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Remote support for maintenance tasks by the use of Augmented Reality: the ManuVAR project

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Abstract. This paper presents an application tool developed to support effective maintenance in the railway sector. Considering that this is a sector where maintenance is especially critical, due to factors such as urgency in corrective maintenance operations, integration of hundred of subsystems and integration of different sources of information, this makes it suitable for an augmented reality based system. The use of augmented reality eases the integration and useful visualization of data meant to help the on-site worker to perform the operations; in a different business case, augmented reality enhances the communication between a remote expert and an on-site worker, allowing better information exchange between both actors.

Keywords: augmented reality, remote communication, industrial application, maintenance

Introduction

The ManuVAR project, funded under the European Union 7th Framework Programme is a response to changes in the European manual-labour market. The ManuVAR project aims to provide a system to support high knowledge high value manual work throughout the product lifecycle [ManuVAR 2011]. The ManuVAR approach is based on utilizing virtual and augmented reality technologies (VR/AR) combined with ergonomic methods.
ManuVAR consortium comprises 18 partners across 8 European countries representing industry, research and academia. In ManuVAR, there are five synergistic application clusters in different industrial areas: terrestrial satellite assembly, assembly line design, remote maintenance of trains, maintenance of nuclear reactors, large machine assembly process design.
The present paper will present the work done in one of these clusters, that has been led by Tecnalia and NEM Solutions. The development compromises three different use cases, related with the design, maintenance and use of train components.

Railway vehicles are complex systems that contain elements associated with a complete range of engineering disciplines [Smith 2011]. From the workings of a modern traction motor to the dynamics of vehicle suspension, to the control systems for signalling and train safety, different expertise is required to address and solve maintenance issues repair faults and prevent them from happening again in the future. This paper describes how augmented reality (AR) technology has been developed to address the need to assist maintenance staff at a remote location faced with a system fault, and where expert advice is sought either from co-workers at the maintenance headquarters, or from the system supplier [Leva 2011].

ManuVAR project and architecture

In ManuVAR project new modular system architecture has been developed to support manual work. In “Tecnalia-case” the implementation of architecture is presented in Figure 1.

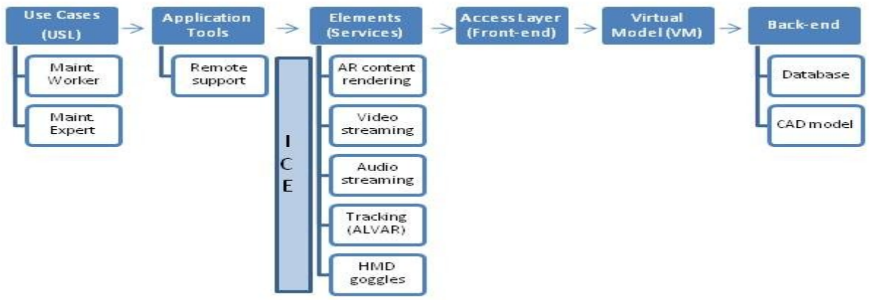

Figure 1: The ManuVAR system architecture in "Tecnalia-case"

In Figure 1 the main components of the architecture are in top row. USL (User Specific Logic), provides interface for different use cases and end-users to login into ManuVAR system. In this case that is for maintenance worker and expert. The actual work task is controlled by using Application tools. In ManuVAR the developed tools are 1) Remote support, 2) Ergonomics analysis and workplace design, 3) Task planning and analysis, and 4) Training. Application tools coordinate the use and interaction of technical Elements (services). The elements are software components, with clearly defined interfaces. In this case they are AR content rendering, video and audio streaming, tracking (Alvar, see the next section), and HMD goggles. The connections between different elements are carried out through ICE middleware (Internet Communications Engine).
The Access Layer (front-end) contains a set of operations that allow the elements to communicate with the Virtual model (VM). VM enables bi-directional communication throughout the lifecycle. It provides also up-to-date reference to the product information during a specific work task performed using the ManuVAR methodology. The VM has been created in the way that the interactions of the front-end user are always reflected to the data in back-end (PLM repositories). Back-end contains in this case the database of service and maintenance operations and manuals. CAD-models of train components are also in the back-end. The ManuVAR methodology and architecture are presented in more detail in [Krassi 2010] and [Kiviranta 2010].

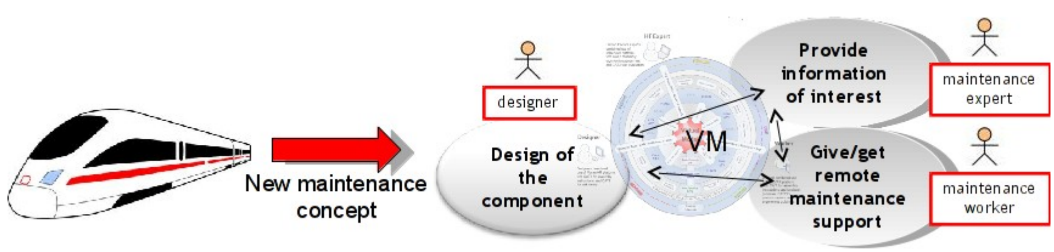

Figure 2: Actors and interactions

Figure 2 shows the interactions performed by the different actors involved in the testcase, that provide the functionality that is presented next.

The Alvar library

ALVAR [Alvar 2011] is a library for making virtual and augmented reality applications, developed at VTT Technical Research Centre of Finland. Alvar offers high-level tools and methods (e.g. an application programming interface (API)) for the rapid prototyping of augmented reality solutions. In addition, low-level interfaces enable development of custom solutions using alternative approaches, where needed. As a whole, it is designed to be very flexible and it requires only one 3rd party library (OpenCV) for all the main functionality. Therefore, it is well suited for the purposes of ManuVAR

project.
Alvar library consists of different modules: Alvar Desktop for PC environment, Alvar Mobile for mobile platforms and Alvar for Virtools for Virtual Reality solutions. In this project, the augmented reality system operated on laptop/PC and exploited the functionalities of Alvar Desktop. In the following we will describe the most relevant features of it.
Alvar provides strong support for development of marker based augmented reality applications. It detects and tracks 2D markers, and calculates accurate 6 DOF (Degree of Freedom) camera pose relative to the marker. This project utilized Alvar specific markers, but the library also supports other 2D barcode type markers, template and image markers. The library also supports free multimarker setups and combination of static and moving markers. Multimarker configuration includes several heuristic methods to recover from unexpected events (e.g. people passing the camera) and to identify markers even if the decoding is not possibly due to e.g. partial occlusion or too long distance. In addition, Alvar contains methods for texture generation to hide markers from the view.
Although Alvar supports feature based (i.e. markerless tracking) as well, in this project we decided use multimarker solutions, as the current feature tracking solutions require a bit of expertise from the user (e.g. how to move the camera to initialize the tracking).
Furthermore, Alvar provides additional tools for AR application development: tools for calibrating cameras, methods for distorting and undistorting points, projecting points and finding exterior orientation using point-sets,. It provides several basic filters such as Kalman library (to be used e.g. for sensor fusion).
Alvar has been successfully exploited for augmented reality in several fields e.g. in interior design [Woodward 2010a], building and construction [Woodward 2010b], manufacturing, maintenance and assembly [Salonen 2009].

Implementation and trials

The first use case developed compromises AR enhanced maintenance support over critical components, with the help of diagnostic systems; since these maintenance activities are going to be the most critical ones, the information coming from the diagnostic system could act as a powerful decision making support tool, or just offer additional information of interest when performing certain specific tasks. The system provides the on-site worker with useful information about the component being repaired. The component itself is identified, and the additional information overlaid, can be divided into three categories: in one hand, data extracted from the diagnostics systems available, that provide parameters such as LCP (Life Cycle Parameters) and KPI (Key Performance Information); those are statistical data regarding the state of the component, including information as for example the MTTR (mean time to repair), MTTF (mean time to failure), availability (ration between the number of working hours and the total number of hours), and so. Other information source is related with the component model, including hidden parts and dangerous zones among others.
Given the diversity and complexity of the components being repaired, the on-site worker might not be able to successfully repair the component, and due to the same reasons, the experts themselves might not be found nearby to the maintenance workshops. The system eases the remote support of the expert using augmented reality tools. The scene captured by the camera integrated in the on-site worker's glasses, is streamed in real-time to the expert. There is additionally an audio connection that allows the expert to guide the maintenance worker. These two elements improve the communication between the two actors, providing instantaneous feedback, allowing the expert to look at the scene by himself, and not depending on intermediate communication. This workflow is represented in Figure 3.

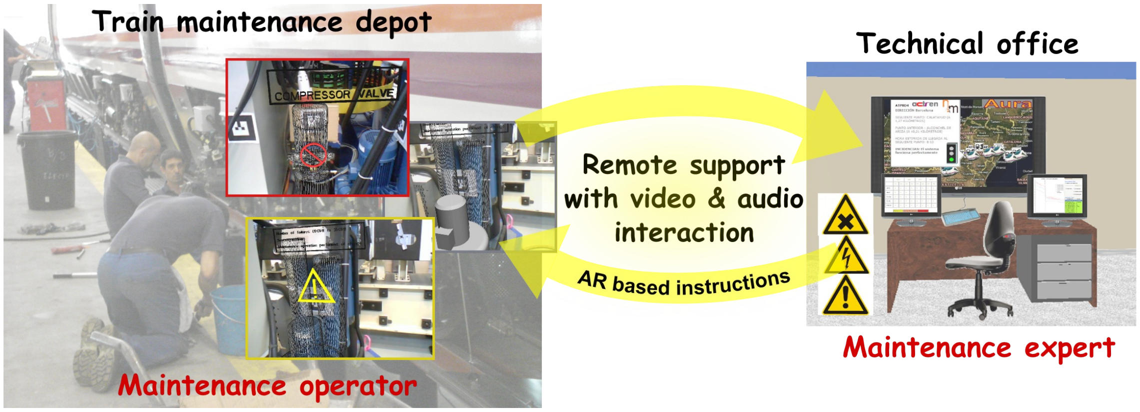

Figure 3: Remote support interaction

The expert has available a graphical interface, composed by a generic palette and a component-specific one. These palettes have several elements, that are activated by the expert, and placed as overlaid information in the on-site worker visualization. The palettes compromise different elements, such as standard signs to mark dangerous, arrows for pointing at relevant zones. The component-specific palette is activated only when the component is detected by the system, and allows the expert to hide and show different parts of the model, or highlight parts to draw the on-site workers attention. An example of the on-site worker's visualization can be seen in Figure 4, where the component outline is rendered in top of the real component, as well as an attention arrow that has been activated by the maintenance expert in order to highlight a specific part.

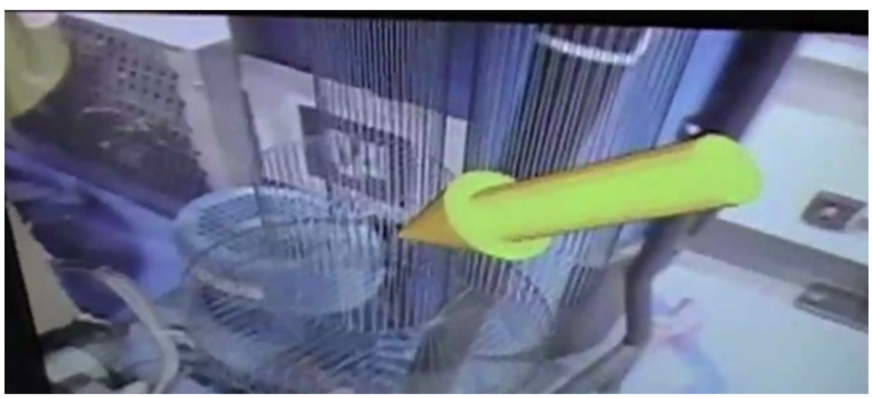
Figure 4: Maintenance operator visualization

Conclusions and future work

The use of augmented reality in industry has been shown to be a breakthrough in the way many operations are performed, such as maintenance, design or training. Still, there are some challenges that must be overcome in order to allow a consistent introduction of the technology; some of them technological, and other about usability and finding the proper applications [Navab 2004].
In this paper, the train maintenance problem has been used as a testcase application to show the potential of augmented reality, considering the following targets:

i) combine efficiently maintenance information coming from different sources
ii) improve time taken to complete maintenance tasks
iii) minimize maintenance task costs
iv) improve the life cycle management of train components

v) improve maintenance operator manipulation skills and decision-making capability
vi) improve the communication between maintenance experts
vii) manage and handle maintenance actions performed for further consults

In the current state of development, the system will be demonstrated and evaluated by potential users in the railway vehicle maintenance sector, by installing it in a real industrial environment at the end of the year and during the first quarter of 2012. The results from this evaluation will provide useful feedback, that will allow to improve and evolve the performance and usability.
From the technical point of view, future work involves going towards a markerless tracking system, to avoid the need of positioning and calibrating the markers in the components. This is a huge challenge that will probably not be tackled from inside the project [Fua 2007], although seems critical for the massive introduction of Augmented Reality applications in the industry. Another focus will be related with the usability of the system, both from the operator and expert points of view. This involves interaction with the model, and the ability to present the information and data in a useful and non-intrusive way.

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