Applying the Augmented Reality and RFID Technologies in the Maintenance of Mining Machines

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***Abstract* - The paper presents the results of MINTOS RFCS project and announces conception of new Augmented Reality system that will be developed in EMIMSAR RFCS project. Current KOMAG's solutions in the field of improving occupational safety are presented in the paper. Training programs that are developed are an innovative solution in the field of training. Development of workers' competences during training with use of Augmented Reality and RFID technologies is realized on a real machine, which will be used at work by training participants in the future. Training conducted directly at the workplace develops both knowledge and practical skills. Apart from construction and principle of operation also machines, safe work methods developing manual skills and safe behaviour are presented during the training. Augmented Reality technology enables superposition of computer image on a real object, which makes possible development of proper workers' behaviour during machine breakdown. Applying the AR technology in the industry enables to increase safety during work – the risk of making a mistake is minimized. Scenarios of training on mobile stands with use of AR technology are strongly connected with real work conditions, in real work environment. RFID technology enables to relate knowledge resources to each mining machine, what simplifies and improves applying the knowledge resources during training. RFID technology can be applied during training conducted in unfavourable conditions in the mine underground as well as in real operation conditions. Applying the RFID technology to aid mining machines maintenance is presented in the context of delivering information about current technical condition of a machine and delivering knowledge about proper maintenance of a machine at the work site.**

Index* - *RFID, Augmented Reality, maintenance, training, knowledge repository, safety, mining

I. Introduction

PROPER maintenance of machines is one of factors conditioning proper manufacturing processes in industrial companies (further named "machine users"). Maintenance of machines is a process, proper realization of which is conditioned by the knowledge of personnel involved in that process, i.e. 1) personnel of maintenance division of a given industrial company, and 2) personnel of service division of manufacturers of machines. Reference [5] shows that this knowledge enables conducting of proper activities in an effective way in compliance with time restrictions, including safe work methods. These relations are presented in Fig. 1.

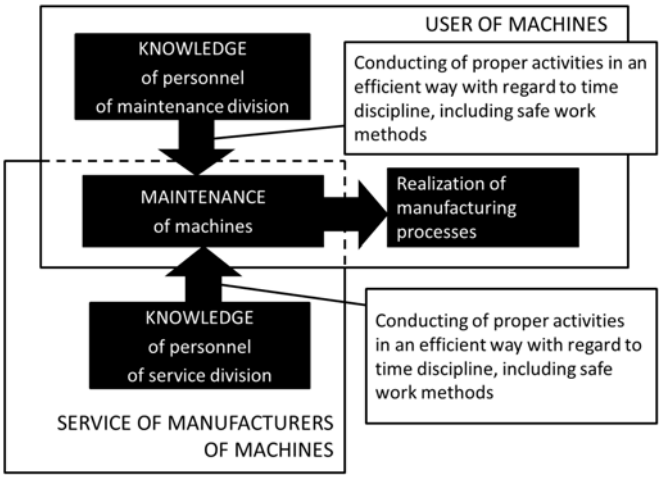

Fig.1. Relations between manufacturing processes in an industrial company, maintenance and knowledge of maintenance personnel

Complex and unique structure of mining machines is their characteristic feature. Due to the size of machines, location of machine stands (places of machines operation) and conditions present in those places, as well as conditions of transportation routes, transportation of machines to the surface is problematic and time-consuming. In consequence, maintenance activities are carried out at machine stands. Unique conditions as regards available space, adhesion of floor, possibility of aiding the manual activities, environmental impact on machine, etc. are characteristic for each machine stand. Unique structure of mining machines as well as unique conditions present at their stands cause that maintenance activities are also conducted in a unique way.

II. Knowledge Resources in Maintenance of Mining Machines

At present participants of the process of maintenance of mining machines use explicit and tacit knowledge. Resources of explicit knowledge include technical manuals and so-called instructions. Technical manuals are used by servicing personnel of manufacturers of machines and personnel of machine users, i.e. collieries. Instructions are developed by colliery itself and only for its own purpose. Resources of explicit knowledge are used on the surface. Sometimes some parts of resources are used at the place where maintenance task is carried out.

Technical manual includes, among others, structure of machine, operational conditions, operational activities,

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maintenance activities that can be conducted by a user of machine, transportation activities and safety requirements that are in force. Knowledge presented in documentation refers to a particular copy of machine. However, it does not include conditions at machine stand. Instructions are in a form of procedures describing each task in a maintenance of machine of a given type at a given machine stand. They describe activities that must be done to complete a given task, including safety requirements that are in force and organizational aspects – organizational units, personnel of which is responsible for conducting the particular activities.

Resources of explicit knowledge include only a part of knowledge, which is used for maintenance of machines. The rest part of knowledge is tacit knowledge and only its part is transformed to explicit knowledge in a form of instruction. So, knowledge resources used by a personnel who conducts maintenance of machines are created and developed on the basis of experience gained during machine life.

Resources of explicit knowledge are based on traditional forms of knowledge presentation such as text and static image. It limits possibilities of presentation of some aspects of knowledge such as e.g.: principle of operation of each machine systems, method of performing of each maintenance activity. Having for disposition only traditional forms of knowledge presentation causes that some resources of tacit knowledge are not formalized, i.e. they are not transformed into explicit knowledge. Dissemination and use of resources of explicit knowledge on a paper carrier make their up-dating and extending difficult, because all participants of maintenance tasks should have identical resources of explicit knowledge.

Tasks in maintenance of mining machines are mainly conducted at machine stands. Geographical dispersion, difficult availability (problem with delivery of machine to the place of its use and problem with delivery of indispensable material resources) and specific conditions also as regards lighting, humidity and pollution are characteristic for these tasks. It does not favour the use of traditional, paper knowledge resources.

Dissemination of resources of tacit knowledge is possible only through experience – during conducting of tasks (e.g. with use of current instruction). Time discipline that is characteristic for conducting the maintenance tasks (especially repairs) and conditions at machine stand (spatial limitations, noise, poor lighting) do not favour assimilation of knowledge.

To conduct the maintenance processes, personnel involved in this process takes part in training, during which a content of resources of explicit knowledge or a content that is a combination of explicit and tacit knowledge is presented. Knowledge used in the maintenance of machines is specific due to unique structure of a given machine and unique conditions at a given stand. Including those problems in training is a serious financial and organizational problem. Training on a particular machine, which is used in colliery, is not conducted. During training on a machine at manufacturer's site mainly machines of similar structure are available, but it is impossible to include conditions characteristic for underground stands of mining machines operation.

III. USE OF STATE-OF-THE-ART FORMS OF KNOWLEDGE DISSEMINATION IN THE MAINTENANCE OF MINING MACHINES

The forms of knowledge dissemination, which:

- give wider possibilities of transformation of tacit knowledge into explicit knowledge,
- present knowledge in a simple and easy to understand way,
- enable quick searching for knowledge resources, which are adequate to current needs of workers who conduct the maintenance tasks,
- enable use of knowledge resources in any place and time, independently on conditions,

should be used for efficient aiding of maintenance of machines.

Meeting these expectations is possible by complementary use of the following solutions:

- interactive technical manuals,
- technical manuals based on Augmented Reality (AR) technology,
- check lists available through RFID technology.

All these solutions were developed at the Laboratory of Modelling Methods and Ergonomics at the KOMAG Institute of Mining Technology in a form of applications.

A. Interactive technical manuals

Interactive technical manuals can include wide range of knowledge, especially content of currently used resources of explicit knowledge supplemented with information about accidents, which happened due to conducting the activities as regards maintenance of a given machine.

Knowledge resources are presented in a form of textual descriptions, static images, 3D models (of machine and its components), interactive animations presenting structure of machine and method of its assembly and disassembly, animations presenting method of machine operation (its selected components or systems) and method of conducting of each maintenance activity.

Interactive technical manuals are developed in two principal versions:

- stationary version (Fig. 2a) – developed for use on surface, on stationary computers. Knowledge resources are on the server and they are available for authorized persons after log-in on their personal computers. Working with application is conducted through web browser.
- mobile version (Fig. 2b) – developed for use on portable computers such as PDA. Knowledge resources and application are located on a given portable computer, where they are used through a suitable browser. Use of PDA in version, which meets requirements of ATEX directive, enables to transfer resources to mines undergrounds. That is why interactive technical manuals can be helpful during conducting the activities in the maintenance of machines.

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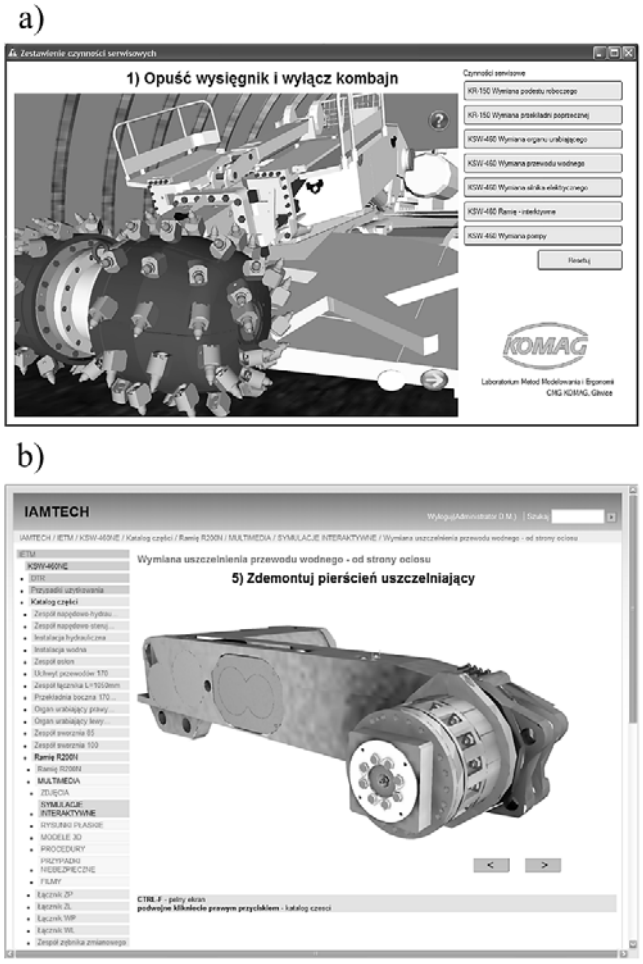

Fig. 2. Interactive technical manuals: a) stationary version, b) mobile version

Making interactive technical manual available on board computer of mining machine is current direction of development in the Laboratory.

B. Use of Augmented Reality technology in dissemination of technical manual

Augmented Reality technology consists in a supervision of additional information, further named associated information, on a real image – Fig. 3. Labels describing each component of machine, animations presenting method of operation of selected installations or tips about next steps that should be undertaken to conduct a given maintenance task are the examples of such information. Pieces of information are assigned to markers on a machine or its model. These pieces of information displayed in a context of markers become knowledge resources.

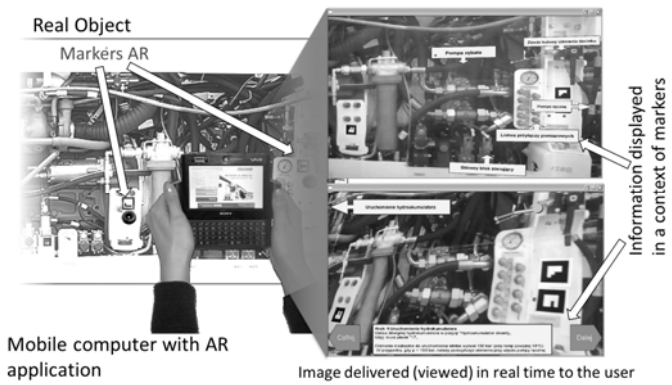

Fig. 3. Idea of Augmented Reality technology

Augmented Reality technology is a quite new solution. Due to this, there is no software with proper functions to aid the maintenance process. The software that is available on the market are computer applications in amusement and advertising sector where such technology is used as curiosity. Special libraries made for recognition of images are available but their use requires knowledge of programming languages such as C++ or C#. Present computer applications, which were developed at the KOMAG Institute of Mining Technology, are based on authors software solutions and on results from completed MINTOS European project, [4].

Use of technical manuals, which are made available with use of Augmented Reality technology, is based on a system including: 1) worker involved in conducting the maintenance of machine, 2) hardware and software equipment and 3) machine (or its model) with markers – Fig. 4.

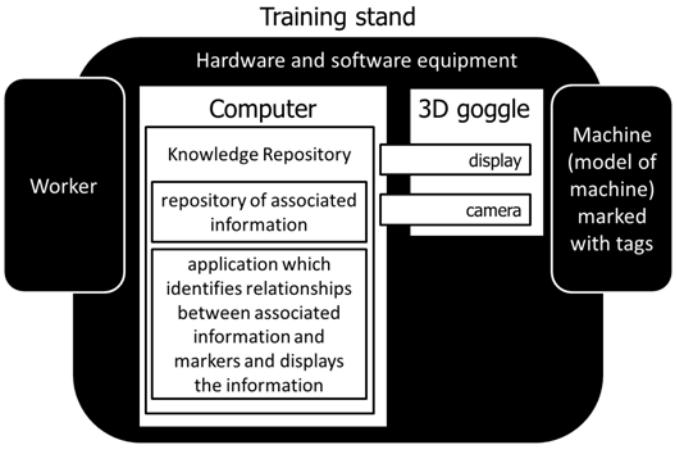

Fig. 4. System for dissemination of knowledge about the maintenance with use of Augmented Reality technology

Computer includes knowledge repository, which consists of repository of associated information and an application within which pieces of associated information are assigned to particular markers and displayed - superimposed on a real image being the background. Camera recording real image and screen on which real image with associated information is displayed are indispensable components. These both components can be integrated with a portable computer (Fig. 5a), and they can also be integrated with head recording-and-displaying equipment such as 3D goggles (Fig. 5b).

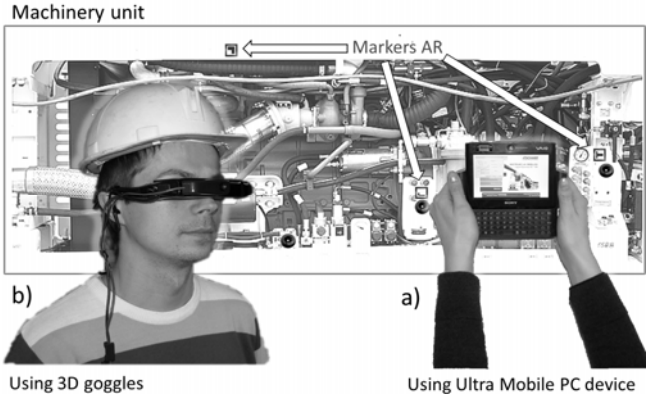

Fig. 5. Use of UMPC computer (a) and 3D goggles (b) in Augmented Reality

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Functionality of hardware-and-software equipment should include recording and displaying of real image, collecting of associated information, recognition of markers as well as identification and displaying of textual and graphical information assigned to each marker on a real image.

In a developed application contextual availability of knowledge resources is conducted by linking markers with associated information and by suitably prepared menu of AR technical manual – Fig. 6.

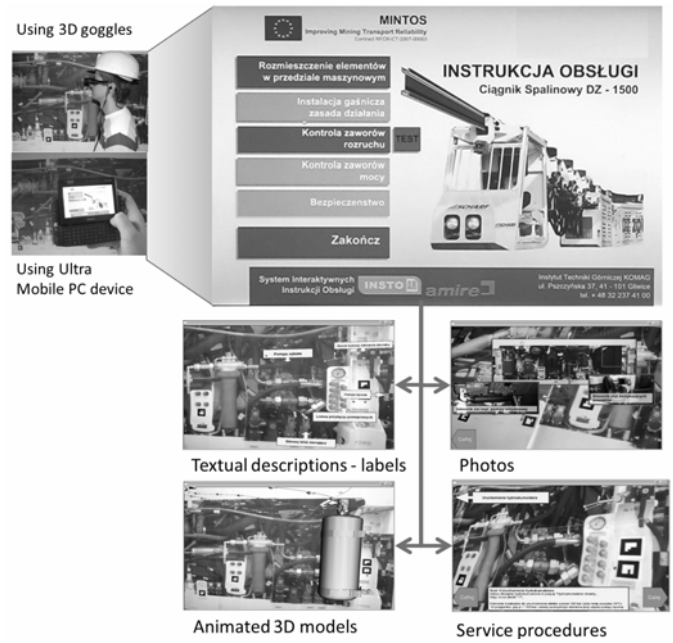

Fig. 6. Menu of application making knowledge resources available with use of Augmented Reality technology

Presented solution can only be used at training stands, [3], [1]. Identification of markers requires good lighting, what can not be ensured at machine stands. Availability of suitable computer, which meets the requirements of ATEX directive can also be a problem.

C. Use of RFID technology in a dissemination of check lists

Solution, which is an adaptation of RFID technology for dissemination of knowledge resources, was also developed at KOMAG to aid participants of the maintenance process [2]. Knowledge resources were developed in a form of check lists. Check lists are in a form of procedures describing activities conducted within the maintenance process. Suitably developed application enables their assignment to tags (also named transponders), which are on a machine. On the basis of reading the tag identifier, conducted with use of a reader, application displays a check list, which is assigned to it. Knowledge resources are thus available in a context of needs of personnel who conducts the maintenance of machines. Available check lists are displayed by internet browser. A group of check lists assigned to each tag is a knowledge repository.

Due to the fact that control lists are in a form of internet websites, there is a possibility of their mutual linking, as well as their linking with check lists, which are not directly assigned to tags, but they are in the check list repository. Thus, there is a possibility of assigning the group of check lists to a given tag, while only one check list is directly assigned to this tag.

Use of check lists, which are available due to use of RFID technology, is based on a system including: 1) worker involved in conducting the maintenance of machines, 2) hardware and software equipment and 3) machine marked with tags – Fig. 7. RFID reader can be a separate component plugged into computer or it can be integrated with a computer. Such system can be used directly at the place where the maintenance activities are conducted. RFID manuals are then hand-held aid. Modification of the system by placing the tags on a model of machine enables its use at training stand.

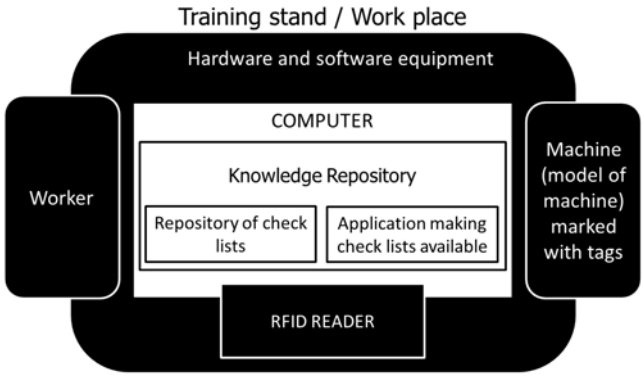

Fig. 7. System for dissemination of knowledge resources about the maintenance with the use of RFID technology

PDA that meets the requirements of ATEX directive can play a role of a computer at the place where the maintenance operations are conducted, while e.g. typical (with no ATEX) PDA or UMPC plays the same role at training stand. Knowledge resources are developed considering a size of computer screen on which they will be displayed – Fig. 8.

Fig. 8. Check lists developed in UMPC (a) and PDA (b) version

Principle of operation of exemplary application, which makes check lists available by RFID is presented in Fig. 9.

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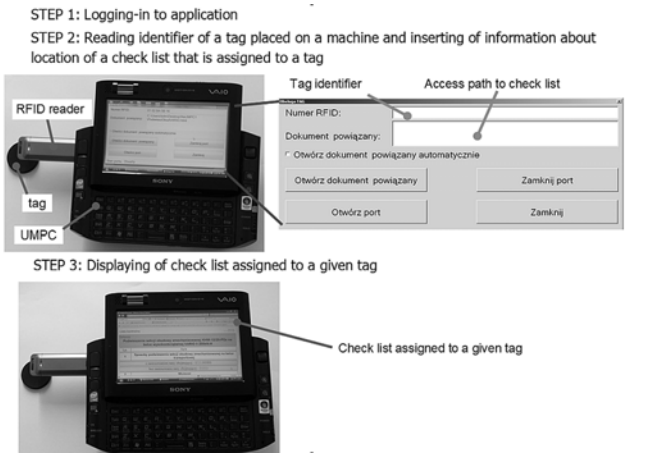

Fig. 9 Principle of operation of application, which makes check lists available by RFID technology

IV. Conclusion

Conditions, in which activities associated with the maintenance of mining machines are conducted, cause that currently used solutions as regards knowledge resources, aiding personnel involved in the maintenance process, are insufficient. Limitations result from traditional forms of presentation of knowledge and from use of paper carrier. System of solutions based on state-of-the-art forms of knowledge dissemination was suggested to overcome that problem. None of these solutions can overcome all the problems associated with currently used knowledge resources by its own. However, complementary use of solutions can make it possible. Life cycle of technical means includes the stages like: designing, stand tests (laboratory tests) of a prototype, manufacturing, maintenance and withdrawal from use. In all those stages knowledge resources are generated, collected and open to be accessible. Usefulness of AR and RFID is especially important in making knowledge resources accessible.

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