AN APPLICATION OF AUGMENTED REALITY TECHNOLOGY FOR PRODUCT VISUALISATION DURING MAINTENANCE ACTIVITIES

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Abstract

This paper presents an application of 3D models and modern visualization techniques - augmented reality (AR) for aiding and training maintenance tasks for technical objects. The application of 3D models and AR at exploitation stages of complex technical objects brings many benefits that are presented in this article. AR techniques are becoming particularly helpful in providing the required knowledge to maintenance staff and users. This way of knowledge presenting is extremely intuitive, especially when compared to the presentation of knowledge in a classic form.

Keywords: *augmented reality, visualization, maintenance, 3D CAD model, maintenance training*

1. INTRODUCTION

Nowadays, technical objects are becoming more and more complex. This is particularly evident in the field of mechatronic systems. The knowledge related to such complex technical objects necessary for their operation is becoming more and more complicated and difficult to process. Interactive technologies, i.e. augmented reality (AR), are becoming particularly helpful in providing the required knowledge to maintenance staff.

Maintenance includes three basic operations: preparation of technical objects for work (setup), repair and preservation. When carrying out activities related to the proper maintenance the personnel use their own knowledge and experience as determinants of their proper performance. Increasingly complex technical objects, in particular technical objects that are individual solutions (often also highly personalized/customized) require specialized knowledge for their proper setup, operation, repair and maintenance. On the other hand, all activities in the area of maintenance must meet growing requirements that have to maximize time savings and minimize the costs associated with maintenance activities. This can be achieved by more efficiently providing knowledge and information to staff at the training stage or thanks to modern interactive techniques also at the stage of carrying out these activities.

New training requirements enforce the replacement of semantic textual information by visual and interactive information grains (Skarka et al., 2012). Augmented reality systems (AR), as an example of the use of interactive techniques, are ideal solutions that enable the integration of text grains and interactive models in a common interface. In particular, augmented reality systems allow the imposition of certain virtual elements that are carriers of information and knowledge about the object on the current state of the real technical object.

AR techniques were born as a result of the disadvantages and imperfections of virtual reality techniques. The main goal of AR is to facilitate the implementation of tasks by the user in the real world and in the context of real objects, which is not provided by virtual reality techniques. Augmented reality techniques allow to connect the real world (user's environment) with the virtual, computer-generated world in such a way that they exist together in one synthesized environment (Azuma, 1997). For example, in this way the AR system can provide information on how to properly carry out the printer servicing process in the context of a real and not a virtual printer (Feiner et al., 1993). This is achieved by providing information through several communication channels. It is therefore possible to visualize (using the video channel) service procedures for the printer by displaying them directly on the actual printer, as well as to provide additional audio information related to service activities (sound channel). For visualisation as representation of objects 3D CAD models can be profitably used. The application of 3D CAD models at various stages of the product development cycle is now widespread. However, the use of product

representation in the form of 3D models is not as popular at the other stages of the product life cycle like exploitation and maintenance. AR techniques allow to use 3D models in an effective way. All information is precisely provided to the user exactly when there is a demand for it (just-in-time, JIT) and in the right place (directly on the actual object for which maintenance is carried out). Applications of this type significantly increase the effectiveness of presenting information related to the product during exploitation and maintenance. This article presents the use AR system which was developed by the author for aiding users of different technical objects in maintenance tasks. Semi-trailers, cars and mobile robots were selected as examples of technical objects for which the implementation of AR techniques was realised.

2. EXISTING SOLUTIONS AIDING MAINTENANCE WITH THE USE OF AR

Augmented reality techniques as an example of interactive computer techniques are extremely interesting, although only in recent years they have begun to develop in Western Europe, the United States and Japan. Research on the subject of AR, especially for the needs of industry, is conducted in a relatively narrow scope and mainly by a few scientific centers. One of the first research works aimed at the development of systems based on AR computer techniques was initiated in the early 1990s (Mizell, 1994). In 1990, Boeing company developed a system to support employees during an installation of a large number of wires in the aircraft being built. The interest in issues related to modern techniques of knowledge presentation was mainly due to the fact that many benefits from their use were noted for increasing the efficiency and intuitiveness of human activities (in particular complex activities that require specialized knowledge). User assistance systems, based on augmented reality, also gave the opportunity to perform tasks in parallel in a real and virtual environment with the possibility of more efficient cooperation between several users (collaborative work) (Billinghurst and Kato, 1999). Since the development of the first AR systems, special benefits have been seen in areas related to supporting the maintenance of technical objects: preparation of technical objects for work, repair and preservation, including staff training in these areas.

One of the first AR systems supporting device maintenance is presented in (Feiner et al., 1993). The KARMA system, despite its simplicity resulting from the use of visualization based on simplified edge models, well supported the user in his service and maintenance tasks.

Another example of using AR to support maintenance operations is ARVIKA (Friedrich , 2002). The authors have developed a system of several application scenarios, one of which is problem solving and operation of production machines, which aims to support personnel and machine users during their startup, operation, maintenance and repair. Such support can take place directly (with the use of a computer) or in interaction with the service center. Examples of applications of the ARVIKA system include assistance in the design of factory installations, maintenance and repair of NATO helicopters or servicing and repair of sliding roofs of BMW cars. Another STARMATE system (Schwald et al., 2001) provides assistance to the user during disassembly and assembly of complex technical devices and their servicing. It is also a training tool for maintenance personnel. This system enables employees to perform tasks requiring high qualifications (often exceeding their possessed qualifications). The system operates in accordance with the idea of "learn by doing" and allows to raise the qualifications of personnel. The authors of the system present examples of applications in disassembly and repair of jet engines, in which the user is supported by the AR system, indicating subsequent service activities regarding disassembly and reassembly of engine parts, necessary tools as well as engine technical documentation.

A more recent example of an AR system is VTT PALMOS (Savioja et al., 2007). The VTT PALMOS system (Plant Model Services for Mobile Process Maintenance Engineer) was developed for maintenance work performed in industrial plants by the maintenance staff of these plants or external service providers. The system allows the user to solve problems of how to quickly locate equipment that requires maintenance, how to get concise and clear information about the equipment of the plant and its condition, or how to combine and use knowledge obtained from many sources of information without the need of using a wide range of computer software.

In the literature, especially in online sources, we can find many other interesting examples of using augmented reality in the areas of support for maintenance and service activities, e.g. with the use of mobile devices (Pocket-lint, 2019), in military area (especially interesting system for operational use and repair of military objects called ARMAR (Singularityhub, 2019)), in the automotive industry (Dailymail, 2019) (Volkswagenag, 2019) (ARMedia, 2019).

3. AN ELABORATED AR SYSTEM FOR AIDING MAINTENANCE TASKS

Initial AR system developed by the author was implemented for maintenance of mobile robots and passenger cars. As a part of further research AR systems was developed in cooperation between WIELTON S.A. and Silesian University of Technology. In this case implementation was realised for the needs related to maintenance of curtain semi-trailers. This implementation for semi-trailers was much wider than presented in this paper and connected also with other areas of company operation like marketing and sales.

3.1. A structure of AR system

Visualization of technical objects with the use of AR techniques in developed system bases on the results of design process realised in the environment of CAD software, eg. PTC Creo Parametric, Autodesk Inventor Professional or Dassault Systemes 3D Experience. It is possible also to use other CAD/CAM/CAx systems. AR system presented in this paper was integrated with PTC Creo Parametric as CAD software for modelling. For the purpose of using such 3D models in AR systems, when we want to use other than PTC software, it is necessary to convert them to universal formats, for example: *.dae, *.fbx, *.stp. Such models, using software such as Blender, Autodesk 3ds max, are then supplemented with photorealistic texture maps. Texture maps allow to increase the level of realism of 3D models. Whereas, when we use an integrated software environment, which base on PTC software all applications are easier, because no conversion to universal CAD formats is needed. In such a way it is possible to use a native format of PTC *.pvz. A structure of an integrated system for AR visualization is presented on Figure 1. The integration includes the following software types: PTC Creo Parametric as a system for 3D modelling (including FEM analysis with the use of PTC Creo Simulate), PTC Creo Illustrate for preparing animation of 3D models, PTC Vuforia Studio for preparing AR scene, and finally PTC Vuforia View as a final viewer installed on Microsoft HoloLens HMD or on a tablet with a camera. All data used by PTC Vuforia Studio, including 3D models, models with results of FEM analysis, manufacturing simulations, kinematic simulations, additional text, sound or graphic data can be stored in a repository, e.g. PTC Windchill.

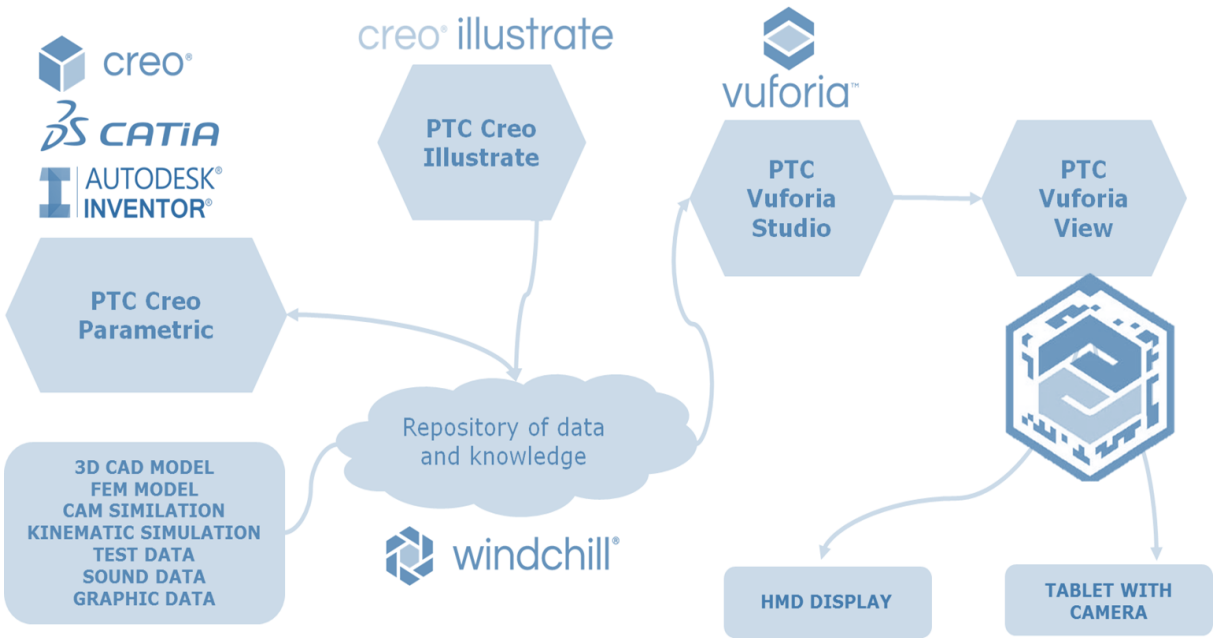


Fig. 1. A structure of a system with AR techniques implemented

If a 3D CAD model is used for aiding maintenance tasks, then additional animation schemes for 3D models are created. Animations involve the possibility of introducing interaction with the 3D model at the stage of its visualization in the AR system. For animating 3D CAD models in the system it is possible to use PTC Illustrate, Blender or Autodesk 3ds max. Final visualisation of animated 3D CAD models in AR environment is possible with the use of PTC Vuforia Studio. Initially the author used Metaio software for final visualisation. Such implementation was realised for maintenance of mobile robots and cars. An immersion to AR environment is possible thanks to the use of hardware solutions: HMD display Microsoft HoloLens or mobile devices like tablets and smartphones. These devices need to install special viewers for AR environments, e.g. PTC Vuforia Viewer or Metaio viewer.

3.2. Functionality of AR system

The application of the developed AR system in the field of maintenance may include two cases. The first relates to supporting staff by training, while the second relates to supporting staff while they are working. In both cases, exactly the same AR system can be used. In the second case, the benefits are particularly visible to less experienced staff or to atypical, customized objects whose operation requires an individual approach and cannot be based on staff experience.

Operation of the AR system in the area of training of maintenance staff may consist in the use of an interactive virtual model of a three-dimensional technical object (the so-called virtual mock-up), replacing the real object, displayed in the AR mode, i.e. directly in front of the user in a 1:1 scale (Figure 2).



Fig. 2. Visualisation of a virtual semi-trailer in a real environment for aiding truck drivers

However, in order to be able to present information and knowledge to the user using the AR system together with the model of the object, it is necessary to use an appropriate display device and a tracking system to properly link the computer-generated information to the real world. As display devices, head-mounted displays (HMDs) and various types of portable devices, i.e. tablets and smartphones can be used (Azuma, 1997). In applications to support activities in a real environment, such as maintenance activities, the best solution will be optical HMD Hololens display that works so that the image of the real world is seen through a semi-transparent display screen, on which additionally (e.g. through appropriate projection) images of virtual objects are displayed.

In the above-mentioned example of application of an interactive 3D model, the AR system allows the user to become acquainted primarily with the simulation of the operation of the presented virtual device/machine. It is possible to visualize the presented object under typical application conditions for the device/machine. For example, we can visualize the operation of an industrial robot in the place where it will work in reality, i.e. in a facility where the production line is located. In addition, the user of the AR system has the opportunity to learn about the construction of the device, assembly, disassembly, etc. It is also possible to present the service instructions for a given device or some of its components.

A particularly important case of using the AR system is associated with supporting the operation of machines and devices based on their real instances, and not as in the first presented case based on a realistic, but virtual equivalent. Appropriate information and knowledge using interactive 3D models and other objects superimpose the image of the real object, thus giving an enrichment of human knowledge. The AR system allows us to properly carry out the maintenance process (e.g. repair or replacement of a worn part) of an actual technical object. A person without proper knowledge can be guided step by step by the system that gives instructions in what order and how to perform a given service. The system supports the user in such a way that even without prior training, he is able to effectively implement the service process. Appropriate instructions using elements presented in the form of text, three-dimensional interactive (including animated) 3D models, and even movies are visualized in the place of the physical device for which the operation is carried out (Figure 3 and Figure 4).



Fig. 3. Presentation of location information and ID numbers of car components with the use of AR application installed on a tablet

Also in this application case, the AR system allows the user to become familiar with the basic components that make up the actual technical object. However, information about the location, name, catalog (identification) number of individual components of the technical object are displayed exactly at the place of implementation of the activity (directly on the real object). The functionality that allows the presentation of components is used to visualize the interior of the technical object. It is possible to visualize the location of individual components that are not normally visible from the outside and are, for example, hidden inside the housing. This information is a hint for an inexperienced user, what is the exact location of the component. This information can be useful e.g. in case of the need to replace or repair such component. All kinds of data and information (e.g. catalog data, i.e. parameters, designations and numbers) of selected components can also be displayed. The information presented should be related to the process of operating a given object, and so, for example, information about the symbolic designation of a given element should enable the correct selection of a spare part to be installed in exchange for the existing one. Finally, a user of the system can also receive information about the type of tool used, which is necessary during the implementation of the activity (e.g. type and size of a spanner necessary to disassemble a machine body cover), including its visualization and simulation of how to use it during the implementation of the activity.

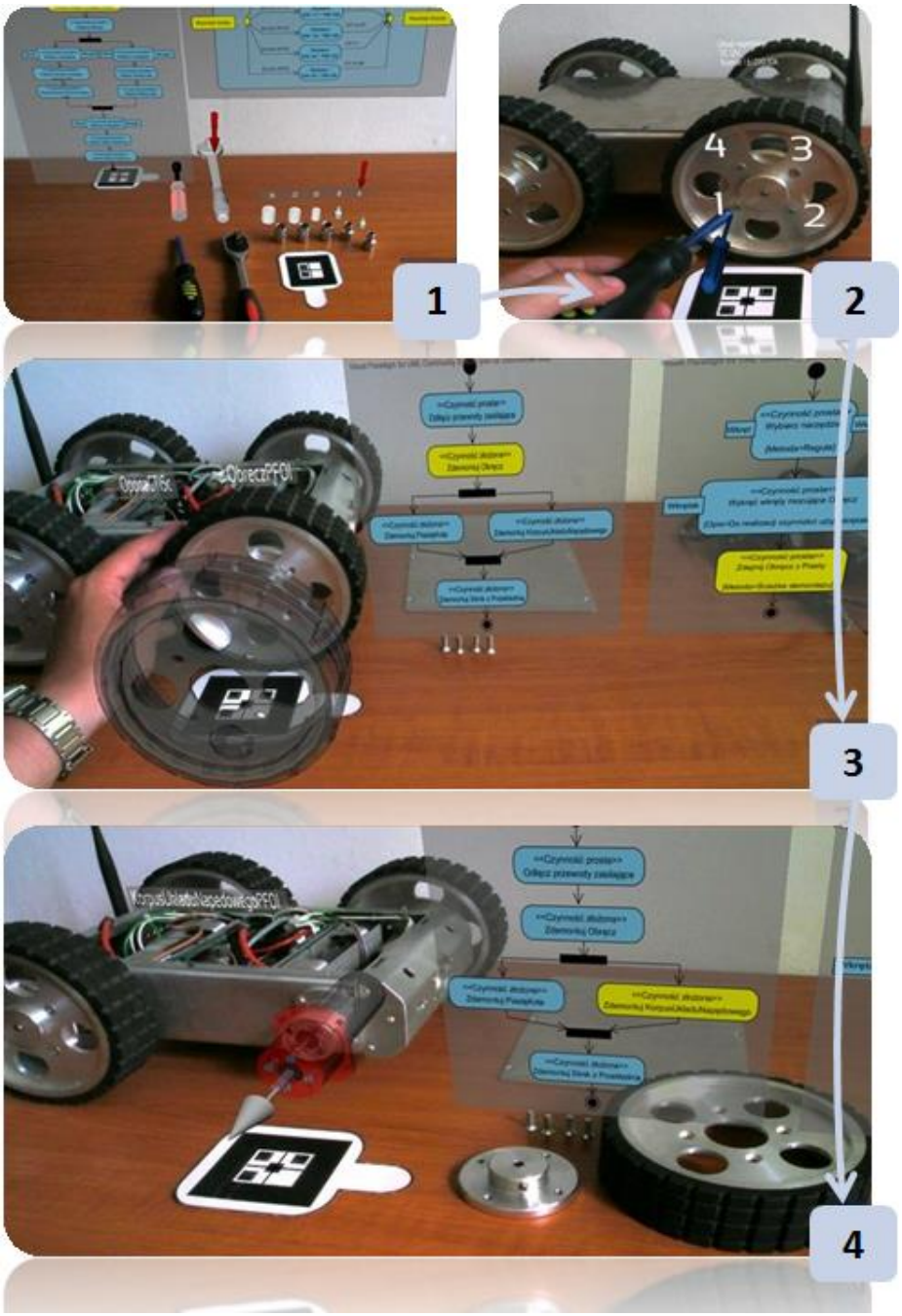


Fig. 4. Presentation of the maintenance operation on the example of a mobile robot: 1 - aiding the selection of tools, 2 - instructions for wheel unscrewing operations, 3 - instructions for wheel disassembly operations, 4- drive system disassembly instructions

The developed AR system supporting maintenance of semi-trailers allows to correctly and quickly perform the process of service (e.g. the repair or replacement of worn out parts). It should be possible for standard and emergency (when it is not possible for prior training) vehicle servicing situations. A person without a proper knowledge (prior training), i.e. a driver of a truck with a semi-trailer), is carried out step by step by the system providing instructions concerning the way and procedure of the service. Instructions visualized in AR mode may contain:

- visual simulation of the activity (e.g. a way of some part disassembly),
- information about the kinds of tools used during the execution of the necessary actions (e.g. a type and size of a key needed for a disassembly), including visualization and simulation of usage during the execution of the task,
- audio records of how to implement a task (with the possibility of enriching videos).

4. SUMMARY AND CONCLUSIONS

The use of augmented reality techniques is an excellent way to support the training of personnel related to maintenance, in the operation of a given type of machine or device, and additionally to support the daily work of such personnel. Moreover, such type of application allows to use 3D CAD models in whole product development cycle in efficient way. AR systems based on data and information from interactive, animated 3D CAD models collected in various types of repositories provide the user with the opportunity to acquire basic skills and skills in operating a given real technical object with maximum elimination of risk of damage any expensive equipment. Initially, user's training can be organised with the use of an interactive virtual 3D model of the technical object displayed in AR mode. Later it can be continued while working on a real object. This way of knowledge presenting is extremely intuitive, especially when compared to the presentation of knowledge in a classic form (printed instructions). Bearing in mind the benefits of using AR systems in this type of applications, it should be assumed that they will be dynamically developed and implemented in industrial plants in close future.

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