

A Mixed Reality Museum Guide: The Challenges and its Realization

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Abstract. Mixed Reality (MR) is an enabling technology for a much more interactive and intuitive experience of museum exhibits, that allows museum visitors to interact with pieces of art, without using complex virtual interaction metaphors. But MR applications for the museum domain must cope with a complex area of conflicts, which covers user acceptance, usability, copyright issues and technical feasibility. This paper describes the whole development process of a MR museum guide application for the Guggenheim Museum of contemporary art in Bilbao. An authoring-based production process, tailored to the specific requirements of MR is proposed, and its utilization for the realization of the Guggenheim MR museum guide is described. The presented authoring process is based on the AMIRE toolset, which comprises a set of tools to support the MR specific authoring tasks for authors who are not familiar with MR methodologies. The conventional programming based development process of MR applications is compared with the concepts proposed in this paper, in terms of cost efficiency, development time and maintainability. The problems arisen during the production process, discovered pitfalls and their mitigation are documented and discussed. These lessons learned during the production of the application found a basis for a set of “best practices” for authoring MR applications, especially when applying the MR technology to explore art exhibits.

1. Introduction

Milgram and Kishino defined a continuum of real-to-virtual environments and called it Mixed Reality (MR) [6]. MR includes Augmented Virtuality (AV), in which real objects are added to virtual ones, and Augmented Reality (AR), in which virtual objects are added to a real environment. A MR environment enhances the users’ perception and improves the intuitive interaction with the real world [2].

The use of MR has good potential for enhancing a museum visit and we need to carefully consider the restrictions of the museum environments. A lot of effort has been invested in using new approaches and new technologies for cultural heritage. For example, the EU-funded project *Archeoguide* allows the visitors to have personalized 3D information of

missing artefacts and reconstructed parts of damaged sites of a Greek temple [1, 4]. Another example is given in [7], where the authors present an interactive multimedia walkthrough for museum installations. The most important aspect in this project was to visualize the augmented 3D model in a highly realistic real-time presentation. The project *Lifepius* [5], a follow-up of the *Archeoguide* project, proposes an innovative 3D reconstruction of ancient fresco paintings. In contrast, the project *Charismatic* [3] is researching and designing artificial virtual humans, which become an interactive part of the attraction and enjoyment of using a system.

Today, most of the MR applications are hard coded by professionals with little reusability of the previous code. Our concept aims to open the development of MR applications to other professionals than programmers and to facilitate efficient methods for the creation and maintenance of MR applications. The authoring environment AMIRE allows people with less programming skills to be involved in an adaptable production process with dedicated phases and tools. AMIRE is developed as open source. With the high reuse of the MR content and easily maintainable MR component libraries, the development time of MR applications decreases and rapid prototyping of MR applications is possible.

In this paper, we use AMIRE to develop a MR museum guide for the Guggenheim Museum Bilbao (a contemporary art museum). We examine the specific requirements and characteristics of the MR technology in the field of museum exhibitions. The development process and the final result of our MR museum guide will be reflected from the developer's and end user's point of view, respectively.

This paper is organized as follows: in section 2 we identify challenges and opportunities of MR museum applications that derive the specification of our MR museum guide. Section 3 presents the realization of the MR museum guide, by introducing our concept of a MR authoring environment and the resulting development process of the museum application. In section 4, we sum up the experiences made during the realization of the MR museum guide and the visitor's feedback of its usage. Finally, section 5 gives a conclusion.

2. Mixed Reality Museums Applications

Currently, audio guides are used widely to offer more information and saving visitors from extensive reading. A museum visitor can explore artworks while listening to an audio recording explaining the piece of art in more detail. In AMIRE, we introduce the MR museum guide to view MR content (3D objects, images, pictures, video clips, audio, and other multimedia) about the artwork and the museum's building. In this chapter some of the general requirements and limitations in a museum environment are discussed followed by concepts how MR should be used in museums.

2.1. Requirements Analysis: Challenges and Opportunities

The MR museum guide aimed at exploring ways of utilizing MR in a museum domain. There are many museum domains, and a contemporary art museum is a more challenging environment than e.g. science museum. This is due to the fact that an art museum contains pieces of art that are meant to be experienced as such. Main challenges identified in the MR museum guide production were:

- The use of visual markers, which are black and white squares used by the tracking technology to align 3D models with the real world. The markers did not behave well in the museum environment. One reason for this was that they were not allowed to be installed permanently in big enough size, as they would have disturbed the artworks and visitors.

- The limitations on combining 3D models and other multimedia elements with the artworks. Artworks should not be “enhanced” or modified by additional visual elements. This is different from e.g. historical exhibits.

Even more challenging was the generation of ideas about how to utilize MR in a museum of contemporary art. In this manner we distinguish the augmentation of artworks and the museum itself as an architectural object. For artworks, “non-artistic” added elements would be documentation about the author, the artwork and its relation to the visitor or its surroundings, even the society. For the museum as an architectural object, the MR elements would be documentation about the architect and his design ideas, and about the construction techniques and achievements.



Figure 1. Requirements analysis with a test user on the museums balcony. The test users’ experiences and comments were documented, and analyzed against the requirements set for the MR Museum Guide in the specification phase.

The MR museum guide should run on affordable, light, easy-to-use and robust equipment (cf. Figure 4). Its user interface and media content should be extremely self-explanatory and user friendly. It should contain information on selected artworks in the permanent exhibition in such a format that using the guide does not disturb the visitor flow in the museum. Viewing the “MR exhibit” must not take much more time than viewing the artwork directly. The content should use MR elements innovatively. The users of the guide would eventually include all visitors with a wide range of characteristics, e.g. ability to use technical devices. These requirements serve as the basis for the specification of the MR museum guide.

2.2. Specification

The first version of the MR museum guide was meant to explore

- the usability of the AMIRE tools in constructing a MR museum guide
- the compatibility of traditional digital media production with MR application production
- different content types and ways of using MR content in an art museum

A MR application describing one artwork or a feature of the museum is called here “a MR exhibit”. A MR exhibit is not only a 3D element on a real-time video window. Moreover, it is a small story about real world, told by mixing digital media elements at a certain place and time in real world. Therefore, MR exhibits should contain a dramaturgy or at least a story with a defined beginning and end.

Altogether eight different MR exhibits were designed, to be viewed by the visitor in no specific order. The exhibits use digital media and mixed reality to describe artists and artwork, to explain museum architecture and to help in moving in the museum (navigation).

In the Specification phase a template for writing manuscripts (or “specifications”) for MR applications was introduced. The template considers the time and place related limitations of MR. It also takes into account other limitations set by the museum environment.

The specification (“manuscript” or “storyboard”) lists the following for each MR exhibit

- the idea of the MR exhibit
- how the visitor’s uses the MR exhibit
- MR element or approach used
- (approximate) duration of the MR exhibit
- location description
- media elements used
- list of requirements that apply to this MR exhibit

The specification process consists of

- preliminary testing of software, equipment and media in the museum environment
- exploring the museum, researching the artworks and artists
- interviewing the museum for ideas, needs and restrictions
- writing the storyboard (MR elements and other media)
- verifying the storyboard in the museum setting
- creating an initial user interface and usage logic

The eight MR exhibits present the visitor an introduction to the museum and to the MR museum guide itself, one main artwork in the museum, the main gallery’s architectural ideas, a map of the museum, navigation hints in one temporary exhibition and the basic information on the artworks in the main gallery.

3. Realization

As we have seen from the requirements and the specification and due to the complex MR methodologies, a broad spectrum of developers and content authors need to contribute to realization of such a MR museum guide. We propose our concept of a MR authoring environment and show how the development process with its iterations and the maintenance phase could be executed with our approach that addresses non-programmers as developers of such a MR museum guide.

3.1. AMIRE as a Mixed Reality Authoring Tool

The realization of the MR museum guide was carried out by using the MR authoring environment AMIRE [8]. The main characteristic of AMIRE is that authors are able to build up a MR application by using a common 2D user interface on a desktop PC and by plugging together predefined components. Additionally, at every point in time, the author is allowed to adopt the end user’s point of view. We found out that authoring MR applications is easier and efficient if the results can be directly viewed (without any transformation steps, e.g. compiling). Figure 2 shows AMIRE with the end-user view integrated in the authoring environment (upper left corner). Through the combination of the successfully approaches to employ software libraries [9] on the technology level and the usage of MR methodologies [10, 11] to support authoring tasks, the author is dealing with predefined building blocks (MR components).

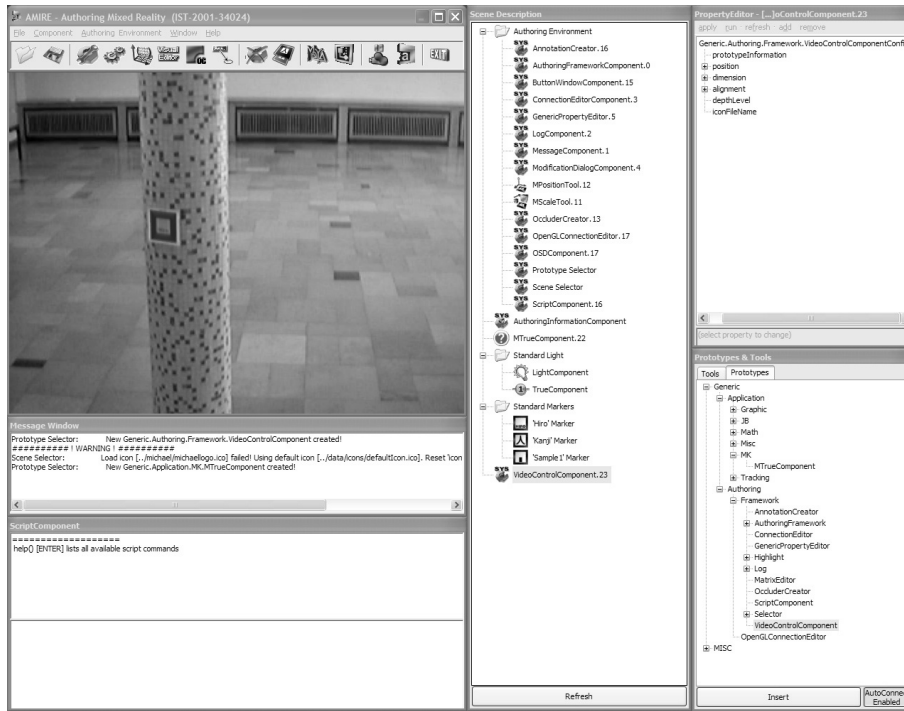


Figure 2. The AMIRE authoring environment.

Using a software framework greatly reduces the complexity of MR application development and provides a production process with four specific phases:

In the *qualification phase*, the author has to identify MR components that are appropriate with regard to the application objectives. The usefulness and applicability of the MR components as building blocks have to be evaluated by reuse engineers in the context of thorough requirements engineering.

During the *adaptation phase*, the author has to customize the MR components in order to fulfil the particular requirements posed by other building blocks or by the application itself.

In the *combination phase*, the author has to define the relationships and interaction mechanisms between a set of MR components.

Beside these standard phases of component-based development [12], MR applications rely on the (correct) alignment of the virtual objects to reference points in reality (represented by markers). This alignment is executed in the *calibration phase*, where the virtual objects that enrich real life scenes (in our case a museum of contemporary art) are precisely aligned, since this a crucial factor with regards to the degree of realism the user of the MR application perceives.

Each phase is executed by using dedicated authoring tools with a common graphical interface. The sequence of the phases in this process is not constrained to be consecutive, existing MR applications can be easily maintained and extended as section 3.3 will describe.

In order to support authors from different domains and with heterogeneous technical skills, the development process does not limit the author to reuse predefined blocks. If the author is not able to find suitable components, he is able to develop his own components or even dedicated authoring tools. Additionally, phases are supported by the provision of authoring tools on different technical abstraction levels, i.e. connections between MR components could be either defined by using a graphical user interface or by using a scripting mechanism.

The benefit of using the end-user's view during MR authoring is amplified by the possibility to allow offline authoring. Still the advantages are available, but instead of using real-time video input devices, pre-recorded video streams enable the author to preview his MR application under different conditions (e.g. lighting conditions in the museum) – even without being physically at a certain location in reality.

Our concept has also the benefit to integrate third party applications in the development process, again to widespread the available tools in order to increase the number of potential

MR authors [13]. As an example, we implemented an extension for the integration of Microsoft Visio [14]. This tool is specialized on schematic drawings. During the realization of our MR museum guide, author's used Visio since they were familiar with this application, to define the networks between MR components, thus to implement the behavior and the dependencies of each component. The AMIRE XML-based exchange format allows modifying the MR application with different authoring tools (even third party applications, e.g. Microsoft Visio) depending on the author's preferences.

3.2. The Development Process of the MR Museum Guide

Figure 3 compares traditional digital media production process with AMIRE authoring process and the traditional way of "hard-coded" MR application development (programming). The important point to notice is the similarity between digital media production and AMIRE production models. Achieving this similarity was one main goal of the AMIRE project, thus MR applications can be developed by people coming from the digital media industry, with a similar tool (AMIRE) than existing media tools. The benefit here is cost efficiency and the "availability of MR to masses".

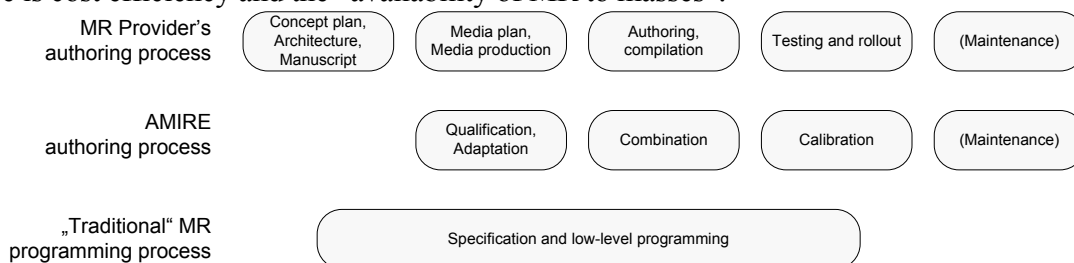


Figure 3. MR authoring process phases and terminology.

In producing the MR museum guide, the above shown model was followed. In the specification phase, the concept plan and storyboard were written, together with initial media plan, as described earlier.

In the production phase, media and MR elements were produced with traditional tools (image and audio editing, 3D design etc.) as in any other digital media project. The AMIRE authoring tool was used to develop the MR application skeleton that could be used with placeholder media elements to verify the functionality of the application even on-site in the museum. In a second steps, AMIRE was used to fill the placeholder objects with the appropriate contents, and thus the final MR application was ready for testing.

The production model separates media development and application logic development. This helped the content developer to assign tasks to different specialists, familiar with their tools. A graphic artist designed the user interface; a sound editor produced audio files as they would have done for a web site or a CD-ROM as well.

The AMIRE authoring environment was then used in testing the MR guide's functionality and usability in the museum. Needed modifications were possible to do on-site.

3.3. Maintenance and Iterations in the Development

During the development process, the design was iteratively evaluated with expert usability evaluation methods as well as with users. The evaluation results were fed back to the author's of the MR museum guide. Since our concept does not rely on time and cost consuming recompilation steps, changes and enhancements in the MR museum guide could be carried out fast and efficient.

Again, the development process involves different author groups. More experienced author build up a MR component skeleton and define the relations between the individual building blocks. Since many of the MR components act as placeholders for media elements (e.g. a MR

component that is able to integrate and visualize a 3D model), the exchange of media content is possible without any complex transformation step.

The possibility to author the MR museum guide without being present at the museum itself, but with using pre-recorded videos of the building and the artworks, allows the author to test refinements and iterate the development process as often as needed. As MR is depending on the accurate calibration of the virtual objects to the reference points in the museum (markers), iterations in the calibration phase are frequently necessary. The MR museum guide was tested and enhanced both in the development environment (e.g. an office) and “in-situ”. The objectives of the in-situ tests were to verify that the exhibits work as planned, and that all media content exists. It helped the developers to find and implement adjustments to media content if possible.

Another advantage of component based systems is the possibility to reuse existing solutions, e.g. to integrate other tracking technologies or to reuse a skeleton of another MR exhibition. This aspect facilitates the development in building up prototypes (the approach of rapid prototyping in the field of software engineering) in an early phase of the project.

4. Lessons learned

Since MR applications are seldom used by non-experienced end-users and mostly are developed (programmed) by technical experts in the field of software development and MR, we depict the experiences the end users made with the MR museum guide. Additionally, we summarize the development of a MR application with AMIRE that was carried out by experts in the field of media production.

4.1. Museum Visitors and Mixed Reality Applications

The experience from the user tests revealed that a museum visitor (cf. Figure 4) likes to listen and look, but not to be active in using the guide. The guide should offer story-like entities which do not require the user to do much. They can start and stop, but everything else should be automatic. The users were happy to get more visual information, especially the 3D models. The problem with 3D models and museums is that it is not allowed to make 3D models of the artwork without a permission of the artist and the owner. The users liked to have different content combined (e.g. 3D content and audio). In the MR museum guide all virtual objects have to be explained for the user, since the use of MR guide is new to the users. Also consistent content and user interface conventions are important to keep. This makes the MR guide much more learnable and easy to use.

When user enters to the museum they often need other services as well (e.g. showing the way to the cafeteria). The museum guide should offer the user a real time location on a map and a navigation guide to go to the desired location.

On the content level all standard good design principles apply. The basic idea of storytelling – beginning, middle and end – is the way also MR exhibits should be designed.

Most notable difference is the way MR exhibits are tied to time and place. They are not viewed sitting at a desk, but require the user to move around and use a potentially unfamiliar tool. This stresses the simplicity of the application and clarity of the media elements. An ideal MR museum guide is very limited in its interactivity: the MR elements should be interactive, but otherwise the exhibits should progress step-by-step, automatically, with no links or branching. The user interface should be fixed and predictable. The comparison here is the audio guide used in the museum. It only has one media element, audio, and the user interface consists of a numeric keypad. For many museum visitors it is still challenging to use.



Figure 4. Museum visitors with the device that runs the MR museum guide.

4.2. The Realization of a Mixed Reality Museum Guide

Figure 5 describes the relative cost and complexity of different media elements used in digital media production. MR applications require more of the most costly work – 3D models, animation and programming. Using the AMIRE tools, the time and competences required in authoring the final application are reduced, and this results in cost savings. Once the basic application was finished, the cost efficiency was even more clearly visible because the authoring tool made on-site maintenance and modification of the application very easy and quick.

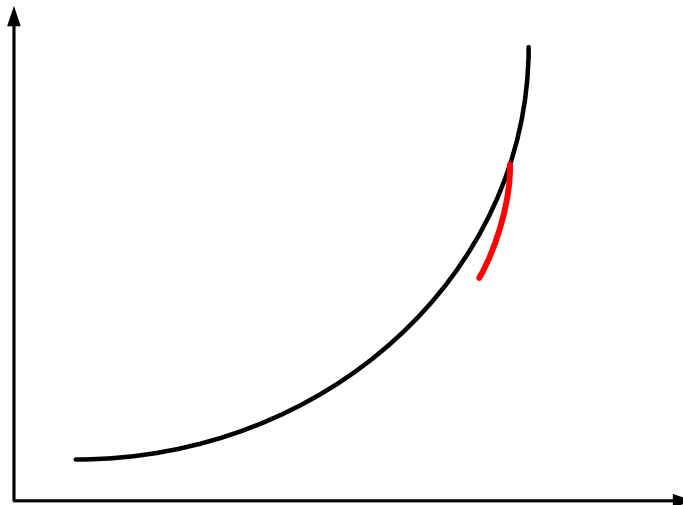


Figure 5. AMIRE effect on content production costs.

One of the major findings of the MR museum guide development was the way the limitations of real world, customers and end users are introduced in the MR design, which has so far mostly happened only on the terms of technology and in laboratory environments. Since the placement of static markers in museums is often critical, the technology used should base on marker-less tracking.

The major challenge in gathering source material (e.g. text, video, 3D models etc.) were copyright issues. Furthermore, 3D models of the artworks do naturally not exist and the museum does not possess architectural drawings in electronic format. Photographic or video material of the artworks or the museum building exists to some amount, but rarely is the best for the intended purposes. The ideal case for developing real MR content about the works of art would be to make the artists be part of content design process. This is of course very difficult and practically impossible.

A main difference between MR content production and normal digital media production is the end user environment. Digital media is used with standard consumer-level computer equipment either indoors or outdoors (PDAs and mobile phones) but in any case in a place that suits the user best. MR applications are location-based, and the designers and users of a MR application are tied to that location.

The authoring tool AMIRE makes developing MR rather easy and quick and the authoring tool adapts well to standard digital media production process. Authoring MR requires also that the user of the tool understands the concept of MR. The authoring tool is aimed at “everyone”, e.g. multimedia designers with no programming experience. Therefore AMIRE could be compared to other multimedia authoring applications (like Macromedia Flash) than to programming environments. This means that the user must spend considerable time getting acquainted with the concept of MR and the way the authoring tool works. No programming is needed, but understanding of programming concepts is needed when any complicated MR scenes with interaction are created. During the development of the MR museum guide, the combination phase took the most effort. AMIRE offers a graphical connection editor, but it does not visualize the whole network, which is even for one exhibit of the MR museum complex (about 250 MR components). The possibility to use specialized third party applications like Visio (cf. section 3.1) was appreciated, e.g. this tool allows the schematic visualization of complex scenes. The functionality of AMIRE to integrate user interaction metaphors that use MR itself ([15]; e.g. calibration of a virtual object by moving a marker in the real space) was not used by the developers in the early phases of the project. The common 2D graphical interfaces look more familiar to them. At least, once they learned how to use the MR interaction metaphors, they find them useful and intuitive.

The user testing was conducted with real end users and the live application (cf. Figure 4). The user testing was part of the production process, and proved to be very useful. Many of the comments and ideas could be instantly included in the MR museum guide, using the authoring tool. Therefore the AMIRE authoring tool actually permitted the rapid development of a prototype MR museum guide, to be further developed. MR is a totally new concept, and testing it with real users is crucially important.

5. Conclusion and Future Work

Design of a MR application for a museum is limited by the environment as well as the intellectual property rights to the artworks. Museums are delicate environments and the use of any technology should not disturb a visitor’s art experience. In this paper we have described a user-centered approach for designing a MR museum guide for a contemporary art museum and introduced the AMIRE authoring tool for the development of the application. We have explained the requirements and limitations for a MR museum application and preliminary design ideas for the case study of the Guggenheim museum application. An authoring process for MR application development is described with the introduction to the AMIRE authoring tool.

The museum environment places more restrictions on the technology than expected. The limitations of the environment are very strict and the art pieces may not be permitted to be enhanced with the new technology. During this work, we concentrate on one exhibition hall and the artwork in that area as well as the museum building, which is art in itself.

The authoring of MR can be integrated in the existing development process of media content, and this improves the applicability of MR in future customer projects. This MR museum guide is produced by a commercial company working in the e-learning content business that utilizes multimedia. The company has participated in the AMIRE toolkit development process, and sees MR and related tools as one potential means of making business.

Our approach to offer component-based generic framework for authoring MR for different group of authors opens up the widespread use of MR in variety of application domains. Due the architecture of AMIRE, the realization is open for extending the number of tools as well as the possibility to adapt it to new technologies in the field of MR (e.g. new tracking technologies).

Since the explained architecture and its tools are designed for cost-effective MR development and maintenance, data integration out of digital libraries is also considered. Using the authoring tool in the four major phases of the development process described in the paper, make it possible for a non-dedicated programmer to develop MR applications effectively with less resources and cost.

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