Mixed Reality Training Application for an Oil Refinery: User Requirements

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Abstract

Introducing mixed reality (MR) into safety-critical environment like oil refinery is difficult, since the environment and organization lays demanding restrictions for the application. In order to develop usable and safe MR application, we need to study the context of use and derive user requirements from it. This paper describes the user requirements for an MR based oil refinery training tool. The application is aimed to train employees of a specific process unit in the refinery. Training is currently done mainly in a classroom and on-site only when the process is closed down. On-site training is necessary, but expensive and rarely possible. The use of mixed reality offers a way to train employees on-site while the process is running. Users can virtually see "inside" the columns and can modify virtually the process..

CR Categories: H.5.1 [Multimedia Information Systems]: Augmented Realities; H5.2 [User Interfaces]: User-centered design.

Keywords: Mixed Reality, Usability, Requirements, Industry

1 Introduction

Designing mixed reality applications for new domains demands careful consideration of the possibilities and restrictions of the environment. MR is a technology that involves the merging of real and virtual worlds somewhere along the "virtuality continuum" [Milgram 1994]. This connects completely real environments to completely virtual ones (cf. figure 1).
The use of mixed reality enhances users' perception of and interaction with the real world [Azuma 1997].

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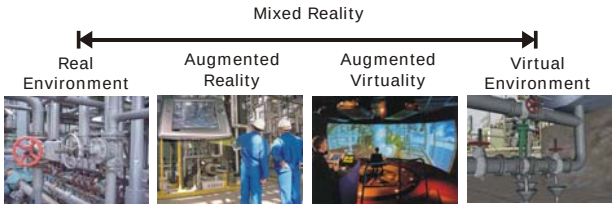

Figure 1: Virtuality continuum [Milgram 1994].

The virtual objects display information that the users cannot directly detect with their own senses. The information conveyed by the virtual objects helps a user perform real-world tasks.

The goal of the future training is to develop more hands-on training in the field. The limitations of the refinery environment and future goals inspired an oil refinery to look into new kinds of training methods and the use of mixed reality. Currently, training of the employees in an oil refinery is done in classrooms and as training in the plant. When the training is conducted in the field, parts of the plant need to be shut down (a very expensive task). Usually, the on-site training sessions are the same time than maintenance breaks, but this is rarely possible. In the on-site training the trainees can look into some of the processes, but they cannot try out different control values.

In the study by Guerlain et al. [1999], the authors developed personal information processing system solution for the roving industrial field operator. It comprises an radio frequency (RF) network to deliver wireless digital information a wearable computer for delivering web-based information and software applications that provide added value in the plant. They found that MR application in the oil refinery needs to be stable and able to handle harsh environmental conditions. They also found the following requirements for the oil refinery environment:

- Intrinsic safety of the hardware;
- Software have to link to live processes and deliver real procedures;
- Users need to be able to climb and use the application with other tools they are carrying and with their protective clothing;
- Accurate communication in an difficult environment (due to the large quantity of pipes, metallic structures and reinforced buildings). According to Azuma [2001] tracking the user's viewing orientation and position is crucial for MR registration and for the use of the application.

This paper reports user-centered requirements for the on-site training tool for oil refinery employees [Haller et al. 2003]. It is conducted in an EU-funded AMIRE (Authoring Mixed Reality) project [AMIRE 2003], which purpose is to create an authoring tool that enables non-dedicated MR application developers efficiently create MR applications. Two

demonstrator applications are also built: training application for oil refinery and visitor application for a museum.

In the following chapter the objective and methods of this study are presented followed by context of use analysis and the gathered requirements.

2 Objective of the Study

The AMIRE project's objective is to develop a usable mixed reality authoring tool and two demonstrator applications. The objective of this study is to specify requirements for the oil refinery training tool using mixed reality. The requirements will be used to assess the usability of the forthcoming demonstrator during and after the application development. The ultimate goal is to develop usable MR training application for safety critical environment for training in the field without stopping the refinery processes.

3 Method and Implementation of the Study

In order to achieve the goal of usable MR application a user-centered development process was adopted based on the ISO 13407 [1999]. The starting point is the active involvement of users and a clear understanding of user and task requirements. This is achieved by studying and understanding the end-user's context of use (ISO 9241-11 [1999]: user, tasks, equipment and environment). Also a model by Gabbard et al. [1999] for user-centered design and evaluation of virtual environments was taken into account.

In this study data was collected with a questionnaire, field observation and two interviews. The questionnaire was sent for the MR customer (at the oil refinery) to make initial context of use for the application. The questionnaire was analyzed before the field visit and interviews. The field observation was conducted at the OMV AG oil refinery at Vienna. Two OMV AG employees guided us through the refinery area and explained the functions of the refinery equipment as well as some needs that the MR training application should fulfill. During the visit some workers were briefly observed when they conducted their normal tasks. After the field observation, the employees were interviewed about the oil refinery unit specific to the application. The interviews were semi-structured, based on the previous questionnaire and took place at the oil refinery.

The context-of-use model based on the ISO 9241-11 [1999] was developed from the data. The user requirements were gathered and sent for the oil refinery customers. They prioritized the criteria in the scale of 1-4 (1 Critical, have to be implemented - 4 Not important) and commented on the criteria. The comments were really important for the understanding of the requirement in a common way and for making more detailed requirements by defining and adding values to where it was appropriate.

4 Context of use analysis

4.1 Users

The oil refinery personnel defined the users of the MR training application. The target group includes people who are new to the oil refinery and who do not know this oil refinery environment, its equipment and piping. They are young process engineers with academic degree. They have a wide range of knowledge, but they are all shortly graduated and have not worked long period in an oil refinery (mainly 17-27 years old, average age being 25 years). All employees use computer daily in their work and English is spoken as a second language by some of these employees. Currently, average training for a new employee takes about one year. It is difficult for a new employee to understand the process details, match the schematic diagram (flow diagram) of a plant and translate it into real refinery equipment without the help of an experienced trainer familiar with the refinery. By himself a new employee could not learn how to operate the plant.

The developed tool should be able to train the user with the whole production process of certain unit and the relation to other units in the refinery. The users can experience the different steps of the production and the network of units within the refinery.

4.2 Environment

The environment of the oil refinery is a very complex area full of pipes, vessels and machines. The pipes in the area are kilometers long and they are all coupled up. It is very difficult to follow one particular pipe from one point to another. Some of the pipes are color coded; green for water, blue for air, yellow for gas etc. The color-coded pipes make up only a small amount of all the pipes, because most pipes are coated with insulation material.

Figure 2: In AMIRE a refinery employee can explore the environment with a Tablet PC and mixed reality technology.

The other parts of the plants (vessels, pumps, reactors, columns etc.) are coded with a letter-number combination. These codes give experienced operator information about the position and use of the equipment (see Figure 2). The whole area is composed of units, which are logical processes. Most of the equipment is operated from a central control room that is situated near the site. The height of the columns can be several tens of meters high. The operating and maintenance personnel need to climb the plant up and down by stairs or on ladders on the sides of the columns. Using HMDs would not be a good solution, because they could hinder more than help them. Moreover, the employees cannot have heavy load on them nor belts or cords that can get tangled up while climbing.

4.3 Equipment and tasks

Most of the working time the employees are in the control room, where they follow the operation of the plant. In the control room they inspect information from unit diagrams, descriptions and handbooks or from experienced colleges. They keep track of the production process with several control devices. By clicking a symbol in the screen, they can see a certain measurement or other information about the device.

In the cases of maintenance, inspection and shutdowns the employees can get more hands on training of the unit on-site in the field. The unit cannot be closed only for training purposes. If a field operator goes out to the plant he is wearing a safety dress, radio set and sometimes bottles or cans for probes, tools, a hose, chemicals etc. to fulfill his duties.

5 Requirements

The study in the oil refinery revealed requirements the MR training application have to meet in order to be efficient and usable in the training of employees. This chapter presents the user requirements in the same order than in the context of use analysis.

5.1 User

The tool should not draw the user's attention while he or she is moving around the oil refinery. The employee must be able to reach all points in the unit without being hindered when walking or climbing up a ladder or column. The user has to have both hands available for work anytime, if needed. The user needs to be able to use the application in the language of the refinery and it must be usable with basic computer skills.

5.2 Environment

The oil refinery environment is very demanding in safety and accuracy of the presented information. The application needs to maintain accurate position of the user and the environment. The oil refinery requires that the tracking of the user's real position and orientation have to be in the accuracy of 1 meter and ±5°. The use of GPS is not accurate enough in the refinery (accuracy of 18 meters), because of all the metal and the high columns in the environment. The application area at the refinery is very large, in this case 1,6 km^2, so the tracking system has to cover large outside areas.

5.3 Equipment and tasks

According to the data, the aim of the application is to allow an employee to go to the oil refinery area by himself to learn about the process in the area. This requires that the tool have to be easy to use, intuitive and self-explanatory. After a short introduction and a few minutes training, anyone has to be able to use it (maximum of 15 minutes training time for non-PC users). The tool should resemble other commonly used tool and the basic functions should work the same way. The application has to offer intuitive metaphors and interfaces for the user with less expertise on computers.

5.3.1 Equipment

Addition to the user interface, the equipment for the application should be easy to handle, possible to be used wearing a safety dress and it has to be possible to carry without hands while climbing. The equipment should be flexible and extensible. The training tool should have the qualities listed in Table 1. The used display has to have adequate resolution for MR objects and video as well as maps and enough resolution space to show important information at the same time.

Table 1. Requirements for the equipment in an oil refinery.

Quality	Requirement
Light	Not more than 3 kg
Small	Max size of a 17" pc screen
Explosion proof	It is the law in the oil refinery area.
Ignition protection	Must prevent ignition sources arising
Resistance to strong magnetic fields	Best available technique
Can be taken to the field	Mobile equipment, easy to carry
Able to be used outside and in a noisy environment	Weather-proof (temperature), splash-proof (water), limited use of audio
Equipment should be shock resistant	It should not break easily
Robust	Like a laptop, no extra qualifications
Equipment should have high performance	The equipment used must be as fast as a medium performance pc (1700 GHz, 256 RAM etc.) and very fast in showing graphics, videos and animation.
High resolution	The display should have adequate resolution and it should be large enough for displaying MR content.

5.3.2 Tasks (Functions)

The training tool should have functionalities that offer the application several ways to present the information in easily understandable ways. Following is a list of functionalities that should be included in the tool. The list is based on the tasks defined by the oil refinery.

- Freeze-mode: the picture can not change in the display even though the camera moves.
- Take a picture of the target and to insert additional information to the picture.
- Application offers the user different ways of getting more information about the selected object.
  - (Hyper)text explanation and navigation through the application's (hyper)text pages.
  - Process flow diagram; it gives the main process streams with all the equipment (also a good tool for orientation from the process point of view).
  - Educational video of the target's functionalities or a pipeline path.
  - Animated video clips.
  - Rotating selected MR objects.
  - Magical lens – virtual view inside the device. Reducing the size of the overlaid virtual objects, while the scale of the real image remains the same.

- Graphics, virtual information from flow, temperature, pressure etc.
- Must offer 3D capabilities and overlaid 3D geometry.
- Offer information of the flow direction in the pipes.
- Follow certain pipe from point A to point B.
- Relation between checkpoints should be displayed in the map as well as in the process flow diagram. The way from point A to point B in the map and in the process flow diagram has a big difference.
- The tool should offer general information as well as detailed information for different groups of users.

The oil refinery is under constant change. The training application needs to be easy to maintain by an oil refinery employee and it must be possible for them to implement their own equivalent application without any help from MR experts. The employees should be able to add and change content of the application. For example they need to be able to add a new checkpoint, change a pump to another one or change an explanation to a process.

6 Conclusions and Discussion

When developing mixed reality applications for a safety-critical large outdoor industrial environment, there are several requirements that need to take into account addition to the basic user requirements. The equipment that is used for the application need to be explosion-proof, it cannot act as an ignition source. It needs to be light weighted and cannot bother the user while moving around the area, especially when climbing. The application itself needs to be reliable and robust. Mixed reality applications are situation aware and the position accuracy has to be very good for safety reasons. Positioning at the oil refinery is a challenge, because of the environment is very complex and full of metallic pipes and machinery. The application needs to be easy to use and intuitive. The user should be able to use it alone with maximum of 15 minutes introduction.

Findings from other studies in industry and in oil refineries as well as in augmented reality support these requirements (for example [Guerlain et al. 1999; Skourup and Stahre 2002; Gabbard and Hix 2001]). Our users emphasize more on the safety requirements of the equipment as well as the use situation of the application.

7 Future work

This study is initial and part of the AMIRE project. In the future a more comprehensive user study should be conducted with the mixed reality application developed in the project. The results are compared against the requirements presented in this paper. Studies in other application fields and different industrial settings would supplement the knowledge of the use of MR in application. This would be desired in order to achieve a comprehensive view of the usability of mixed reality applications. The training application can also be expanded to be application for maintenance and knowledge sharing as well. According to Skourup and Stahre [2002] demands on the operators are high and physical working conditions are rough and demanding. Operators have an obvious need for information access, decision support and tools for collaborations with peers and experts, not necessarily located at the same place. The distances between units are significant. Mixed reality as well as wearable computer system have the potential to support operators in such an environment and with the specific tasks.

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