Proactive Ergonomics Based on Digitalization Using 3D Scanning and Workplace Modeling in Texnomatix Jack with Augmented Reality

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Summary

This paper suggests a vision of present possibilities of modern ergonomics, and an application model of the proposed system in the digital environment of digital plant. Future trends and visions use a proactive approach of modern ergonomics integrated with sustainable success management. The implementation of new approaches digital plant of ergonomics and occupational safety and health management assumes synergic effect brought by the harmony between proactive ergonomics and risk management in everyday working operations. It makes it possible to improve both safety and production quality. The application of innovative methods and progressive software tools as digitalization using 3D scanning and workplace modeling in Texnomatix Jack with augmented reality, enables plants to increase their production quality, to reduce the number of defective products, to carry out efficient maintenance, to identify risks on time, to increase human factor safety and reliability before launching the actual operation of the system, as well as to prevent losses in the very pre-production phase.

KEY WORDS
ergonomics
quality production
digital plant
digitalization workplace
3D scanning
augmented reality

INTRODUCTION

The term ergonomics is understood to be a scientific discipline dealing with study of mutual relations/interactions among people and other system components as well as professions that are applying the theoretical knowledge, principles, empirical data and methods intended for design processes oriented to optimization of well-being for persons and for optimization of the global system efficiency [1]. The ergonomic aspects considered during development of a new working system or for correction of an already functional working environment enable to discover all problems and deficiencies of the projected or existing system. Evaluation of the working system ergonomics is a useful tool for scheduling of the required preventive or corrective measures. In this way it is possible to eliminate the unacceptable working conditions that can cause a higher fatigue level of workers, reduction of their working productivity, increased number of accidents at work and occupational diseases, higher absence and fluctuation of employees etc. [2]. In order to avoid the above-mentioned negative phenomena, it is necessary to create healthy and high-quality workplaces in accordance with the individual ergonomic requirements.

It is possible to achieve continuous improvements in quality management and also to search for reserves in the area of human factor reliability management, by means of innovatory approaches and innovative technologies [3]. These utilize, for example, digital environment tools for ergonomic analysis in order to achieve the above-mentioned goals. Such approach is currently one of the key factors in achieving survival and competitiveness of each organization.

TOOLS AND METHOD

The application part of the presented paper is derived from the basic framework model of ergonomic workplace creation. This model consists of the following steps:

1. Video analysis of workplace - a fast identification of the input requirements using "video-data".
2. Digitalization using 3D-scanning of the working environment – a fast identification of the input requirements for conducting a primary optimization (original arrangement of the workplaces, dimensions of the individual devices, localization of obstacles and limitations).
3. Creation of the primary model in the TECNOMATIX JACK module developed by Tecnomatix. The TECNOMATIX JACK module is useful for creating a detailed solution of the working environment with regard to influence of a job performed on the human factor, as well as for fast evaluation of the working positions, and for other ergonomic analyses performed in order to make necessary improvements to the given workplace condition [4].
4. Augmented reality - The principle of the augmented reality, which is implemented in the framework of the preventive method applications.

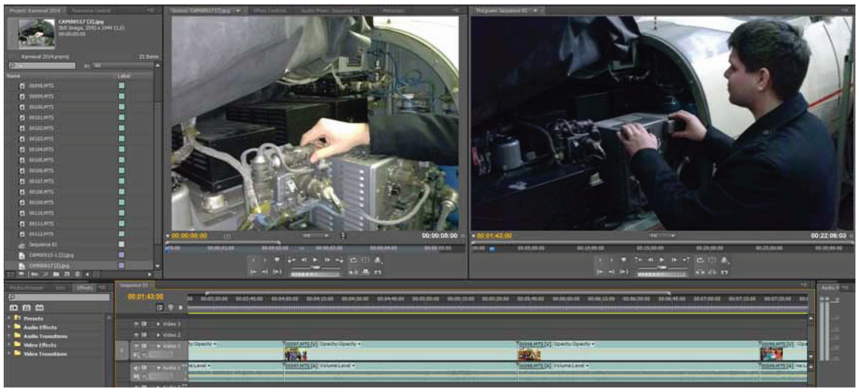

Fig. 1. Video analysis of working place of service works on the main control unit of avionics systems aircraft L-39 Albatros

Source: Authors

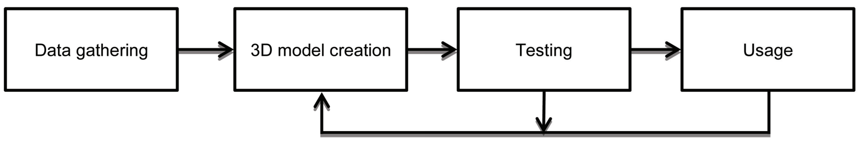

Fig. 2. Digitization and usage pipeline

Source: Authors

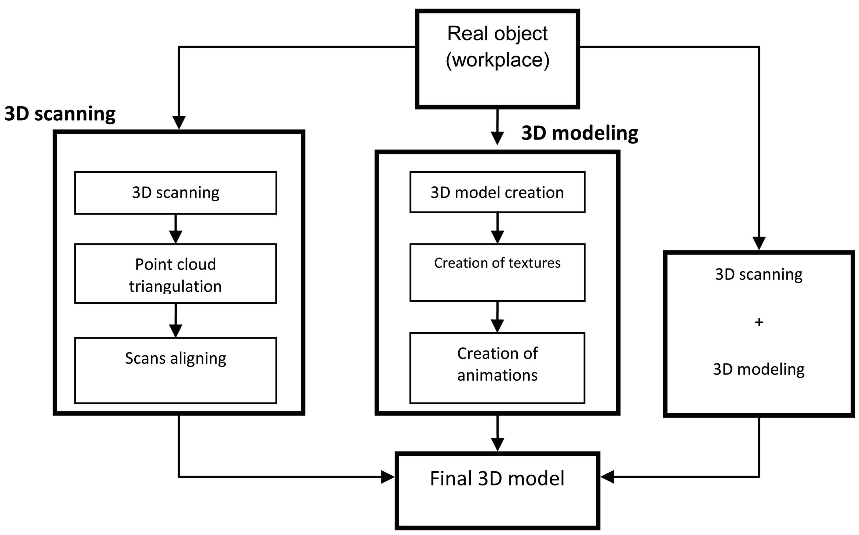

Fig. 3. 3D model creation process 3D scanning result and imported 3D model in TX Jack are depicted in Fig. 4

Source: Authors

VIDEO ANALYSIS

Video analysis of employment is helpful for modeling so that after a comprehensive inspection of video and audio recording it is possible to identify critical points in which there are unacceptable job positions and disruptive external influences in the working environment.

DIGITALIZATION USING 3D-SCANNING AND WORKPLACE MODELING IN TECNOMATIX JACK

Technomatix Jack (TX Jack) allows identification of risks which result from a work activity. In order to ensure fast and accurate modeling in this application, it is necessary to know the real condition of a workplace. Answer to this problem is digitization of a workplace using virtual reality technologies and 3D interfaces. Output of a digitization process is a 3D model that contains detail information about workplace.

Digitization process and subsequent using of a 3D model (e.g. visualization, simulation or 3D printing) consist from several stages [5]. Everything begins with collecting information and analysis (data gathering phase). When the data are prepared, creation of a 3D model begins (3D model creation phase). A check of model for errors follows after 3D model creation (testing phase). Usage of the final model is the last step (usage phase). This process is depicted in Fig. 2.

There are three ways how to create a 3D model of a workplace (see Fig. 3):

- **3D scanning** – a 3D model can be created almost automatically by using a 3D scanner,
- **3D modeling** – a 3D model can be created manually using CAD/CAM applications,
- **Combination of 3D scanning and 3D modeling –** this approach combines advantages from both.

For digitization service works on the main control unit of avionics systems 3D scanning was used. 3D scanning process consisted from two stages: 3D scanning and data processing [6]. 3D scanner used for this digitization was Leica ScanStation 2. Some of its parameters:

- scanning method – time of flight,
- scanning density – up to 1 mm,
- range – up to 300 m,
- scan rate – up to 50,000 points/sec.,
- field of view – 360° (horizontal) / 270° (vertical).

The main aim of the proactive ergonomic approach is compatibility of the wide range of new technologies, innovative ideas and procedures, including augmented reality which enables application of the human factor simulation into practice (see Fig. 5).

AUGMENTED REALITY

Augmented Reality (AR) merges real world and virtual environment. A virtual object is added into real world in order to improve or to add more information for an observer. AR is computer-generated data integration with the real world, which among others can be done with computer graphics rendering on a real-time footage. AR can be used for many things, such as displaying mobile directions to head-up display, in the medical field, the AR may help doctors to insert information on a patient's medical record (such as x-ray result from the patients), or to reconstruct old buildings and historic objects as reality which can be seen at the present, or maintenance on the control unit of avionics systems aircraft [6]. More information about this technology is given in [7]-[13], [14], [16]. According to the method how virtual objects are aligned with real scene image there are two systems in use:

Marker systems – special markers are

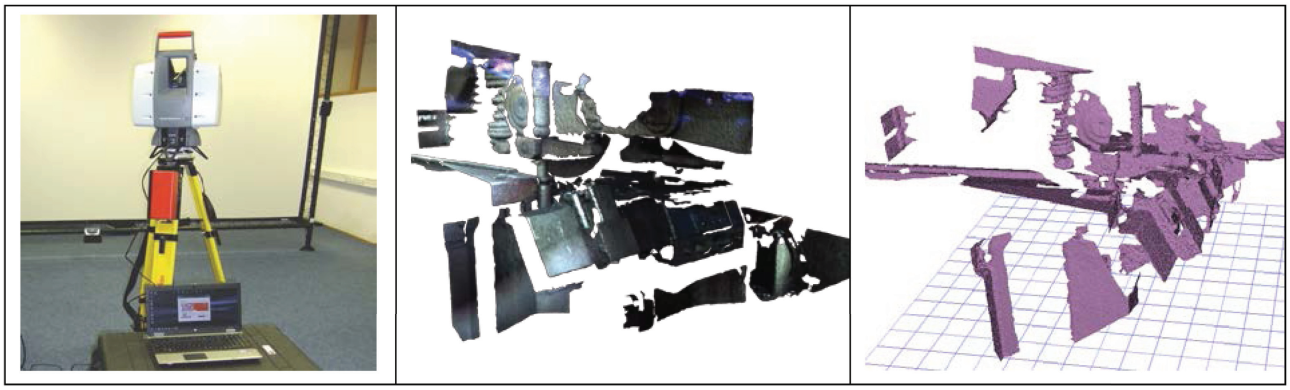

Fig. 4. 3D scanning result and imported 3D model in TX Jack

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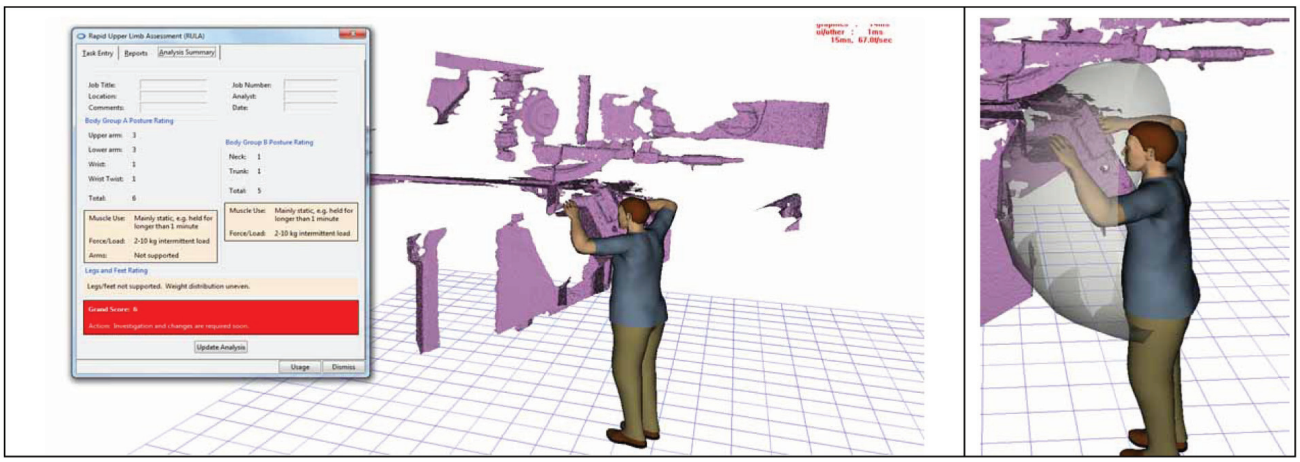

Fig. 5. Operation process study; results obtained from TECNOMATIX JACK software support: and RULA method (left), reach zones (right)

Source: Authors

used in a real scene. The markers are then recognized during runtime and replaced with virtual objects.

Markerless systems – processing and inserting of virtual objects is without special markers. Additional information is needed, for example image (e.g. photo (semi-markerless system)), face recognition, GPS data, inertial and electromagnetic tracking devices, etc.

Both augmented reality and augmented virtuality systems are quite similar and they belong under mixed reality definition. A goal of mixed reality system is to merge real world with virtual one into new environment where real and virtual (synthetic) objects exist together and interact in real time. Relationship between mixed reality, augmented reality and augmented virtuality is defined by Fig.6 [8], [9].

HEAD-MOUNTED DISPLAY AND ELECTROMAGNETIC TRACKING DEVICE

A head-mounted display (HMD) is display device, worn on the head or as part of a helmet that has a small display optic in front of one (monocular HMD) or each eye (binocular HMD). Based on how a user sees mixed reality there can be two types of systems:

Optical see-through systems where the user sees real world directly and computer generated objects are added to this view. This category of systems usually works with semi-transparent displays.

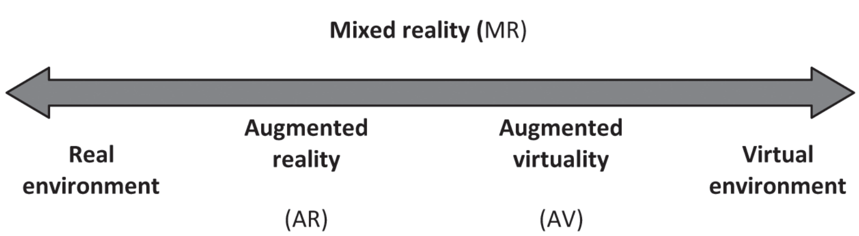

Fig. 6. Milgram's definition of real to virtual world transition (reality-virtually continuum)

Source: Milgram

Video see-through where captured real world image with added virtual objects is displayed to the user. This is usually realized via camera – display system [10].

ELECTROMAGNETIC TRACKING DEVICE

Electromagnetic spatial measurement systems determine the location of objects that are embedded with sensor coils. When the object is placed inside controlled, varying magnetic fields, voltages are induced in the sensor coils. These induced voltages are used by the measurement system to calculate the position and orientation of the object. Electromagnetic device is usually composed of two parts (Magnetic source and sensor (Fig.8)).

Magnetic source -The source is the device which produces electro-magnetic field and is normally the reference for position and orientation measurements of the sensors. It is usually mounted in a fixed position to a non-metallic surface or stand, which is located in close proximity to the sensors.

Sensor(s) - The sensor is the smaller

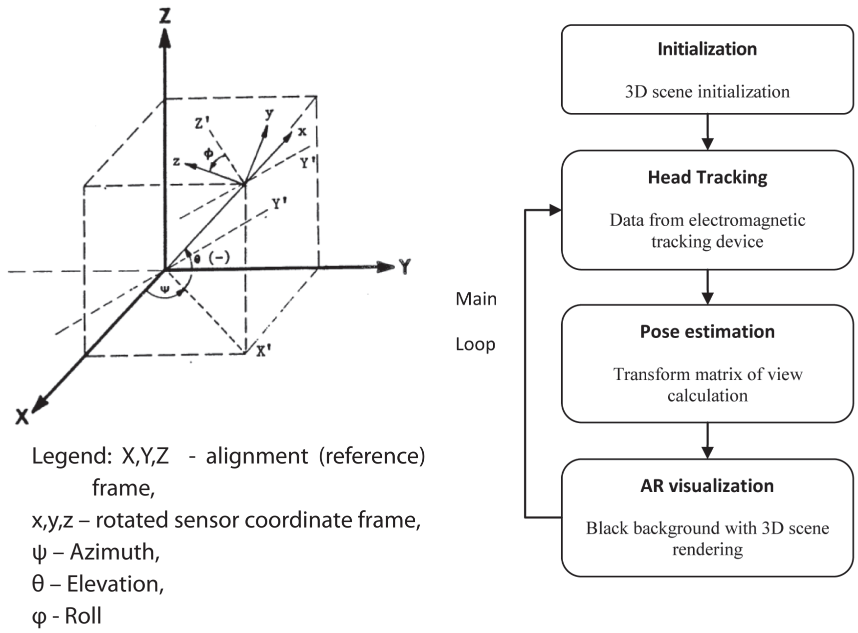

Fig. 7. Reference frame of system Polhemus Patriot [10] (left) and the architecture of the markerless AR system using electromagnetic tracking device and the visualization of virtual scene (using head mounted display) (right)

Source: Authors

device whose position and orientation is measured relative to the source.

Those parts are used to calculate position and orientation sensor in 3D space. The azimuth, elevation, and roll angles that define the current orientation of the sensor coordinate frame with respect to the designated reference frame (Fig. 7). Markerless augmented reality consists of four main components (Fig. 7): Initialization, head tracking, pose estimation and AR visualization.

HEAD-MOUNTED DISPLAY AND ELECTROMAGNETIC TRACKING DEVICE

The component *Initialization* sets virtual 3D scene which was created using 3D models in OBJ format. The component *Head Tracking* acquires human head position and orientation using electromagnetic device. After that the component sets transform matrix of view (*Pose estimation* component). The latest component (*AR visualization*) displays the virtual scene in the real world using head-mounted display.

HEAD TRACKING

Polhemus PATRIOT (Fig. 8) is used for head tracking in our solution. PATRIOT provides dynamic, real-time measurements of head position (X, Y and Z Cartesian coordinates) and orientation (azimuth, elevation and roll). PATRIOT can update data continuously, discretely (point by point), or incrementally. Sensor is located on the top of head-mounted display and it measures correct position and orientation of user head. The origin of coordinates system of virtual scene is identical with magnetic source. Fig. 8 shows a schematic representation of a system for markerless augmented reality.

POSE ESTIMATION

This component is next step after determination of human's view on real space with electromagnetic tracking device. Every virtual world has virtual camera which captures virtual scene. In this step the human view must identify with virtual camera. That means the transformation matrix of view is set. Determination of matrix parameters is needed for correct view of the virtual scene into the real world. The OpenGL uses 4x4 matrix for transformations (1). The 3 matrix elements of the column far right (m_{12}, m_{13}, m_{14}) are for translation transformation. The element m_{15} is homogeneous coordinate. It is specially used for projective transformation. The 3 elements sets, (m_0, m_1, m_2), (m_4, m_5, m_6), (m_8, m_9, m_{10}) are for transformation, such as rotation or scaling.

$$\begin{bmatrix} m_0 & m_4 & m_8 & m_{12} \\ m_1 & m_5 & m_9 & m_{13} \\ m_2 & m_6 & m_{10} & m_{14} \\ m_3 & m_7 & m_{11} & m_{15} \end{bmatrix} \quad (1)$$

AR VISUALIZATION

The system is implemented on MS Windows platform. Marker less augmented reality application using 3D model in OBJ format and for rendering which is used is OpenGl libraries (see Fig.7 (right) section "AR visualization").

For displaying a head mounted-display nVisor ST60 (see Fig. 8, Fig. 9) was used. This HMD uses optical see-through technology to create illusion of three dimensional objects in the real world. For displaying Liquid crystal on silicon (LCOS) technology was used. Displaying resolution is 1280×1024. Weight of this HMD is 1300 g.

The proposed system for markerless

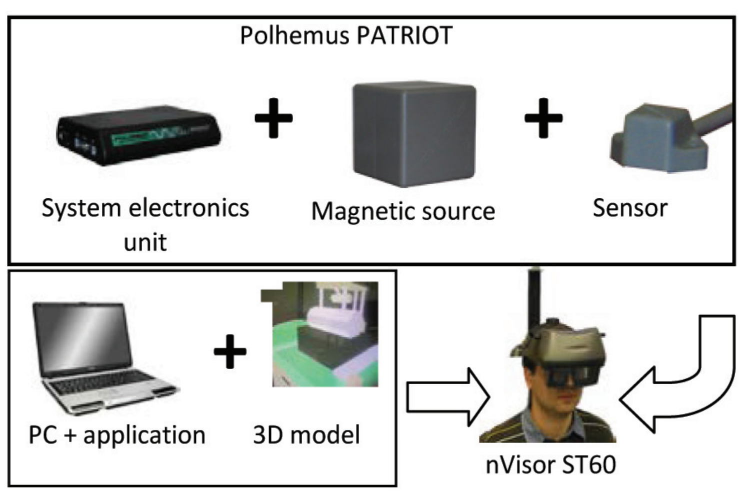

Fig. 8. The schematic representation of a system for augmented reality using a head racking device and 3D visualization (using head-mounted display). Polhemus PATRIOT consists of three main parts (System electronics unit, magnetic source and sensor).

Source: Authors

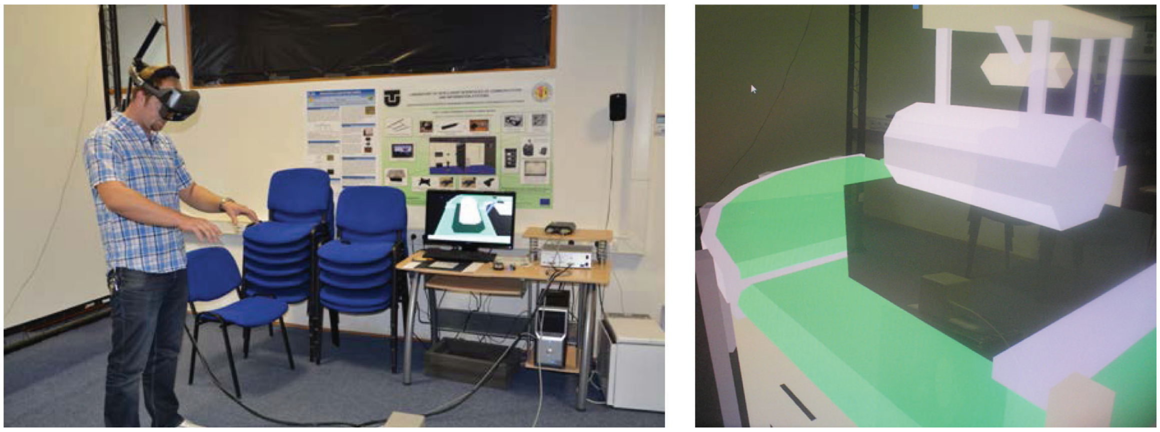

Fig. 9. The user works with AR system: The user with head mounted display is on the left and real user's view with added virtual 3D objects is on the right [8]

Source: Authors

AR display, presented in the paper, was constructed at the DCI FEEI TU of Košice (Department of Computers and Informatics, Faculty of Electrical Engineering and Informatics, Technical University of Košice). Advantage of this application is that the user doesn't need any marker for calculation of the position.

RESULTS, DISCUSSION AND CONCLUSIONS

Product quality can be reached thanks to healthy and satisfied employees who are committed and involved in the corporate processes that respect particular social aspects. Organizational issues such as management approaches, job design, participative problem solving, psychological stress, job satisfaction, performance effectiveness, product/service quality, and quality of work life are addressed by engineers specializing in socio-technical methods in system design. We should consider other important factors (such as time pressure, teamwork, designing work systems, processes and workstations that prevent injuries and cumulative trauma disorders, motivating people to work safely, devising jobs that are satisfying and minimize mental stress, designing manufacturing systems that maximize quality and productivity while taking human limitations into account) if we want to improve safety and production quality. It is better to prevent possible problems by means of a well-timed intervention than to eliminate the consequences retroactively. The principle of the augmented reality, which is implemented in the framework of the preventive method applications, is illustrated below (Fig. 9).

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