AIDING THE PROCESSES OF MACHINERY DESIGN, MAINTENANCE AND DIAGNOSTICS USING AUGMENTED REALITY

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Summary

The paper presents the results of a research on applications of Augmented Reality (AR for short) which have been carried out in the Department of Fundamentals of Machinery Design, Silesian University of Technology, Gliwice, Poland. AR is a technology rising from Virtual Reality (VR). Generally, the main aim of application of AR technology is to aid the user in his/her operation in the real world. There are briefly described the applications of augmented reality concerning three important stages of a product lifecycle. The first one is the implementation of AR in machinery designing. The second one concerns aiding a technician in his maintenance work. And the last one is the application of AR in machinery diagnostics.

Keywords: augmented reality, virtual reality, designing, maintenance, diagnostics.

ZASTOSOWANIE POSZERZONEJ RZECZYWISTOŚCI WE WSPOMAGANIU PROCESÓW PROJEKTOWANIA, OBSŁUGI ORAZ DIAGNOSTYKI MASZYN

Streszczenie

W artykule zaprezentowano wyniki badań prowadzonych w Katedrze Podstaw Konstrukcji Maszyn (KPKM) nad zastosowaniem poszerzonej rzeczywistości (*ang.* augmented reality) we wspomaganiu prac inżynierskich. Poszerzona rzeczywistość wywodzi się z wirtualnej rzeczywistości. Podstawowym celem jej stosowania jest wspomaganie człowieka w wykonywaniu przez niego różnych działań. W artykule przedstawione są przykładowe systemy poszerzonej rzeczywistości opracowane w KPKM. Zastosowania tych systemów odnoszą się do kilku podstawowych etapów związanych z cyklem życia produktu, tj. projektowaniem, obsługą i diagnostyką tego produktu.

Słowa kluczowe: poszerzona rzeczywistość, wirtualna rzeczywistość, projektowanie, obsługa, diagnostyka.

1. INTRODUCTION

A term "Augmented Reality" (AR) [1, 2] was originally used to describe systems that join virtual information with a view of real environment and present them to user's eyes. AR in comparison with Virtual Reality (VR) joins in one space virtual information with information concerning the real world surrounding the user. Virtual information is provided in a form of labels, shadows, animations, geometrical elements appearing on the camera view presented to the user's eyes or even sounds heard by the user. A characteristic feature of AR systems is that they place real objects and virtual data in one space. Virtual information should be accurately oriented (aligned) with respect to real objects. Therefore significant task is to provide a quick, accurate recording and merging process. Usually, user of such a system wears a Head-Mounted Display (HMD) and with the help of this device can see augmented reality image.

There are many practical applications of AR systems [1]: medicine, designing, manufacturing, maintenance and repair, assembling, robotics, military (HUD), even in entertainment. In all the applications mentioned the main goal of using AR system is to aid the user in his/her operation.

2. APPLICATIONS OF AUGMENTED REALITY

In the following chapter presented are the three AR systems which have been elaborated in the Department of Fundamentals of Machinery Design, Silesian University of Technology. The first of them aids the user in the designing process [3]. It allows evaluating virtual concepts of a product presented in the real world surrounding. The second AR system was made to help the technician in his/her maintenance work on Electronic Gaming Devices (EMG) [5]. The last one facilitates performing a diagnostic task that depends on sound level measurements around the machine and reasoning about it state [6].

2.1. Designing

Information, originated from diagnostic measurements concerning existing versions of a designed product or similar one, can be used to keep to a minimum (in design stage) potential inefficiencies or failures which can occur during operation of a designed machinery system [3]. By this reason, proper usage of information about failures and inefficiencies in machinery allows designing more reliable versions of machinery.

A designer of machinery could be aided by different modern computer techniques. AR is the one of the modern computer techniques which can aid the designer by providing necessary information during designing [3]. AR system developed in the Department of Fundamentals of Machinery Design, Silesian University of Technology, can provide information about symptoms of failures and inefficiencies (e.g. exceeded limit of vibrations, noise, temperature or pressure) in previous versions of machinery to be designed. It is possible also to provide information how to reduce these failures and inefficiencies.

Information can be displayed for the designer in the form of interactive 3D models, text, pictures, tables, diagrams etc. that may be presented in any place of real environment (on a table, on a wall etc.). Representations of machinery systems might be easier to understand if they were available, not in the form of manuals with text, tables and pictures, but rather as 3D models and drawings superimposed upon the real world. The goal of the research was to provide a solution for the interactive AR system aiding the user in the design process [4].

Let us consider how the designer interacts with AR system. During design process the user with HMD on head sits in front of a computer. The user looks through HMD over the cards from a special catalog with markers and the AR system displays virtual models of previous versions of a designed product and/or some information in the form of virtual text onto these cards. The user by changing pages can preview all data about a selected model of the designed product. The designer can also export the selected 3D model to CAD/CAM/CAx software CATIA v5r16 and then in CATIA workplane see that model. It is possible to improve the model in order to eliminate inefficiencies and failures in the prospective machinery system. During the design process the user has permanent access to the information from a database of AR system. It is possible to get information (in any form) about causes of failures and procedures to eliminate those failures. This information is displayed in the real environment.

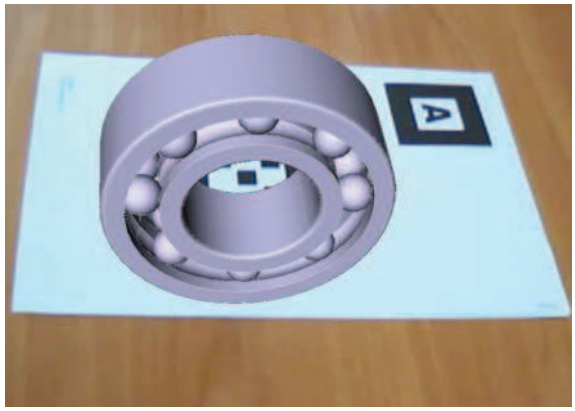

Fig. 1. Example of aiding a designer by AR system

When the design process is accomplished the user can export the finished 3D model of machinery system back to AR software and preview results of her/his work. The model is displayed (also in 1:1 scale) in the real environment, onto the card from the catalog. A designer can pick up the catalog and manually manipulate the model for an inspection. All the helpful information from AR system and models of machinery systems can be viewed by the user in the real environment from any perspective in a very efficient and intuitive way [3, 4, 8].

Future work will be concerned on the development of presented AR system. For that purpose the authors are going to elaborate a subsystem which can allow designing machinery systems with improved diagnosability. The subsystem should aid the user by providing him/her with indispensable information (e.g. information how to chose the optimal place for sensor) not only in order to design reliable machinery systems but also to design products with improved diagnosability.

2.2. Maintenance

The primary objective of the project done within thesis [5] was to create a knowledge base for selected devices that are capable of using AR technology to aid in systems preventive maintenance and development of the various electronics of the slot machines. Based on evolving literature, and criteria analysis it was decided that an AR system, which enhances the effectiveness of the system with the aid of sound, using a Personal Data Assistant should be assembled. It was also made apparent that revisions of the methods employed to capitalize on the full potential of AR were necessary, making the following steps vital to the deployment of the technology as it was intended: developing assumptions of the system, making requirements of the system, and introducing examples how the system can be used during a preventive maintenance of devices.

The evolution of this project resulted in a PDA-based AR system, whose function is to fulfill two distinctive tasks [5]: one being to enable the selection of the troubled device and the other being

empowering individuals with the capability of identifying specific malfunctions.

The first function is designed to enable the selection of a faulty device, via a touch-screen tool, while also displaying information concerning the proper function of the respective system. Information is transmitted as sound through headphones, and its developments will be viewable on the PDA's screen. The second function of AR system is the ability to locate the failure within the given device; the screen will display detailed inquiries with possible answers of either yes or no. Based on the answers, the user is informed about potential solutions to the problem/s at hand. The system's information will be generated through two distinct sources: employee research from previous encounters with that particular model or a paralleling model of a given piece of equipment, and the manufacturer's instructional publications.

2.3. Diagnostics

There are three stages of machinery diagnostics process where AR can be applied [7]. In the first step (preparation of the object to the test) AR system can facilitate tasks concerning connection of pieces of measuring equipment, e.g. by indicating the location of sensors or/and the right order of connecting them. In the second step (tests of the object) the AR system may show in the appropriate order the location of measurement points, warn away from some dangers (rotating elements of the machine, high temperature) or forthcoming damage of the machine. In diagnostic reasoning AR system could present some measurement results, could inform about elements of the machine or phenomena that may be reasons of any inefficiency.

It was decided to elaborate a system whose functioning is adjusted to the standard [9]. Basing on this standard are carried out the classes in the laboratory of the Department. The classes consist in measuring noise in 21 points placed on virtual half-sphere around the machine. Particular requirements concerning way of measuring and dimensions of the half-sphere (its radius, distances between the reflecting plane and other planes) are presented in the standard [9].

Noise level measurements are used for reasoning about technical state of the machine. These measurements are also performed to determine an influence of the noise generated by machine on a human organism and its operation.

A conception of a project assumed elaboration of a system, whose functioning principle was based on video see-through HMD idea of AR system, but HMD was replaced by a monitor.

The system performs two main functions [6, 7]: shows measurement points in the right order (Fig. 2) and next, using measurement results, informs about noise level in every measurement point (Fig. 3).

The elaborated system consists of an USB camera, display monitor, PC computer with software, cables and the square marker, printed on a rigid piece of paper, used for tracking. Its structure allows estimating correctly the camera position. Matlab and ARToolKit for Matlab [8] were used as computational software. ARToolKit, basing on the view of the marker in the image of the camera, determines the camera position (by calculating the Transformation Matrix) using various methods of image processing such as thresholding, labelling, edge and corner recognition. Next ARToolKit superimposes virtual information appropriately oriented to objects in the image of the real environment and sends the augmented image to the monitor [8].

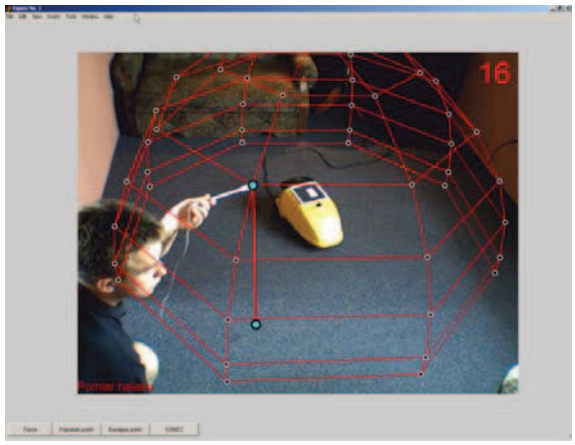

Fig. 2. Example of implementation – measuring noise level [6]

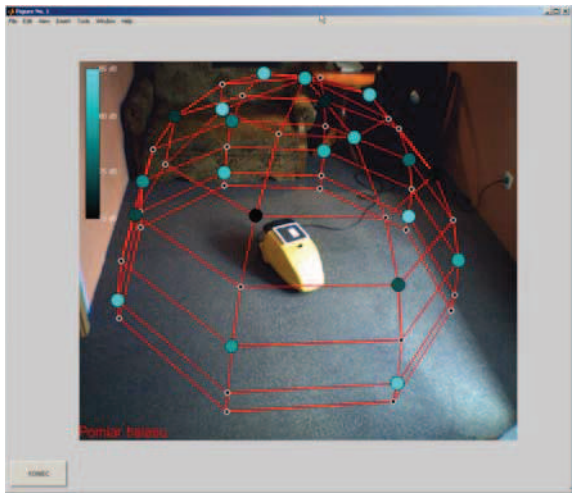

Fig. 3. Example of implementation – measuring results [6]

The system under operation presents the user the location of the current measurement point, its projection on the ground and its identifier according to fig. 2. The user has to put the microphone on a projection point, and then move it upwards to the measurement point. This task is quite difficult, because 3D model of virtual information is projected as 2D image. The user does not know if the microphone is exactly in the respective measurement point.

When the measurements have been done and the results have been collected, system presents them to the user using coloured circles. A colour shade of circles depends on measurement results. In the figure above is a screenshot of an image generated by the system and presented to the user.

3. SUMMARY

In the paper a very innovative AR technology was shortly introduced. Furthermore, three implementations of AR tightly connected with product lifecycle have been presented. All of the mentioned applications have been developed in the Department of Fundamentals of Machinery Design (Silesian University of Technology at Gliwice,).

Multitude of possible applications of AR, e.g. in maintenance, training, computer-aided design, diagnostics, and many others, proves the very large usability of this incoming technology.

The authors are going to carry out a comprehensive research on AR technology and its applications. The main interests focus on knowledge engineering in intelligent AR systems, CAD supported by AR, and applications of AR in machinery maintenance and diagnostics.

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