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An application based on Augmented Reality and mobile technology to support remote maintenance

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Abstract

Product maintenance is a service offered to customers which represents an interesting business for companies. Their interest is both providing a good service in terms of quality and at the same time cutting operational costs. In this view companies are seeking tools that enable them to reach both goals, among those offered by the rapidly evolving ICT sector. The paper describes an application based on augmented reality and mobile technologies aiming to support remote maintenance operations, and improve maintenance services that companies offer to their customers. The paper describes the main idea at the basis of the application, the requirements as well as its implementation. Finally a case study is presented.

Categories and Subject Descriptors (according to ACM CCS): H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities

1. Introduction

Systems and products maintenance is one of the major businesses for companies operating in the industrial sector. This is particularly true for companies operating in the B2B (business to business) sector, where products are not produced in series, but are made on purpose and customised for customers. These are situations were maintenance requires particular operators' skills in order to be accomplished. When a system has a malfunction, or stops working properly, usually it happens that a skilled technician is sent to the location to solve the problem. It can also happen that the malfunctioning problem is not so complex, and could have been solved also by a technical person locally, if properly instructed, without the intervention of the skilled one.

Therefore, one can think of a situation where the maintenance task is accomplished locally by an unskilled operator under the supervision of a skilled one, who is connected remotely. This solution would decrease the maintenance costs by limiting travel expenses, devoting the allocation of skilled operators only in case of serious faults, and improve the overall service quality, since the intervention would be rapid. This is why recently companies, in order to improve maintenance service and cut operational costs, are interested in the recent advances in mobile technologies, which would allow performing trouble shooting tasks remotely.

Mobile technologies are well suited to allow communication between an unskilled operator and a skilled one, who can make a remote diagnosis of the problem. Once detected the problem, the skilled operator has to instruct the unskilled one about the actions to perform in order to repair the system. The issue here is how the skilled operator can communicate these actions to perform to the unskilled one. Certainly a verbal description is not very efficient, and more practical and effective ways should be investigated.

Augmented Reality (AR) offers interesting technologies to connect the two operators, and allow the skilled operator to communicate to the unskilled one the steps to follow to perform the maintenance task, by directly superimposing the instructions onto the system. AR has been widely used in product maintenance since the very beginning (as described in one of the first surveys on AR [A*97]) and there is much literature on the subjects (for a review see [ABB*01] and more recently [VKP10]), but less has been done on the use of AR as a tool to allow remote maintenance.

The paper describes an application based on mobile technologies and AR, aiming to support remote maintenance

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tasks. The application takes inspiration from the work of the same authors described in [FCB13] where a haptic assembly simulation is connected with an AR application in order to allow a remote training (from a skilled operator to an unskilled one). Compared to the previous one, the application presented in the paper is based on a new communication modality. In addition, with respect to the work described in [FCB13] the authoring time is totally cut down. A case study is presented together with the description of the main concept of the application and its development.

2. Related works

Since the beginning, AR has been considered an interesting support in industry for maintenance applications, assembly and repair of machinery, as described in one of the first surveys on AR [A*97]. For example, Feiner et al. in [FMS93] describe KARMA, a prototype of an Augmented Reality system that presents a simple end-user laser printer maintenance application based on a see-through Head-Mounted Display. One of the main advantages of using an AR application compared to traditional documentation is that the operator can access the information necessary for performing the activities directly in the working area, without the need to refer to the traditional printed manual.

AR as described in [WBE*12] also allows an efficient training modality for maintenance and assembly that accelerates the technicians' acquisition of new skill on maintenance procedures. Haritos et al. [HM05] describe a mobile AR application for training in the field of aircraft maintenance, in order to replace the traditional modality of training, i.e. on-the-job training. The AR training system can be useful for both job task training and guidance for job tasks for novice technicians in a real working environment.

Regenbrecht et al. in [RBW05] present some application examples, where AR is used in automotive and aerospace industry. This article presents potential industrial applications of AR and particularly the use of this technology for product maintenance and assembly.

In [FCB13] the authors describe the implementation of a collaborative application where a haptic assembly simulation is connected remotely with an AR application in order to allow a training from a skilled operator to an unskilled one. The main drawback of this application is that it requires a long authoring time. Furthermore the application is specifically developed for one product, and it takes time for being adapted to a new product.

Fiorentino et al. [FUMR12] present a method to provide technical data in augmented reality maintenance operations by embedding markers in engineering drawings. They also provide a set of 3D virtual model navigation functions triggered with gestures recognised by a video/depth camera.

The application for remote maintenance presented in this paper is based on the combination of mobile tools with AR technologies. It allows companies to perform remote maintenance activities of various industrial products, with no need of structured environments or high speed connections. On the basis of the experience described in [FCB13], the application presented in this paper aims to reduce the authoring time. It is based on classic I/O interfaces that the skilled operator uses for instructing the unskilled one.

3. AR application for remote maintenance

The main requirements for the application for remote maintenance, based upon the previous experiences and the requests provided by some companies, are the following:

- the application should allow the two operators, expert and unskilled, to smoothly communicate so that they can easily identify, on the basis of the encountered problem, which is the part of the system that needs to be repaired or fixed. This communication can be verbal (in case they speak the same language) as well as based on the exchange of pictures or symbolic information.
- once the diagnosis has been performed and the parts to fix identified, the skilled operator should be able to indicate precisely both the operation and the place where to perform it. The AR application should display digital information in the real context, precisely.
- the skilled operator should be able to check whether the maintenance operation has been successful or not. The application should allow the skilled operator to see how the fixing task advances.
- the application should be able to work even in case of slow internet connections. Sometimes the system to repair is in places where no stable and fast connection exists. Let's take as an example the transportation sector. It might happen that a train stops working in a place where there is not a fast internet connection. This implies that the quantity of information exchanged should be as limited as possible.

The possible occurring situation related to a limited internet connection during the maintenance operation, has required the development of an application based on a restricted data transfer. Therefore, the application does not use video streaming but it is based on the transfer of two-dimensional images. These have a two fold use: they are used as markers with the unskilled operator who performs the maintenance operations, for the correct overlapping of virtual images on the actual scene; and also as a reference image used by the skilled operator to indicate the operation. As regards the operations to fulfil, the expert user moves and places a series of symbols on the real scene. This involves the transfer of a very small flow of data relative to the position of a pointer that indicates the precise point in the actual scene where the maintainer must interact. A chat system ensures the communication between the two operators. The application is designed to be used together with a video streaming, whether the internet connection speed supports it. If the connection is too slow, the application allows the exchange of picture, and provides a chat service for the diagnosis part of the maintenance operation.

3.1. Application architecture and development platform

The architecture of the application is of type Client-Server, which well supports the connection of a skilled operator with an unskilled one remotely located. In Figure 1 the system architecture and the information flow are shown.

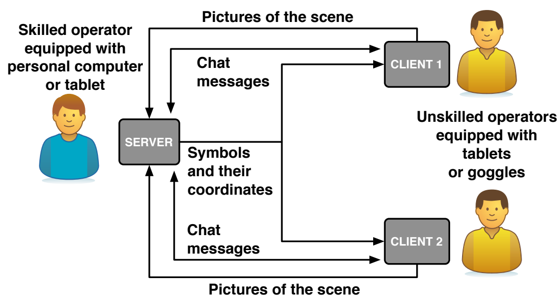

Figure 1: *System architecture: skilled and unskilled operators communicate through a server/client system. Unskilled operators send pictures of the real environment to the skilled operator, who uses them to locate instructions that will be sent back through symbols. A chat system is also implemented to allow a verbal communication among the users.*

The unskilled operator/operators (client) take some pictures of the real environments and send them to the skilled one (server). These pictures are used for the client as a marker to correctly superimpose instructions on the real environment, and for the server as a way to indicate the components to disassemble and assemble. The skilled operator makes use of some symbols to indicate where to act. These symbols are stored both on the server and the client applications, thus the information sent is basically what kind of symbol to display, and its current position. Server and clients can exchange also text messages through a chat system. The skilled operator can simultaneously communicate with one or more unskilled operators acting on the same system.

The application is developed using the Unity3D 4.3.4 environment (http://unity3d.com), integrated with the Qualcomm Vuforia 2.8.9 tool (https://www.vuforia.com) used for tracking the real scene, and allowing to superimpose digital information onto the real environment. The Vuforia tool is a software tool distributed by Qualcomm Connected Experiences Inc. It is based on Computer Vision algorithms for the recognition of images that will be used as a marker for augmented reality applications. In particular Vuforia allows us to use image scenes as markers. This is particularly important, since no structured environment is required for the AR components.

Among the available platforms integrated with Unity3D (Metaio, ARToolKit - UART, etc.), we have selected the Vuforia tool as it is robust, easy to use, provides accurate and consistent monitoring results but most importantly it is stable even in bad lighting conditions, partial or almost total occlusion of the target (or marker), and has a wide viewing angle.

The application has been developed so that it can be used with various hardware devices. Currently, the experienced operator can indicate the operations to perform through a personal computer, equipped with the traditional input and output devices (keyboard, mouse and monitor), or a tablet or a mobile device equipped with the Android operating system or iOS.

The unskilled operator can use a tablet (which is also equipped with the Android operating system or iOS) through which he sees a series of statements projected directly on the objects of which he is doing maintenance. Alternatively, the maintainer can wear helmets or any kind of AR goggles, which allow him to view the maintenance instructions simultaneously with the execution of the operation.

Tablet and smartphones have the disadvantage of having to be supported by the operator to view images projected onto the real scene. This means that the operator cannot, except in cases of operations that can be made with one hand, display instructions while operating. This problem is overcome by the use of AR goggles. These, however, have another limitation: while the tablet is both an output and the input interface, since its surface is touch-sensitive, goggles require additional input technologies and techniques, such as gesture recognition, voice command etc.

3.2. Description of the use of the application

The application allows the user, in the first screen, to decide whether to be server or client, that means choosing to start the session as skilled or unskilled operator.

Figure 2 shows the server application while Figure 3 shows the client application.

On the server application the skilled operator can choose what kind of symbol displaying (left side of the screen) among: unscrew, screw, location indication, warning, disassemble and assemble. Through the arrows he can move the symbol to the correct location. Finally through the chat system he can also send or receive messages.

In the client part of the application the unskilled operator through the AR window sees the symbol the skilled operators chose and moved, superimposed onto the real environment in the correct location. In the top right part of the screen are located the buttons to take a picture of the real environment. These pictures are used as markers. In particular the button allowing to take a picture only appears if the program recognises the picture as a potential good marker.

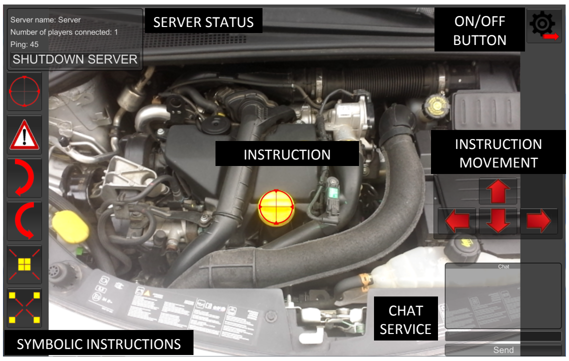

Figure 2: *Server application: on the left side of the screen the skilled operator can choose what kind of symbol displaying, and with the arrows he can move it to the correct location. Through the chat system he can also send or receive messages.*

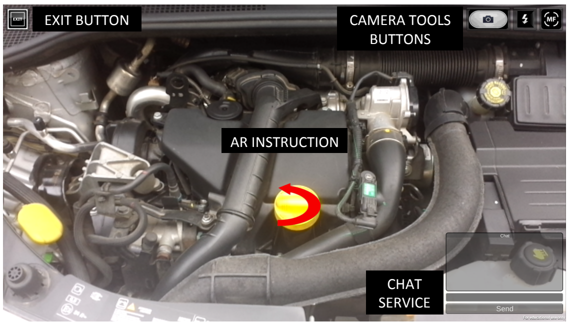

Figure 3: *Client application: the unskilled operator through the AR window sees the symbol onto the correct location. In the top right part of the screen are located the buttons to take a picture of the real environment. The button allowing to take a picture only appears if the program recognises the picture as a potential good marker. Also through the chat system he can send and receive messages.*

Finally also through the chat system he can send and receive messages.

As said, the client part (Figure 3) of the application tracks the position of the tablet in relation to the real scene by using an image ("image target") acquired by the unskilled operator. In this case, the image target is based on a photograph of the car engine. Once taken the picture, this is sent to the server using TCP-IP via a UDP port.

During the various phases the client can update the image and send to the server, allowing the server to see the new scenario on which the client is operating.

3.3. Case Study

The application was tested using as a case study an internal combustion engine of a car. The case study selected is purely indicative and has been used to test the effectiveness of the proposed approach on real-maintenance operation.

The skilled operator has guided the unskilled operator during the filling phase of the cooling system simulating an emergency indicated by the cooling temperature warning light. Thus in this case the diagnosis part of the maintenance operation is done by the product itself.

The effectiveness of the application has been evaluated, as well as based on the success of the operation, also in function of the accuracy and care of the smallest details throughout the maintenance phase.

In order to make the simulation as realistic as possible, the skilled operator did not know the unskilled operator's dangerous situation. The unskilled operator contacts support and a skilled operator assists the unskilled operator, explaining the problem. The skilled operator understands the problem and says to park the car in a flat area, stop the engine, engage first gear, pull the hand brake and allow the engine to cool.

The unskilled operator starts the application of remote support on his mobile device and connects with the skilled operator.

The skilled operator tells him to open the hood and sends him a picture.

Then the skilled operator indicates the water tank cap, inserts an alert (Figure 4), advising unskilled operators to wait the water-cooling (Figure 5).

Successively the skilled operator tells him to check that the water level is between the maximum and minimum, and given that water level is below the minimum, the skilled operator indicates to unscrew the tank cap with the corresponding icon (Figure 6) and to add water in the tank (Figure 7).

This case study shows the potentiality of this application in common and simple situations, but it is straightforward that it can be used in much more complex cases.

4. Conclusions

The paper has described an application combining mobile and AR technologies to support remote maintenance of industrial products.

This application is specially developed to work with slow connections, thus the exchange of information is reduced as much as possible. This application, also works within unstructured environments, thus the AR tracking library has been chosen so as to allow the tracking of real scenes without the need of fiducial markers.

The application is thought to allow companies to increase

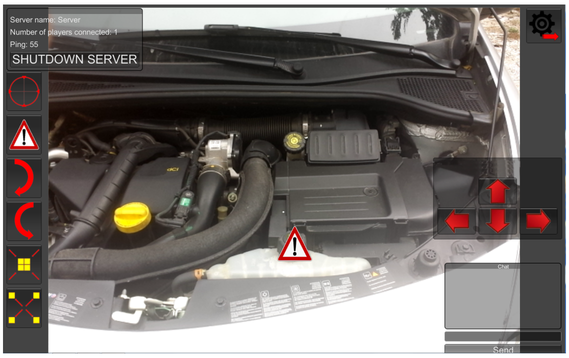

Figure 4: *The supervisor indicates the point at which the unskilled operator should be careful.*

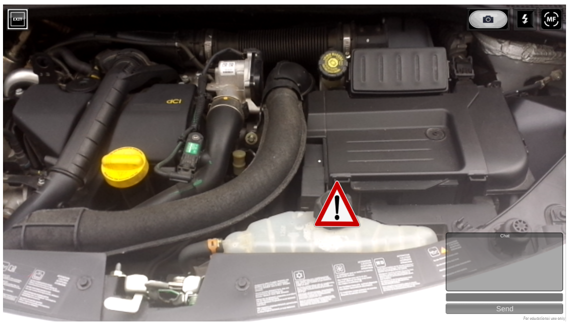

Figure 5: *The unskilled operator sees the alert symbol on the real scene.*

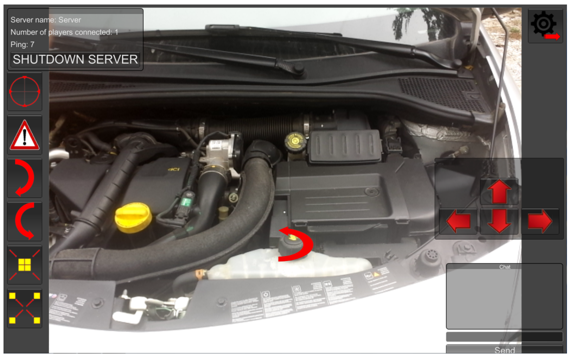

Figure 6: *The supervisor indicates the tank cap that the unskilled operator have to unscrew.*

Figure 7: *The unskilled operator receives via chat the instruction to add water in the tank.*

the quality of maintenance services, allowing a rapid intervention, and cut operational costs, by reducing the travel expenses. A case study developed to test the effectiveness of the application has also been described.

Aknowledgment

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