Applied Computer Science, vol. 13, no. 2, pp. 5–14
doi: 10.23743/acs-2017-09

Submitted: 2017-04-10
Revised: 2017-05-06
Accepted: 2017-06-21

augmented reality, digital factory

Dariusz PLINTA[*], *Martin KRAJČOVIČ*[**]

APPLICATION OF THE AUGMENTED REALITY IN PRODUCTION PRACTICE

Abstract

Current requirements which are connected with designing new, or realizing the existing production systems, cause continuous and rapid changes in products and processes. This means that classical approaches of production systems design have to be extended by advanced technologies and methods, such as digital factory, virtual and augmented reality, computer simulation, reverse engineering, etc. The article describes new computer technologies, which were applied in production practice, with a particular focus on the augmented reality technology.

1. INTRODUCTION

The contemporary global market requires from producers quick realization of orders, low cost and high quality of products. These requirements create the need for collaboration of all professions from engineers and managers to shop floor workers, and sharing knowledge and experience (Brzeziński, 2007; Gregor, Medvecký, Mičieta, Matuszek & Hrčeková, 2007). Nowadays competitive environment requires utilization of new software systems for design, testing, process planning, manufacturing and assembly. Application of such a digital framework for production allows to achieve higher quality, flexibility, quickness and efficiency. The use of new concepts of computer-aided manufacturing and process planning can be done simultaneously with product design, shortening time of production and working towards lean manufacturing practice. Such an approach allows for quick identification of potential problems and elimination of their negative consequences for the organization.

[*] University of Bielsko-Biala, Production Engineering Department, Willowa 2, 43-309 Bielsko-Biała, +48 33 8279 234, dplinta@ath.bielsko.pl
[**] University of Žilina, Industrial Engineering Department, Univerzitná 1, 010 26 Žilina, Slovak Republic, + 421 41 513 2718, martin.krajcovic@fstroj.uniza.sk

2. AUGMENTED REALITY

Augmented Reality (AR) is one of the fastest growing part of virtual reality. The basis of augmented reality is the ability to combine elements of the real and virtual worlds into a single view (Azuma, 1997; Haas, 2004; Westkaemper, Bischoff, Von Biel & Duerr, 2001). Augmented reality is a technology supported by human visual perception. The combination of real and virtual objects makes possible to transfer to the user a variety of additional information. The condition of this technology is to preserve the link with the user and real environment. In the virtual reality we create a model of a real production system, which can be used as a model for augmented reality. In the second mentioned technology (AR) we do not replace all the real world, but only the selected virtual elements corresponding to objects from the analysed real environment. The view can be realized using a monitor and a camera or with a head mounted display (Bajana, 2013). In practice, we can use two types of augmented reality systems:

1. Systems using position sensors and transparent display. The position sensor sends information about the position and direction of the user. Basing on this information, the scene generator prepares for display virtual objects located in the user's area of vision and projected on semi-transparent mirror through which the user sees the real scene.
2. Capturing real camera image for the registration of markers which indicate virtual objects position. A video camera captures the real scene and sends it to the computer. The software on the computer is looking for markers, calculates the camera position and distances between markers and assigns them to marker image of the virtual object and then displays the resulting image of the real scene with virtual objects.

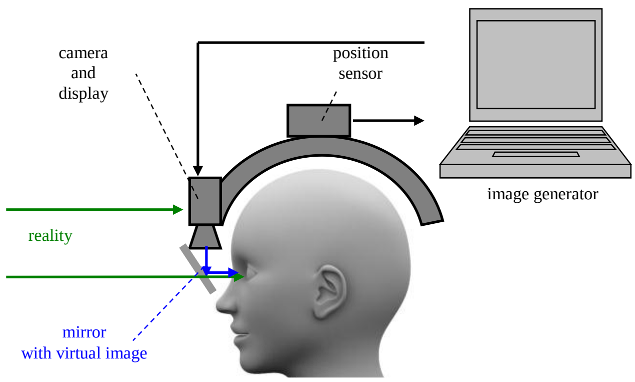


Fig. 1. Basic principles of augmented reality systems

3. CREATION OF A REAL PRODUCTION SYSTEM IN VIRTUAL REALITY ENVIRONMENT

A virtual model of a real production system can be created using various CAD programs, or using special applications dedicated to this purpose, such as CeitTable (Furmann & Krajčovič, 2009).

A production system model generally can be created in the following steps:

1. Preparation of 2D/3D objects:
   a) Usage of libraries of 2D/3D objects from the applied software. Current objects of the library can be further complemented and expanded by new own objects.
   b) Acquiring new 3D models using reverse engineering methods and 3D laser scanning technology, DMU (Digital Mock Up) and FMU (Mock Up Factory) models.
   c) Creating new models using CAD applications.
2. Modelling of the production system:
   a) Defining the production area.
   b) Copying objects from the library to the created production model.
   c) Defining transport relations between objects.
3. Layout optimization:
   a) Sankey diagram.
   b) Intensity-Distance diagram.
   c) calculation the overall transport performance.
   d) triangular method.
   e) safety work analysis.
4. Visualization of the production system:
   2D or 3D layout of the production system, which is presented by computer monitor, or using virtual technology and augmented reality.

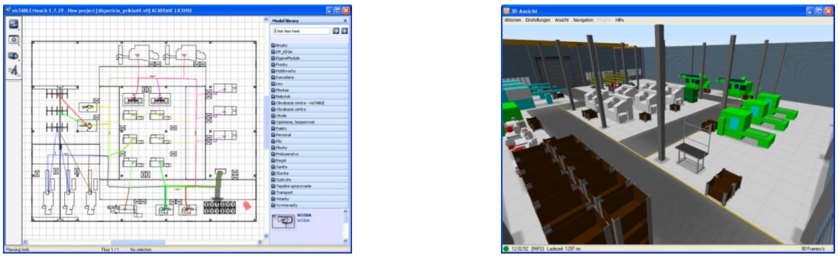
The creation of a virtual model of a real system requires the following activities:

1. Replacement of dimensionless workplaces by objects with real shapes and dimensions of machines/workplaces,
2. Placing in the created model a required number and particular types of machines/workplaces according to the results of capacity calculations.

At the beginning of the modelling process we should prepare earlier mock-ups of machines and workplaces and create the first (ideal) arrangement. This initial deployment will be supplemented by transport links between machines visualized by the material flow diagram (Fig. 2a).

Additionally, we should take into account:

a) service areas of workplaces,
b) material flow in the production hall and between halls,
c) needs of transportation and material handling,
d) building structures and media installations.



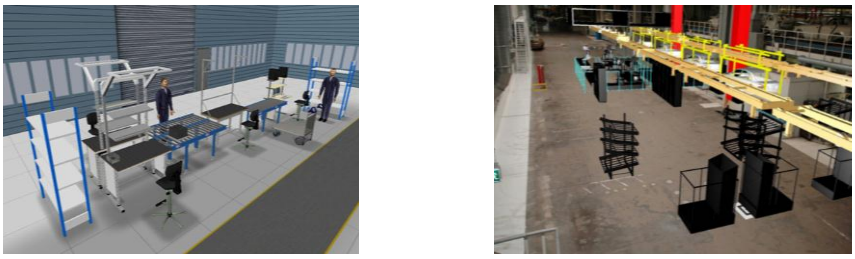
a) 2D model b) 3D model

Fig. 2. Virtual models of production systems (Plinta & Krajčovič, 2015)

The result of the described work is a realistic virtual model of workplaces or production halls, which respects all the existing constraints in production presented in a 2D or 3D view (Fig. 2).

4. PRODUCTION SYSTEMS VISUALIZATION WITH AUGMENTED REALITY

At universities in Bielsko-Biała and Zilina, we are currently developing the concept of Digital Factory with progressive approaches to visualization of digital information (Furmann & Krajčovič, 2009; Gregor, Plinta, Furman & Štefánik, 2011; Plinta & Krajčovič, 2015; Štefánik & Furmann, 2011). It seems appropriate to apply augmented reality (AR – Augmented Reality) technologies for designing and visualization of production systems (Bajana, 2013).



Virtual reality – computer-modelled environment

Augmented Reality – a combination of the real environment and virtual objects

Fig. 3. The difference between the virtual and augmented reality (Plinta & Krajčovič, 2015)

Research on the use of AR in designing of production and logistics systems is currently focused on the application of augmented reality systems based on creation of a real scene and identification of tags (markers) in the camera recorded scenes, which define user position and orientation in the modelled scene (Gabajová, 2013; Gabajová, Krajčovič & Plinta, 2013; Mirandová & Gabaj, 2011).

The below example is related with the concept of interactive projection system created at the University in Zilina, which is based on the projection on the planning table. The current version of this system uses 3D visualization layout of the production system presented on a monitor screen or a wall using a data projector. It is a projection of the 3D model to a 2D view.

By using augmented reality in designing of production systems with the planning table, we can create extended visualization in which 3D models are placed directly on the planning table. 3D models emerge from the layout, what is presented in figure 4. Using markers placed on the production layout drawn on a planning table and 3D models of machines, it is not necessary to use any additional data projector displaying the designed production system.

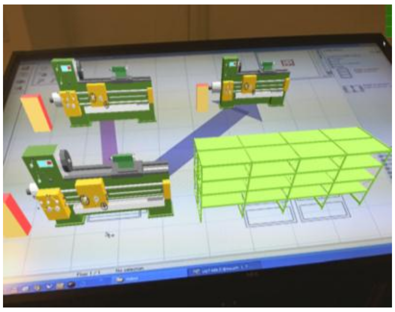


Fig. 4. Visualization using augmented reality technology on the planning table (Mirandová & Gabaj, 2011)

The proposed solution uses markers to identify the position and type of the 3D object, which are displayed above them, and also to determine the position and orientation of the user's viewpoint (camera) in the observed scene (the projection area of the table). The production system which is created with a planning table can be also presented by means of augmented reality in the real environment of the production hall. Showing virtual objects in a real environment, we can observe and analyse production systems for identifying possible organizational problems and evaluating the final position of particular workplaces in production halls. Using such tools, we can find possible collisions with other workplaces, walls, with power devices, machinery and equipment for power distribution, interconnection of production machinery and equipment with the current transportation and handling system, and potential problems with installing new machinery and equipment, etc.

5. AUGMENTED REALITY IN THE PICKING PROCESS

The picking process consists of several following steps (Fig. 5) (Krajčovič, 2011; Mirandová & Gabaj, 2011):

1. Identification of the worker – the worker is logged into the system and confirms his identity;
2. Identification of the picking contract – chosen from a list of specific contracts of the searched order;
3. Identification of the storage of each item – identifying the exact location of items and obtaining the storage coordinates in relation to a given reference point of the coordinate system;
4. Proposal for order picking items and determining routes beats – on the basis of the list of items, a list of collecting items is created from the first to the last, according to the principles of finding them, for example with the shortest path;
5. Realization of the picking process – the process of collecting items;
6. Registration of the picked material – update of the residual inventory of selected items.

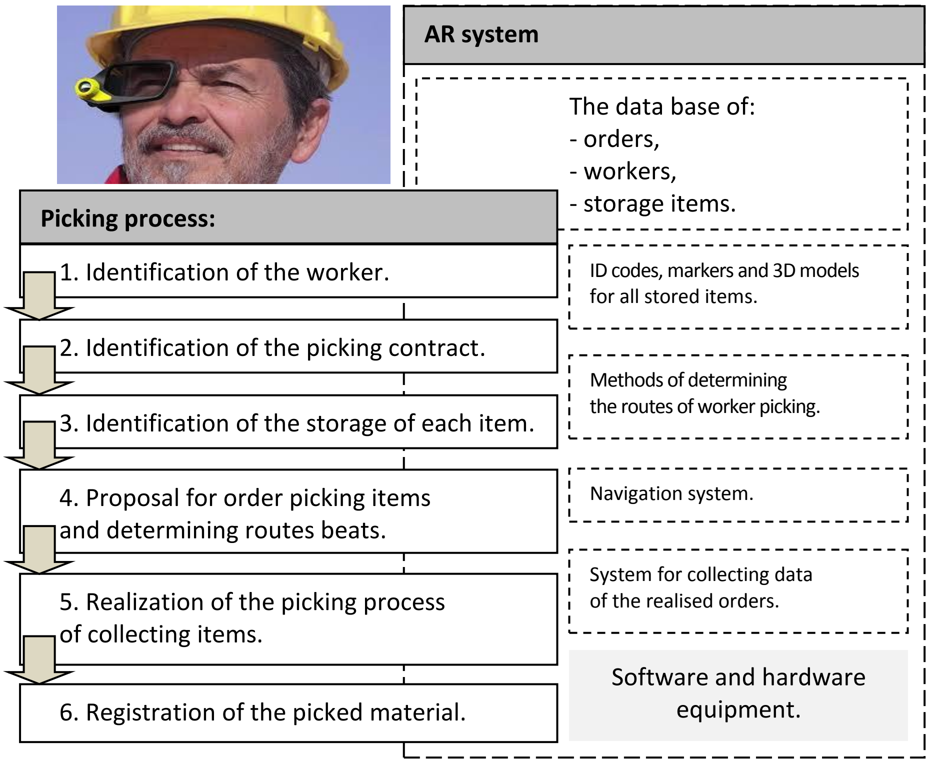


Fig. 5. Picking process with AR

Generally, the process of picking using augmented reality is connected with additional activities, like:

1. Extracting information about orders and stored items from WMS.
2. Extracting information about ID code of markers for all ordered items.
3. Determining location and selection of navigation markers to determine the directional navigation.
4. Generating information for navigation in the store.
5. Preparing glasses for augmented reality and booting the system.
6. Using technical means of augmented reality trip between picking locations.
7. Collecting data about the realised orders.

Integration of the augmented reality technology into the picking process gives us a possibility of eliminating the most common mistakes in picking items from the stores.

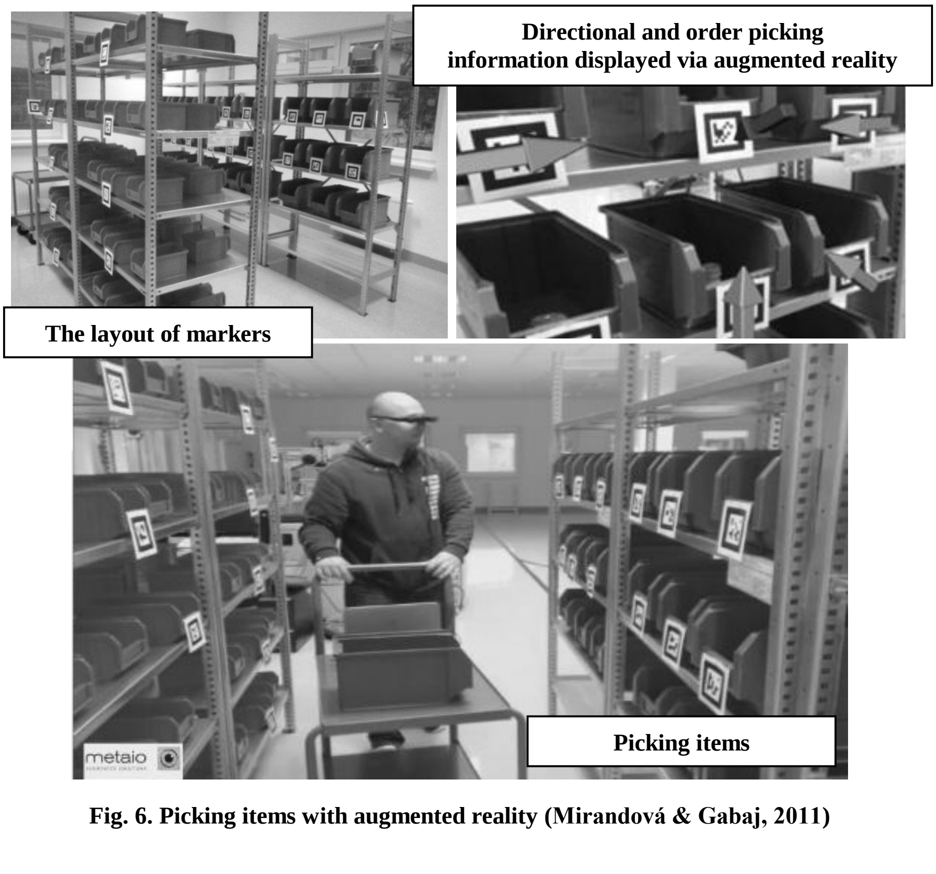


Fig. 6. Picking items with augmented reality (Mirandová & Gabaj, 2011)

6. AUGMENTED REALITY IN ERGONOMICS

Augmented Reality and Virtual Reality may appear to be effective solutions for complex analyses of developed designs of prototype workplaces, according to requirements of work safety and ergonomics in the following areas:

- management of health and safety,
- manual weight lifting,
- work with computer monitors,
- use of personal protection,
- use of machines and tools,
- design of workplaces.

A workplace designed in an appropriate manner allows the operator to work in the most effective way possible. In the time of rapid changes in demand it is necessary to flexibly react to customer requirements. Because of that it is necessary to rebuilt and change the existing working and assembly workstations to improve the working process, and especially working conditions.

An example of ergonomic analysis using virtual reality created in ErgoMax is presented in figure 7.

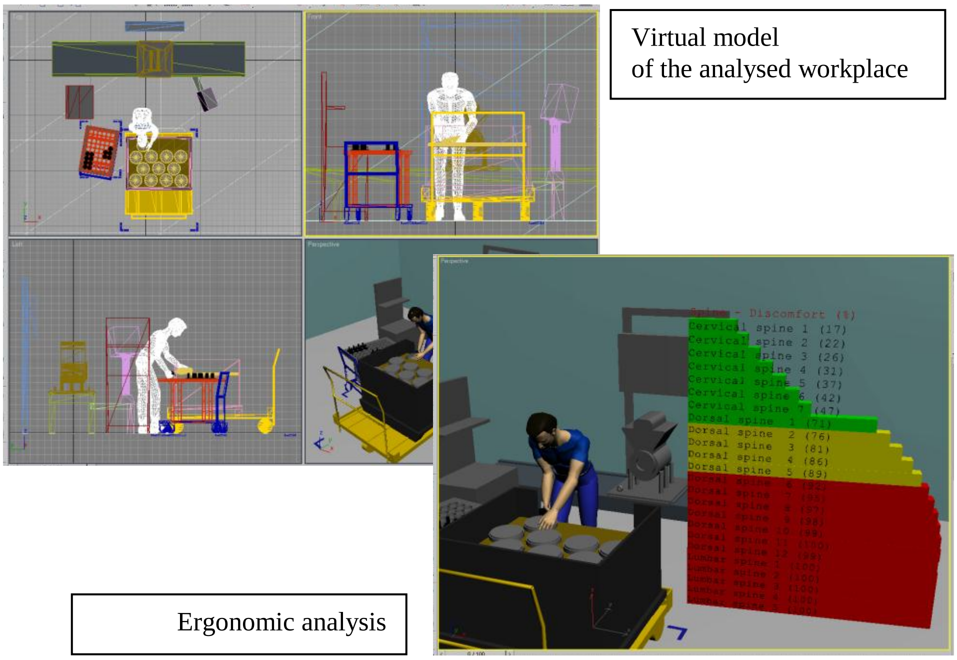


Fig.7. Ergonomic analysis using virtual reality (source: own study)

Virtual workplace is a system consisting of an appropriate VR hardware and software. Stages of VR application in analysis of workplaces include:

1. CAD model transfer to VR application and improvement of 3D object appearance by applying visualization techniques, such as texture mapping, lighting effects, reflections etc.
2. Programming objects' behaviour – movement as a response to a user-generated event (mouse click, keyboard button press, entering the defined collision zone) or an event generated by another object.
3. Creating user interface – the interface must be intuitive and allow easy launching of all the necessary functions of the virtual model.
4. Application testing – verification of the analysed workplace and their possible improvements.
5. Application in practice – finished application may be used in the process of education of future operators of the workplace, which will shorten the time needed to introduce an operator to work on the new workplace with full efficiency and safety.

Modern information technologies give us a range of possibilities to test new ways of working and to design and evaluate workplaces. Such analyses can be conducted with different software, like for example Delmia, Tecnomatix and features in the CAVE environment. These technologies are constantly being developed for new practical applications. They will be very helpful as the current versions already shorten time of designing workplaces, ergonomic analysis and significantly reduce costs (Dulina & Smutná, 2010; Januszka, 2012).

7. CONCLUSIONS

The rapid development of computer technologies and advanced software solutions support the designing process and allow for testing different things in a virtual environment. This gives us a possibility to save expenses for prototyping and implementing corrective actions caused by wrong decisions which appear during the designing stage. Extending modern technology usage to almost all areas of business activity has led to the definition of the digital factory concept.

The contribution shows a possibility of linking traditional approaches and methods of production design and organization of production processes (preparation and analysis of input data, the use of optimization algorithms) with new technologies of digital data processing (virtual reality and augmented reality technology) and methodology for designing and visualizing production systems.

REFERENCES

Azuma, R.T. (1997). A Survey of Augmented Reality. [online] *Teleoperators and Virtual Environments* 6, pp. 355-385.

Bajana, J. (2013). Innovative presentation of information using augmented reality. In L. Dulina (Ed.), *Advanced Industrial Engineering* (pp. 155-170). Bielsko-Biala: FCNT.

Brzeziński, M. (2007). *Wprowadzenie do nauki o przedsiębiorstwie*. Difin.

Dulina, Ľ., & Smutná, M. (2010). *Methods and software support in industrial ergonomics*. Zilina: Slovenská ergonomická spoločnosť (SES).

Furmann, R., & Krajčovič, M. (2009). Interactive 3D Design of Production Systems. In *Digital Factory 2009 – Workshop Handbook*, Zilina: SLCP.

Gabajová, G. (2013). Picking process using augmented reality. In L. Dulina (Ed.), *Advanced Industrial Engineering* (pp. 41-66). Bielsko-Biala: FCNT.

Gabajová, G., Krajčovič, M., & Plinta, D. (2013). Navigation with augmented reality. In *InvEnt 2013 – modern technologies - way to higher productivity*. Zilina: University of Zilina, EDIS.

Gregor, M., Medvecký, Š., Mičieta, B., Matuszek, J., & Hrčeková, A. (2007). *Digital Factory*. Zilina: KRUPA print.

Gregor M., Plinta D., Furman R., & Štefánik A. (2011). Digital factory – 3d laser scanning, modelling and simulation of production processes. In J. Matuszek, M. Gregor, B. Mičieta (Eds.), *Metody i techniki zarządzania w inżynierii produkcji*, Bielsko-Biała: Wydawnictwo Akademii Techniczno-Humanistycznej.

Haas W. (2004). *AK-Digitale Fabrik. Bericht Roadmap*. Ingolstadt: Audi.

Januszka M. (2012). Projektowanie ergonomiczne z zastosowaniem technik poszerzonej rzeczywistości. In. *XI Forum Inżynierskiego ProCAx*, 2-4.10.2012.

Krajčovič M. (2011). Projektovanie výrobných dispozícií s podporou rozšírenej reality. In *Produktivita a inovácie*. Zilina: University of Zilina, pp. 27-29.

Mirandová G., & Gabaj I. (2011). Use of augmented reality in storing and picking components from warehouse. In J. Matuszek, M. Gregor, B. Mičieta (Eds.), *Metody i techniki zarządzania w inżynierii produkcji*, Bielsko-Biała: Wydawnictwo Akademii Techniczno-Humanistycznej.

Plinta D., & Krajčovič M. (2015). Production systems designing with the use of digital factory and augmented reality technologies. In R. Szewczyk, C. Zieliński, M. Kaliczyńska (Eds.), *Progress in automation, robotics and measuring techniques: control and automation.* Cham, Heidelberg: Springer, pp. 187-196.

Štefánik A., & Furmann R. (2011). Computer simulation – aided designing of production and logistics systems. In: *AI magazine - journal about the automotive industry, mechanical engineering and economics*. Vol. 4, No. 2, pp. 46-47.

Westkaemper E., Bischoff J., Von Biel R., & Duerr M. (2001). *Factory Digitalizing –An adapted approach to a digital factory planning in existing factories and buildings*. Werkstattstechnik 91/2001.