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Ergonomic design with the use of augmented reality techniques

Projektowanie ergonomiczne z zastosowaniem technik poszerzonej rzeczywistości

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The paper presents an innovative system for aiding ergonomic design of work spaces. Aiding is realised with the use of augmented reality techniques which allow to move the design process from a flat surface of a computer's monitor to a real space around the designer.
KEYWORDS: ergonomic design, CAD, work space design, augmented reality

The process of developing a technical product (Product Development Process - PDP) is complicated and complex, which results from the need to take into account an increasing number of factors. This number depends not only on the construction of the technical means, but also on the course of the subsequent manufacturing process and the remaining stages of the product's life cycle. The most important factors taken into account in the process of developing a technical objects include technical and economic factors as well as ergonomics and safety. Accepted solutions are subject to verification and validation. Despite the new possibilities of presentation and analysis of created elements, physical prototypes still play an important role in the verification of products. In addition, there is a tendency to create prototypes of technical means on several stages of PDP. In some cases, this is an expensive procedure, not dictated solely by the need to present the product to a customer who has no knowledge allowing another verification of this product. In industrial plants, there is often a need to verify the co-operation and relative positions of machines from different suppliers. A natural step in the development of product visualization support systems seems to be the use of advanced computer techniques [6]. Their example are Augmented Reality (AR) techniques [1]. AR techniques allow you to combine a computer-generated world with the real world in such a way that they constitute one unified environment. The use of AR techniques gives the possibility of transferring many stages of the process of developing a technical product from a computer's monitor to the real environment [2].

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In this article, the authors present a developed prototype system to support work space design for users of work stations. The purpose of the developed system is to facilitate and accelerate design and construction works thanks to the operator of the program through the ergonomic design process. The system simultaneously uses AR techniques to visualize the user's work progress.

Application of the system

The task of the developed prototype AR system, named ARSpaceWork, is to support the designer in the design of technical objects, and above all the working space of workstations. The stage of the design and construction process, which is the most important in the context of the visualization of work effects, runs in the actual space surrounding the constructor, not on a computer monitor [3]. The real space is called the scene of augmented reality (the AR scene). This space is enriched with virtual computer-generated objects that are subject to the process of developing a technical product (fig. 1). Before the system, the task of guiding the user (designer) over the successive stages of the PDP process was set up, including the mechanisms of associations and analogies, to direct the user's imagination to ergonomic solutions. The AR system was supported by the user in the selection of the elements of the scene, with a special focus on signaling and control objects. In addition, the program helps the user in determining the optimal location of all elements of the scene using the method of determining the significance and priorities of objects. One of the most important functions of the system is the ability to interact with selected objects through any manipulation of their location and orientation in the surrounding real space. Thus, the design process is transferred from the flat screen of the computer to the interactive real space in which the designed devices will be used after their creation [3] (fig. 1).

Developed system can be applied especially in the case of designing: control panels, equipment of cockpits, technical objects from catalogue elements (such as extended profile systems and their connections), industrial devices as well as water, electric and gas installations in rooms.

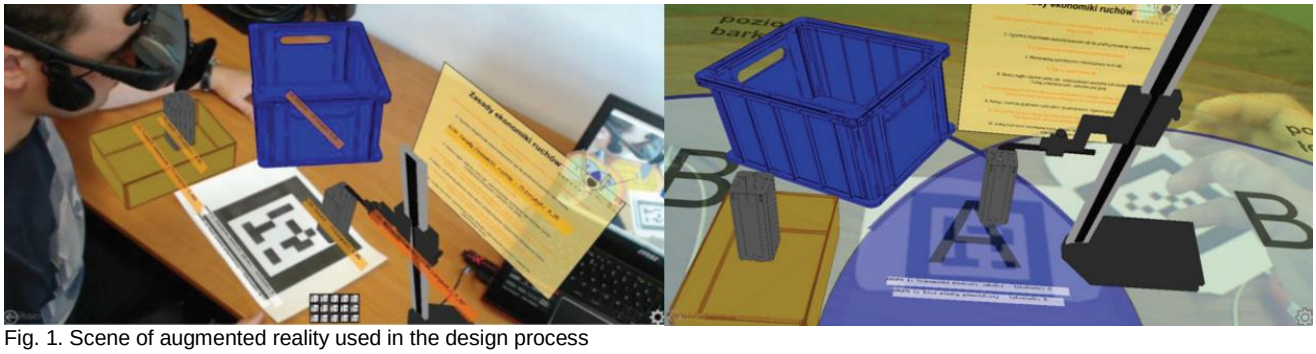

Fig. 1. Scene of augmented reality used in the design process

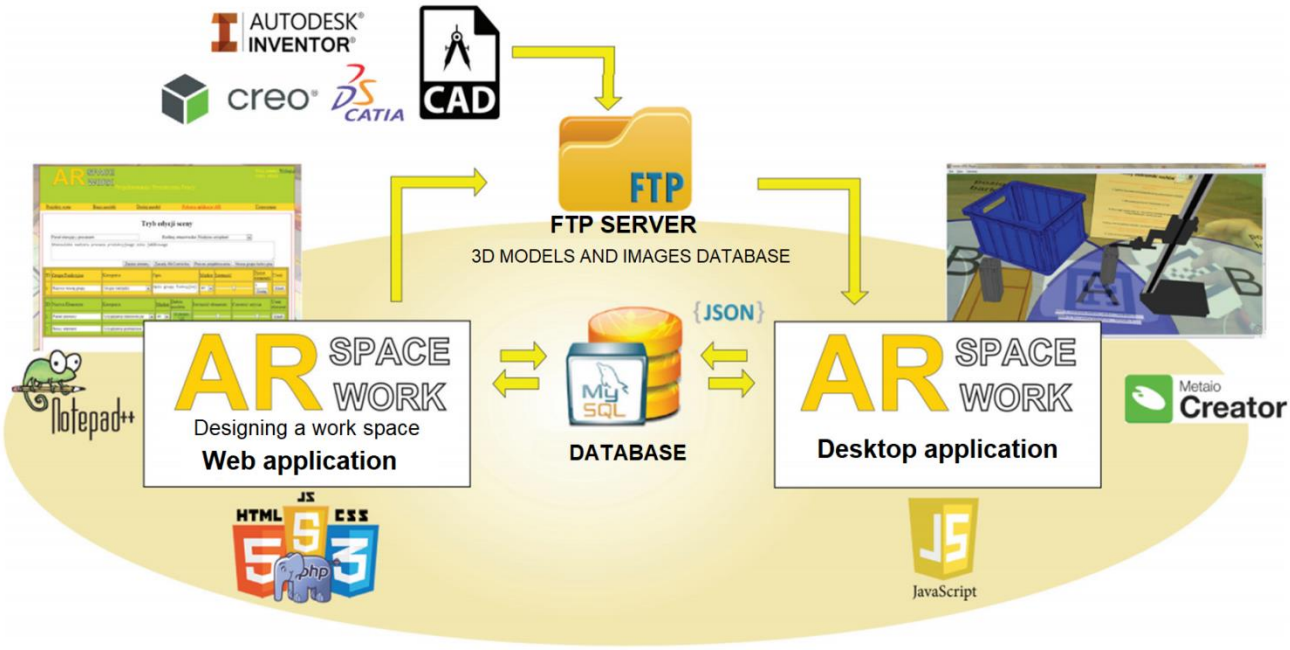

Fig. 2. ARSpaceWork system architecture

System architecture

The application of the system is related to three applications: CAD (any CAD environment, e.g. Dassault Systems CATIA, Autodesk Inventor or PTC Creo Parametric), web and desktop (fig. 2). The latter two applications have been developed for the needs of the presented AR system. The web application mainly provides an interface for creating and selecting models of projected scene elements and for communicating with the user. On the other hand, the desktop application enables the deployment of selected models in the wider reality environment. The CAD environment is used to develop models for the needs of the 3D model repository used in the AR system and to prepare the final design and construction documentation in the form of 2D drawings.

The operation of the AR system is based on recording images from a recording device (e.g. cameras) and recognizing on it a two-dimensional AR/QR markers placed in the real 3D space in front of the system user. On the AR/QR tags, the desktop application imposes CAD spatial models that simulate objects on the scene on the projected image. The idea of the system is to design a virtual device/system directly in real space in front of the user instead of on a flat computer screen. Objects are thus seen in a scale of 1:1 (or any other scale) and the designer has the ability to continuously verify the designed system, especially in relation to other real objects located in its surroundings. The system guides the user through all stages of the design process: conception, design and construction in the AR environment. It allows setting the priorities of the scene elements and helps in their optimal placement, allows the analysis of the range of hands and work zones of the employee, provides an ad-hoc knowledge base and simulations of the operator's work at the workstation.

The system requires: a computer with a clone and mouse, a webcam and a display (preferably HMD). The AR system (in the field of desktop and desktop applications) is based on the Metaio Creator program environment as well as HTML, CSS, PHP, JavaScript and SQL Internet technologies.

Design and construction process

Due to the innovative nature of the developed AR system, an original method of ergonomic design was created. This process is based, to the maximum extent possible, on the classical design and construction process - the changes were mainly introduced in the field of visualization and interaction. The whole process was concentrated around several successive stages of creating the AR scene project, depending on the use of the work space design or technical means. The design and construction project begins with the design and the stage of the initial design of the AR scene (e.g. a planned working position of the fitter on the production line). The first two stages are implemented in a web application. The last stage is the construction of a workstation scene in the real world. It is implemented in augmented reality mode.

The process of designing and preliminary designing in the proposed method consists in selecting existing elements

and/or subassemblies from the repository (3D model database and images). The repository can contain standardized, cataloged or other elements saved by the user, coming from the design and construction process. New 3D elements can be added to the database at any time directly from the CAD system. The selection of the appropriate types of elements of the AR scene (and thus the working space), and especially of the control and signaling devices, takes place on the basis of their search in the database of models with parameters determined in the search filter. The result of the process of designing and initial design is a list of priority elements that will be used to develop an assembly model of a technical means or workplace. Elements can be divided into functional groups, which allows later manipulation of all group elements in the real environment at the same time. It is also possible to transfer elements between groups depending on the needs.

The actual construction stage associated with the development of the assembly model is carried out in a desktop application on the AR scene (in the real environment around the constructor). The constructor has at his disposal all the loaded elements of the scene (models indicated in the web application), which he can freely manipulate - determine their correct relative position and orientation. To make it easier for the user to make decisions regarding the placement of elements on the stage, object labels have been implemented in the system. A single label contains the name of the element and the priority determined on the basis of the parameters of this object. The purpose of the priority is to indicate to the user (designer) which element is more important (taking into account the adopted criteria). This is particularly useful when designing a work space. In this case, the final element priority consists of various parameters controlled by sliders in the desktop application on a scale from 0 to 10. They are: element significance (IE), frequency of use (CU) and significance of the group (IG). Additional parameters related to the spatial model are the portability coefficient (WP, which is 1 or 0) and the mass factor of the element (WM). The mass ratio of the element also has a scale from 0 to 10 and increases to a maximum value when the element's weight exceeds 9 kg.

The system enables creating a database of design knowledge represented by graphic objects (e.g. pictures, drawings, diagrams). In the case of using the system to support the work space design, the basic rules implemented in it are the principles of grouping devices according to McCormick [4, 5]. For the needs of the system verification, a few graphics on the employee's hand range and optimum work zones have been developed - using the example of the workspace design process. In addition, the database includes graphics with principles of movement economics and McCormick grouping rules [4]. The elements stored in the database also include paintings prepared on the basis of anthropometric atlases, showing the range of the worker's limbs and optimal working zones. Additionally, a list of principles of movement economics has been added to the database (e.g. the principle that main manipulation and controlled movements should be carried out within the appropriate working comfort zones). The use of these elements is included in the design process. Its course is checked using the checklist available when using the system.

Based on the stored project knowledge represented on the AR scene in an intuitive, graphical way, the PDP process is carried out, including the validation (assessment) of the solution in terms of meeting the ergonomic requirements. The built-in AR scene with optimally placed elements can then be sent to the CAD system. Importantly, when exporting models from the AR scene, their relative location is remembered. If necessary, the model of the work space or the designed technical means sent to the CAD system may be further modified or used to develop the final project documentation, which completes the design and construction phase. Since the validation of the solution took place during the design process, it is not necessary to carry out further validation research solutions (e.g. with the use of a physical prototype).

Conclusions

Due to the complexity of problems related to the development of a technical measure, the result of this process often depends on the experience of people assessing a given solution. The earlier the irregularities of the solution are identified, the faster and the better the project process will end. The presented system of augmented reality to support ergonomic design meets the expectations. By using AR techniques, the design and construction process moves from the plane of the monitor to the real environment of the designer / constructor. The developed solution allows intuitive manipulation of virtual three-dimensional objects in the surrounding space. Current validation and finding optimal solutions are also possible. In the described support system, the design interface is the human being and his surroundings, which is an innovative approach. The use of the system eliminates the need to create costly prototypes or at least limits their number. Future work of authors will aim to develop the system and closer integration with currently used CAD systems, which will allow its wider dissemination.

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