Tangible interfaces for digital museum applications

The Virtex and Virtex Light systems in the Keys to Rome exhibition

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Abstract— **Virtex is the acronym for VIRTual EXhibit. It is an innovative approach for museum storytelling, based on a tangible interface. This article illustrates how the Virtex and Virtex Light systems have been integrated in the international exhibition Keys to Rome and how tangible interfaces can be used to enhance visitor experience in the museum.**

***Index Terms*—tangible interface, museum, smart object, 3D printing, multimodal interface.**

I. INTRODUCTION: KEYS TO ROME

On September 23, 2014 the international exhibition Keys To Rome [1] opened in four locations: in the Imperial Fora Museum in Rome, in the Bibliotheca Alexandrina in Alexandria, in the Allard Pierson Museum in Amsterdam and in the City Hall of Sarajevo. It was the final exhibition of V-MusT, the European Network of Excellence on Digital and Virtual Museums and had the aim to connect and show the diversity and unity of cultures within the Roman Empire. In each local exhibition, visitors explored a specific collection of objects, while technology had the task of connecting them all by showing histories and objects from the other three locations.

On the occasion of the commemoration of 2000 years since the death of emperor Augustus, he was chosen as the central figure of the exhibition that covered all the history of the Roman Empire. For this reason, two keys objects of the Augustan era have been realized with Virtex technology: the Ara Pacis and the statue of Augustus of Prima Porta [7].

II. VIRTEX AND VIRTEX LIGHT

Virtex is an innovative approach to museum storytelling, based on an interactive 3D printed replica of an object, used as tangible interface [5] and storytelling device. Users can freely touch and hold the replica and interact with it thanks to electronics and sensors inside. A first Virtex prototype has been created in 2007 [3] [8].

Two versions of the interface have been developed, called *Virtex* and *Virtex Light*. Virtex is conceived to be manipulated by the user and contains a wireless orientation sensor that makes the on-screen visualisation of the object follow the movements of the replica in the hands of the user. This system is designed to tell the story of movable objects, but also to show an object interactively from all sides, when that object cannot be present.

Virtex Light, on the contrary, tells the story of non-movable objects such as monuments and sites. As it is fixed on its pedestal, it does not contain any orientation sensor. The replica of the monument or site acts as an interactive model, giving an overview of the monument or site and telling its story.

Fig. 1: Augustus of Prima Porta statue in the Vatican Museums

Fig. 2: The Ara Pacis monument in Rome

For the Keys To Rome exhibitions we decided to use two objects that were not present in the four museums, but which are important witnesses of Augustan art and propaganda, and therefore not only valuable artistic objects but also loaded with historical and symbolic meaning. The Virtex technology was used to illustrate the meaning and history of the statue of Augustus of Prima Porta (fig. 1), while Virtex Light was chosen to explain the complex iconography of the Ara Pacis (fig. 2) and tell the story of its discovery and *anastylosis*.

III. The Concept: Setup and Requirements

In a museum, the Virtex application can be displayed next to the original object to explain it or used alone to present to visitors an artefact that is not physically in the museum.

The 3D printed replica should be an exact copy in 1:1 scale of the original artefact, but it can have easily a different scale, suitable to hold the object and explore it.

Once the user is handing the replica, he is welcomed by a short introduction and some context on the artefact.

By touching the sensors on the surface of the interactive replica, content is triggered for display to the visitors using interactive storytelling. This is a non-linear narration formed by self-standing short pieces of information that, all together, form the whole story related to the object. As each part of the narration is not dependent on the rest, the order in which the parts are told is not important. Thanks to this major feature, non-linear storytelling is used to stimulate the user to explore the object. The user decides which pieces of information are presented and builds up his own narrative path.

A Virtex setup requires a screen and a computer. A computer is necessary to communicate with the electronic components inside the replica and visualise the correct content once a sensor is touched. The screen displays a virtual model of the real object that can be explored in detail by using the printed replica object as a controller. Once a sensor is touched, the virtual 3D model is zoomed in on the touched feature and the related content is displayed on the screen. It can consist of images with text and audio file, or a short video. The 3D visualisation is enriched with lost or invisible information on the artefact, such as a lost or degraded coloration.

A Virtex setup always tries to make the link with the real object, whether this object is present next to the Virtex setup or not, through the images or video that show the real object and through the displayed virtual 3D model that is as realistic as possible.

IV. Workflow

The process of creating an interactive replica of an object can be subdivided in eight main steps:

- First it is necessary to digitise the selected object to obtain a 3D model of it. The most suitable technique of digitisation depends on the complexity and material of the object and on the permissions granted by the owner.
- It is then necessary to process the acquired 3D model in order to meet the requirements of 3D printing. The 3D model needs to be closed without any irregularity concerning polygon size, orientation or structure.
- The next step defines the topics and content that the application will show so that the interactive zones of the object can be designed to hold the sensors.
- Once the "points of interest" have been defined, the 3D model needs to be divided in parts with space to host the electronics inside that make it interactive. Channels and support structures need to be designed to hold the sensors and the internal wiring. The goal is to make the electronics as much as possible invisible, but still easily accessible for servicing. The design needs to be robust and sturdy and able to withstand daily manipulation by visitors. Parts that need to fit into each other need to have the right mechanical tolerances for proper assembly.
- Next, the 3D model needs to be printed. The selection of the material and printing technique depends on the size and complexity of the object and the requirements of the curator. It is important to keep in mind that the replica will be touched by a large number of people, so it has to be resistant to all kinds of manipulation (including falling on the ground) and needs to be cleaned easily.
- Once the 3D printed replica is ready, the electronics and wiring need to be integrated and the parts assembled. Testing of the assembly is required.
- In parallel, content for the application needs to be created, consisting of text, images, possibly audio and video. This content can be multilingual.
- In order to correctly display the content of the application, software able to read the sensor and orientation data, and linking the content to the sensor data has to be created, installed and tested in the computer.

V. Virtex Implementation: Augustus of Prima Porta

A. Optimisation and Design of the 3D model

The replica of Augustus of Prima Porta was created from the 3D model acquired in the context of The Digital Sculpture Project [2], by laser scanning the plaster cast of the Prima Porta statue, present in the Erlangen museum, by the team of Bernard Frischer. The original statue resides in the Vatican Museums. In order to be printed with a 3D printer, some zones of the 3D model that were difficult to scan, needed to be completed by digital sculpting to create a closed volume. The model was also verified and corrected for geometrical and topological imperfections.

Fig. 3: Virtex implementation of Augustus of Prima Porta

The optimised 3D model was then carefully divided into two parts (upper body and legs) to be able to contain internally the electronic components that make it interactive. The orientation sensor, battery and printed circuit board that communicates with the touch sensors were put on a sliding support structure that fits in the upper body of the statue (see fig. 3).

The orientation sensor (InertiaCube3W) integrates the orientation data with the touch sensor data coming from the printed circuit board into one wireless signal that is transmitted through a USB wireless receiver connected to the computer.

As the original statue of Augustus is 2.05 m tall, it was decided to create a 35 cm tall replica (1:6 scale), big enough to appreciate the fine details of the decoration of the armour but small enough to be handled easily by the museum visitors and children. This size was also suitable for fitting the electronic components inside the replica, and resulted in an affordable cost for the 3D print.

As the touch sensors at this scale needed to be very small, we used the smallest surface mounting push buttons that were available, as other types of touch sensors such as proximity switches were larger. Using simple push buttons also reduced the amount of electronics inside.

In all interactive zones of the statue, support structures for the push buttons and channels for the wires to the printed circuit board were designed. The push buttons were glued into these small support structures during assembly. The position of the push buttons was not only dictated by the content and the story to be told, but also by practical assembly and design issues. For reasons of assembly and maintenance, the head was separated from the body, to be glued into the body at assembly.

The electronics inside use a 9V reloadable battery. By putting the statue on a supplementary support (see fig. 4), the electronics for reloading the battery could be housed invisibly into this support. Also the receiver that maintains the wireless communication with the orientation sensor is housed inside this support.

Fig. 4: The interactive statue on its support for reloading

B. 3D Printing and Integration of Electronic Components

The replica was 3D printed in white polyamide that is a very fine, granular powder that allows the creation of a light but robust object of any complexity. The printing technique uses a laser, which sinters the powder together layer by layer. The result is an object with a faintly granular surface and a high definition of details. The object was then coated in order to become more resistant to the frequent manipulation and easier to clean.

Push buttons have been manually integrated and glued in the designed slots in the replica. The orientation sensor and the printed circuit board have been fixed with very small steel and nylon screws onto the sliding support. The battery clips into the designed space on the support.

The Augustus statue replica has six buttons. Five of them are connected to content about the symbolic meaning of the statue, like for example the identity of the figures depicted on its armour, the meaning of being barefoot or the use of the *contrapposto* position, similar to classical statues. The sixth button on the back of the model triggers the proposed colour schema of the statue based upon the study of professor Liverani.

C. Museum Setup

The Allard Pierson Museum has a full size plaster cast of the statue, painted with the colours detected by prof. Liverani on the original statue (fig. 5). Visitors using the Virtex setup see in this way (a copy of) the real object and can discover more about the history and meaning of the statue through the Virtex application (fig. 6). This setup is part of the permanent exhibition on Roman culture that was redesigned as part of the Keys to Rome exhibition.

Fig. 5: The Augustus setup at the Allard Pierson Museum

Fig. 6: The Virtex setup at the Allard Pierson Museum

VI. Virtex Light Implementation: Ara Pacis

A. Optimisation and design of the 3D model

In order to tell the visitors of the Keys to Rome exhibition the story and meaning of the Ara Pacis, a Virtex Light setup was created. Supports for the push buttons and the electronics were added to the 3D model. It was designed to be printed as one single object (fig. 7), with the electronics and wiring hidden on the inside (fig. 8).

Fig. 7: The Virtex Light implementation of the Ara Pacis

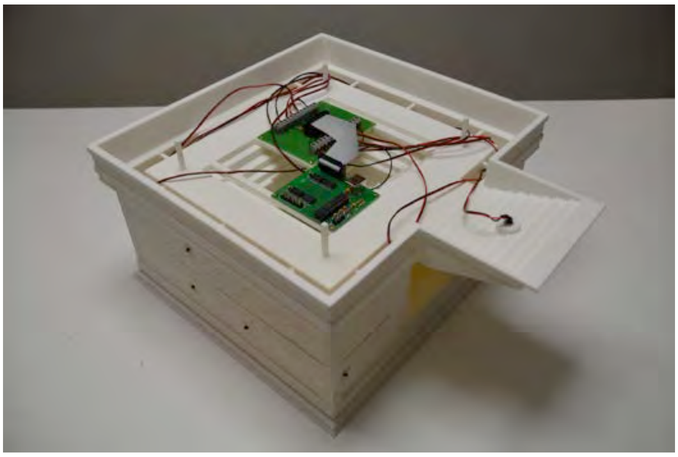

Fig. 8: The inside of the Ara Pacis

B. 3D Printing and Integration of Electronic Components

Just as the Augustus of Prima Porta replica, the Ara Pacis was printed in polyamide at a scale of 1:37 (to use the maximum dimensions that could be printed). It has no orientation sensor inside (as it is designed to be fixed to the museum furniture), so it only contains electronics (DigiBee controller) to communicate the status of the push buttons to the computer over a USB link.

In the Ara Pacis replica, thirteen push buttons have been integrated on those parts of the monument that are linked with its symbolic meaning in the Augustan propaganda, with the history of its excavation and of its *anastylosis* (fig. 9). The application is also used to show its proposed original appearance according to the studies on the colouration that have been carried out on the monument.

Fig. 9: The Ara Pacis application

C. Museum Setup

The Virtex Light application of the Ara Pacis is displayed in the permanent Roman collection of the Allard Pierson Museum in Amsterdam, and was displayed until May 2015 in the temporary exhibition *The city of Augustus* in the Imperial Fora Museum in Rome.

In the Allard Pierson Museum the replica is shown together with a plaster cast of one of the decorated panels of the Ara Pacis, providing the visitor a close view on the richness of the decoration of the monument (fig. 10).

Fig. 10: The Ara Pacis replica at the Allard Pierson Museum

In the Imperial Fora Museum, the application is not connected with any physical object, due to the fact that the monument is situated not far from the museum.

VII. The Technology

A Virtex or Virtex Light setup requires a replica of an object or monument containing touch sensors (such as simple push buttons or more sophisticated proximity switches). A Virtex object also contains an additional sensor that provides real time data about the orientation (or even movement) of the object. The touch and orientation data is used by a computer to visualise the object on a screen or projection, based upon the orientation data and tell the story of the object, based upon the zones that have been touched.

The goal of this setup is to create a multimodal experience where the user can hold the smart object [4], feel it, manipulate it in real time and explore its story through images and sound. The user is in full control of the object and its content, creating a personalised experience.

Due to the short time to produce the Virtex implementation for the Augustus statue, we have chosen to use an integrated and wireless solution (InertiaCube3W) by InterSense, where the orientation sensor is also sampling the touch sensor data (through a small printed circuit board provided by InterSense, that communicates with the sensor through an I2C bus) and sending all this information to the computer through a dedicated wireless communication, reaching as far as 30 m.

This allows the use of a Virtex system also for guided groups where the information is projected on a large screen, and where the guide has the freedom to walk around and pass the object around amongst the group members.

If the size or cost of this InertiaCube3W solution is prohibitive, it could be replaced by an Arduino solution based upon a 9-DOF sensor (1 by 1 cm large) with Bluetooth communication to the computer.

In the described Virtex solution, we have used the smallest surface mountable micro push buttons available to integrate in the 3D printed Augustus statue.

The Virtex Light solution uses a DigiBee controller [6] that communicates the status of the touch sensors to the software through a USB interface. Push buttons need a printed circuit board with some simple hardware to turn the status of the push buttons into a digital 2-byte number that is transmitted to the computer.

We had the software written as a Unity3D application under Windows 8.1, for both Virtex and Virtex Light applications. The software consists of a communication module (that interfaces with the Virtex or Virtex Light hardware), a 3D visualisation module that shows the 3D model of the object in all its orientations and zooms in on the points of interest, and a information module that shows a series of subtitled images (in one or two languages with a timing per image) or a (subtitled) video.

The computers used to display Virtex or Virtex Light applications are barebones Windows 8.1 PCs, with a variety of screens in different sizes and resolutions. The application also can be used together with a projector, to facilitate guides using the application for a larger group. This option has not been used in the Keys to Rome exhibition. In Amsterdam, smaller 15 inch screens are used, while in Rome, a larger 24 inch screen is used.

It was decided to use small screens in Amsterdam due to the position of the objects in the exhibition, in order to facilitate the flux of visitors. As a matter of fact, a small screen is optimal for being seen from a small number of visitors, preventing that big groups create a bottleneck in the exhibition path by stopping for long time in front of the application.

VIII. Impact of Virtex technology on museum visitors

The main innovative aspect of the Virtex approach is the psychological impact on the users. Thanks to this application, they are invited to touch the object, something that is normally forbidden in museums. Holding the replica in their hands, having the freedom of exploring its details both by looking at them closely and by feeling them under their fingers makes their relationship with the object more intimate. Users also become actors in the communication process, as they have the freedom to select content inspired by their own curiosity.

The Virtex replica is an interface to the stories of the object. The great flexibility in the creation of content for a Virtex setup, that can include written text or audio files, together with the tactile exploration and experience of the object, makes it a perfect installation to enrich the museum visit of visually impaired and disabled people. In this sense, Virtex can be considered as an instrument for the inclusion of all the audiences in the museum, as the same setup works for both normal and disabled people.

Another important feature of Virtex technology is its extreme flexibility in setup solutions. Using a small screen makes the application available for individuals and families, while a large screen projection is more suitable for large groups. Guides can use the content of the application as a support for their explanation of the object.

Finally, Virtex can be integrated in the museum next to real object, but can also be used to show something that cannot be physically present in the exhibition, like an extremely valuable object that cannot travel, a monument or a building. In this way, also these objects can be made accessible to the public of an exhibition in all their richness, accompanied with their stories.

IX. Conclusion

Virtex and Virtex Light are new ways to tell the story of museum objects, monuments and landscapes. Through a tangible interface, that creates a much closer bond with the object but also gives a visual and tactile feedback, stories are told about the object, monument or site. This provides a much better way to remember the information and to create impact for the user. The multimodal nature of the interface (touch, image, sound) to a smart object, linked to storytelling provides a new experience for museum and site visitors.

The Virtex and Virtex Light setup is suited for individual visitors and small groups. If implemented with projection, it can also be used for larger guided groups.

In the Virtex setup, the object can be passed around in the group, creating a social experience that stimulates the exploration and critical assessment of the object.

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