissemination. Starting with traditional museum exhibitions that attracted unto now some 134,000 visitors, and eight publications, from both academic conferences and broad public media, we also achieved widespread outreach through presentations at a Science festival, a blog (with more than 30,000 page views) and several YouTube videos. This could explain the interest from state-of-the art museums, like the Vatican Museums and the Louvre, who are eager to show the *Etruscanning* installation.

**The Monte Michele tomb 5 test-bed**

Monte Michele Tomb 5, located near Formello, has many similarities and differences from the Regolini-Galassi Tomb. The similarity is in the dating and the layout of the tomb, as well as objects; both tombs contained chariots. The reason why we selected this grave was because of the differences. The Monte Michele tomb was excavated and documented in the 1980’s, whereas the Regolini-Galassi Tomb was discovered in 1836 and only documented in a very selective way. All the objects that were found in the tomb were quite damaged and had to be restored by the Villa Giulia, the National Etruscan Museum in Rome. Another big difference is that the physical tomb is a difficult archaeological site to visit and interpret. It is located out of tourism paths, although some visits have been organized
for the public by the Museo dell'Agro Veientano, and the only artefacts from the tomb on display are the objects in the Villa Giulia Museum.

For this tomb we needed to create an application that could be used in the presence of the original objects and focus on the needs of the public. When completed, this application will be located in both the Villa Giulia Museum and in the Museo dell'Agro Veientano, in Formello.

In the case of Villa Giulia exhibition, the perception of real objects in the showcases and the virtual fruition of the interactive application will enhance each other if they can be placed in close proximity to each other. The application will be focused on archaeology stratigraphy and excavation, rather than on the virtual reconstruction of the ancient context. In this way, a different design approach is necessary and other layers of information will be given. In both museums, the space around the showcase is limited. Instead of using a large projection for presentation, the application will be visualized on a large screen and the public will interact close to the screen with a touch screen or a touch pad.

The Virtual Reconstruction of the Regolini-Galassi Tomb on show during the exhibition *Etruscans. Eminent Women, Powerful Men* in the Allard Pierson Museum, Amsterdam (photo: Daniel Pletinckx)
Exchange mechanism in museum domain

This project was triggered by the exhibition entitled *Etruscans. Eminent Women, Powerful Men* at the Allard Pierson Museum (Amsterdam, NL) and the National Museum of Antiquities (Leiden, NL). Furthermore, we wanted to create a real exchange in such a way that collaboration on the loans from several Italian partners would be used to create digital content that we could give to the Italian partners in return. In this way, a sustainable and more fruitful relationship was created between cultural institutions. One of the side effects is that, since we have a multidisciplinary team, the museum partners were in contact with more technical researchers from other domains. This also resulted in exchange, and sometimes confrontation, of different perspectives.
The Regolini-Galassi Tomb is one of the most remarkable Etruscan tombs we know, not only on account of its rich contents but also because so many of the 327 objects date from the orientalising period. Moreover, the grave goods are varied in character and many of the items are of outstanding quality. The tomb was found in 1836 by Archbishop Alessandro Regolini and General Vincenzo Galassi, who wrote several accounts of their discovery. The first publication on the tomb appeared in the same year, in 1836; the first drawings were produced by L. Grifi, a qualified architect.

Although the tomb has been studied by a large number of scholars, certain mysteries remain unsolved. There is still a great deal of uncertainty regarding the precise positions of the objects in the tomb and how we should interpret the totality of grave goods.

Detail of the plan of the Regolini-Galassi Tomb by Grifi, drawn in 1836 but only published in 1841. It shows the burial chamber, the private space in which the princess was interred with all her personal possessions around her. Far right is the huge gold disc fibula, then the gold pectoral and the two bracelets (Q). The two bronze cauldrons or lebetes (P and O) also come from the Near East / display influences from the Near East and underline the aristocratic character of this tomb.
During our 3D reconstruction of the Regolini-Galassi Tomb we were forced to ask ourselves very practical questions about the placement of the objects and their original location. We re-evaluated and reinterpreted all available sources in an effort to find answers to difficult questions. The tomb was discovered and documented a long time ago, but never methodically excavated, and the excavated objects were purchased by the Vatican Museums just a year after the tomb’s discovery. As a result, a great deal of information about the precise location of the objects in the tomb was lost. This also explains the many, often contradictory reconstructions.

The provisional virtual reconstruction of the anticamera. This space between the main burial chamber and the two side chambers functioned as a public space in a home and recalls the atriums in later Roman atrium houses. This is where objects such as the empty bronze bed, the small trolley, and two tripods, enclosed by small bucchero figures of mourners, were found. Hanging on the wall were bronze shields and on the ceiling bronze dishes. There are two triangular windows, one towards the burial chamber of the princess with two silver cups on the sill and a hanging situla (a bucket-like vessel), the other, to the right, in the wall to the side room in which the cremated remains of the man were interred in a cinerary urn, also surrounded by small bucchero figures of mourners.
3D Reconstruction

In many respects, the increasing deployment of 3D visualization techniques has created a new research instrument. To keep this instrument as transparent as possible, we presented the major steps in the 3D visualization of the Regolini-Galassi Tomb in an online blog, at http://regolini-galassi.wordpress.com/ (see also page 27). This has been a practical way to document the interpretation, indicate possible revisions in the process, present the uncertainties in our reconstructions, record the information and, finally, enable or facilitate multidisciplinary research. We applied four stages in our formalized approach: the identification, assessment and correlation of sources, and the construction of a hypothesis in the form of a tree diagram.

The innovative 3D visualization techniques we employed also encompass three-dimensional virtual reconstruction. This means that we endeavoured to recreate historical structures, built by human hands, in this instance, the Regolini-Galassi Tomb and the objects within. The purpose was not to reconstruct the past, but to create an image of what we know of this past. In other words: a virtual reconstruction constitutes a consistent visualization of structures built by people, based on the available sources, such as information from archaeology, anthropology, history, the natural sciences. As such, creating a virtual reconstruction should be viewed as a multidisciplinary activity, constantly subject to change.

3D Scan of the tomb

The project methodology can only be described as complex, from the gathering of existing data to the integration of this data via topographic digital measurement. We used various types of data: point clouds from a 3D scanner, photogrammetric data and GIS-data. A ‘time of flight’ 3D-scanner (Riegl z390i) measured the tomb in 3D as a high-resolution model (with 6 mm spaces between the dots) and with maximum precision (3-4 mm). Once the 3D scanner had measured objects as three-dimensional point clouds, triangulation was employed to ascribe three-dimensional volumes, determined by surface areas. We then worked the 3D model of the tomb in its present state into a representation of the tomb as it may
Cross-section of the tomb obtained using a laser scan, made in June 2011. This shows that the passage slopes downwards, although it is possible that the slope was not always as steep. It also shows the remains of the window to the right side room; to the left, in the main chamber, are the stones which formed part of the wall that closed this chamber off from the *anticamera*.

Laser scan of the *anticamera*, with view of the left side chamber and the burial chamber with female interment directly ahead. The latter was closed off by a wall whose stones can be seen to the rear.
have looked in Etruscan times, with the objects in their context, based on historical sources and archaeological interpretations.

**The floor plan illustrations**

The various floor plans we consulted from publications relating to the Regolini-Galassi Tomb display a large number of significant and substantial differences. Two excavation reports were published immediately after the excavation in 1836 – which only took five days. However, the first drawings were not published until five (Grifi) and ten (Canina) years later. Various authors have noticed the differences between the two 1836 reports and have pointed out disparities between the nature of the objects as we now know them and what is recorded in the excavation reports.

If we compare the two drawings with the actual tomb, it is clear that these could not have been made inside the tomb. For example, neither represents the ceiling correctly. Canina’s rendering of the tomb’s architecture and size of the objects is better, perhaps because he was trained as an architect and an archaeologist. However, the most significant difference is that Canina depicts more objects in the tomb than Grifi, probably because interpretation of the archaeological finds was still on-going in Grifi’s time.

**The tomb**

The original tumulus was constructed in the seventh century BC and covered by a second tumulus in the sixth century BC, which created space for additional tombs, probably intended for descendants of the same family. Although these tombs around the outside of the mound proved easy prey for tomb robbers, they protected the older tomb at the centre from almost inevitable plundering.

The tomb has a short *dromos* in the form of a narrow passage, with rectangular blocks rising to form a corbel vault. The most important space at the rear of the tomb was closed off by a wall incorporating a small window. There are also two oval side chambers, carved from the tuff. The lower part of the tomb is cut from the tuff bedrocks, the upper half built of square blocks which have been used to create a wedge-shaped corbel vault.
We have used the five spaces as the starting point for our consideration of the tomb: the entrance passage (*dromos*), the *anticamera* (antechamber), the right side chamber with the interment of the prince, the left side chamber and the closed area where the princess was interred. We intended to present all five spaces in our reconstruction, based on evaluation and integration of the source material.

According to Pareti, who has compiled the most comprehensive catalogue of the tomb, the objects were distributed as follows:

- Objects numbered one to 226 came from the chamber where the princess was interred;
- Objects numbered 227 to 233 came from the right side chamber where the prince was interred;
- Objects numbered 234 to 328 came from the *dromos*, the *anticamera* and the left side chamber (the storeroom).

**The passage (*dromos*). The *holmos***

In the entrance passage were three bronze objects: a *holmos* (a cauldron stand), and two large cauldrons, one somewhat smaller than the other. On drawings of the tomb the *holmos* stood at the beginning of the *dromos*. In daily life, a ceramic *holmos* was used to prepare food and keep this warm. Charcoal was burned in the conical foot, so heat would rise to the bell-shaped element supporting the cauldron of food. The top of the bronze *holmos* from the Regolini-Galassi Tomb is closed, however, so it could not have been used in this way. This may mean that it was a replica, a model of a domestic implement made especially for the tomb. The material is also unusual, for such stands are almost exclusively made of ceramic and few bronze examples are known.

**The *anticamera*. The empty bed as ceremonial focus***

In the small *anticamera*, before the wall with a window, which closed off the burial chamber where the princess was interred, there was a bronze bed, accompanied by a series of small bucchero figures of female lamenters or mourners and two iron tripods. Beside the bed was a small cart on wheels, interpreted as an incense burner or food trolley. Also in this space
were various bronze and iron skewers; beneath the keystones of the corbel vault hung two rows of *paterae* (libation dishes) on nails.

Although the Romans did not consider themselves descendants of the Etruscans, they adopted a number of their practices, such as certain funerary traditions and tomb architecture, from a shared indigenous ancestor. In Etruscan culture, as in many ancient civilizations, tombs represented the home in the hereafter. On this premise we may regard the entrance to a tomb as the *vestibulum* (hall), which leads to the atrium. In ancient Latin households the atrium was the symbolic bedroom of the mother, and the bed, the *lectus genialis*, faced the main entrance. In Roman wedding ceremonies, the marriage was consummated in the *lectus genialis*, in honour of the ancestors, the *gens*.

There were no objects or other traces found on the bronze bed to suggest that human remains had ever lain there. If the bed was indeed empty, this would fit the hypothesis that the bed symbolized the sanctity of marriage. The mourning figures around the bed and the urn in the right side chamber, containing the cremated remains of the man, may also support the symbolic meaning of the empty bed.

**The right side chamber. The interment of a prince**

In the right side chamber there was a large cinerary urn containing cremated remains that have been interpreted as that of a prince. Around this urn were several of the 33 small bucchero figures of mourners found in the tomb. Given that these figures also stood around the (empty) bed in the antechamber, there must be a connection between the two. The side chamber also contained a number of metal objects. Pareti also places the two-wheeled chariot (*biga*) found in the tomb in this chamber, together with two iron fire-dogs and an iron dagger. The *biga* must have been taken apart before it was brought into the tomb, as it would otherwise not have fitted through the entrance to the side chamber.

**The left side chamber. A storeroom**

The left side chamber was probably a storeroom, as it was full of ceramic and bronze vessels, including large bronze cauldrons. Several interpreta-
Side view and frontal view of the gold disc fibula from the burial chamber of the princess, drawn by Canina (1846). This fibula comprises three components. The disc represents the world (and the sun?), the hinged parts represent the water or river which give entry to the underworld, represented by the lowest element of the fibula, on which a tiny head of Hathor appears. There are also images of Hathor on the necklace pendants. Hathor is the Egyptian sun goddess and mother of Ra who pilots the solar boat. As a fertility goddess, a bringer of life and an underworld deity, she represents a clear allusion to the hereafter.
tions also place some silverware in this chamber, although this is uncertain. A bronze biconical urn, often used as a cinerary urn, may have been one of the objects found in the tomb, symbolizing the ancient origins of the deceased’s family.

The closed chamber: The lebetes

The closed chamber contained the majority of the gold and silver objects found in the tomb, all associated with the interment of the princess. This space was separated from the rest of the tomb by a wall incorporating a window in which two silver cups stood. It is also possible that a wooden situla (a bucket-like vessel), decorated with silver, hung in the window.

Further orientalising influences are evident in the three lebetes, the bronze cauldrons also found in similar form in the Near East. Two lebetes are virtually identical, with five lion heads on long necks around the rim. The third lebes is smaller and has six griffin heads. There were also decorated silver chargers, probably from a Phoenician workshop, affixed to the wall, and two rows of more than ten bronze paterae (libation dishes) nailed to the ceiling.

Evaluation

3D visualisation of the Regolini-Galassi Tomb has not only proven to be an essential tool for obtaining more knowledge about the tomb and Etruscan funerary customs, it also provides an attractive way to present research results. In our multidisciplinary approach to the realization of this 3D visualization, we re-examined and reinterpreted earlier publications on the find context, and reached new conclusions regarding the location of the objects in the tomb. We were able to place the objects virtually in the tomb, allowing us to identify inconsistencies in the source material and to determine the most plausible configuration. Using 3D visualization as our research instrument, we were able to study the tomb on another level. The final result takes the form of an innovative, interactive 3D experience, based on natural interfaces (bodily movements and gestures).
The online blog on the 3D visualization of the Regolini-Galassi Tomb

DANIEL PLETINCKX

Intro to the blog

The focus of Etruscanning has been to use innovative visualisation technologies in researching cultural heritage topics and present the results of this research in innovative exhibitions. The innovative 3D visualisation technologies include also 3D virtual reconstruction, which means that we try to visualise a certain man-made structure or landscape of the past. Virtual reconstruction does not reconstruct the past but visualises what we know about the past. In other words, it constructs a consistent visualisation of a man-made structure or landscape based upon all available sources, such as archaeology, anthropology, history, physics, etc. As such, developing these visualisations is a multidisciplinary activity and always susceptible to change (fig. 1).

Fig. 1: Meeting of the team at the Vatican (photo: Christie Ray)
The following content is derived from a blog that was initiated to document the process of virtual reconstruction of the Regolini-Galassi Tomb (fig. 2) in a transparent way, but also to create an open discussion about that process and its results with experts, external to the project, and interested individuals. This has not been a trivial task, as a blog is a totally different way of communicating scientific results than an academic publication. A blog shows the interpretation process from the inside and stimulates reaction and reflection. We have noticed that for many experts, this difference is confusing and that many of them still see a blog as a formal way of publishing.

The following chapters in this publication attempt to summarise several topics that were explored in the blog; showing the process of interpreta-
tion of sources using 3D, digitisation and digital restoration of museum
objects and integration into an interactive museum installation based
upon a natural interaction interface.

**Virtual reconstruction of the Regolini-Galassi Tomb**

Virtual reconstruction is an iterative process, in which visualising the re-
constructed scene in 3D helps the interpretation process. We summarise
briefly the process here, showing the different iterations. In a separate
chapter, we will discuss topics that were difficult to conclude upon. To
support further research, we have provided our argumentation for these
difficult topics.

We started by modelling the tomb and all objects in the antechamber,
trying to reconstruct this unique burial site at the moment of its closure.
This virtual reconstruction is based upon dummy objects that have an ap-
proximated form and material, but modelled with the right dimensions
(fig. 3, fig. 4). The dummy tomb is also schematic but is actually quite pre-
cise in dimensions. To interpret where the objects were standing original-

Fig. 4: Closer view on the antechamber and its objects (image: Visual Dimension)
ly in the tomb we used the oldest drawings that were made by Luigi Grifi, who produced the drawings shortly after the excavations.

In this reconstruction, we have assumed that the floor was horizontal and that there were stairs down to this floor level. If this was not be the case, most objects, such as the chariot and the lebes (a bronze cauldron decorated with animal heads) on top of a support (called holmos), would need to have stood on a sloping floor.

In our early reconstructions (fig. 3, 4), many discrepancies are visible when comparing the perspective drawing (fig. 2) and the ground plan (fig. 5). First of all, the objects are bigger than depicted on the drawings. The bed stands in the middle of the antechamber and the eight shields cannot be positioned as depicted, as they are too big. In this first iteration, we have depicted the shields 2 by 2, in an overlapping way, but this is very unlikely.

In the ground plan (fig. 5), the numbers in red refer to the catalogue number of Pareti (1947). It is remarkable that the tripods G (Pareti 309 & 310) are depicted as empty, as one might reasonably expect a tripod to support some object.

In a second iteration (see fig. 6a), we updated the visualisation of the antechamber of the Regolini-Galassi Tomb. Not all important objects have a place yet, for example the wooden situla with silver decoration could have hung in the window, but we wanted to do some research before deciding on this.
Fig. 6a: 3D visualisation of the Regolini-Galassi Tomb (image: Visual Dimension)

Fig. 6b: 3D visualisation of the antechamber of the Regolini-Galassi Tomb (image: Visual Dimension)
Fig. 7a: Detail of the map of the Regolini-Galassi Tomb by Canina (1846)

Fig. 7b: Detail of the plan of the Regolini-Galassi Tomb by Grifi (1836)

Fig. 8: View inside the right niche (image: Visual Dimension)
We have placed the statues of the mourners around the bed and around the cinerary urn (see fig. 6b). Perhaps these mourning statues should not be placed between the bed and the urn, as these mourners would have had their backs turned on the urn. This could be a possible explanation why all drawings show mourners only on the left side of the bed (see detail of the ground plan of the tomb in fig. 3).

We reconstructed the *biga* (war chariot) and have put it inside the right niche, next to the cinerary urn that contains the ashes of the warrior (fig. 8). We verified that the reconstructed *biga* – which is presently not on display at the Museo Gregoriano Etrusco, as there are some doubts about the reconstruction – could have entered the tomb and the niche when taken apart. The beam that connects the chariot to the horses (see fig. 9) is not depicted in the reconstruction but could have fit inside the niche.

The left niche has a large collection of storage vessels (*ollae*) and other utilitarian vessels, though many of the smaller ones are not depicted. The bronze vessel in the foreground (see fig. 10) is a Villanovan urn that is clearly older than the other objects in the tomb and likely contained the ashes of an ancestor (see also fig. 11). In this niche, we also have put the Etruscan inkpot (see also fig. 12) that is said to have been found in the Regoloni-Galassi Tomb. This object is quite fascinating, as it is covered by Etruscan writing, but its function and its provenance are quite unclear. This delicate object looks as though it does not belong in a storage room, perhaps appearing more suitable for the *cella* or the right niche, as very
Fig. 10: View inside the left niche (image: Visual Dimension)

Fig. 11: Bronze Villanovan urn from the Regolini-Galassi Tomb (photo: Daniel Pletinckx)
little is known about where it was found during the excavation.

**Changing perspectives through reconstruction**

**The Lebetes and the Holmos**

This chapter contains some topics that turned out to be very difficult to conclude upon. In most cases, further research could help in solving the standing questions and hopefully come closer to a probable reconstruction of the tomb and its contents.

Among the most outstanding objects from the Regolini-Galassi Tomb are the three *lebetes* (bronze cauldrons). Two of these *lebetes* (fig. 13) are nearly identical and have five protruding lion heads (fig. 15), the third one is smaller and carries six lion heads (fig. 14), looking inwards (fig. 16). In most publications, the latter *lebes* is said to carry griffin heads, but detailed analysis shows that these heads have only lion features and lack any of the features typically designated for griffins (compare fig. 15 and 16).

When looking into all available sources for details on the position of these *lebetes* in the tomb, some really challenging questions arise. First of all, in none of the drawings we find all three *lebetes*. In the very first drawings of the tomb layout by Grifi, two *lebetes* are depicted (see fig. 17, letters O and P). The legend that goes with the drawing says O is the large *lebes*, while P is the small *lebes*. This is the oldest and most precise localisation of two of the *lebetes*, in other words, the most probable placement, so we used this as the basis for the virtual reconstruction. The inconsistency that the smaller *lebes* (having six heads) is depicted with only five heads (see fig. 17, letter P) is possibly due to a misunderstanding by the person who made the engraving; this kind of error is quite common when a third person is making the drawing.

Another possibility could be that the *cella* contained the two five-head-
Fig. 13: One of the two bronze lebetes with five lion heads (photo: Vatican Museums)

Fig. 15: Detail of a lion head of the larger lebes (photo: Daniel Pletinckx)
Fig. 14: Bronze lebes with six lion heads (photo: Vatican Museums)

Fig. 16: Detail of a lion head of the smaller lebes (photo: Daniel Pletinckx)
Fig. 17: Detail of the cella of the Regolini-Galassi Tomb by Grifi 1836

Fig. 18: The two five-headed lebetes, the reconstructed tripod and remains of one of the original tripods (from Pareti, 1947)
ed lebetes, but that one of them was confused with the smaller six-headed one.

But where is the third larger lebes? None of the available drawings ever shows three lebetes. None of the reports or texts mentions this third lebes. When looking at both larger lebetes in detail, we cannot find any difference, so it is probable that these heads have been cast from the same mould and may have been produced together, so chances are high they were placed together in the tomb. If this was the case, why did the excavators not report they had found two identical lebetes together?

A related question is whether the lebetes were positioned on the ground, or if they sat atop a support structure, such as a tripod. Among the tomb objects, there are two nearly identical iron tripods that have the right dimensions to carry the larger lebetes (Pareti catalogue, numbers 308 and 310). In the Vatican museum, the two five-headed lebetes are displayed together with these tripods. In fact, as they are heavily damaged and corroded, one lebes is shown on a physical reconstruction of the tripod (as can also be seen in fig. 18 from the Pareti catalogue from 1947).

On the other hand, both Grifi (1841, tav. VI) and Canina (1846, tav. LVIII) described and depicted another iron tripod in detail and noted that there are two of them.

In the Vatican museum, we currently have a very similar tripod in bronze (fig. 20) from one of the tombs that surrounded the Regolini-Galassi Tomb (i.e. the Tomb of the Tripod), but the Canina drawing is too detailed and the differences are too many and too obvious to accept that Canina had confused both objects.

Both Grifi (1841, tav. XII) and Canina (1846, tav. L) have clearly depicted these tripods (see letter G in fig. 6, compare with letter G in fig. 3), so we need to ac-
Fig. 20: Bronze tripod from the Tomb of the Tripod (photo: Daniel Pletinckx)

Fig. 21: Bronze holmos from the Regolini-Galassi Tomb in the Vatican Museum (photo: Daniel Pletinckx)

Fig. 22: Several examples of lebetes on top of a holmos support
cept that there were two more tripods in the tomb that we no longer have today. The tripods were possibly made from bronze, rather than iron, as the drawing fig. 19 suggests a very good conservation.

Finally, we have also a bronze holmos that was standing in the ante-chamber (fig. 21). The combination holmos – lebes is very common (see fig. 22), so we could envision one of the lebetes positioned on the holmos.

All interior views of the tomb by Grifi and Canina (see fig. 23, 24, 25) show that the two tripods next to the bronze bed are empty, so we have three lebetes, five possible supports for the lebetes, and two of them are empty. Naturally, we were inclined to put the two iron tripods in the cella with a large and a small lebes on top, and we put the third lebes on the holmos (see 3D visualisation).

Unfortunately, this does not comply with the available evidence; the holmos is always depicted empty, both in perspective views (see fig. 23) and in the plan views by Grifi (fig. B25) and Canina (fig. 25), indicated as B. Pareti notes that the lebetes could not have been put on the holmos, which is made of thin sheets of bronze and would not have been capable of carrying heavy weights. This is only true for a 5-headed lebes, which is heavy, but not for the 6-headed lebes, which is much lighter. Thus, the key question becomes whether or not the holmos carried the 6-headed lebes.

It is important to note that the bronze holmos is not a functional object; it is most likely a bronze replica of a ceramic holmos. A ceramic holmos was used for cooking and warming food, with charcoal burning in the cone shaped foot of the holmos and hot air flowing between the bell shaped top part of the holmos and cauldron, standing on the holmos. When we analyse the different Etruscan objects that are described as holmos, we see an evolution (see fig. 26) from a very practical kitchen tool, 25 cm high, that supports and heats vessels through burning charcoal in the lower section, to a more elaborated stand (over
Fig. 24: The entrance of the Regolini-Galassi Tomb by Grifi (1836)

Fig. 25: The entrance of the Regolini-Galassi Tomb by Canina (1846)

Fig. 26: Evolution of Etruscan holmoi (all objects are dated 7th century BC)
1 m high) that still looks as though it would have the same function, but with one or two spherical parts added between the foot and the support. These spheres presumably allowed the smoke and sparks to settle. The “handles” between the spheres provide additional strength and handling capability when turning the holmos upside down to remove the ashes after use.

The top part of the bronze holmos of the Regolini-Galassi Tomb is closed on the inside, so it cannot function at all, hence it is considered to be a replica intended only for funeral use, but depicting a household device used for cooking. Also, only a few bronze holmoi have been found in Etruscan graves (see for example fig. 27).

But both the holmos and the six-headed lebes tell us a story too. Mentioned earlier, the bronze holmos is a symbolic replica of a ceramic holmos that was used in Etruscan times as a stand to warm food and that was put in the tomb for the deceased to be able to continue to feast in the afterlife. The bronze lebes is a cauldron that was probably used to serve wine mixed with honey and spices. With the lebes on top of the holmos, the rim sits at 1.24 m above ground level, which would be suitable for taking wine from the cauldron. Examining the object closely, we see that both objects in their current state are deformed and have specific corrosion and deformation marks.

Most of the perimeter of the conical foot of the holmos is corroded. This indicates the likelihood that the holmos would have been standing on the damp floor of the tomb. The contact with the soil and the changing humidity in such a tomb would trigger chemical processes that oxidise the bronze and could cause local corrosion. From a recent survey by CNR-ITABC, we know that the dromos, the access to the antechamber, was slightly sloping at the entrance, so it is probable that the holmos would have been positioned on a slightly sloping floor.

As shown in fig. 31, the bell shaped top part has a distinct deformation.
Fig. 28: Corrosion and deformation marks on a bronze holmos and lebes from the Regolini-Galassi Tomb before recent restoration (photo: Vatican Museums)

Fig. 29: Corrosion and deformation marks on a bronze holmos and lebes from the Regolini-Galassi Tomb after recent restoration (photo: Vatican Museums)

Fig. 30: The foot of the holmos is corroded due to contact with the damp floor (photo: Vatican Museums)

Fig. 31: Top part of the holmos with distinct corroded (left) and deformed (right) zones (photo: Vatican Museums)
We propose that this matches the corrosion of the foot, which caused the holmos fall down and hit the bronze cauldron next to it, causing not only this local deformation, but also an overall deformation of the object, as can be observed from fig. 28. Such a collapse only can happen if a heavy object, such as the lebes, was on top of the holmos and would have reinforced the global and local deformation of the holmos.

The top part has also a distinct corrosion pattern that could only be explained if the holmos was lying on the ground and most of the top part was touching the damp floor of the tomb. The lebes, which was potentially placed on top of the holmos, has the same kind of corrosion and deformation patterns (see fig. 31). The object has also hit something significant that has caused a large zone to be corroded away, probably through contact with the tomb floor. As this corroded zone is not on the bottom but a side part of the object, the corrosion is probably not due to the fact that the object was simply placed on the ground when being stored in the tomb. As such, it is quite possible that the lebes was on top of the holmos, and that both fell down due to the corrosion of the foot part of the holmos. Both objects may have hit other objects or the wall of the tomb; the lebes may have rolled down the slope of the dromos (which had a steepness of about five degrees) to end up in an atypical place somewhere at the end of the antechamber, leaving the excavators questioning whether there was a relationship between the holmos and the lebes.

This hypothesis is supported by the fact that the holmos – although in

Fig. 32: Deformation and corrosion patterns on the 6-headed lebes (photo: Vatican Museums)
Fig. 33: Golden disc fibula from the Regolini-Galassi Tomb, 7th century BC
(photo: Vatican Museums)
a restored state – is physically capable of carrying the smaller six-headed *lebes*, despite the remarks of Pareti (in the catalogue of the Regolini-Galassi Tomb objects, in 1947) that the *holmos* is made of a thin sheet of bronze that could not have supported the *lebetes*. This could be true for the larger and much heavier five-headed *lebetes*, but it works for the six-headed *lebes*, which is much lighter.

We can conclude that both the six-headed *lebes* and the bronze *holmos* contain specific corrosion and deformation patterns that make the hypothesis plausible that they were together and on top of each other. Further study will show whether these observations provide a potential solution to the position and supports of the Regolini-Galassi *lebetes*?

**The golden disc fibula**

One of the top pieces from the Regolini-Galassi Tomb is the large golden fibula that was found in the *cella*, where the princess was buried. One part of the object is decorated by lions, so we can assume that this part should be the top of the object. This part is decorated with two rows depicting the tree of life. The middle part is decorated with zigzag lines, the universal symbol (and the Egyptian hieroglyph) for water. The bottom part looks at first sight like a pond full of ducks. On the reverse side of this bottom section, there is a pin to fasten the fibula. In the middle part, there is a catch used to fasten the pin. This object from the Regolini-Galassi Tomb has been dated between 675-650 BC.

Since the excavation, several theories have been developed on how this fibula was used. Canina proposed in his 1846 publication that the object would cover the back of the head (see fig. B36). Canina probably relies on the observation by the excavators that the fibula was found where the head of the deceased was supposed to be. However, this suggested use is quite impossible, as none of the parts of the object are made of flexible material. The reason for such an error probably lies in the fact that, after the excavation, most of the objects were locked up in a room in the house of Galassi, the general of the papal army, before being sold to the Vatican. It looks like the researchers did not have any access to the objects in the first years after the excavations, leading to the creation of many misinterpretations and confusion.
Fig. 34: Side view and front view of the RG disc fibula by Canina (1846)

Fig. 35: Use of the fibula from the Regolini-Galassi Tomb following Canina (1846)
Around 1910, Pinza proposed another interpretation that showed the fibula as a large decorative element used to close a cape, and was depicted together with all of the other elements that had been found, such as jewellery, golden leaf decorations, bronze elements that were interpreted as part of a throne, a silver cup, and more. This proposed use of the fibula is quite unrealistic; not only is the fibula too big and is the decoration of the fibula tilted over 90 degrees, the object itself is far too fragile to have been used in practical life due to the ultrafine gold granulation.

Fig. 36: Pinza proposed the funeral objects from the Regolini-Galassi Tomb as status objects of a princess (before 1915, painting by Oreste Mander)
Current research, however, attaches a more funerary-oriented meaning to the object. When searching for other similar fibulae, several other objects are known today that not only look very alike in shape and structure, but also seem to contain the same symbolic elements. The first comparable fibula has been found at the Ponte Sodo necropolis, at Vulci, and has very similar dating to the previous object (675-650 BC). This fibula (see fig. 37) is currently at the Staatliche Antikensammlungen, in Munich. We see a very similar structure and decoration, although it is somewhat smaller than the RG disc fibula. The upper disk contains depictions of animals, people and probably the sun (the depiction resembles closely a swastika). The horizontal section is also decorated with the same zigzag pattern used to represent water.

The second comparable fibula is older (dated 825-775 BC) and smaller, with a possible provenance from Etruria. It is currently in the collections of the British Museum, in London. Again, the similarity in shape, structure and decoration (note for example the water pattern) is striking. On the disc, four “stars” are depicted that resemble very much the sun symbol found on the Ponte Sodo disc fibula.

Several other very similar fibulae are known. The Allard Pierson Museum has three Etruscan fibulae that are very similar. One of them still has
the middle part preserved, while in the two other, this part has broken off but the point where this middle part was attached is still visible. The decoration is also very similar to the disc fibula from the British Museum, containing four stars or four swastikas.
Maurizio Sannibale, the curator of the Museo Gregoriano Etrusco, has written several excellent papers on the symbolism of these objects, but in short, these fibulae appear to depict the transition from the world of the living (the upper disc) into the underworld (the lower part) over the river that separates both. All these fibulae also have a similar physical structure, with the needle of the fibula behind the bottom section, leaving the top part free-standing. The top part of all fibulae is flat, while the bottom part is curved. All of this brings us to believe that such a fibula must have played an important role in the funerary rites and burials in Etruscan culture. All three parts of these fibulae contain the symbol of life, or the symbol for water or the tree of life. The bottom section on all of these fibulae is curved and could potentially symbolize the belly of a pregnant woman, as the Etruscans believed that through death, one was being reborn in the underworld.

Since many small fibulae were found in the Regolini-Galassi Tomb, there is a consensus that the deceased princess had been wrapped in a shroud. The fibulae would have been used to fasten the shroud around the body. We suggest that the pin of the large disc fibula was used to fasten it onto the shroud, as it seems to have had a practical function.

Despite the beauty and rich symbolism of this large disc fibula, little has been published concerning its possible use and position on the body of the deceased. One publication discusses both the Regolini-Galassi and Ponte Sodo fibulae, proposing the placement of the fibula on the abdomen of the female deceased. If positioned this way, the fibula would fit just under the breastplate. It is remarkable that the bottom part of the RG

Fig. 43: Four of the eighteen fibulae from the Regolini-Galassi Tomb that were probably used to fasten the shroud (photo: Daniel Pletinckx)
fibula ends in an image of Hathor (see fig. 44), which could have a symbolic significance (Hathor is the Egyptian goddess of love, fertility, transition to the afterlife and rebirth). Maybe there is a relation between this class of disc fibulae and the depiction of a winged Hathor or Isis goddess that is often found on many sarcophagi over the belly of the deceased.

In any case, the earliest drawings of the finds are of little help to solve this issue. While Grifi, in his earliest publication (probably 1836), still depicts the fibula in a position near the head (fig. 17), he leaves the question open in his 1841 publication and fails to depict the fibula at all (see fig. B46). Canina, in his publication in 1846 (see fig. 46), seems to suggest a position on the lower part of the body, placed upside down.
In other words, at this point of the research it is very difficult to draw any conclusion from the analysis of the function of the disc fibula, or from the analysis of the documentation that came from the excavations. Further research is definitely needed.

Fig. 47: The entrance of the Regolini-Galassi Tomb (photo: CNR-ITABC)

Fig. 48: Objects from the Regolini-Galassi Tomb in the Vatican Museums (photo: Christie Ray)
Digitisation and digital restoration

Although the Regolini-Galassi Tomb yielded one of the most amazing collections of Etruscan objects, which may be seen on display in the Vatican Museum, the tomb itself is currently not accessible to the public.

In June 2011, CNR-ITABC made a laser scan of the Regolini-Galassi Tomb. A ‘time of flight’ Riegli Z390i laser scanner was used. The 3D model was built using measurements about 6 mm apart on the surface of the tomb, with an accuracy of maximum 3 mm.

Here are some first results, showing only the shape of the tomb. From here, the photographs of the walls are being mapped onto this shape, yielding a photorealistic visualisation of the tomb.

Fig. 49: Digitising the Regolini-Galassi Tomb by laser scanning (photo: CNR-ITABC)

Fig. 50: Cross-section of the 3D model of the Regolini-Galassi Tomb (laser scan: CNR-ITABC)
Fig. 51: Longitudinal view of the 3D model of the Regolini-Galassi Tomb (laser scan: CNR-ITABC)

Fig. 52: View on the antechamber of the Regolini-Galassi Tomb (3D model and laser scan: CNR-ITABC)
Fig. 53: View from left niche into right niche (3D model and laser scan: CNR-ITABC)

Fig. 54: View from antechamber towards exit (3D model and laser scan: CNR-ITABC)
Fig. 55: The cella of the Regolini-Galassi Tomb at excavation in 1836, by Samuel James Ainsley in 1843 (image: British Museum)

Fig. 56: The Regolini-Galassi Tomb before restoration (photo: Vatican Museum)

Fig. 57: Current state of the antechamber and cella of the Regolini-Galassi Tomb (photo: CNR-ITABC)

Fig. 59: Large stone blocks in the cella of the Regolini-Galassi Tomb (photo: CNR-ITABC)
The tomb, however, has been restored significantly (fig. 57), as part of the roof of the cella had collapsed into the interior of the tomb (as can be seen from fig. 55 and fig. B5756 An earlier survey of the tomb by Malgherini also shows this damage in the cella (fig. 58).

Currently, there are several large stones located inside the Regolini-Galassi Tomb. Further research will determine if these stones were originally part of the separation wall between cella and antechamber (the so-called window).

As can be seen from the images above, only a small part of the antechamber of the tomb has a horizontal floor; most of the antechamber and the dromos (entrance part) have a significant slope. Hence, the question that arises whether or not this slope is original, or if there were stairs ending in a horizontal or faintly sloping floor. CNR-ITABC were able to penetrate the ground just inside the dromos entrance and determined that the current floor level is approximately 1 meter higher than the ancient floor. The deposit of soft terrain decreases gradually between the dromos entrance and the final chamber, which has only 5 cm of earth above the ancient floor level. To determine the original state of the dromos and the entrance of the tomb, further excavation and analysis would be required.

After the excavation in 1836, the tomb was left open, without any main-
tenance or protection. Fig. B61 shows the situation in 1838, as drawn by Mrs. Hamilton-Gray during her visit of the tomb (as described in her book *Tour to the Sepulchres of Etruria in 1839*, published in 1843).

The digitisation of museum objects from the Regolini-Galassi Tomb began on August 24, 2011. The photographic department of the Vatican Museums made extensive and specific photographs that allowed us to create 3D models for the exhibitions in Amsterdam and Leiden that opened on October 13, 2011.

The objects were put on a turntable within an object tent that creates a very even distribution of light on the objects, creating an ideal environment for photographing objects to be used in digitisation.
Since we wanted the 3D objects to look like new (as we would reconstruct the tomb to appear as it had just after closure), most of the work goes into either the digital restoration of the objects, any hand-modelling based upon the existing or new photography, or by editing the digitised models (made by dense stereo-matching of photographs). The resulting 3D models have been optimised and visualised in real-time with special techniques to obtain a high degree of realism without an excessive amount of data.

Several objects were documented through the Object VR technique, by photographing the object while it is being rotated on a turntable. In fig. B65, the six-headed lebes is recorded in 36 photographs with consecutive rotations of 10 degrees. These images do not only provide a very detailed documentation of the object, but also allow for future use on the Internet or in multimedia systems in exhibitions.

The Regolini-Galassi Tomb contained several outstanding silver and gold objects, now preserved in the Museo Gregoriano Etrusco in the Vatican.
Fig. 65: Restored silver and gold patera from the Regolini-Galassi Tomb (photo: Daniel Pletinckx)

Fig. 66: Detail of this silver patera showing the nail hole and the deformation of the pieces (photograph: Daniel Pletinckx)
One of the most interesting objects is a patera, in silver and plated gold, that was nailed to the wall of the tomb (see fig. 65, showing its restored state, inv. nr. 20364) and that was used for libation offers in religious rituals. This patera most likely broke into pieces after being hit by stones from the collapsing roof in the cella of the tomb.

This patera is one of a set of silver objects from this tomb that were produced using a Phoenician style with Egyptian decorations. A very similar patera is preserved in the National Museum of Antiquities (RMO) in Leiden, the Netherlands, and has been integrated in the exhibition Etruscans: Eminent Women, Powerful Men next to the Etruscanning VR installation that shows the virtual Regolini-Galassi Tomb. The provenance of this particular patera is unknown, but scholars believe it originates from the Etruscan Barberini tomb that had been excavated in 1855. The object is dated around 630 BC.

Since all of the objects in the 3D virtual reconstruction of the Regolini-Galassi Tomb are visualised in their original state at the closing of the tomb, extensive digital restoration has been applied to most objects. As the 3D visualisation of the Regolini-Galassi Tomb happens in real time to ensure the digitally restored objects to have very fine detail, we developed an innovative digital restoration technique that can be applied to most of the
objects of the tomb. This technique simulates the surface details of the objects (such as engraving, granulation or embossing) and turns them into a very efficient visualisation that can be used in real time systems.

To demonstrate this approach, we will explain the steps used in the digital restoration of the above mentioned *patera*. We start with the drawings by Grifi in 1841 of the first restoration of the *patera* and an improved restoration by the restoration labs of the Vatican Museums in 1999.

When comparing both restorations, one can see that there are slight differences between these restorations, but the 1841 drawings also show more detail than the 1999 restoration. It could be possible that some
detail was lost in the first restoration or in undoing the first restoration. When analysing the engravings, one can see that several motifs are repeated one or more times; we can almost always find information about missing parts by looking at other instances of the same drawing on an-
Fig. 72: Digital restoration of the engraving of the patera (Visual Dimension)

Fig. 73: Detail of the patera with appropriate lighting to visualise engraving and embossing (photo: Vatican Museums)
other place of the engraving. When doing so, very little uncertainty is left what to fill in and only a few details, such as a bird or a tree, have been filled in by analogy. We also closely compared it with the similar *patera* from RMO (fig. 68) to come to the most probable digital restoration of the engraving (see fig. 72).

In the second step, we simulated the production process of the *patera* by creating a displacement map from this engraving. The displacement map shows the small height perturbations that are created by the engraving (and subsequent deformation of the metal around the engraved lines) on the front of the object and the embossing (created by hammering from the back of the object). After studying carefully the high-resolution images of the object, the virtual embossing is created manually by simulating the impression of the blunt chisel (see fig. 73).

All these different processes yield different displacement maps that are composed as layers in Photoshop. The resulting displacement map is a precise simulation of the relief of the complete, undamaged *patera* (see fig. 74).

The *Etruscanning* VR application uses Unity 3D as software to create and visualise the virtual tomb, with its animated objects and narrated sto-

Fig. 74: Simulated displacement map of the whole *patera* (Visual Dimension)
ries. In Unity 3D, a displacement map can be transformed into a normal map, which allows the relief of the objects to be visualised very efficiently. In this way, we visualise details of less than 1/10th of a millimetre on the surface of this object through a very lightweight 3D object (together with 80 other 3D objects) in a real-time system, running on a small, cheap computer (in our case a Mac mini). On the other hand, displacement maps are an optimal and easy approach for digital restoration.

In the Leiden exhibition, the digitally restored patera could be compared with the similar patera from the Barberini tomb, on display next to the VR installation, demonstrating the added value of digital museum objects.

Like the bronze patera, the bronze holmos of the Regolini-Galassi Tomb is a very elaborate and beautiful object that has also suffered significant damage and corrosion (see fig. 28). To reveal the beauty of this object, we have unwrapped its decoration and used this image to create a line drawing of the engraved decoration. Based upon this engraving and upon detailed study of the applied embossing, we have created a displacement map of the decoration of each part of the holmos.

The displacement map is created in the same way as for the other ob-
Fig. 76: Bronze holmos from the Regolini-Galassi Tomb (photo: Vatican Museums)

Fig. 77: Unwrapped decoration of the holmos cone (image: Visual Dimension)

Fig. 78: Displacement map of the holmos cone (image: Visual Dimension)
Fig. 79-81: Digitally restored holmos, placed in the Regolini-Galassi Tomb (image: CNR-ITABC)
jects: we simulate the engraving and embossing process in different lay-
ers of a Photoshop image which is laid over the unwrapped texture.

The displacement map is transformed into a normal map in Unity3D,
giving a very nice real time rendering of the bronze object.

The six-headed lebes also suffered deformation and damage (see fig. 82), so we performed digital restoration on this object as well. In this case, we derived the unwrapped texture from a 3D model that was made from dense stereo matching on a set of photographs taken with an object tent (see fig. 82, fig. 83, fig. 84).

We first identified the full engraving of the lebes on the unwrapped tex-
ture, completing the missing parts. Then, we painted the embossed fea-
tures in a similar way as the other objects, through observation of those features on the many photographs taken.

The displacement map was imported in Unity3D and translated into a normal map for real time visualisation (see fig. 86 and fig. 87, compare with fig. 82 and fig. 83). All digitally restored objects have been integrated into the new version of the application (see fig. 115, fig. 116, fig. 117).
Fig. 83: Photography of the lebes in an object tent for creating the 3D model (photo: Vatican Museums)

Fig. 84: Detail of the engraving of the lebes (photo: Vatican Museums)
Fig. 85: Displacement map superimposed upon the unwrapped texture of the lebes (image: Visual Dimension)

Fig. 86-87: Digitally restored six-headed lebes (image: CNR-ITABC)
One of the outstanding silver objects from the Regolini-Galassi Tomb is a *situla*, a ritual bucket to contain holy water or milk. The *situla* is only preserved partially and consisted of a wooden cylindrical bucket decorated with a silver cover showing three animals and palmettes, as the symbol of life.

The silver decoration was found by the excavators in a fragmented state and was only partially recovered. Presumably, the *situla* was suspended in the triangular window opening (see fig. 89) and when the *situla* fell, it broke and many fragments that fell on the ground were destroyed by corrosion.

We digitised the *situla* by turntable photography, so that the cylinder could be unwrapped as one image, and close-up photography, so that the hinge and the chain could be modelled in 3D by hand. The main goal

![Fig. 88: Silver and wood situla of the Regolini-Galassi Tomb (photo: Vatican Museums)](image)
of unwrapping the cylindrical silver sheet was to digitally restore it. The physical restoration was not documented and probably dates back to the 19th century.

Fig. 89: Situla suspended in the triangular window of the tomb (image: CNR-ITABC)

Fig. 90: Photographing the situla on a turntable at the Vatican Museums (photo: CNR-ITABC)
Fig. 91: Unwrapped decoration of the situla (image: Visual Dimension)

Fig. 92: Detail of the restored situla decoration, showing a griffin (image: Visual Dimension)
The resulting photographs were assembled into one image, depicting the cylindrical surface of the *situla*. As can be seen from fig. 91 and fig. 92, the silver sheet has also been embossed and engraved. The digital restoration focused on understanding the production process and improving the physical restoration, which had been made using parts that do not contain any engraving or embossing. It appeared also that a few small parts of the original silver are missing (see for example the wing of the griffin, fig. 92).

The digital restoration was implemented through the creation of a displacement map, which is the most efficient technique to deal with embossed and engraved objects, as has been demonstrated on the *holmos* and the *patera*. In Photoshop, we created extra layers on top of the unwrapped *situla* decoration image, one layer for the engraving, one layer for the embossing. Additional layers have been introduced to simulate the deformation of the metal when engraving. We also created a transparency map to indicate the form of the cut-outs in the silver sheet.

Study of the unwrapped image showed that the palmettes were made by hammering the shape with a tool in the form of the palmette, a process
we were able to simulate in Photoshop. The resulting transparency and displacement maps are used in the interactive real time visualisation system that has been implemented by CNR-ITABC (see fig. 94).

Fig. 94: The digitally restored situla in the Regolini-Galassi Tomb (image: CNR-ITABC)

Fig. 95: View when entering the virtual tomb (image: CNR-ITABC)
The *Etruscanning* application

The interactive application was inaugurated in the Allard Pierson Museum in Amsterdam on October 13, 2011, and in the National Museum of Antiquities in Leiden on October 14, 2011. The first version of the application that was installed during the exhibition allowed the user to interactively explore the Regolini-Galassi Tomb by walking on a map of the tomb.

This first version of the application shows about 80 objects that were digitised using several techniques. The tomb itself was digitised using a laser scanning. Most objects were hand-modelled from new photography that was made by the photographic department of the Vatican Museums. Some objects (such as the *lebes*, fig. 82) were modelled by automatic photogrammetry from images. Other objects would rely on existing physical reconstructions, such as the chariot (fig. 96).

In the first version, many objects needed more work, as most objects would need to go through a process of extensive digital restoration to

![Fig. 96: View on the objects in the dromos (entrance) (image: CNR-ITABC)](image)
Fig. 97: View on the objects in the antechamber (image: CNR-ITABC)

Fig. 98: View on the main burial chamber (cella) (image: CNR-ITABC)
bring them back in their original state at the moment of the burial. This included removal of corrosion and repair of broken or damaged parts. For others, the current reconstruction needed to be revised, based upon the most recent archaeological understanding about these objects (such as the chariot, in fig. 96).

Some objects present the results of extensive digital restoration. The *situla*, for example (see fig. 98), was recreated digitally based upon the current physical restoration. This recreation was made by simulating the production processes of the object, such as engraving and embossing the sheet of silver that is wrapped around the wooden bucket.

For the first time, a visualisation of the woman buried in the Regolini-Galassi Tomb was presented to the public. In this first version of the application, we limited the visualisation of the objects to the golden pectoral and the golden disc fibula, but the subsequent version would incorporate more jewels, and the fibulae and golden leaf decoration on the shroud.

A lot of new research has been conducted concerning the position of

Fig. 99: View on the deceased princess (image: CNR-ITABC)
the golden disc fibula. In the first version of the application, we chose to visualise the fibula on the abdomen, although this was a hypothetical placement (see fig. 100).

The *Etruscanning* partners have improved the VR application from the first version that was presented and have since developed new ways of visualisation and interaction that have been applied in the second version of the application.

The first version of the interactive VR application showing the reconstructed Regolini-Galassi Tomb was first installed in the Allard Pierson Museum, in Amsterdam, and the National Museum of Antiquities, in Leiden.

The most innovative element of this first version of the application was the use of a natural interaction interface in combination with a map of the tomb placed on the floor, allowing the user to move inside the 3D space just by walking around on the map of the tomb.

The application allows the public to explore the virtual tomb, see the
Fig. 101: Putting the final touch in the exhibition on Etruscans in the National Museum of Antiquities (photo: Daniel Pletinckx)

Fig. 102: Installation of the special projector at the Allard Pierson Museum (photo: Daniel Pletinckx)
Fig. 103: Etruscanning setup: map, large screen and projector (photo: Daniel Pletinckx)

Fig. 104: Exploring the tomb by natural interaction (photo: Daniel Pletinckx)
digital artefacts in close-up, and listen to stories told by the prestigious Etruscan personages that were buried nearly 2700 years ago in the tomb. In the first version of the application, all of this is possible by moving around in front of the projection, in a simple and natural way. The user would walk on a map of the real grave, attached to the floor, on which some hotspots were indicated. Changing position from one hotspot to another, movement also takes place in the virtual space, exploring the tomb and the objects, and triggering the storytelling. This solution not only results in an amazing interaction for the public but allows also people of every age to enjoy the virtual content without any prior knowledge of 3D interaction.

The story is told in the first person by the two people that are buried in the tomb. They are ghosts, living today and knowing our culture and society, but guiding us around in their tomb just after the burial, speaking from their point of view of Etruscan nobility. The stories are linked to the objects in the tomb, which are visualised in close-up, highlighted by extra virtual illumination.

During the exhibition, the image was projected on a large 12 m² screen from above by a special projector with mirrors, so that the visitor never
Fig. 106: Outside view of the Regolini-Galassi tumulus (photo: Daniel Pletinckx)

Fig. 107: The Etruscanning project team in the Regolini-Galassi Tomb (photo: Daniel Pletinckx)
gets in the way of the projected image. Together with the physical involvement of the user, this produces a strong sense of immersion.

This VR installation in both museums was the first result of a two year multidisciplinary project *Etruscanning* that was further developed by the Allard Pierson Museum, CNR-ITABC and Visual Dimension, in close cooperation with the National Museum for Antiquities of the Netherlands, the Gallo-Roman museum of Tongeren, the Vatican Museums, the Soprintendenza dell'Etruria Meridionale di Villa Giulia and CNR-ISCIMA.

On October 13, 2011, the double exhibition Etruscans was opened in Amsterdam in the Aula of the University of Amsterdam, attended by 700 people, including a large Italian delegation, with representatives of the museums that cooperate in these exhibitions and the *Etruscanning* team.

This academic session was opened by Wim Hupperetz, director of the Allard Pierson Museum and coordinator of the *Etruscanning* project, which created an interactive VR application to explore the Regolini-Galassi Tomb through natural interaction for the exhibition. The exhibition in the Allard Pierson Museum focuses on *Powerful Men*.

On October 14, 2011, the exhibition on *Etruscans* opened in the National Museum of Antiquities in Leiden, and focused on *Eminent Women*.
Fig. 109: Academic opening of the Etruscans exhibition in the Aula of the University of Amsterdam (photo: Daniel Pletinckx)

Fig. 110: Presentation by Wim Hupperetz (photo: Daniel Pletinckx)
As the *Etruscanning* VR application shows the Regolini-Galassi Tomb, in which both a leading woman and man were buried, it was shown in both exhibitions. Fig. 111 and fig. 112 show the setup in Leiden during the evening of the opening, during which around 1300 people visited the museum.

The first version of the interactive virtual reality application was presented in both museums and shown with storytelling in Dutch. English and Italian versions of the narration was recorded. Both versions were shown at the ArcheoVirtual 2011 exhibition at the Borsa Mediterranea del Turismo Archeologico (Nov 17-20, 2011, in Paestum, Italy). This version was also integrated into a prestigious exhibition on Etruscan culture in the Gallo-Roman museum of Tongeren, Belgium, that opened on March 15, 2013.

The *Etruscanning* research continues, on the digital restoration of the objects, on their optimal representation in a real time 3D system and on the use of gestures to select and manipulate objects. An updated edition of the first version of the application, providing more focus on the digitised museum objects, was shown at the Museum Night in Amsterdam on Nov 5, 2011.

The development of museum VR installations based upon natural in-
Interfaces, such as this Etruscanning project, is an exciting, new way of integrating interactive 3D into museums and exhibitions. CNR-ITABC developed a very first version of this technology in the temporary exhibition “Colours of Giotto” with a lot of success. The assessment of the fitness for use and robustness of implementation of this Etruscanning application has been carried out by the European V-MusT.net Network of Excellence, that focuses on museum technology and virtual museums. The research is carried out in the Virtual Museum Lab of the Allard Pierson Museum, which is a leading partner within the V-MusT.net consortium.

Every year, the Virtual Heritage Lab at CNR-ITABC organises the ArcheoVirtual exhibition and shows the best applications in digital visualization for archaeology. In 2011, the V-MusT.net Network of Excellence, coordinated by CNR-ITABC, used the venue to organise two workshops on museum technology, as well as several other meetings.

One of the ArcheoVirtual stands that attracted the most interest was Etruscanning with the VR visualisation of the Regolini-Galassi Tomb. The version of the application that was on display was only offered in Italian, which was later incorporated into subsequent versions of the application.
Fig. 113: ArcheoVirtual organiser and V-MusT coordinator Sofia Pescarin (right) with Mohamed Farouk (left) and Karim Omar (middle) of CultNat, Egypt (photo: Selma Rizvic)

Fig. 114: The Etruscanning application at ArcheoVirtual (photo: Selma Rizvic)
Throughout 2012, CNR-ITABC in Rome worked hard on creating a new version that was demonstrated at both the Italian Science Festival in Genoa (Oct 25 – Nov 4, 2012) and at the ArcheoVirtual exhibition that took place in Paestum, Italy (Nov 15-18, 2012).

At the Science Festival, many children were able to use the application, which was hosted and evaluated by the V-MusT European network, and at the end of the festival, the stand had been visited by approximately 4000 visitors.
At ArcheoVirtual 2012, where a large number of new virtual museum applications where demonstrated, the *Etruscanning* application was also evaluated by the V-MusT team. Overall, the visitors were very positive about the new application.

By the end of the ArcheoVirtual 2012 exhibition, *Etruscanning* received the award for Best Application in the category *New Interaction* and was the virtual museum that was Most Appreciated by the visitors of the exhibition.
Fig. 119: The restored holmos at the entrance of the Regolini-Galassi Tomb (image: CNR-ITABC)

Fig. 120: The restored bronze shields in the Regolini-Galassi Tomb (image: CNR-ITABC)

Fig. 121: The main burial chamber (image: CNR-ITABC)
The new version of the application not only contains many more digitally restored objects, but also allows users to navigate freely through the tomb and to select objects.

In April 2013, the final version of the *Etruscanning* application was installed permanently in the Vatican Museums.
Virtual Reconstructions in the Museum

Evaluating User Experiences of a Virtual Museum Application Embedded in an Exhibition

CHRISTIE RAY

I. Introduction

For some time now, museums have been adopting and incorporating technology into their exhibition spaces. While some museum directors remain adamant that technological applications do not have a place among their museum collections, many are openly embracing the technology, seeing the value of such applications to enrich and enhance their collections and exhibitions. The range of technological applications that are associated with museums are often categorized using the term virtual museums (VM) to refer to anything from online catalogues, applications for mobile devices, to on-site installations. The following paper will use a case study, the Virtual Reconstruction of the Regolini-Galassi Tomb, including the approaches and results of evaluating this case study, to examine whether this VM installation provided any added value to the traditional exhibition into which it was embedded.

II. The Etruscanning project and the creation of the virtual reconstruction of the Regolini-Galassi Tomb

There are two prime objectives of the project: international cooperation for the digital acquisition, restoration and representation, with the final applications to be made available to exhibitions in Italy, Belgium, Germany and the Netherlands, and to support and enable the creation, presentation and exchange of 3D reconstructions by cultural heritage institutions. The methodological approach includes considerable evaluation throughout the length of the project, allowing the application developers...
the opportunity to improve the application based on the results of the different rounds of evaluation.

The Virtual Reconstruction of the Regolini-Galassi Tomb, as it was presented, provided museum visitors with an interactive and immersive experience, whereby the user could explore the virtually reconstructed tomb and the objects that were once inside. The Regolini-Galassi Tomb, like so many other sites from antiquity, had the original objects found within the tomb were removed during the excavation process, but the collections can be viewed today in the Museo Gregoriano Etrusco of the Vatican Museums. Unfortunately, during the excavations conducted in 1836 by priest Alessandro Regolini and the general Vincenzo Galassi, the contents of the tomb and the original location of the objects was not methodically documented, leaving later scholars to piece together the archaeological record from fragmented reports and illustrations made years after the excavation had occurred.

As one of the most well-known tombs from the Etruscan period because of its impressive finds, and as a tomb which has a complicated and unclear archaeological record, the Regolini-Galassi Tomb was an ideal candidate for virtual reconstruction. Using the archeological reports and illustrations, together with additional scholarship on the tomb, its finds and the Etruscan civilization, the Etruscanning consortium endeavored to virtually reconstruct the Regolini-Galassi Tomb to show it as it might have looked when it was sealed. Essentially, our approach was to use the existing interpretations of the tomb to create our own interpretation, which would be presented as an interactive virtual reconstruction.

Applying a complex digitization process involving laser scanning (Riegl z390i), photogrammetry and 3D modeling (3D Studio Max, Blender, Autodesk Photofly/123D Catch, Photoscan, ARC3D, Unity 3D), the Regolini-Galassi Tomb and its objects were produced virtually and optimized for a real-time engine to allow users to explore the tomb using natural interaction. A Kinect sensor was used as the natural interaction user interface with which users were able to virtually explore the tomb and its contents using a map of the tomb on the floor with certain ‘hot spots’ indicated to guide the user through the rooms of the tomb. Upon reaching each ‘hot spot,’ the user hears a short story relating to a nearby object, told from the perspective of one of the deceased Etruscans for whom the
tomb was constructed. As the user physically walks from one ‘hot spot’ to another, the Kinect sensor tracks their position inside the virtual tomb, matching their position on the floor map of the tomb to correspond with their position in the virtual reconstruction of the tomb. The user is not obliged to follow a prescribed path through the tomb, rather they are free to explore the ‘hot spots’ in any order they choose. The Virtual Reconstruction of the Regolini-Galassi Tomb was presented using a large projection screen of 12 m² in a darkened room, with accompanying audio, creating an interactive and immersive experience.

III Preliminary evaluation: from aims to approaches

The inclusion of the Virtual Reconstruction of the Regolini-Galassi Tomb into the Etruscan exhibition at the Allard Pierson Museum (APM) and the Rijksmuseum van Oudheden (RMO) was a unique opportunity to evaluate the same installation in two different environments. Since the development of the application was ongoing, it was also possible to have the results of the evaluation make an impact on subsequent versions of the application. The approaches to evaluation were selected to suit the research questions the project team had produced throughout the development and implementation period, prior to the first version of the virtual tomb reconstruction being installed in the exhibition space. This section will briefly review the evaluation aims and approaches employed at the APM and RMO, while the following section will focus on the methodology and results of the A-B study conducted.

Evaluation at the APM and RMO consisted of two main approaches, observation and user interviews, with a third approach being the A-B study which will be discussed later. The purpose of the observational approach was to identify user demographics, to evaluate the technical functionality of the application, and to examine the environment and atmosphere into which the application was placed. The interviews provided greater insight into some specifics of the user demographics, but were primarily held to determine the level of interaction and immersion experienced by the users, and to identify how users felt about experiencing a technological application, including the elements of the application such as the virtual 3D objects, within the context of a traditional museum environment. The
evaluation period ran in line with the opening and closing of the exhibition, with an update to the application applied in January 2012.

Observation was conducted on sixteen different occasions during the opening hours of the exhibition, with the majority of the observation taking place at the APM. The results of the observation were useful for determining certain aspects about the user demographics, such as length of interaction with the application by users (avg. 12 minutes) or identifying the underrepresented user groups (children, aged 2-13, unless part of a school group), but it also allowed us to identify the elements which had an impact on the environment into which the application was placed. Since the presentation of the application requires a dark and quiet room, the environment was monitored for elements that affected the presentation atmosphere, such as additional sources for light or sound which compromised the quality of the presentation. At the APM, the presentation was placed in a dark room which was situated half way through the Etruscan exhibition, while at the RMO, the presentation was placed in an open room that was part of the wider exhibition space, with other sources for light and sound nearby which would disturb the presentation.

Observation was used in combination with user interviews to validate the findings from the observational approach. For example, in the first version of the application, it was observed that the camera movements between the virtual rooms of the tomb were too fast for the users who were experiencing the tomb reconstruction on the large projection screen, causing many users to exhibit visible signs of dizziness as a result of the camera movements. The user interviews confirmed that, for many users, the size of the projection screen combined with the abrupt movements of the camera were causing feelings of motion sickness. These findings were returned to the application developers who, in the second version of the application, tailored the camera movements to eliminate the sudden turns and maintain a forward-looking position, using slower, controlled turns to view the side chambers of the tomb. When the second version of the application was installed, dizziness as a result of the camera movements was largely eliminated.

There was a good deal of overlap between the content covered in the user interviews and the results of the A-B study, including the level of immersion and the level of difficulty in interacting with the application,
however the interviews conducted with museum visitors provided more detailed insight into the personal experiences with the application. For example, 100% of users questioned said that they felt they had learned something new from the installation, including learning about the original context of the objects, or the use and decoration of Etruscan tombs and burials. While all of the users questioned acknowledged the value of presenting virtual objects, there was agreement that the virtual objects should not act as a replacement for the real objects.

IV  A-B Study: From purpose to procedure

The A-B study on the Virtual Reconstruction of the Regolini-Galassi Tomb was conducted at the APM on Thursday, March 15, 2012, three days prior to the closing date of the Etruscan exhibition. The participants were selected at random and divided into two groups; group A would visit the installation of the virtual tomb before visiting the exhibition, while group B would visit the exhibition prior to visiting the installation. Each participant would fill out four questionnaires throughout the experiment, including one before the experiment, one after the exhibition, one after the installation, and one after the experiment had been completed. Since this experiment was taking place in the Netherlands, about an installation which was presented in Dutch, and using questionnaires that were also translated and answered in Dutch, the results represent the responses of the Dutch audience and does not include any reactions from non-Dutch speakers.

Museum visitors were selected at random to participate in the study and were provided with a detailed set of instructions for their participation (both verbal and printed). Unfortunately the late date of the study in the course of the exhibition meant that the volume of visitors was reduced, compared to the high visitor numbers experienced in the opening weeks of the exhibition. Additionally, the unseasonably warm and sunny weather also may have had an impact on the number of visitors in the museum during the day of the experiment. Participation in the experiment was subject to the agreement by each individual to participate, and many individuals who were approached to participate declined for a variety of reasons, such as having too little time to participate in the study, or not
wanting to separate themselves from any companions they may have come to the exhibition with. Large tour groups and guided student tours were not selected for participation, so as not to single out individual visitors from their group or have their responses influenced by their associates. At the end of the day, a total of sixteen individuals participated in the study, eight in each group.

The aim of the A-B study was to determine the added value of including a virtual museum application embedded in a traditional museum exhibition. The “value” of the application would be measured in terms of educational content retention, contextualization of objects between virtual and real environments, and the visitor experience. To do this, the two-group (A-B) method was selected and included a series of four questionnaires that were filled during specific points of the participant’s experience. The first questionnaire had the participant provide some basic demographic information about themselves, including their age, gender, occupation, education, interests, computer usage, museum visits per year and their familiarity with the Etruscan civilization.

The second and third questionnaires were filled out after each participant had experienced the designated portion of their museum visit. For group A, who saw the installation before the exhibition, the second questionnaire was related to the content presented in the installation and about elements of the installation itself. Following the second questionnaire, group A participants viewed the exhibition and subsequently filled out the third questionnaire about the exhibition. The questions regarding the content of the installation and the exhibition were primarily the same, apart from the questions specifically referring to the content or accessibility of one or the other. Group B did the experiment in the reverse order to group A; starting first with viewing the exhibition before experiencing the installation. The questionnaires included a series of questions which required the participant to rate their opinion on a five-point scale between “agree” and “disagree,” and included a “no opinion” option.

The final questionnaire was directed towards determining the added value of embedding the installation into the exhibition. In this questionnaire, participants were asked to provide their opinion on a five-point scale between “installation” and “exhibition,” with a “no opinion” option as well, to determine which element of their experience provided the
clearest information about the objects or their context, but also where financial support should be allocated. Participants were also asked to identify which age group they felt that each the exhibition and the installation were best suited, and were provided with open questions about the most memorable part of their museum experience and the relationship between the installation and the exhibition.

V The results of the A-B Study

The results of the A-B study will be presented here, beginning with the results of the first questionnaire on user demographics, moving to the comparative results of the second and third questionnaires, and finishing with the results of the final questionnaire regarding the added value of embedding the Virtual Reconstruction of the Regolini-Galassi Tomb into the Etruscan exhibition.

The average age of the participants in the study was 61.25 years old, with the oldest being 78 years old and the youngest being 20 years old. While these results suggest an imbalance in the sample group, presenting the majority of visitors as aged 60+, the observation and user interviews confirm that the demographic of the sample group is a faithful representation of the visitors to the Allard Pierson Museum. Of the participants in the study, 62.5% were male and 37.5% were female. When participants were asked to identify their interests, they selected history (93.75%), ancient civilizations (81.25%), archaeology (68.75%), museum collections (62.5%), and historical architecture (50%). The frequency of computer use

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![Fig. 1](image-url) – Element presenting the clearest information on the Etruscans

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among participants was largely on a daily basis (81.25%), with fewer participants using computers weekly (6.25%) or seldom to never (12.5%).

Although the study was conducted close to the closing of the exhibition, only 31% of the participants had already seen the corresponding female part of the exhibition at the Rijksmuseum van Oudheden, with 68.75% of participants visiting the Etruscan exhibition for the first time at the APM. The frequency of museum visits among participants ranged from 1-2 times per year (6.25%), 3-6 times per year (31.25%), 7-12 times per year (37.5%), and more than once per month (25%). Despite the high interest level of the participants in history, archaeology and ancient civilizations, and the frequency of their museum visits, most participants indicated their knowledge about the Etruscan civilization as being somewhat limited; 50% stated that they knew some information about the Etruscans, while 12.5% said they knew very little, however 25% said they knew lots about the Etruscans and a further 12.5% identified themselves as having expert level knowledge.

The questions included in questionnaires two and three were, for the most part, identical and concentrated on the educational content included in both the installation and the exhibition. The difficulty of the questions increased within each questionnaire and the results indicate increasing or decreasing uncertainty in the ability of the participant to respond with confidence. Overall, the results showed that the participants were able to answer a range of questions about the Etruscans, but the exact educational impact of either the exhibition or the installation in isolation are unclear, due to the varying pre-existing knowledge levels of the Etruscans by the participants. For example, in the questionnaire that participants filled in after the installation, a question about the funerary rites of the Etruscans (that male warriors were never cremated) was answered with a resounding “disagree,” which is the correct answer. Alternatively, in the questionnaire filled in after the exhibition, the question about the funerary rites of the Etruscans was re-phrased to suggest that male warriors were always cremated. This question was designed to be intentionally misleading as to prompt the participant to question the knowledge they had gained throughout the exhibition and the installation. While the questionnaire filled in after the installation had clear results, with 81.25% selecting the correct answer, the questionnaire filled in after the exhibi-
tion showed more uncertainty, with only 56.25% selecting the correct answer. This suggests that the installation provided the clearest, most direct information about the funerary customs of the Etruscans, and while the exhibition also provided this information, the approach to presenting this content may not have been clear or direct enough for the participants to provide a confident response to the question.

The final questionnaire, which was aimed at determining the value of embedding the virtual museum application into the exhibition, included a range of questions regarding both the installation and the exhibition, as well as the relationship between the two. Participants were asked to use a five-point scale to select their preference between the installation and the exhibition, as well as an option to express no opinion. While the most of the participants felt the exhibition provided the clearest information about the Etruscans (46.6%), they also said that the element which provided the clearest contextual information about the objects was the installation (46.6%) (see Tables 1 and 2). It may be interesting to note that, of the participants who said the installation provided the clearest context for the objects, those in group B, who saw the exhibition before the installation, had a more even distribution between the installation (25%) and the exhibition (37.5%), while those in group A showed a strong preference for the installation (71.4%) over the exhibition (14.3%).

![Fig. 2](image)

**Fig. 2** – Element presenting the *clearest context* for the objects

Although the installation was selected by the participants as being the element which provided the best context for the objects, there was a strong spread between the group A and B when asked which element best related
the objects to the people who used them. Group A, who saw the installation before the exhibition, said that the exhibition best related the objects to the Etruscan people (42.8%), while group B, who saw the exhibition before the installation, said that the installation best related the objects to the Etruscan people (50%). This inversion suggests that both parts together form a balanced museum experience for the visitor, whereby the exhibition and the installation complement each other to provide a complete picture of the relationship between the objects and the Etruscans. In fact, when asked about how clear the relationship between the exhibition and the installation was, the majority of the total participants said that the relationship between the two elements was “absolutely clear” (53.3%, with 26.6% of participants selecting the option between “neutral” and “absolutely clear”).

When asked to reflect upon their museum experience, 71.4% of participants said that what they experienced, namely the combination of the installation and the exhibition, fit with their personal opinion of what they felt a museum experience should be. Only 7.2% offered a “neutral” response, while none of the participants offered responses that went below “neutral” and none selected a response of “no opinion.” This is a positive result, which suggests that the concept of what museum visitors define as a museum experience is shifting away from the more traditional approach of displaying objects accompanied by a short text, moving towards an experience that is more interactive and includes a wider range of multimedia formats to convey information about the collections.

In two separate questions, participants were asked to identify the age groups that they felt the installation or the exhibition were best suited for. When asked about which age group the exhibition was best suited for, the highest percentages were given to groups aged 14-25 (69%) and 26-40 (46%).* When asked about which age group the installation was best suited for, the highest percentages were also given to groups aged 14-25 and 26-40 (64% for each group), with only 7% of participants suggesting the installation was best suited for the age group of 0-13 years. Although participants were able to select more than one age group for each question, the array of responses suggests that both the installation and the

* Visitors were able to make more than one selection for questions relating to suitable age groups of the exhibition or the installation.
Participants were asked in two separate questions about whether the installation added to the exhibition or whether the exhibition added to the installation. For both questions, the majority of participants placed their responses between “neutral” and “absolutely,” which indicates the compatibility and complementary nature of embedding the installation into the exhibition. When they were asked to offer two examples for how the installation added to the exhibition, participants responded that the installation allows “understanding of the spatial aspects of the objects,” that it “shows the objects in combination with the environment,” and that the installation showed “how things were used and tomb rituals were explained better.” When providing two examples of how the exhibition added to the installation, participants said that the exhibition provided “tangibility or authenticity,” and that the “digital is something other than real life, but digital never wins at being ‘real.’”

VI Conclusions

The results of the A-B study presented above, combined with the results of the observation and user interviews conducted throughout the exhibition period, offered a great deal of insight into the user experience of the presented case study, the Virtual Reconstruction of the Regolini-Galassi Tomb. While the use of observation and user interviews had a direct impact on the development of and updates to the installation, the A-B study conducted at the Allard Pierson Museum provided the clearest understanding of the added value of embedding the installation into the more traditional exhibition style used in Etruscans: Eminent Women, Men of Power. Reflecting upon the results of the A-B study, the added value of embedding the installation into the exhibition was three fold; contextual, educational, and museological.

The participants of the A-B study recognized the importance of the installation for providing a clearer understanding of the original placement and purpose of the objects from the Regolini-Galassi Tomb. Providing contextualization virtually, as it was done in the Virtual Reconstruction of the Regolini-Galassi Tomb, gives museum visitors an opportunity to better understand the objects, their use and origins, while protecting the exhibition would be ideally suited for a wide range of visitor age groups.
original objects from the potential harm that can come from physically handling and moving objects to prepare for a traditional, object-based exhibition. Furthermore, the installation provided a unique opportunity to experience virtual objects in a virtually reconstructed environment, which is something that would not be possible using the original objects. Generally, the participants in the study were able to identify and praise the improved contextualization of the objects that the installation offered. Although their expressed attitude was that such virtual representations of objects and environments should not attempt to replace the presence of authentic objects, rather they should complement and supplement the more traditional style of object-based exhibition presentations.

The Virtual Reconstruction of the Regolini-Galassi Tomb offered additional education value, to supplement the content provided in the exhibition. When participants evaluated their experience after the installation and the exhibition, the results showed greater confidence in participant responses when they had experienced both the installation and the exhibition. When examined separately, users were able to provide correct responses to the questions asked after each the installation and the exhibition, but once both parts of the study had been completed, the results show that the participants were more certain of their answers than they were after completing only the installation or the exhibition. The content presented in both the installation and the exhibition serve to reinforce each other, creating a more enriching experience for the museum visitor.

The museological value of embedding the Virtual Reconstruction of the Regolini-Galassi Tomb into the Etruscan exhibition is reflected in both the enhanced contextualization of the presented collections and the reinforcement of educational content shared between the installation and the exhibition. More than this, however, the results of the A-B study show that the way museum experiences are being defined by visitors is evolving to include a broader range of content dissemination styles, including a more generally accepted presence of technology integrated into museum presentations. The acceptance of technology and VM applications in museums by visitors will undoubtedly impact the future study of museology, especially as more museum directors are starting to recognize the value of incorporating technology in museums.
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Facts & Figures

Number of Partners: 5
- Allard Pierson Museum, Amsterdam
- Consiglio Nazionale delle Ricerche, Rome
- Gallo-Romeins Museum, Tongeren
- National Museum of Antiquities, Leiden
- Visual Dimension, Ename

Number of Organizations Involved: 12
- Allard Pierson Museum
- Consiglio Nazionale delle Ricerche
- Culture Unit of EACEA – EC
- E.V.O.CA
- Gallo-Romeins Museum Tongeren
- LVR-LandesMuseum Bonn
- Museo Nazionale Etrusco di Villa Giulia
- Musei Vaticani – Museo Gregoriano Etrusco
- Museo dell’Agro Veientano
- National Museum of Antiquities
- Soprintendenza all’Etruria Meridionale
- Visual Dimension

Duration of Project in months: 24
Number of People Involved: 20
Number of Venues: 7

Number of visitors: 134.000
- Allard Pierson Museum (Amsterdam, the Netherlands): 50.000
- Rijksmuseum van Oudheden (Leiden, the Netherlands): 75.000
- Gregorian Etruscan Museum, Vatican Museums (Vatican City): starts April 2013
- Gallo-Romeins Museum Tongeren (Tongeren, Belgium): starts March 2013
- ArcheoVirtual 2011 (Paestum, Italy): 2500
- ArcheoVirtual 2012 (Paestum, Italy): 2500
- Science Festival Genoa 2012 (Genoa, Italy): 4000

Versions of the Application: 2
Language Options in the Application: 3 (Italian, Dutch, English)
Number of Objects Found in the Regolini-Galassi Tomb: 327
Number of Objects Virtually Reconstructed: 45
Hours Spent on Disc Fibula Reconstruction: 40
Photos Taken to Reconstruct the Holmos: 60
Hours Spent Scanning the Regolini-Galassi Tomb: 8
Average Length of Interaction with the First Version of the Application by Users, in minutes: 12-15

Awards: 2
- Natural Interaction Award – ArcheoVirtual 2012
- Public Appreciation Award – ArcheoVirtual 2012

Publications by Project Members: 8

Blog: [www.regolinigalassi.wordpress.com](http://www.regolinigalassi.wordpress.com)
Number of blog posts: 28
Number of page views (from July 2011 to Feb 2013): 33000
Number of unique visitors per month: 700

Newspaper and magazine articles: 5
Volkskrant, NRC Handelsblad, Computer Idee (The Netherlands), Archeo (Italy), Etruscan News (USA)

Video’s on Youtube: 4
- [http://www.youtube.com/watch?v=iiW4dbfo5yU](http://www.youtube.com/watch?v=iiW4dbfo5yU) (English version 605 views)
- [http://www.youtube.com/watch?v=w21q3peytYQ](http://www.youtube.com/watch?v=w21q3peytYQ) (Dutch version 2416 views)
- [http://www.youtube.com/watch?v=WBS48y6wT9k](http://www.youtube.com/watch?v=WBS48y6wT9k) (Italian version 880 views)
- [http://www.youtube.com/watch?v=Je0oqqFmu9M](http://www.youtube.com/watch?v=Je0oqqFmu9M) (Dutch version 1326 views)
Video's on Vimeo: 2
https://vimeo.com/61736198 (English version)
https://vimeo.com/61799751 (Italian version)
About the Authors

**Wim Hupperetz**, Director of the Allard Pierson Museum, the archaeological Museum of the University of Amsterdam, is a trained archaeologist and heritage specialist in the field of museology, cultural landscape and urban environment, focused on achieving extra value through a multidisciplinary approach and ICT applications.

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**Daniel Pletinckx**, co-founder and director of Visual Dimension bvba, is a civil engineer specializing in information technology and digital imaging, including 3D and virtual reality, as well as a consultant and designer of new systems for Cultural Heritage and tourism.

**Christie Ray**, a trained museologist and archaeological illustrator, is a PhD candidate with the V-MusT.net project at the University of Amsterdam, focusing on evaluating the user experience of virtual museum applications within the context of the museum environment.

**Maurizio Sannibale** is head of the Department of Etrusco-Italic Antiquities (Museo Gregoriano Etrusco) in the Vatican Museums. He completed his studies at the University of Rome “La Sapienza,” where he graduated in Arts, specializing in archaeology, which he followed with a Postgraduate Diploma in Archaeology, as a pupil of Giovanni Colonna. He is a correspondent fellow of the National Institute for Etruscan and Italic Studies.
(Instituto Nazionale di Studi Etruschi ed Italici), in Florence, and of the Pontifical Roman Academy of Archaeology (Pontifica Accedemia di Archeologia). He is the author of about ninety publications, including several monographs on Etruscan topics, dealing with various aspects of artistic and craft production, with particular attention to jewellery, bronzes, sculpture and figured vases. Recent work has been dedicated to iconographical topics, Etruscan religion, and connections among ancient Mediterranean cultures.
This publication complements and supports the work conducted as part of *Etruscanning*, a European project focusing on using innovative 3D multimedia technologies to support exhibitions on Etruscan culture. The results of the project described in this publication, namely the Virtual Reconstruction of the Regolini-Galassi Tomb interactive installation, can be experienced by the public in the permanent exhibition space of the Museo Gregoriano Etrusco, in the Vatican Museums.