

Mixed Reality @ Education

Michael Haller

Upper Austria University of Applied Sciences (Media Technology and Design)

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Abstract:

Augmented reality is a new way that augments virtual and artificial objects on the real environment. The aim of this paper is to show the integration of this technology in the education. Can we improve our lessons by using this technology or is it only a hype and consequently worthless for us? Different examples using the AR approach will be presented. Finally, we show the advantages and disadvantages of this technology.

Introduction

When Ivan Sutherland introduced in 1961 for the first time the head mounted display (HMD), nobody noticed that it was the start-up of the new technology of Augmented Reality (AR). Milgram defined a continuum of real-to-virtual environments and called it Mixed Reality (MR). It includes pure 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 (cf. Figure 1).

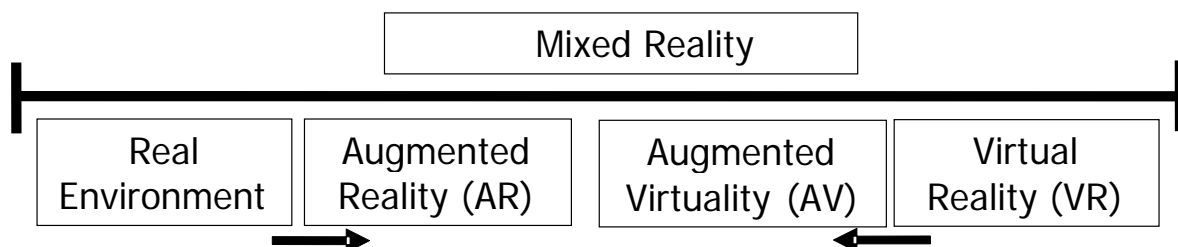


Figure 1: The Mixed Reality Continuum of Milgram includes two stages, starting from the augmented reality environment and ending in the augmented virtuality environment.

A Mixed Reality environment enhances the users' perception and improves the intuitive interaction with the real world [2]. VR technology completely immerses a user inside a synthetic environment. While immersed, the user cannot see the real world around him. In

contrast, AR allows him to see the real world with superimposed, virtual objects. Therefore, AR supplements the real world rather than completely replacing it. In most cases, a VR environment includes a very complex technical installation and thus its technology is mostly used for expensive training simulations (e.g. flight simulators, ship simulator). One of the main goals of AR is to reduce these costs and to use cheaper hardware with the goal to achieve the same results.

In the following section, we start with a discussion about related work. Then, in the next section, we demonstrate three possible augmented reality applications for education, followed by a description of the benefits. Finally, we conclude with a summary and future work.

Related Work

The MagicBook [3] interface supports new forms of educational experience, where textbooks no longer are static sources of information. This work explores the transition between Physical Reality, Augmented Reality (AR), and immersive Virtual Reality (VR) in a collaborative setting.



Figure 2: Students get a more exciting overview of the earth using MR technology [6].

Woods et al. extended the MagicBook idea and developed the Augmented Reality Vulcano Kiosk, which teaches people about volcanoes and tectonic plates (cf. Figure 2) and the S.O.L.A.R system (solar-system and orbit learning in AR) [6]. Poupyrev et al. presented in [4] the “Tiles”, a MR authoring interface for easy and effective spatial composition, layout and arrangement of digital objects in MR environments. Another good example of using AR in

education is Construct3D, a mathematics training program based on the Studierstube-framework [5]. The authors of Construct3D use see-through head mounted displays to allow users to collaboratively view 3D models of scientific data superimposed on the real world. A very important goal of Construct3D is the collaboration functionality that supports both, teacher and student to work together. In addition, teachers can get more detailed information about the exercises (e.g. the solutions), while the students get only less information displayed in their HMDs.

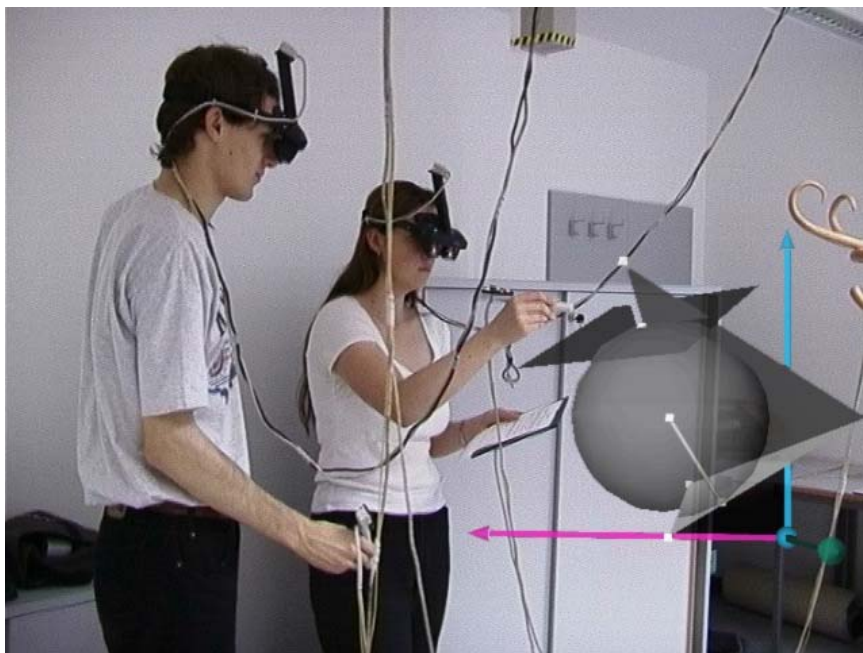


Figure 3: Students can explore math in a more exciting way using Construct3D [5].

Augmented Reality for Education

In the following sections we present three different applications that can be used for education and training. The first application describes an AR based training program for an oil refinery. The second application, FaiMR, is a furniture assembly program and shows how people could get trained during an assembly process. FaiMR is specially designed for furniture assembly, but it can be used everywhere, where assembly instructions are needed. Both applications are based on the AMIRE (Authoring Mixed Reality) framework [7]. AMIRE is an EU-funded project and its purpose is to create authoring tools that enable non-dedicated MR application developers to create MR applications. With corresponding visual programming interfaces, non-programmers get the possibility to author their MR applications instead of coding them. And finally, we present the ideas of a novel future-lab using augmented reality technology in a projection screen environment.

AR based training program for an oil refinery

The motivation for the refinery was to develop more attractive teaching environments to achieve more productivity and more attention of the employees. Currently, refinery training lasts for more than one year, where the employees get mostly a theoretical background in the classes. When they do on-site training in the refinery, a teacher has to follow the trainee individually. Moreover, this training situation becomes a hard task for the trainees, because they may not switch to their lesson material, when they are standing in front of a huge column. In the classes, they often get taught 2D schemas and sometimes they see models and parts of the machines. But when they go to the outdoor training, the reality seems to look completely different, and they often feel lost. Consequently, it would be very useful to get a hardware device for outdoor training support with additional information depending on the location. Autonomous navigation training through the refinery without the help of a trainer and without stopping the production process is the main goal of the oil refinery in the AMIRE project. Moreover, the goal is to use AR technology to enhance the users' perception during their training tour that should be achieved by a seamless overlapping of virtual information onto the real objects.



(a)



(b)

Figure 4: In AR the user can use either an HMD (e.g. using the MicroOptical device as depicted in (a)) or a Tablet-PC (b).

The first idea was to use an HMD as depicted in Figure 4 as output device and a laptop in the backpack. By using the MicroOptical output device, the trainees would not be handicapped with their hands for further operations. Unfortunately, employees of a refinery have to wear safety glasses. Moreover, they should not be limited in their field of view and they need a very intuitive input interface, which hindered us to realize this idea. Consequently, in our system we used a Tablet-PC with an attached camera to the back of the device for capturing

the real environment in real-time. For the tracking of position and orientation we had also to find another solution instead of using GPS for achieving the position and an inertial tracking for the orientation. A refinery is full of steel that reflects and disturbs the GPS system and thus it makes it un-usable. We measured an inaccuracy of 16 meters in the refinery by using a GPS receiver. We used the marker tracking system ARToolKit [8]. The camera of the Tablet-PC registers the markers that are mounted on the different refinery machines and consequently the application gets of the ARToolKit library the 3D position and orientation relative to the camera.

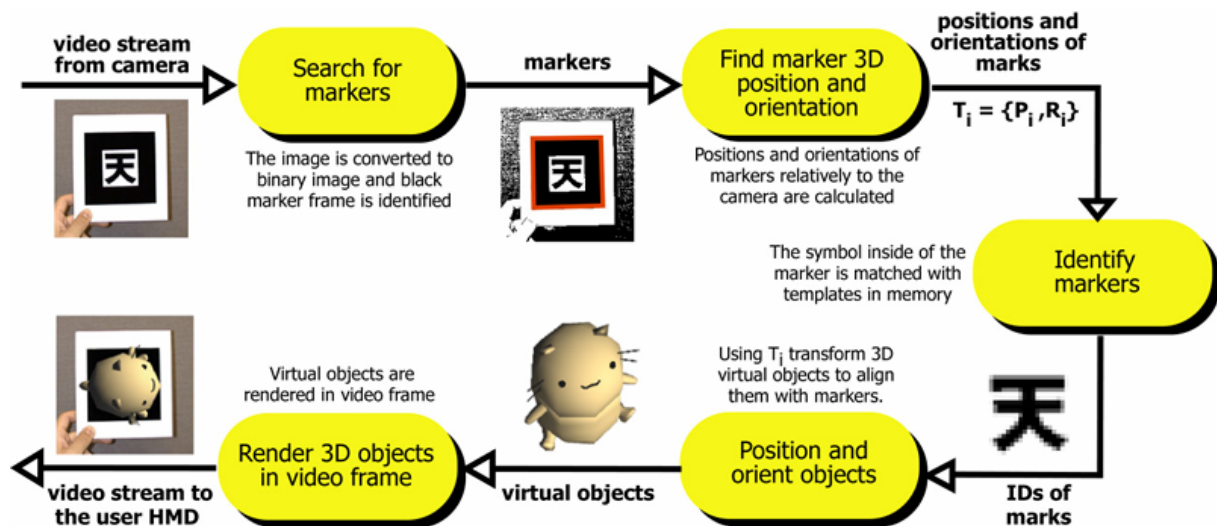


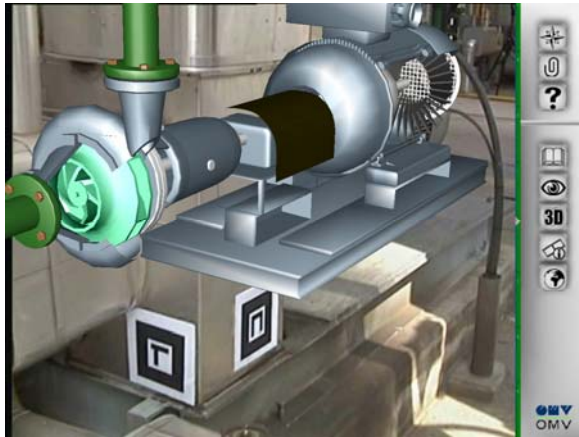
Figure 5: The basic principles of the ARToolKit. The marker is recognized by a camera and the position and its orientation is forwarded to the OpenGL renderer accordingly [8].

Of course, all augmented 3D objects in the real world have to be measured once at the beginning of the calibration step. This task would be very difficult without the help of corresponding tools. AMIRE offers a set of tools that support the authors to “implement” and to calibrate their AR application in a more efficient way. A more detailed description can be found in [9, 10].

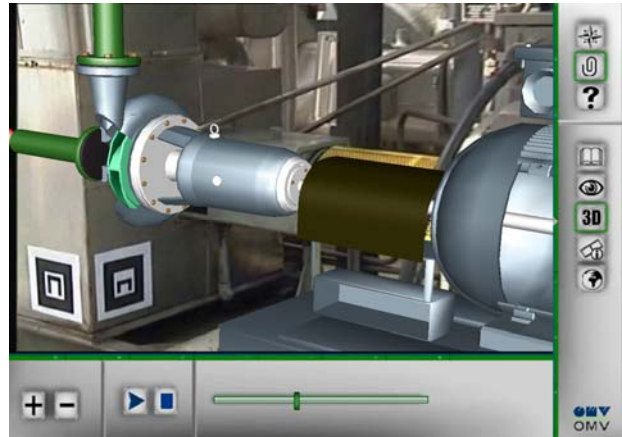
The decision of using a Tablet-PC was a trade-off between finding a device with the best performance and finding a hardware that is small and intuitive enough for supporting fast AR-training. Using an input pen allows the user to touch the screen in a very intuitive way. Moreover, current Tablet-PCs have already enough graphics power (though that they have already new generation GPU chips inside). On the other side, they are still too heavy (> 1.4 kg) and the trainees have to hold the device in a way that they have to focus to the marker to get a superimposed information. Figure 6 shows some snapshots of the current refinery application. Once a marker has been recognized by the system, the users get different interaction possibilities depending on their position and the object they are looking to. In the

first figures (a) and (b), the trainee gets a 3D model showing the inside parts of a pump superimposed on the real one. Without the use of Mixed Reality, the user would see only the reality. Thus, seen from the outside, only the motor and box of the pump would be visible. During our tests we recognized that the refinery employees liked the 3D animation a lot, but they found it also good enough to get a pre-rendered animation or a movie (cf. figures (c) and (d)). Moreover, the use of ARToolKit for tracking was of course not the best decision – the marker detection depends on the quality of the used camera and the environment condition. In the refinery the steel is reflecting a lot, and thus a jittering of the markers can occur. The tracking system fails whenever a marker gets invisible or/and occluded by another object. A good solution for that problem is to use more than one marker for tracking one object. Another solution is to give to the employees the possibility to freeze the actual camera input stream once the marker has been recognized and when the object is augmented accordingly. After freezing the actual input stream, the user can hold the Tablet-PC in a more comfortable way, because the object still remains recognized, even if the camera is not pointing to it. Another important thing that has been recognized during our tests was the fact that older oil refinery employees are already familiar with CAD maps and with 2D schemas. Moreover, they inspect information from unit diagrams, descriptions and handbooks. Therefore, 2D information is more significant for experienced people instead of 3D rendered objects: by clicking a symbol in the screen, employees can get an overview description of the whole refinery and about their location (cf. Figure 6 (e)). Moreover, they can see a certain measurement or other information about the device. It is more difficult for new employees to understand the process details, to understand the schematic diagram (flow diagram) of a plant and to translate it into real refinery equipment without the help of an experienced trainer. Finally, visual hints give the user a visual feedback in the real environment. Figure 6 (f) depicts an example, in which the trainee gets a transparent virtual object superimposed onto the real pump. Once the users click on this object they get more information about it.

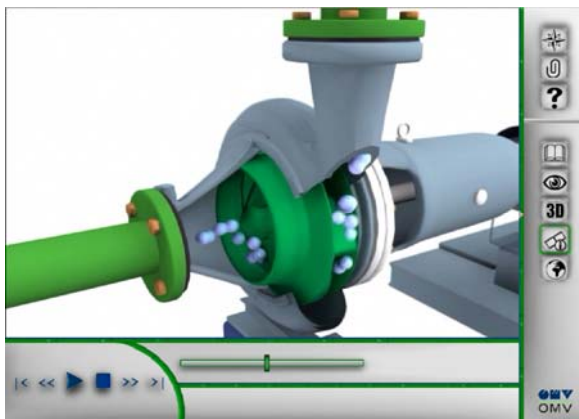
The usage of a Tablet-PC was a good decision regarding the usability. Trainees did not feel lost during the tests and they found it very useful to interact with the pen on the input-screen. The disadvantage of the device is the weight. 1.4 kg is still too heavy thinking of a training tour that normally takes between 1 hour and 1.5 hours. A smaller device, such as the iPAQ handheld PC, would be helpful. Another important feature would be the direct connection to the control point, in which data (e.g. temperature, pressure) could be shown on the output device in real-time.



(a)



(b)



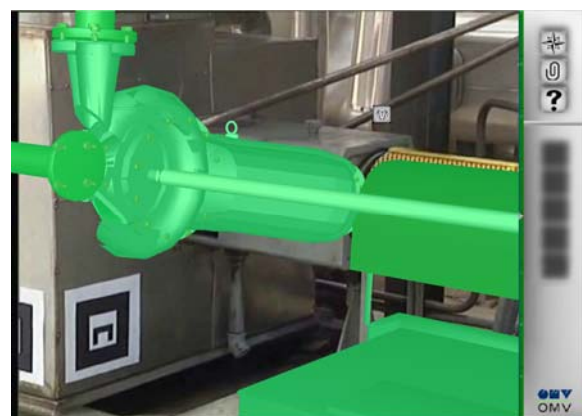
(c)



(d)



(e)



(f)

Figure 6: The different superimposed information in the oil refinery application. (a) and (b) show the superimposed 3d geometry that is oriented and placed accordingly the movements of the user. Moreover, the trainee can get small explanation animations (c) and movies (d). An overview of the refinery is given in (e) and finally we use hints (f) for giving the user a feedback with which of the objects the user can interact with.

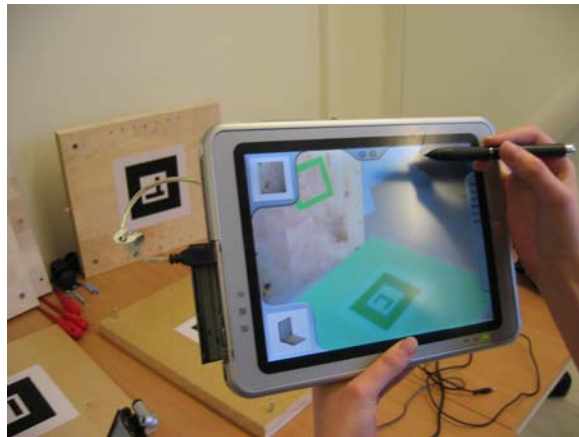
FaiMR (Furniture Assembly Instructure using Mixed Reality)

Mixed Reality is also a very useful and powerful instrument for the visualization of processes, including the assembly process. In the oil refinery application users didn't get a description how to assembly a plant, because it was not required by the oil refinery company. People simply do not have time to bother with instructions and studying manuals. Our goal in the FaiMR project was to provide a powerful, flexible and easy-to-use AR based wizard tool for assembling furniture. Again, both setups a HMD setup and a Tablet-PC version are thinkable. A possible scenario is depicted in Figure 7, where the user wears a head mounted display and a camera mounted on in front of his HMD. For tracking the position and orientation, we used the ARToolKit, described in the above section.

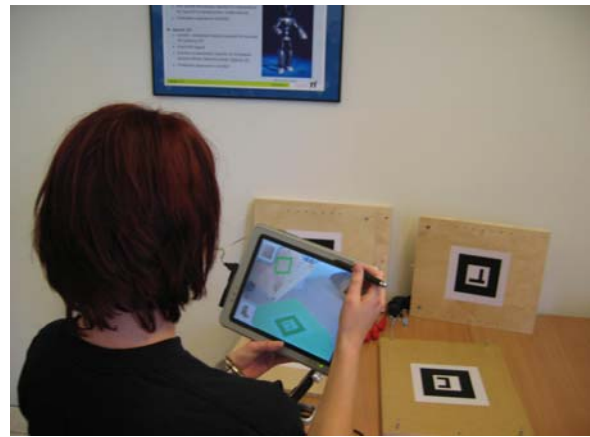


Figure 7: The user can use an HMD to get the necessary information where to place the next wooden feet of the table.

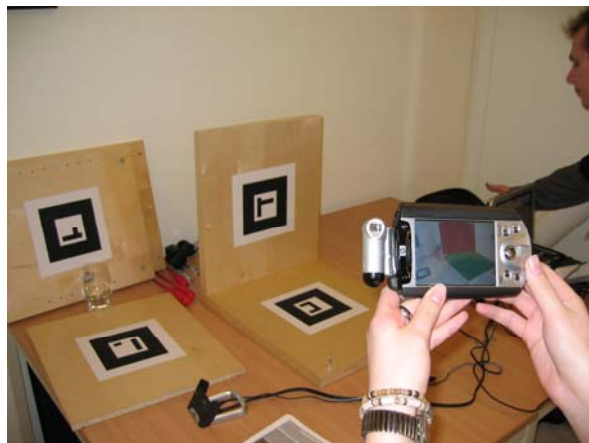
In the second version, the user takes a Tablet-PC. The most important advantages here are the intuitive user interface and that the users get a step-by-step description about the assembly process. All wooden components have a marker and can be tracked individually. Augmented, highlighted boards help the user to find the right boards and to mount them in the right order. Moreover, users get information where to place the different components and how to connect them. Again, the application is based on the AMIRE framework, and thus it is authored using the AMIRE authoring tools. In addition we ported the AMIRE framework together with the IMS (TU Vienna) to the iPAQ environment.



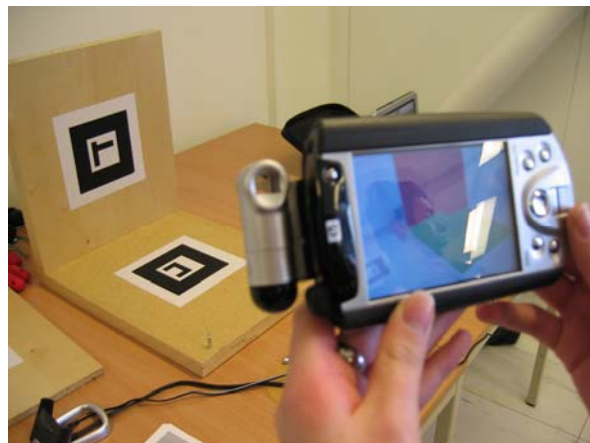
(a)



(b)



(c)



(d)

Figure 8: In FAI-MR the user gets step-by-step 3D-instruction that is augmented onto the real objects.

The AR based Future-Lab

The AR based applications presented before have shown an example, how people could get help using AR technology in an autonomous way – without the help of a teacher or trainer. But the fascinating technology of AR can also be used in addition to support the teachers during their training session. In this section, we want to introduce a future-lab based on AR technology. Our Future-Lab is a computer-augmented room including elements like complex objects (e.g. machines which are to explain) with integrated information and communication technology). We think that a projector based AR system would be the best solution for a collaborative work with the students. Figure 9 shows a possible AR setup. Instead of a virtual workbench, people still see the real objects – and only additional information is projected

accordingly. In this example two cameras track the users' hand-movements and thus allow a very intuitive interaction with the real and virtual objects.

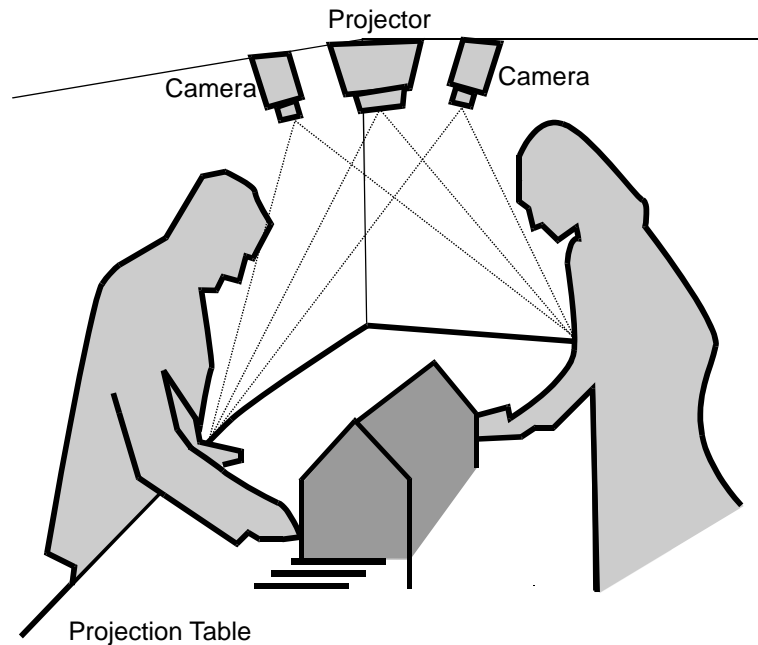


Figure 9: 3D models and augmented objects are projected to the projection table. Thereby teachers can show to students complex things in a more intuitive way.

The "world around us" is the interface to information and for the cooperation of people. It requires an integrated design of real and virtual worlds augmenting reality. In this approach, the computer as a device disappears and is almost "invisible" but the functionality is ubiquitously available (ubiquitous computing).

But teachers do not have to work with their students in the same room. A possible scenario could be as follows: we plan to combine the enhanced bandwidth capabilities of broadband networking with Mixed Reality technology to prototype the next generation of teleconferencing interface. Traditional videoconferencing has numerous limitations, including lack of spatial cues, a very limited screen space and a separation between real and digital objects in the world. We will use Mixed Reality technologies to superimpose output from a 3D virtual viewpoint camera system over the real world.

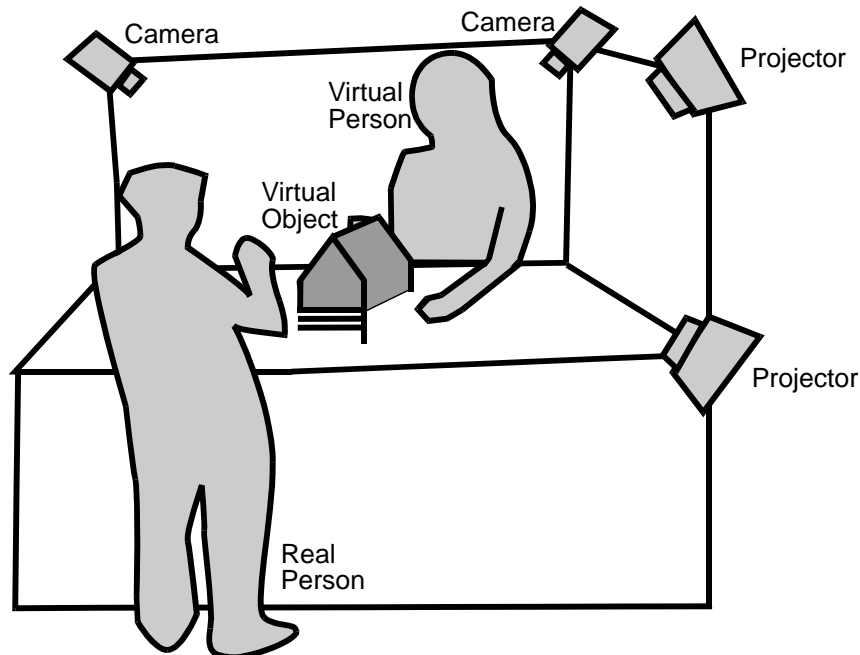


Figure 10: In this scenario the real person can communicate with the other person (virtual) and show her the virtual object. In contrast to traditional teleconference scenarios the remote person is seen in 3D and seems to be really present in the room.

A similar approach is postulated by Cheok et al. from the Mixed Reality Lab of NUS [11]: users will see life-sized live 3D virtual images of remote collaborators standing in the real world in front of them (cf. Figure 10). It combines Mixed Reality and traditional telephone conferencing system, where the users are not seen in a flat 2D window, but in a full 3D environment. Thereby, New Media and multimodal interfaces that support communication are of tremendous importance in ensuring efficient collaborative teamwork. The user interfaces have to be intuitive as possible. The use of HMD reduces the acceptance of the people to use this technology. We noticed that after a short fun-factor of wearing an HMD, people do not like to use a MR setup where they are embodied by a full wired hardware setup.

Expected results and benefits of using Mixed Reality

Using Mixed Reality technology allows an exciting training, in which users can actively explore new things without the help of experienced people. Trainees are actively involved in

the education process and thus they remember more than without using MR. The following scenarios show some possible examples including new ways of the integration of this media:

- **3D books:** for example the Olympic Games of the Ancient Greece, where the students can read a real book, and then see 3D figures of Greek athletes on the actual pages, moving and jumping. Moreover, it would be very fascinating to be able to "fly" into the book and experience what the Ancient world felt like.
- **Training simulators:** The use of "mixed reality" greatly enhances training realism in training-simulators. Computer-generated objects, that normally are invisible in the reality, are superimposed onto the real world and thus support more detailed information about the production process.
- **Live virtual tours:** for example imagine walking through the Guggenheim museum of Bilbao by using MR technology. Especially there, the reconstruction of the building would be very fascinating. Moreover, the overlapped scribbles of Frank O. Gehry would make the tour unique.
- **Architecture:** for example converting an architectural drawing and have them appear in 3D form right onto your desktop. You can see the 3D building appearing in 3D in your real world, and then "fly" into the inside of the building and explore it floor by floor. Interior decoration can become so much more realistic and exciting when you can conduct a real 3D renovation.

Of course, we will find more possible MR applications and we believe that it is just a starting point to get new ways of using this fascinating technology.

Conclusion and Future Work

In contrast to VR, the users still can see the reality in a Mixed Reality environment. Consequently, we achieve two benefits. First of all, we do not have to replace the huge amount of objects of the real environment. Moreover, also the trainer or the teacher does not have to be integrated in the virtual scenario as an avatar. Another advantage is that the users do not feel completely lost and alone and they have still the feeling to be in the real environment – moreover, they believe more in the results of an AR training: we recognized that VR has still the touch of a computer "game" and therefore it is really hard to convince people that the existing simulation is not just another game. But also VR has its benefits: dangerous and stressful situation can be simulated that would be too critical to explore in reality. In contrast, in an AR training environment not all of the real objects have to be mapped into the virtual world. Consequently, we can reduce the amount of virtual objects tremendously which results in a better performance. On the other side, the augmented

objects have to be shown in real-time to the users' display. If there is no seamless integration of the virtual objects into the real environment, users feel often sick. Therefore, we still have to improve the visual representation of AR applications to achieve better training applications.

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