

Training and Assistance to Maintenance in an Augmented Reality environment

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Abstract

The background of this paper is an industrial environment, where complex mechanical tasks have to be performed. In this context, for instance power plants or aircraft manufacturers, maintenance tasks require either a lot of documentation and training or a big amount of experience. No matter, if documentation is available in paper form or in electronic form, e.g. on a laptop, the worker cannot simply focus on his work, but has to concentrate on the separated documentation as well. This paper presents the concept of a system, using Augmented Reality for an enhanced 3D workspace, which integrates the documentation and further help into user's environment and especially in his view. Interaction with the system is performed in a multi-modal way, combining speech and a virtual pointing device.

1 Introduction

The need for extensive documentation for a certain task is the starting point for the work presented. The focus is on tasks in the industrial context, i.e. automobile, aircraft or power plant industry, for those objects as well as their maintenance are quite expensive, such that the implementation of an Augmented Reality (AR) system appears profitable. Nevertheless, this approach is adaptable to other domains.

AR has its roots in the Virtual Reality (VR) research. The basic idea of AR is the combination of a real scene, i.e. the view of a user, and a virtual one, generated by a computer. This provides the user with an augmented view and can be used here to generate an enhanced 3D workspace. The user gets some basic information, how to perform a task step by step and can get additional help through plans, pictures or videos on demand.

More background on AR and related ideas can be found in section 2 and a brief overview over the hardware and the technical details can be found in section 3. Further information on system components, tracking and calibration procedures can be found in (Schwald & de Laval, 2003). The design, implementation and configuration of the 3D workspace of this AR system is one of the main aspects of this paper and described in section 4.

While the easy access to documentation is one important request of the addressed complex tasks, having hands free for working is another one. In order to fulfil this demand, the system allows controlling by speech commands as well as selection of objects with a virtual pointing device. The concept of the user interaction is outlined in section 5.

2 Augmented Reality in Industry

The combination of a real scene with a computer generated virtual scene is the main idea of AR. In many cases, the user has to wear a kind of goggles, a so-called Head Mounted Display (HMD), where a video stream from the real scene, captured by cameras mounted on the display, is augmented with virtual objects and shown in the goggles, e.g. in the domain of cultural heritage (Gleue & Dähne, 2001). The system presented here, uses an optical see-through HMD. The user is looking through a half-silvered mirror that combines the real view with the projection from small displays inside the HMD.

Implementations of AR demonstrators for industrial applications, date back to the early 1990's (Caudell & Mizell, 1992) and were advanced in the recent years, e.g. repair of copier machines (Feiner & Seligmann, 1993), wire bundle assembly in airplanes (Curtis & Mizell, 1998) or the insertion of a lock into a car door (Reiners et al., 1998), using different technologies. A case study of AR systems for the maintenance of power plants can be found in (Klinker et al., 2001). Recent work was done within the Arvika project (Wiedenmayer & Oehme, 2001), (Alt et al., 2002). Apart from industrial applications, AR is a growing field for current research in domains such as medicine, engineering design, cultural heritage and others.



Figure 1: Stand, mechanical element and user equipment

3 User Equipment

The augmentations superimposing the real scene can be placed in different ways, as described in section 4.1. One possibility is to overlay parts of the mechanical element, e.g. to highlight a screw, that has to be unscrewed. To allow such an overlay in a correct way, i.e. independent from the viewpoint of the user, position and orientation of the head (eyes) of the user, and the mechanical

element has to be known. The determination of position and orientation in real-time is performed by two six degree of freedom (DOF) tracking systems, an electromagnetic and an optical infrared tracking system. These tracking systems are mounted on a stand, as shown in Figure 1. Furthermore the user is wearing a lightweight helmet, integrating the HMD, a six DOF tracking sensor, headphones, a microphone for speech control and a video camera for demo purposes. The lightweight helmet is connected to a transmission unit on user's belt and the transmission unit is connected to the system's PC. More detailed information on user equipment, the stand and tracking systems can be found in (Schwald & de Laval, 2003).

4 The 3D workspace

Information is provided to the user in form of a 3D virtual workspace, meaning that 3D information, thanks to the HMD, surrounds the user so as to help him in his tasks. In the two subsections below, we describe the contents of this interface and its visual aspect.

4.1 Maintenance procedures

A maintenance procedure consists in a scenario divided into steps, again divided into actions. An action is a very basic task, such as removal of a screw for instance. The creation of scenarios and of the corresponding database of information is very similar to the procedure of creation of classical user paper or electronic documentation. The objective is to build in parallel documentation for this new system and reuse as much as possible existing information databases. For this purpose, an editing tool was developed to help scenario authors. Its simple interface enables to easily connect a database with a maintenance procedure and its visualisation. Thereby it also ensures that the database and the scenario are appropriate for the system.

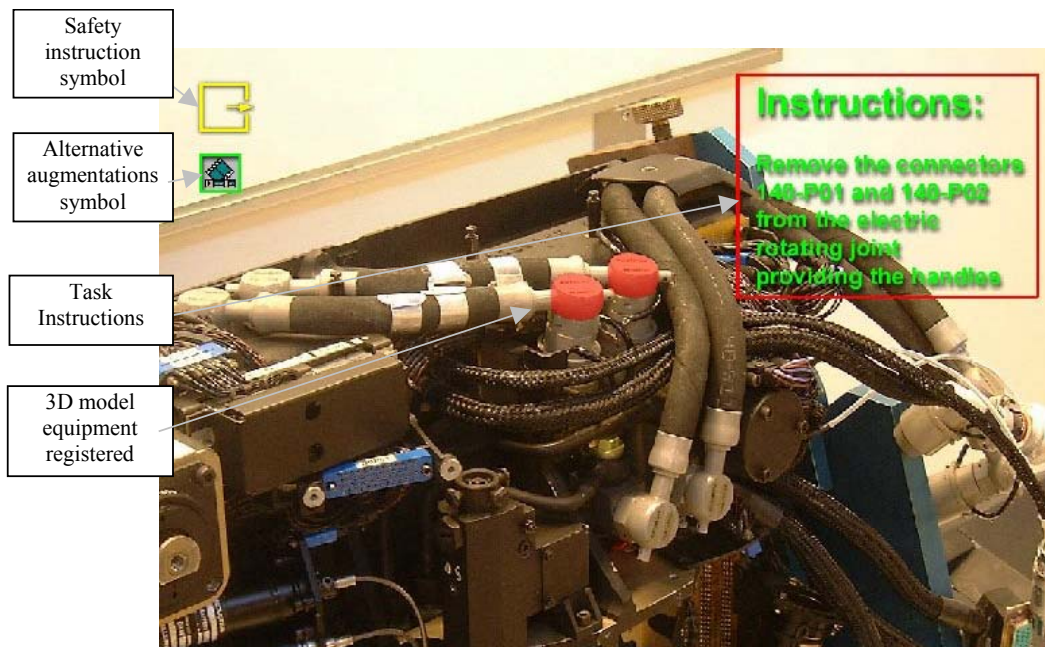


Figure 2: An augmented view: scenario instructions

At launching of the system, users can choose equipment and a maintenance procedure related to this equipment. While performing their tasks, they receive at each step of the procedure all the information needed to perform this task (see Figure 2). This information depends on the user's level of competence, as a beginner would not have the same needs in terms of information as someone who is more experienced. In this purpose, information displayed can be default, meaning displayed to all users, or alternative, meaning displayed only to user's request. The list of alternative augmentations available in a given step is indicated by a list of symbols as illustrated in Figure 2.

4.2 Visual aspect of the interface

The interactive 3D-augmented workspace, created around the user, can contain different types of information. The most frequently used are 3D models of pieces of equipment and text instructions. But users have also access to any kind of plans, pictures, symbols, videos and help menu.

To be able to visualise all these augmentations (=information data), several registration modes are proposed:

- *Headset registration*: Information registered to the headset (HMD) is always visible in front of the user's eyes, wherever he moves. Typical headset-registered information is instructions, symbols, and warnings. They indicate the contents of the task as well as the important safety notions.
- *User registration*: information, such as a complex plan, can be placed next to the user at the same place at any time. A window placed for example on the left-hand side of the user will always remain at that position, for user's position and orientation is known.
- *World registration*: Information is placed in a fixed place of the world, as if it was positioned there in reality. Typically a picture showing the list of tools needed during the procedure is placed above the tools table.
- *Equipment registration*: 3D models of real pieces of equipment or arrows pointing on these elements are overlaid on their real counterparts. They enable to illustrate on the equipment itself its functioning, if necessary and more generally to focus the attention of the user on the equipment's parts of interest.

This way of working with 3D "augmented" elements enables each user to feel that the equipment and its documentation as well as the maintenance procedures are all integrated in one single environment.

5 User interaction

The requirement for the user interaction is to be simple and intuitive to make the user willing to use the system. Users mostly need their both hands to perform their maintenance tasks, such that an interaction tool like a mouse was not envisaged. Therefore simple speech commands are used to give users the possibility to navigate through the maintenance scenarios. Thanks to these speech commands, users can access any available information, at any time.

To make the system simple to use but flexible as well, some tools are provided to interact with 3D-workspace and modify its configuration:

- *Look&feel module*: it enables to define the visual aspect of the 3D workspace in terms of windows size, colour, position, mainly depending on the application. Users are proposed to choose the look&feel profile most suitable for them.
- *Virtual Pointing Device*: In combination with speech commands, the VPD enables users to designate augmentations to modify their characteristics, such as the position. In a

future version of the system, this tool could be used to retrieve information about pointed elements (such as pieces of equipment).

An extension of the documentation related to equipment worked at can also be performed online: the “annotations” functionality enables users to record any comments using the microphone. Saving this information in the database enables to improve and update the information available in real time. Users will then be able to access to this information for future use. In a future version of the system, it could be envisaged to record as well information thanks to the video camera fixed on the HMD.

6 Results and Conclusions

The system was implemented within the Starmate project, funded by the EU. The project is close to its end and the system is almost fully implemented: the feasibility of an AR-based system, dedicated to assistance to maintenance is now proved.

The follow-up of the project is currently being discussed. Indeed the prototype developed would have to be quite significantly improved to have a system usable in real work environment. The main improvements would be related to user equipment: the objectives are to have a lighter system that would be more easily installed and moved. Another idea would be to join Starmate to telemaintenance so as to benefit both from the system itself in terms of assistance and from a distant expert, capable of giving instructions as well. Contacts we have had up to now with potential users & customers of the system are quite encouraging and lead us to think a bit more seriously about possible commercialization of the system.

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