A MIXED-REALITY-SYSTEM FOR NON-DESTRUCTIVE RECONSTRUCTIONS

The AmbiViewer as Tool in Historical Preservation

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Abstract. Reconstructions are always altering and frequently destroying the remains of historic sites. To overcome this situation only techniques combining real-world and virtual elements are producing satisfiable results. Using a Mixed-Realitiy-system (MR) has numerous advantages: The virtual model of a reconstruction is established at the precise location where the historic construction was erected, while the preserved remains of the building are embedded in the model. If the historical appearance is uncertain, the virtual character of the model permits different opinions and a variety of states from different points of view.

1. Introduction

Reconstructions, the duplicated constructions of historic buildings or features in present times, are always altering and frequently destroying the remains of historic sites. Even if reconstructions are non-destructive, they always show only one state and one opinion in time. Reconstructional efforts on historic properties without altering the initial findings are impossible.
On the other hand, if leaving the original site undisturbed to preserve and retain it, models in all variants are created to display a specific historical context. Usually these models are shown in an educational facility nearby. This common setup limits the presentation essentially by leaving the historic remains in isolation.
Either way, the inherent and obvious implications of both approaches are not easily to overcome. Only techniques combining real-world objects and virtual elements like Mixed-Reality-systems (MR) or Augmented-Reality-systems (AR) are capable of producing satisfiable results.
This paper will introduce the AmbiViewer program, a software-system developed from scratch to mix virtual models into real-world scenes while being on site. Specifically designed to display architectural objects it utilizes cameras and GPS-receivers connected to a computer. It is capable of composing the view of a virtual model into in a real-time video stream by synchronizing the images from the real-world and perspective renderings.

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2. Reconstruction

Preservations, rehabilitations, restorations and reconstructions have found different ways and means to incorporate preserved ruins with new structures. While preservations almost leave the historic findings untouched, reconstructions are an effort to rebuild a state, which is considered an original one. Rehabilitations and restorations are in between.

2.1. ALTERATING THE SITE

In all cases alterations of the preserved ruins is inevitable, and this always means partly destructions, and sometimes as a whole. Despite these questionable circumstances around every reconstructive the biggest drawback of this approach is the reconstruction itself. Because the state of a historic site is already altered into a different one, this state is only one state at one point in time, in other words, it is a historically one, too. Sometimes this approach romantically disguise history, sometimes it preserves it, and sometimes, as e.g. in the case of the Renaissance, it creates new artifacts, which are valuable by itself.

Figure 2. The Palace of Palenque, Mexico, with it reconstructed tower.

In any case, the approach to physically alter ruins never leaves any other opinion behind. The altered state is fixed, and therefor fixes the perceiving reception of the reconstruction and its underlying historical findings.

2.2. CAUSES AND INTERESTS

The question is, why reconstructional efforts are so desirable, and the answer is easy and well known. People as laities often have not the skills to imagine a historic construction based on some stones laid-out in the dust. Reconstructions are erected for educational and sometimes ideological purpose, despite the risk of manifesting mistakes, intended or not. In addition, reconstructed sites provide the knowledge of new discoveries for all kind of people and therefor are attractive, and even more, become attractions. Such sites achieve quite an economical impact, and whole regions are dependent on the experiences of travelers to remote location.

Touristy interest are usually the driving force behind reconstructions, and therefor the destruction of historic ruins.

3. Virtual Reality

With the introduction of computers and related technology another approach has emerged and is advancing: virtual reconstruction. Computational three-dimensional models, whereof virtual realities are based on, have a number of advantages. They are not altering the state of the historic site anyhow, their state itself is not fixed and can easily be changed, and working with virtual models depends not on any physical location. It can be done in a cozy den as well as on site. Additionally these models are transferable and deployable, everybody with interests on it can obtain, and with the right tools, manipulate them.

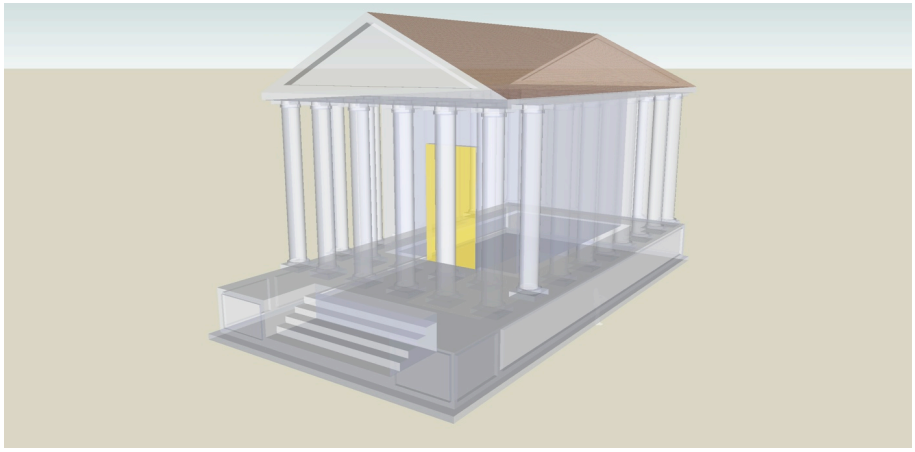

Figure 3. Virtual Model of a Roman Temple, made with GoogleSketchup.

Virtual models are focused on the construction itself. Lesser care is taken of its surrounding. Often these models are build upon single-colored flat panes, even if the surroundings is more elaborate the virtual model is always limited to the proximity of the site. To reduce the irritation caused by those limitations the background is covered with fog and cloud. The technique of eliminating distant parts of a model in order to limit the amount of pixel calculations is widespread in digital graphics.
To overcome this shortcoming real-world images are composed manually to enhance photo-realistic models with an even better real background. Otherwise the virtual model is isolated. However, a photomontage is no longer a virtual, but a mixed representation.

3. Mixed Reality

The term "Mixed Reality" is used to describe the merging of real world objects with virtual objects in its broadest sense. It covers all combination between real and virtual worlds, including Augmented-Reality and Hybrids. Although his term is widely accepted, it should be noted that the usage of the expression is only as technical description. By no means a "mixed reality" should be assumed as real.

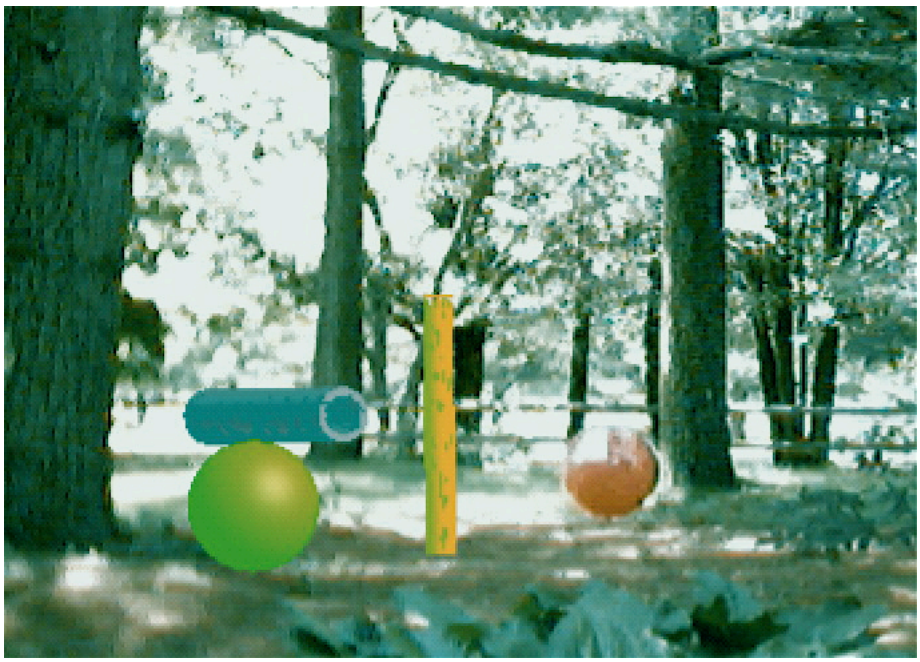

Figure 4. Real Scene mixed with simple three-dimensional Objects, made with AmbiViewer.

In the realm of historic preservation and reconstruction Mixed-Reality is understood as a remodeled virtual construction at the same location in the specific environment where a former real construction was existent.
The historic construction is virtually created by computational means and then projected on an image taken from the real scene. This does not only leave the historic findings untouched, it also allows modification on the model. In addition the environment is taken as it is, incorporating even remote landmarks into the mixed scene. The evaluation process, whether a reconstructed virtual model is meaningful or not is as directly as possible and can match a conventional reconstruction. However, it is not correct, it can be changed.
With the right tools at hand, like head-mounted-displays and other gadgets, Mixed-Reality-System can also provide impressive simulation to entertain visitors and travelers and turn the site into an attraction.

4. Technical Overview of the AmbiViewer-system

The AmbiViewer-system is particularly intended to display objects with a notably size. By matching the view of a real camera with the perspective rendering it projects three-dimensional virtual objects into real-world images. The actual software utilizes cameras with mounted GPS-receivers and an additional GPS-receiver placed on a marker-object. All devices are connected to one laptop computer.

Figure 5. AmbiViewer-system with Computer, Marker, Camera and GPS-Receiver –system.

4.1. IMAGING

Images are real world scenes captured by the optical system of a camera. These images or, in the case of a video stream these frames determine the parameter for the composite images, especially format and resolution. The values taken from the original source are applied to the renderings and then the final compositions. By no means the viewport of a rendering needs to be any larger than the final composite image could be in order to preserve valuable computational performance.

Figure 6. Digital Video Camera-*system attached GPS-Receiver*

In addition, the computational process of digital video does allow manipulation using image processing. Transforming a realistic photo into an image with less information, or more abstraction can provide impressions yet unknown to the field of Mixed- or Augmented- reality systems. This filtered image stream or filtering in real time is still in an experimental state.
The imaging part has also one limitation: because the system uses a fiduciary feature, this marker needs to be visible for the camera. Otherwise the process of detecting the marker and calculating the perspective is simply not initiated.

4.2. GPS

Using the Global Positioning System (GPS) as part of the system provides it with affordable positioning devices. Since 2001, after the signals of the satellites were no longer jammed, this technology has quite remarkable evolved and now is changing our lives substantially. This technology provides devices to locate almost every outdoor position on the surface of the Earth in an accuracy less than one meter, and they have become very affordable. A common GPS-receiver now sells less than $ 100 US.
However, the use of GPS-receivers as part of the AmbiViewer-system lies not in the well-known field of tasks in mapping and global navigation, when one receiver marks a point. Instead a group, at least two receivers are used for measurement tasks. Connected to a computer, the distance between a GPS-receiver located on a fiduciary feature, usually a marker ball, and another one located on a camera is calculated from the positioning informations to determine estimated viewing directions and, by detecting the marker, to calculate the field-of-view of a camera.
Otherwise the use of a calibrated camera would be mandatory. This common limitation to Augmented-Reality-Systems was considered unacceptable, because it would curtail the set of suitable cameras for the task and skyrocket the expensive.

4.3. MARKER

In combination with an attached GPS-receiver the design of the marker, or fiduciary feature, can be as simple as possible.

Figure 7. Marker Ball with attached wireless GPS-Receiver.

The single mandatory feature is the length of one detectable distance of the marker at a known position. Compared with markers and marker-systems from other systems with groups of markers or a whole wealth of geometric shapes this single characteristic does allow the simplest geometric shape, the sphere. A sphere has some additional advantages. It provides the same view from all directions, and partly obscured markers remain detectable. It is contemplated, that the diameter of a sphere can be determined even if only one third of it is visible.
The three-dimensional marker with an attached GPS-receiver should be placed at or near the location where the historic construction was located. It is used to calibrate the cameras in order to synchronize the virtual canvas with the image plane of the real-world camera. It is also the one element that alters the preservation, however it is distinguishable and not permanent. Also the use of a captive balloon is under evaluation

4.4. MODELER

Although reconstructions are restricted to their
Virtual reconstructions and their renderings are commonly in a fixed state, even if they sometimes provide a timeline. Deploying a sophisticated Mixed-Reality system onto remote sites simply asks for a tool that does not rely on prefabricated models out of the studio or laboratory.

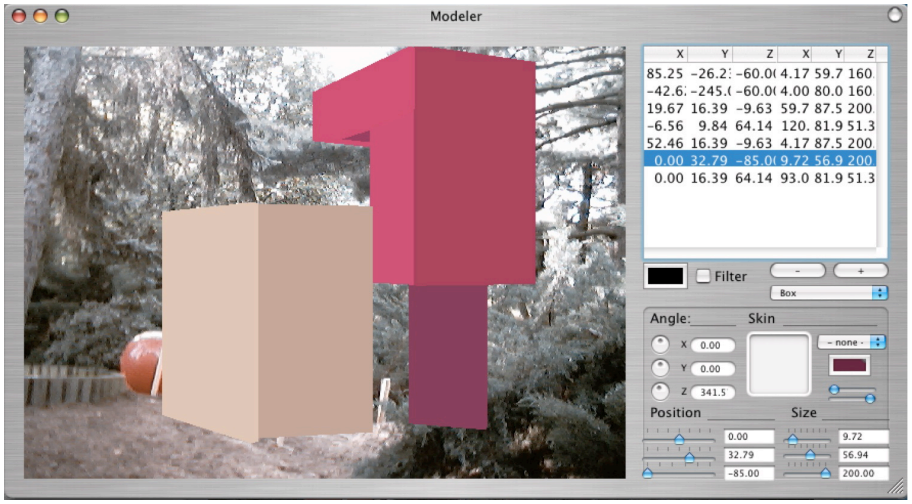

Figure 8. Interactive Modeler with User Interface.

For this purpose an Interactive Modeler is developed to create and manipulate three-dimensional shapes on site. Accessing the parameters to manipulate the geometry and the surface of three-dimensional shapes enables users to modify a reconstruction in every aspect. Notably professional users would be given the potential to check and revise their hypothesis regarding specific reconstructed models.

4.5. COMPOSING

Similar to most Mixed-Reality-Systems the final step, composing the real-world image based on a photo and the rendering, is layering. Compared with other techniques as photomontages or even artwork there are no final corrections. The quality of the resulting depends directly on the measurements and calculations inside the system.
While this technique enables real-time working and also fast changes of both the model and the camera direction, it should be noted that the perceived quality of the result highly depends on the specific educational background of the viewer. If there is a lack in quality, as e.g. lighting, an amateur or a tourist would complain while a professional user would have no problems to focus on the intended view.

Figure 9. Composite Images with big marble Column.

5. Future Development of the AmbiViewer-system

Working with the first prototype, with the final version in 2005, has shown some shortcomings that need to be addressed in the next version.

5.1. FILE FORMAT

The AmbiViewer is one of very few programs that make use of geographic information in three-dimensional models. Usually this information is ignored, although every architectural object has a unique unchangeable location. If a model is created with conventional CAD-programs, this model can be placed elsewhere, because the exact geographic position is not applied.

5.2. RANGE OF GPS-DEVICES

A special problem is the limited range of the devices. While the GPs-receivers of the actual version of the AmbiViewer-software are directly connected to the computer, either as wired via a serial connection or wireless by the 'Bluetooth'-technology, future versions will be based on networked connections as well. This allows greater distances, especially between the receiver on the marker and the cameras, and, if IP-based connections are implemented, will exceed the possible range to almost any global position with access to the Internet.
This approach is based on the use of additional computers. Compared to the actual prototype with only a single computer it will not only reduce the clutter but also balance the calculative demands.

5.3. BANDWIDTH LIMITATIONS

Although the use of one computer does not limit the theoretically number of cameras anyhow, and with it the number of perspectives for the rendering, it has been evaluated that for practical use nor more than three cameras are reasonable),

Figure 10. Simultnious view of 6 Cameras with Camera 1 down

For this reason a one-to-one solution (one camera-one computer) would be desirable. If more views are needed from different locations at the same time, an established network is mandatory to disseminate and distribute the positioning information and the model.
In addition the graphical performance (as frames per second) would stay on a level for a real-time experience.

5.4. ENVIRONMENTAL PARAMETERS

Because a known object is inserted in the images of the real world, the fiduciary feature, it can be used to detect the specific lighting in changing

weather. While the position of the sun is derived from the exact time and geographic position as taken from the GPS-receiver, and, under the condition that the surface of the marker is known in color and reflection, observations on the marker can used to simulate the exact lighting situation. Applying parameters in the virtual model for ambient and direct light sources according to the actual situation simulate the reconstruction almost naturally.

5.5. COMPLEX COMPOSING

The biggest challenge is still the foreground-background problem. The double layer technique only allows placing the virtual model in front of the scene. With techniques around to detect and subtract those parts of the scene, which are the foreground, e.g. a tree, these part can be placed on an additional layer, which is placed on top of the composite image. It should be noted though, that especially the feature detection without a-priori information, as compared to the case of the marker, is very demanding.

6. Conclusion

Although the AmbiViewer-system is still under development, the prototype already proves that an on-site reconstruction is no longer based on physical constructions. Projecting and displaying virtual models on the exact spot where a historic building was located enables researchers and visitors the unique experience of the site with all its remains and also an insight how the state of the building was at its time, but does not limit it to the one and only state it would, if it was really rebuild.

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