SUPPORTING THE DIAGNOSTICS AND THE MAINTENANCE OF TECHNICAL DEVICES WITH AUGMENTED REALITY

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Summary

The article presents the method for the support of diagnostic processes with the use of an original computer system in which augmented reality is applied. The proposed solution constitutes a significant step towards improving actions directed at the assessment of the technical condition of complex technical devices. The research problem presented in the article was defined through the determination of the scope of diagnostic tasks which the personnel may find difficult in certain technical conditions. The research method consisted in the selection of a technology facilitating effective execution of diagnostics of complex technical devices. In the developed solution diagnostic processes are executed via the visual presentation of the following: the location of the components of the device, the diagnostic tasks, the descriptive hints, the measurement values, the location of the measurement points, and the 3D models of the components.

Keywords: augmented reality, diagnostics.

WSPOMAGANIE DIAGNOSTYKI OBSŁUGI URZĄDZEŃ TECHNICZNYCH Z WYKORZYSTANIEM RZECZYWISTOŚCI ROZSZERZONEJ

Streszczenie

Artykuł przedstawia metodę wspomagania prowadzenia procesów diagnostycznych z zastosowaniem technologii rzeczywistości rozszerzonej. Rozwiązanie jest znaczącym krokiem w kierunku usprawnienia działań, których celem jest ocena stanu technicznego złożonych urządzeń technicznych. Problem badawczy określony został poprzez zdefiniowanie zakresu prac diagnostycznych sprawiających trudności przy określonych uwarunkowaniach technicznych. Metoda badawcza polegała na wytypowaniu technologii umożliwiającej skuteczne wspomaganie prowadzenia procesów diagnostycznych złożonych urządzeń technicznych. W opracowanym rozwiązaniu prowadzenie procesów diagnostycznych realizowane jest poprzez wizyjna prezentację operatorowi systemu: lokalizacji elementów składowych urządzenia technicznego, czynności diagnostycznych, podpowiedzi opisowych, wartości pomiarowych, lokalizacji punktów pomiarowych, modeli 3D elementów składowych urządzenia.

Słowa kluczowe: rzeczywistość rozszerzona, diagnostyka.

1. INTRODUCTION

The constant technological progress facilitates the development of complex mechanical and electronic constructions, concurrently making their efficient and correct diagnostics more and more problematic [1, 2]. The incorrect operation of a device may result in standstills or even threaten the well being of the technical personnel using it. It is also an essential factor responsible for the continuity of a production process. When the diagnostics of different types of complex technical objects is performed by a few staff members only, it means that they have to be knowledgeable about the architecture of the device as well as the sequence in which each operation needs to be undertaken. One of the ways to solve this problem, is the application of tools supporting the diagnostic processes. The increasing computational capabilities of modern computers make it possible to construct tools that can use digital image analysis and processing techniques in real time [3], which significantly increases the effectiveness of work of the technical staff.

One of the technologies using the techniques of digital image analysis and processing is augmented reality [4, 5], which is a technology joining the real world with the virtual reality [6, 7]. In augmented technology, virtual objects are projected onto a part of reality that is recorded by a camera or a set of cameras. This technology is already widespread in military applications, but it is also becoming more and more popular in civilian applications as well. It is assumed, that a significant development of systems using augmented reality will take place in the near future, which will cause great changes

concerning human-machine interaction, and shape new perception of the surrounding world [8].

2. STRUCTURAL AND FUNCTIONAL MODELS OF THE SYSTEMS

As a result of the analyses of market demand and the necessity to improve the effectiveness of tasks conducted by the technical personnel, an original system using augmented reality to facilitate the diagnostics of technical objects was developed at the Institute for Sustainable Technologies – National Research Institute in Radom. A characteristic feature of the system is its functionality. The instructions are supplied in the online mode, which provides visual support for the system user at the time of the diagnostic process, which means that no prior training or the presence of a trainer are required.

The main structural elements of the developed system include a server, a projection device, a digital camera recording the analogue image and processing it to the system seen by the user, a computer, original software for image processing and analysis, and a manipulator (Fig. 1).

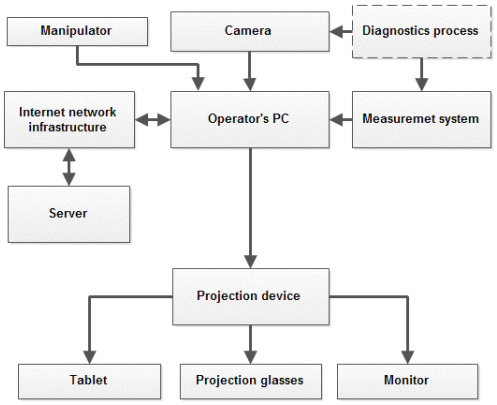

Fig. 1. Hardware structure of the system for the support of diagnostics processes of complex technical devices using augmented reality

The projection device is selected based on the complexity of the performed diagnostic operations, the specificity of the diagnosed device, and the requirements of the system user. The projection device can have a form of a traditional computer screen, a tablet or projection glasses [9]. The tablet also plays a role of a computer. The hardware structure of the system is also composed of the Internet infrastructure, which constitutes a communication medium between the user and the instructions. The image displayed by the projection device is in the real time mode enriched with virtual objects in form of 3D models [10], markers and descriptions generated by the original computer software based on the digital instructions prepared in advance in order to show the user the exact location of an element, and inform what diagnostic tasks need to be performed.

The positions of virtual objects are set with reference to the system of coordinates, whose beginnings are highlighted with the markers [11, 12] (the specially prepared pictograms) that are placed on a technical device. The algorithm for the enrichment of the real image with virtual images is as follows:

- The acquisition of the image of a technical device with markers placed on it;
- The analysis of the recorded image to locate the markers;
- The calculation of coordinates of the markers and their orientation in relation to the cameras (the system operator);
- The identification of the markers by means of their comparison with the established models;
- The calculation of the coordinates of virtual objects in relation to the systems of reference and orientation of the individual markers;
- The rendering of virtual objects on the recorded image and the projection of he modified image;

As a result, the image of a technical device, enriched with virtual objects, is obtained (Fig. 2).

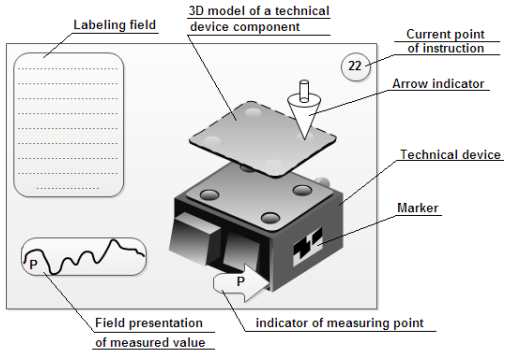

Fig. 2. View of the image presented to the user in the system for the support of diagnostic processes with the use of augmented reality

As for the software, the system functions according to the client-server technology (Fig. 3).

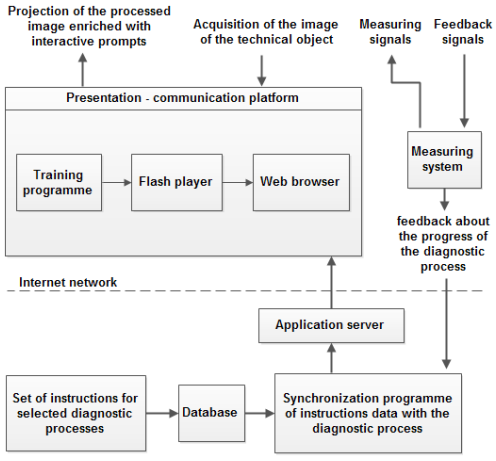

Fig. 3. Structure of the system for the support of diagnostic processes with the use of augmented reality

On the server side, the software is composed of the application server in which the software for the synchronisation of the instructional data with the condition of the diagnosed technical device, and the database and the set of instructions dedicated to selected diagnostic processes are located. On the client side, a training programme functioning within the presentation and communication platform in form of a Web browser and the Flash runtime environment, is located [13]. The advantage of such a design over stationary solutions is such, that the user is not obliged to install the dedicated software on the computer to which the camera and the projection device are connected. From the software side, the system is also adapted to work in cloud computing.

3. STRUCTURAL AND FUNCTIONAL MODELS OF THE SYSTEMS

Diagnostics with the developed system is performed by means of a visual presentation of the following: the localisation of the components of the device, diagnostic tasks, tips in a textual form, measurement values, the localisation of measurement points, 3D models and components of the device. Apart from the identification of the condition of the device, the methodology also assumes the application of the device in such areas as:

- Repairs (actions aimed at restoring functional properties of the device that has failed, during which operations related to regeneration or replacement of damaged components are carried out);
- Maintenance operations (actions recommended by the manufacturer of the device aimed at the maintenance of the components of the device in a condition enabling its effective and correct operation);
- Technical personnel training (improvement of skills and acquisition of competencies necessary to perform tasks related to the diagnostics, repair and maintenance of technical devices);

A person operating the system receives visual impulses from the projection device constituting a part of the user communication interface. The selection of the projection device depends on the conditions in which the system is used, the complexity of the planned diagnostic tasks, or the individual preferences of the user. In the case when the operator should have full freedom of movement, the most advantageous type of a projection device are projection glasses, as they do not require the involvement of hands and do not hamper the mobility of a user, which is highly beneficial in the case of devices with large dimensions. Projection glasses are in fact two miniature screens mounted in a frame. They can be worn in exactly the same manner as typical glasses or sunglasses.

Fig. 4. Example of the application of augmented reality in a developed system for the support of diagnostic processes

The camera used for the recording of the technical device can be static or dynamically shifted

along the diagnosed area together with the movement of the operator. In order to achieve its dynamic location, the camera is mounted at the back of a tablet or in projection glasses. The manipulator allows the user to move from one point to another of a prepared instruction. For that purpose a typical remote is used.

The individual stages of the diagnostic process presented to the operator can be performed with or without feedback. The instructional data synchronisation programme located in the server part of the system is responsible for the uptake of feedback. It reads the information about the state of the diagnostic process based on the data acquired from the software of the measurement system and inputs a correct entry in the database. This entry is then read by the training programme, which displays information supporting the user (e.g. information about the correctness of the undertaken action) and therefore enables the user to move to another training point.

Crucial in the developed method employing augmented reality are the interrelation between the visual projection enriched with instructions, the virtual objects, the user, and the technical device itself (Fig. 5)

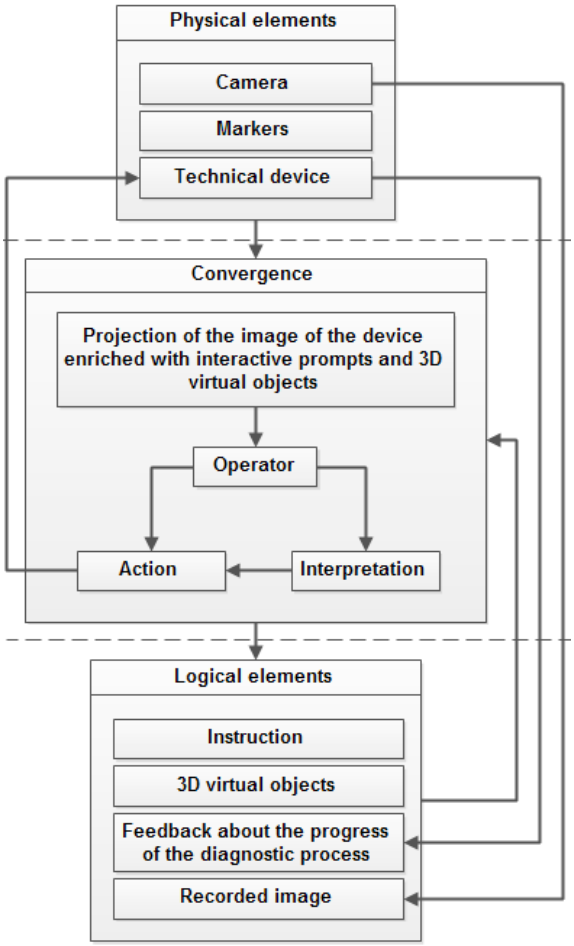

Fig. 5. Dependencies between the physical and logical elements in the method for the support of diagnostic processes with the use of augmented reality

The diagnostic process is performed with the use of physical and logical elements that have influence on the decisions made by the user. Based on the projection of the image of the technical device, which is enriched with instructions and virtual objects, the user analyses and interprets the state of the diagnostic process, and then makes decisions concerning further tasks described in the instruction. The actions of the operator, through feedback on the course of the diagnostic process, are visually signalled, and as a result the correct finalisation of tasks is confirmed. In the case of tasks that are not connected with the element generating feedback, the accuracy of the performer actions is recognised by the user based on the comparison of the physical condition of the device with the visual presentation composed of the virtual objects and the text.

4. SUMMARY

The described solution composed of a methodology and an original system for the support of diagnostic processes employing augmented reality technology, constitutes an important step towards improved human-machines interactions. By applying the developed solution, the time needed for a diagnostic process can be shortened (particularly with reference to complex technical devices), the costs of staff training reduced, number of technical employees decreased as a result of a widened scope of tasks that can be performed by a single worker only, and the effectiveness of training improved. The application of the developed system in industrial conditions can have a significant influence on the maintenance of the continuity of the production process, as it reduces the number of threats connected with the unavailability of the staff responsible for the diagnostics, which is particularly important in enterprises employing not many people, but at the same time manufacturing or using many different products. The developed solution has an open character, which means that the system and the proposed methodology can be supplemented with new elements and data. It is possible for the solution to be used in different application areas including e.g. the current operation, servicing or repair of technical devices, which indicates its significant developmental potential.

REFERENCES

[1] Niziński S., *Diagnostyka obiektów technicznych*. Zagadnienia ogólne. Wydawnictwo UWM, Olsztyn, 2001.
[2] Niziński S., Wierzbicki S.: *Zintegrowany system informatyczny sterowania pojazdów*. Diagnostyka, nr 30 t.2/2004. s. 47-52.
[3] Szmuc T., *Modele i metody inżynierii oprogramowania systemów czasu rzeczywistego*. Uczelniane Wydawnictwo Naukowo-Dydaktycze AGH, Kraków 2001.

[4] Haller M., *Emerging Technologies of Augmented Realisty*. Idea Group Publishing, Hershey USA, 2006.
[5] Yu D., Sheng Jin J., Luo S., Lai W., Huang Q., *A Useful Visualization Technique: A Literature Review for Augmented Reality and its Application, limitation & future direction*. Visual Information Communication. Springer, 2010.
[6] Ma D., Gausemeier J., Fan X., Grafe M., *Virtual Reality & Augmented Reality in Industry*. Springer, Londyn, 2011.
[7] Burdea G. C., Coiffet P., *Virtual Reality Technology*, Second Edition, Wiley-IEEE Press, 2003.
[8] Zhou F., Duh, H. B. L., Billinghurst M., *Trends in augmented reality tracking, interaction and display: A review of ten years of ISMAR*. IEEE International Symposium on Mixed and Augmented Reality 15-18. Cambridge UK, 2008.
[9] Cakmakci O., Rolland J., *Head-Worn Displays.* Journal of Display Technology: A Review vol. 2/2006.
[10] Dugelay J. L., Baskurt A., Daoudi M., *3D Object Processing, Compression, Indexing and Watermarking*. Wiley, 2008.
[11] Sun R., Sui Y., Li R., Shao F., *The Design of a New Marker in Augmented Reality*. IPEDR vol. 4. IACSIT Press, Singapore, 2011.
[12] Uchiyama H., Marchand E.: *Object detection and pose tracking for augmented reality: Recent approaches*. 18th Korea-Japan Joint Workshop on Frontiers of Computer Vision (FCV), 2012.
[13] Pedersen A., Polanco J., Winnie D., *Flash platform from start to finish*, Adobe Press, 2010.

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