

Applying Mixed Reality Technology to Cultural Applications

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Abstract

Cultural organisations such as museums and galleries face the situation that they have to compete for the favour of visitors or the public in general with numerous suppliers of different educational or entertaining offers. As a consequence, they are looking for new ways of presentation to increase demand for cultural related edutainment.

This paper intends to promote the idea of applying mixed reality technology to cultural applications. Hence, it describes two scenarios of new ways for presentation and interaction that adopt existing technologies to cultural application demonstrations. Consequently, it does not provide detailed algorithmic or scientific background, as this is out of the scope of this paper.

The first example describes a Mixed Reality-supported interactive museum exhibit. It features an easy and intuitive interaction via pointing gesture and allows the museum visitor to explore artworks in a highly interactive way. The second example applies Augmented Reality (AR) technology to the cultural domain. In this scenario an application concept for a virtual art exhibition in the real museum or gallery environment is proposed. Gallery or museum visitors will be enabled to enter a number of virtual art exhibitions, which consist of digitised pieces of art, and paintings that complement the real exhibitions.

1 Introduction

Cultural organisations such as museums and galleries face the situation that they have to compete for the favour of visitors or the public in general with numerous suppliers of different educational or entertaining offers. As a consequence, they are looking for new ways of presentation to increase demand for cultural related edutainment.

Interactivity seems to be one of the key factors to attract visitors. Hence information technology in general and in the recent year Mixed Reality technology in particular received attention as they promise a wide range of interaction potentials.

But anyhow, just applying technology is not enough to reach success. Bob Raiselis, an exhibit developer, summarised in his article “What makes a good Interactive Exhibit” some key characteristics that should be considered when trying to build interactive exhibits, like

- be inviting, i.e. the exhibit raises the interest of visitors and invite them to spend some time with it,
- be understandable, i.e. the navigation scheme of the exhibit should be instantly understandable and the visitor should be able to get the exhibit to “work”
- be explorative, i.e. invite visitors to explore the exhibit and let them discover things by themselves
- be accessible to people of varying ages and development

The two scenarios that are described in the following try to consider these recommendations. Although they have been implemented as prototype applications only and yet are tested under synthetic conditions, initial reactions from users could be gathered already.

In the following, two different application scenarios for the creation of interactive exhibits are given. Each description starts with the general intention and objective of the particular exhibit, explains its

functionality and finally describes the realisation and implementation issues that have been considered. Finally, first comments and next steps will be outlined.

2 Scenario one: The interactive exhibit applications

The objective of the interactive exhibit application is to create an intuitively usable experience for exploring digitised paintings on a technical exhibit canvas using a new interaction based on pointing gesture recognition. The visitor is able to create his/her own exhibit selecting different paintings for exploration. Once selected, he/she can interact with the selected painting in an easy and intuitive way.

The display of digitised paintings on an interactive screen could be used by smaller museums that are too limited in space to present all their paintings in a traditional way. The visitor's direct interaction with art pieces is expected to lead to a deeper involvement with and understanding of the art piece, whereas the manipulation of original paintings is obviously prohibited. Interactive exploration of the paintings is achieved by offering the user to take a look at details of paintings, interactively emphasising particular parts e.g. by highlighting, incorporating multimedia explanations, for particular highlight and so on.

The interactive exhibit scenario attracts visitors by matching the customary association of artworks in a museum such as the presentation of paintings on a canvas with innovative human-computer-interaction methods. The combination of intuitive interaction techniques and the presentation of multimedia content on a projection screen are used to generate a novel experience during an exhibition visit.

2.1 Description of application scenario

With the IT-supported interactive museum exhibit visitors are able to create their personal exhibit and can choose between different paintings for exploration. Once a painting is selected, the visitor can explore the chosen painting in an easy and intuitive way. In addition, the visualisation of digitised paintings on an interactive screen offers smaller museums the opportunity to present larger portions of their collections that otherwise would not be offered due to limited space.

The user/visitor of the interactive museum exhibition will be invited to take up a position in front of the canvas (large-scale projection screen) indicated e.g. by footstep markers on the floor, which show the designated interaction position. In this scenario application, an image menu displaying nine pre-loaded images offers the user/visitor a selection of one of the paintings that can be explored in more detailed by the user (see figure below).



Figure 1: Example of an image selection menu

A small red point (a laser pointer metaphor) provides direct visual feedback from the first time that the user/visitor points at the canvas. Pointing at one of these thumbnail images for at least one second will trigger the application to replace the image menu with the selected image and to display it in full screen mode (see Figure 2). Rotating objects are located at the right hand side border of the image and offer

particular interaction modes. Actions such as the selection of functionality can be triggered by pointing at the rotating objects in the same manner as explained above for the thumbnail images.



Figure 2: Scene with Marc Chagall painting and button menu on the right

2.2 Interaction modes

The application scenario features a deliberately limited number of functionality to minimize the complexity of the application. A click on the rotating frame with the Mona Lisa by Leonardo da Vinci lets the user return to the image selection menu. The rotating model of a pocket lamp allows spot light-based exploration of the currently selected image and the rotating magnifying glass enables the user to switch to an exploration, whereby details of the image are zoomed in on at the position pointed to by the user.

The spot light-based exploration aids the visitor to focus on interesting parts and to darken currently uninteresting parts of the image. If pointing does not take place, the canvas is left black and only the rotating button objects at the right hand edge of the canvas are visible. Pointing at the canvas achieves the effect of having a virtual pocket lamp at the fingertips of the user (see Figure 3 - left).



Figure 3: Gesture-based exploration with a virtual spot light (left) and magnifying glass (right)

The magnifying glass-based exploration allows the visitor to focus on interesting parts of the currently displayed image and to zoom in on details at which the user points. With a virtual magnifying glass in his/her hand the visitor is able to let the lens pass over the image enlarging appropriate areas of interest (see Figure 3 - right). Additional sensitive areas can be added to the images to trigger rendering of explanatory information either in visual or audible form.

2.3 System Implementation

The goal of the interactive application is to provide a robust and easy-to-maintain solution for an IT-based interactive exhibit. In the following the technical details for the implemented system are described.

2.3.1 Hardware

The equipment for the interactive museum exhibit consists of two standard PCs with approximately 2GHz processors and 1GB RAM each: one is used for the rendering of the scenario application and the other for pointing gesture recognition and tracking. Furthermore, the PC used for tracking purposes is equipped with a frame grabber card. Two progressive scan cameras are connected to the frame grabber card feeding the system with grey-scaled images of the interaction volume in real time. It is possible to attach infrared filters to the cameras and to flood the scene with additional infrared light to ensure constant light conditions and to enhance the robustness of the video-based tracking system (see Figure 4). Assistance from infrared light beamers is only necessary, if the setup is running under extreme light conditions (e.g. if one of the cameras is looking directly into a window).



Figure 4: Camera and (optional) infrared light beamer

Some constraints with the camera set-up have to be considered. Both cameras need to be placed nearly orthogonal. For the demonstration set-up, one camera was attached to the ceiling above the user at a distance of approximately 2.5 metres from the ground. The other one was attached at the right side at a distance of about 2.5 metres from user and 1.5 metres above the ground.

The position in which the user can interact is pre-defined with respect to the camera set-up. Motivating the user to take the correct position for interaction can be easily achieved e.g. by adding markers like footsteps on the floor in front of the interaction canvas. The position of the cameras with respect to the user and the displaying canvas depends on various parameters like

- Focal length of the camera lenses;
- Dimension of the rendering canvas; and/or
- Designated speed and accuracy of the tracking system.

The above-mentioned distances of the cameras are proposed values for a canvas of approximately 3m width and 2m heights and a user position located about 3m in front of the canvas.

Projection Hardware

The project hardware used for the demonstrator consists of off-the-shelf components. The rendering system is running on a standard PC. The currently used configuration features a dual AMD Athlon™ MP 2000+ processor, 1GB of memory and a NVIDIA Quadro4 900 XGL graphics board. The software is run under MS Windows 2000.

As output device any standard video beamer with a resolution of at least 800 * 600 pixel or higher and a projection canvas of approximately 3m width and 2m height can be used. The current setup of the implemented prototype uses a back projecting system by OTLO VR Systeme GmbH, Rostock, Germany (<http://www.otlo.de>) with a Liesegang ddv 1800 beamer (see Figure 5).



Figure 5: Sketch of projection canvas (back projection version)

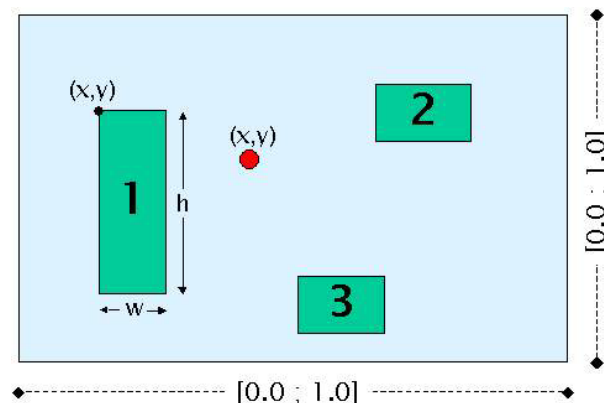
Tracking Software

The purpose of the tracking software module is to recognise and to track a static pointing gesture of the user to enable most intuitive interaction with the scenario application. The definition of an abstract gesture description allows the tracking system to adapt to different and even technically unversed users without any learning procedure. The video-based module uses two cameras, which observe the user in front of the display canvas. It identifies whether the user is pointing at the canvas and extracts the pointing direction in case. Due to a direct link with the rendering module the user gets an immediate visual feedback on the canvas in real time (laser pointer dot, magnifying glass, torch light).

The tracking module is separated into two different operation modes:

- Tracking of the pointing direction and its target point at the canvas and
- Observation of predefined regions that can be used like virtual buttons (pointing for a period of ~1 second at a button object leads to a 'button selected'-event handled by the scenario application).

Both modes (pointing direction and region selection) are usable at the same time.



**Figure 6: Sketch of the virtual interaction area
(pointing position (red dot) and three different button regions (green boxes))**

Several different computer vision and image processing algorithms are used to ensure a fast and robust identification of the pointing gesture occurrence. Smoothing of the tracking results lead to an immersive experience during the interaction and keeps the visitor free from any technical device. The tracking system is nearly self-calibrating. Only a few parameters have to be set or adapted during and after the installation of the system by the support staff of the museum. Furthermore, a simple graphical interface ensures the easiest handling of the tracking application (see Figure 7).

Due to the separation of the tracking module and the scenario application, it is easy for the support staff to change or replace the content on the scenario side of the virtual exhibit without any need of changing any parameter in the tracking software.



Figure 7: Screenshot of pointing tracking software showing the two (superimposed) camera images (top view, side view) and the application control window

3 Scenario two: An AR-enhanced personalized gallery

The objective of this scenario application is to demonstrate possibilities in creating a personalized virtual exhibition of paintings. Many museums and galleries face the situation that only a small amount of the art pieces and paintings available can be presented to the public. Digitised art pieces and paintings of those in stock can easily be made visually accessible to visitors with the proposed system.

The AR-enhanced personalized gallery scenario makes use of an existing mobile Augmented Reality system. Depending on the choice of virtual art exhibition the visitor has made, an exhibition room that is only equipped with a set of empty picture frames will turn into a real art exhibition. As soon as the visitor is looking at one of those empty picture frames through the AR-glasses of the mobile system, he/she observes a particular digitised painting and may get additional context information about the painting e.g. in audible form (as being already offered by common earphone type devices).

3.1 Scenario description

At the entrance to the exhibition room that contains the virtual art gallery, a visitor will be equipped with the mobile Augmented Reality system. The system consists of a computing unit (sub-notebook-size mobile computer), the AR-glasses (a binocular style display) and optional earphones. At this point, the visitor selects his/her personal favourite from a number of different virtual art exhibitions, and the system will be configured accordingly.

Once the kind of virtual art exhibition to visit has been fixed, the visitor enters the exhibition room, which only consists of empty picture frames. The visitor moves along to one of the picture frames. As soon as he/she takes a look at the frame through the AR-glasses, he/she can observe a digital version of a particular painting. The painting is displayed in the display unit of the AR-glasses and superimposed into the view. This maintains the visual impression of looking at a real image. Using the earphones, the visitor can listen to additional information about the painting.

Each of the empty picture frames of the exhibition room is associated with a different painting that belongs to the virtual art exhibition the visitor has selected. The additional information about each of the paintings displayed will be rendered correspondingly.

If the virtual art exhibition contains more paintings than picture frames are available in the exhibition room, the visitor can virtually enter the next exhibition room from a menu.

3.2 Interaction

The scenario has been designed in such a way that it meets the common expectations and maintains experiences with art exhibitions, although the visitor is equipped with a technical device.

Interaction in the Indoor Augmented Reality Scenario must be considered from two different perspectives, the interior perspective or the interaction with the system, and the exterior perspective or the interaction with the exhibition environment.

3.2.1 Exterior perspective

The AR-enhanced personalized gallery scenario tries to simulate a real exhibition of paintings as realistically as possible. Visiting a traditional art exhibition typically does not imply any specific interaction. Hence, the need for interaction with the system has been reduced to the absolutely necessary. For the visit of the virtual art exhibition, however, two basic interactions are necessary, first entering the exhibition room, and second looking at the paintings. Here, the main difference becomes apparent, as the visitor needs to use the AR-glasses to see the digitised paintings.

The visitor naturally performs the exterior interaction by relocating himself in front of different frames. The AR-system keeps track of changes of the viewing focus. By analysing the current view through the AR-glasses, it is able to identify which picture frame is active. It then retrieves and displays the corresponding digitised painting superimposed into the visitor's view through the AR-glasses.

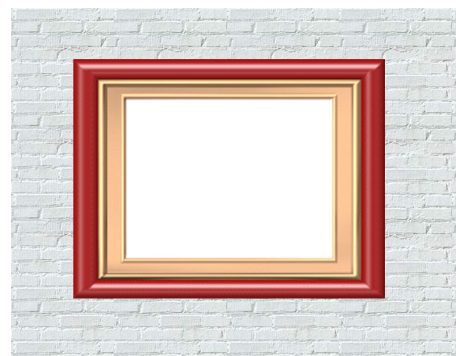
3.2.2 Interior perspective

The direct interaction with the AR-system is restricted to either control the functionality of the system, i.e. to activate or deactivate aural information provision, or to specify which subset of digital paintings that belong to a larger virtual painting exhibition is presented. Here, the metaphor of either "virtual exhibition rooms" or "virtual floors" is used to provide well-known semantics of exhibitions. This type of interaction is realised by a menu-like structure of items and two special keys (a selection button and a toggle button for up-down/left-right navigation within the menu) that have been attached to the AR-glasses. By pressing the corresponding buttons, a menu is displayed and the choice can be taken by navigating to the option wanted and confirming it.

In fact, the AR-enhanced personalized gallery scenario must be considered to be a generic example of a virtual exhibition, which is taking place in a real environment. It offers individualised parallel exhibitions for visitors in one exhibition room and increases accessibility to pieces of art that otherwise could not be shown. In addition, it features on-demand and context-sensitive information for the visitor, either in aural form or - in a more elaborated form - even audio-visually.



Prototype of mobile AR-system



Original view without AR-glasses



Augmented view through AR-glasses

Figure 8: Sketch of the generic idea of the AR-enhanced gallery

3.3 System implementation

The basic idea of the Indoor Augmented Reality Scenario is to present the digital counterparts of paintings in an intuitive way, i.e. to meet the expectations of a visitor as optimally as possible. Two generic requirements have to be met: first the provision of a technical system, which offers the superimposition of digital images into the view of a visitor, the AR-system, and second an adapted environment in which the digital images will be shown.

For the demonstrator, a video-see through solution for mobile AR-applications has been applied, which in its basic form has been developed in the EU project ARCHEOGUIDE for an outdoor scenario. The technical aspects of the mobile AR-system is further detailed below. Basically, the mobile unit the visitor is equipped with performs all the computations needed for video augmentation, i.e.

- To compute the camera position;
- To render the digitised paintings with respect to the orientation of the camera view; and
- To fuse the video stream delivered by the camera with the rendered digitised painting; and finally
- To render the augmented scene on the output device.

3.3.1 Environment specification

One of the essential goals of the AR-enhanced personalised gallery scenario is to seamlessly embed the application into the real environment of a gallery or museum. Therefore, a virtual arts exhibition is considered to take place at a particular location in the museum environment, i.e. the exhibition room that should contain the virtual art exhibition.

The conditions that have to be met in order to realise the robust functioning of the AR-system are controlled and ideally constant lighting conditions as well as fixed set of positions, where the digital paintings should be visualised. At this point, technical requirements, on the one hand, and the purpose of a realistic impression, on the other, can be linked to realise the provision of empty picture frames in which the digitised paintings should be (virtually) rendered.

However, as the AR-system needs information about which painting should be augmented into which frame, some configuration information must be coded. As the solution provided here does not include a positioning system for the identification of the actual position, visual codes are used, that can be extracted from the camera images. These can either be e.g. distinguishable coloured or patterned frames (which may interfere with the paintings to be shown) or visual marks that can be detected and analysed to determine the identification of a frame (and hence the specifies the link to the painting to be presented). Figure 9 illustrates the general functional arrangement of the AR-system.

3.3.2 The prototype system

The prototype system, which is used with for the demonstrator, consists of a number of software and hardware components. The components are carefully chosen and implement the whole AR-system. Each of the components provides either very particular functions or performs specific tasks to realise the augmentation pipeline sketch above. The different hardware and software components are described below.

Hardware.

The AR-system consists of a number of hardware components that need to be carefully chosen with respect to maximum reliability and robustness. Although only a prototype system has been assembled, it already contains all necessary characteristics of a production system. The composition of the different hardware components is described first and this is followed by a short introduction of each single component.

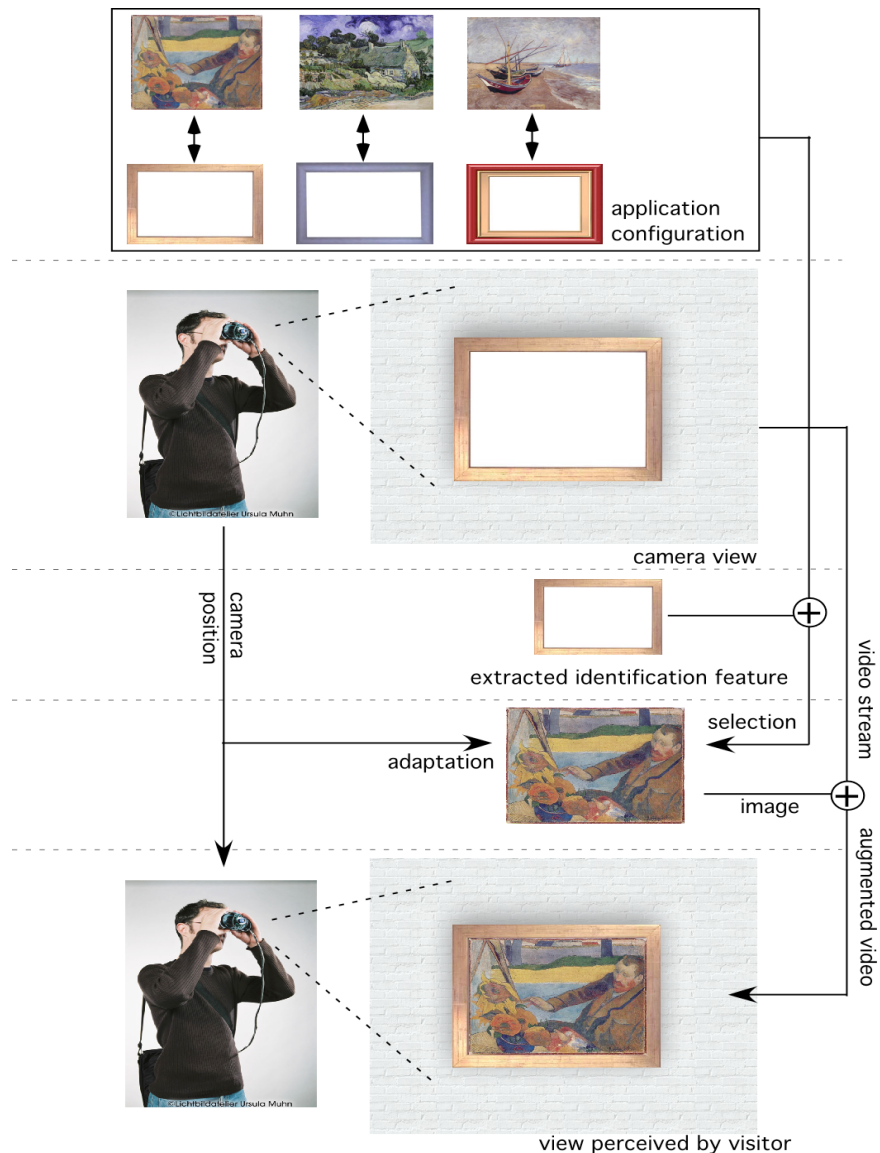


Figure 9: Process of superimposing the digitised painting into the visitor view

Mobile Unit. The hardware set up of the AR-system is composed of two basic devices: the computing unit and the so-called AR-glasses. While the computing unit is needed to execute all software components and to provide all necessary hardware interfaces, the AR-glasses are needed, on the one hand, to provide the video data stream for the computation of the position/orientation of the camera, the identification feature extraction and the background images for the image fusion and, on the other hand, to display the augmented scene with respect to the current view perspective.

Like the computing unit, the AR-glasses are a compound device, consisting of a binocular-type device and a camera device mounted on the front-side of the binocular. Mounting the camera on the front-side of the binocular has two advantages. First, as the offset between the eyes and the camera is limited, the interference with well-established experiences using ordinary binoculars is reduced to a minimum. Second, the AR glasses can be integrated into a compact and easily manageable unit.



Binocular device



Camera sub-system



AR-glasses

Computing unit. The requirements for the computing unit are manifold. Although an off-the-shelf laptop can be used as the computing unit in general, it has to cope with a number of important constraints. From the technical perspective, the computing unit has to provide an excellent computing performance, on the one hand, and an excellent graphics performance, on the other hand. However, mobile versions of high performance computing and graphics processors like Mobile Intel® Pentium® 4 and IBM PowerPC G4 or the OpenGL supporting ATI Mobility Radeon 9600 and NVIDIA® GeForce™ FX Go5600 of today deliver the necessary computing and graphics power. Furthermore, a sufficient number of standard interfaces such as USB and FireWire/IEEE 1394 must be available to connect the necessary peripherals to the computing unit.

From the point of view of the user, ergonomic characteristics such as extended battery lifetime, minimal weight and small size are important. Unfortunately, there is a trade-off between the technical and user perspectives. Most laptop configurations offered today either focus on high performance, large screens, etc. or on long battery life, reduced weight and dimensions. Even though optimal configurations are rare, well-balanced configurations are already on the market and will be steadily improved, thus making any specialised hardware development obsolete.

Display unit. The display unit serves as the main output device of the mobile unit. It is used to present the virtual paintings superimposed onto the displayed video stream. Two different choices are possible for AR displays. One type uses a see-through scheme with the overlay images displayed “in-between” the real scene and the eye of the user. Thus superimposition of the real and the virtual image takes place in the eye of the user, which allows real stereoscopic views, if both eyes are fed with separate images. The other type has a closed back, as in VR applications displaying a readily mixed image composed of the background and the virtual objects. In this scheme true stereoscopy is harder to obtain but, on the other hand, no extra calibration of the HMD with respect to the eyes of the user is required. The AR-system simply provides the display unit with a readily mixed background image composed of the real view and the virtual objects, which is then shown to the user.

As stereoscopy is not an essential factor for the proposed application, the second option has been chosen. The device used for the display part of the AR-glasses is the Glasstron-based n-Vision VB-30, which is carried on a band around the neck of the user.

Camera. The determination of the exact position and orientation parameters of the user, the so-called pose, is based on a video-tracking algorithm (see below) that analyses the current view of the user for special features. The camera that is attached to the display unit permanently captures the field-of-view and transfers the image sequence to the main modules of the mobile unit.

The more images the system can process, the more accurately the pose of the user can be extracted. Consequently there are two primary requirements for a suitable camera: image quality and the maximum frame rate it is able to capture. Moreover, the camera must be able to capture colour images because the image sequence is used for tracking, as well as for providing the background image in the display unit. Like frame-rate, image quality, i.e. pixel resolution and colour depth, is mainly determined by the interface used to link the camera with the CPU.

Today, IEEE1394/FireWire cameras are most common in this field. As this interface has become also quite common for computing units such as laptops, it is currently the best price-performance ratio available.

Software.

The software module of the AR-system contains a number of specialised functional components for the image fusion (rendering), the determination of the pose of the user (tracking), the control of the application (application controller), the identification of the painting to be displayed (localisation) and some others like data management modules, video-capturing modules etc. The latter are not considered here in detail.

Rendering. The rendering component is responsible for all visualisation tasks that are needed to create the augmentation of the real scene. The visualisation is performed using the VR framework Avalon, which has been developed at ZGDV over recent years. This framework is capable of simultaneously rendering video streams, still images of various formats, VRML models and other formats.

Driven by the application controller, it executes the commands to display the current camera view as the background image and fuse it with a modified digitised painting that is adapted to the current field-of-view for exact superimposition. As Avalon provides a number of interfaces to control a rendered scene, including e.g. audio rendering, there are many options for enhancing the visualisation beyond the application focussed on here.

Tracking system. The tracking system determines the position of the camera pose, i.e. the current view perspective of the visitor onto a picture frame from the camera stream. The approach used is an extended version of the tracking proposed and implemented in the ARCHEOGUIDE project. It features marker-less tracking based on pre-defined reference images. The view of the user, i.e. the current live video image, is compared with the reference images and a correlation score is computed. The best score is retained and the 2D transformation between the current video-image and the reference image is determined. This transformation (translation, rotation and scaling) then is used for the adaptation of the digitised painting and its superimposition into the camera view, i.e. the placement inside the picture frame visible in the live images of the camera view.

However, the approach has some limitation in terms of the distance to the viewed scene and the viewing angle, which limits the freedom of movement of a visitor while perceiving the superimposed view. Extending the approach with mosaicing techniques leads to a more robust result with respect to movements, orientation and position of the visitor.

Localisation. The task of the localisation unit is to identify features from the live video image that enable the execution unit to determine, which digitised painting has to be processed for superimposition. This can be done in several ways. An easy approach is to use unique visual patterns that can be embedded into the empty frames. This purely video-based approach has the advantage that no additional equipment is needed for the AR-system. However, the drawback is a certain disturbance of the environment (e.g. artificial patterns are located inside or near the picture frames).

An alternative is to use specialised positioning infrastructures that allow the determination of the current position, e.g. IrDA markers, signal strength from wireless Ethernet installations or such like. However, these approaches require additional efforts and reduce flexibility in the environmental setting.

Application controller. The application controller is the execution unit that controls the overall behaviour of the AR-system. It processes the application logic, i.e. interprets the configuration or application file, which contains the information about the correspondences between identification features and digitised paintings.

It also interprets and executes user interaction commands like switching between different subsets of the virtual exhibits that belong to a particular virtual art exhibition. Besides the control of the rendering of the digitised painting, it also takes care of rendering additional information that may be defined for particular or all digitised paintings.

4 Initial evaluation & conclusions

The paper has described two different approaches for the creation of interactive exhibits in the context of cultural heritage. Both address the specific needs in the context of interactive cultural heritage applications and offer extended interaction and utilisation of digitised art works. Although neither the interactive museum exhibit nor the AR-enhanced personalised gallery have been tested and evaluated at real cultural heritage institutions like museums, some conclusions can already be drawn from the demonstration of the exhibit demonstrators within the context of the project artnouveau and art-e-fact as well as within the 3ML event.

Both approaches offer a sufficient set of interactivity at a very generic level and hence meet the requirement to be as intuitive and understandable as possible. Furthermore, they enable exploitation of various forms of digitised art works, such as resulting from the digital preservation actions currently fostered by the European Commission in the field of cultural heritage. However, it is yet to be discovered whether or not interacting with virtual exhibits will directly lead to an increase in the level of interest of the user and thus the impact on the quality of education through hands-on experiences. This is considered to be a next step, which will include the incorporation of the approaches into real exhibitions at cultural institutions.

The presented prototypes, however, cover only a limited range of potential applications. Nonetheless, they are excellent examples how to apply existing technology to cultural applications and in their generic form could form the basis for a larger set of interactive applications in specific cultural fields.

5 Acknowledgements

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