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## Augmented Reality Aided Manufacturing

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### Abstract

The purpose of the article is to introduce possibilities of manufacturing process by using special virtual tools from scientific field named augmented reality (AR) and their implementation on the real example from product manufacturing area. After the introduction which sketch basic information about this mentioned scientific area of augmented reality aided manufacturing, the first point quickly provides view on the current situation in AR of manufacturing processes. The following step is oriented on explanation of main philosophy of AR in order to apply their in the particular applications. The last part of article observes real examples of possibilities to create AR, not only by commercial software but also by virtual environment which is offered by open source platform. All these mentioned possibilities and examples are implemented in the special virtual environment of the AR, where users can see not only visual information about an exact manufacturing process but also necessary text and audio information about workplaces, parts, work conditions etc.

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### 1. Introduction

Computer technology equipped with suitable software is advantageously used in various branches of practice at present time. It is difficult to imagine the development and production of new products in modern enterprise without exploitation of appropriate computer aided (CA) systems. Most of present CA systems are mainly determined and used in the area of computer design of new products but only complete application of these modern computer technologies to all periods of product design and manufacturing can bring the

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maximum profit for the enterprise. Computer aided manufacturing (CAM) systems are used many years in practice in the area of production in relation to computer support. Prevalent area of exploitation of these systems is computer aided of program creating for NC (numerically controlled) production equipment what represents from the point-of-view of completed production process only one of its part. There are also others processes of product manufacturing process for example: automated work-in-process transport and product storing, automated handling with the products, performing the measurements in automated inspection stands, etc. All these parts are defined by systems of computer aided manufacturing engineering (CAME). For better presentation of manufacturing processes and better realization of education in these areas is use of augmented reality very good idea. From this point of view is definition and practical application of augmented reality aided manufacturing very good idea, too [1].

## **2. Computer aided manufacturing, virtual manufacturing and augmented reality aided manufacturing**

Computer aided manufacturing (CAM) systems are systems for preparing the data and the programs for controlling of numerically controlled machines for automated production of the mechanical parts, whole assemblies, electronic circuits, etc. These systems use mainly the geometrical and other data, which has been gained during computer design of the part, respectively product by the computer aided design (CAD) system. The history of computer aided systems is mainly the history of CAD and constructing thus it is at the beginning joined with history of computer graphics. It was not possible to create and to manipulate with solids by computer before the computer graphics was introduced. CAD and constructing was reduced only to computing. History of CAM becomes from 50th years, when the conception of NC machines was designed. This was first impulse for entrance of electronics and later computer technology into the production support. However, more extensive development of CAM systems was enabled by creating the conception of computer numerically controlled (CNC) production machines, which is dated to 1970. Since the CAM systems allows the data about product geometry, which has been created by CAD system, to be used directly for creating NC programs for NC and CNC production machines. The big systems covering the areas of computer aided design and also following computer aided manufacturing appeared at 80th years; these systems are so-called CAD/CAM. Area of personal computers (PC) was not attractive for CAM systems for long time. It was mainly due to the fact, that CAD systems for PC were designed only for 2D drawing in regard to their small calculating performance and these did not dispose with functions for creating of solid models, from shape of which is possible to derive programs for NC production machines and also it did not allow to create the NC programs effectively, because of their small calculating performance. At the beginning of 90th years the big CAD/CAM systems working on workstations were only available for the area of CAM. Calculating and graphical performance of the machines working under Unix has been increased much rapidly against the PC, mainly thanks to products of Silicon Graphics during 1990 - 1994. Until uncommon development in the area of developing the PC components during the second half of 90th years, with entering the PC with processors Pentium, Pentium Pro, Pentium II, which are competitive by performance to workstations, but their price is only partial, has enabled to the developers of CAM systems to be oriented also to the area of PC and thus enable benefits of CAM to more users [2].

Virtual manufacturing is defined as an integrated, synthetic manufacturing environment exercised to enhance all levels of decision and control. It can be classified as design-centered, production-centered, and control-centered. Design-centered virtual manufacturing is a simulation environment for designing and evaluating the manufacturability of a product. Production-centered virtual manufacturing is a simulation environment for generating process plans and production plans. Control-centered virtual manufacturing is a simulation environment for shop floor production activities. Virtual manufacturing includes the fast improvement of manufacturing processes without drawing on the machines' operating time fund. It is said that

virtual manufacturing is the use of a desktop virtual reality system for the computer-aided design of components and processes for manufacture. It is unquestionable that virtual manufacturing aids real manufacturing processes and systems and it is perfected as the information technologies, the manufacturing systems and the business demands develop. In this context, virtual manufacturing should be recognized as an advanced information structure of real manufacturing systems, which integrates the available information tools and the virtual environment immersiveness to achieve business-manufacturing goals [3, 4].

Augmented reality (AR) is a growing area in virtual reality research. The world environment around us provides a wealth of information that is difficult to duplicate in a computer. This is evidenced by the worlds used in virtual environments. An AR system generates a composite view for the user. It is a combination of the real scene viewed by the user and a virtual scene generated by the computer that augments the scene with additional information [5, 6]. The application domains reveal that the augmentation can take on a number of different forms. In all those applications the augmented reality presented to the user enhances that person's performance in and perception of the world. The ultimate goal is to create a system such that the user can not tell the difference between the real world and the virtual augmentation of it. To the user of this ultimate system it would appear that he is looking at a single real scene. The real world and a totally virtual environment are at the two ends of this continuum with the middle region called Mixed Reality. Augmented reality lies near the real world end of the line with the predominate perception being the real world augmented by computer generated data. Augmented virtuality is a term created by Milgram to identify systems which are mostly synthetic with some real world imagery added such as texture mapping video onto virtual objects. This is a distinction that will fade as the technology improves and the virtual elements in the scene become less distinguishable from the real ones. Milgram also places augmented reality systems on the low end of the Extent of Presence Metaphor. This axis measures the level of immersion of the user within the displayed scene. This categorization is closely related to the display technology used by the system. Each of these gives a different sense of immersion in the display. In an augmented reality system, this can be misleading because with some display technologies part of the "display" is the user's direct view of the real world. The third, and final, dimension that Milgram uses to categorize Mixed Reality displays is Extent of World Knowledge. Augmented reality does not simply mean the superimposition of a graphic object over a real world scene. This is technically an easy task. One difficulty in augmenting reality, as defined here, is the need to maintain accurate registration of the virtual objects with the real world image. This often requires detailed knowledge of the relationship between the frames of reference for the real world, the camera viewing it and the user [7, 8].

Augmented reality aided manufacturing (ARAM) represents the new idea in application of augmented reality technologies in area of manufacturing processes representation. ARAM is a special subsystem of the system Computer Integrated Manufacturing including the augmented reality aided systems of all activities connected with realization of product manufacturing (programming of manipulation, machine tools, transport and store devices, measuring, testing and diagnose of parts and assembled product). This stage of augmented reality aided systems in complex CIM fluently establish on application of augmented reality aided systems in technical (construction and technological) preparing of production and is inevitable for secure of concurrent engineering conditions. Main idea of augmented reality aided manufacturing is presented on Fig. 1 [9].

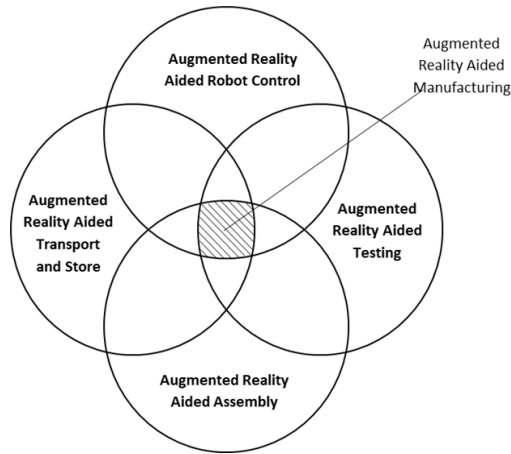


Fig. 1. Main idea of augmented reality aided manufacturing (ARAM)

### 3. Augmented reality aided robot control

Augmented reality, as a sub-area of the virtual reality, utilizes hardware and software tools for creation of the mixed environment that combines real scene usually present in the form of video sequence with augmented scene consisting of virtual models of additional objects. There are several techniques among those commonly used in augmented reality that are tried to implement into the system of robot programming. The central object of newly created environment realized on the Department of Computer Aided Manufacturing Technologies in Presov (Slovakia) was robotic device from Swedish producer ABB - compact robot IRB 140 [10].

When creating the environment of augmented reality that would be suitable for realization of real-time tasks (for example the programming of the robotic device) we have to consider the matter of continual space calibration in order to keep the real and virtual scenes spatially aligned in the final form of one consistent working place. For this purpose we use well known 3D digitization device Kinect in combination with a specialized software tool called Skanect.

Kinect firstly allows us to obtain the 3D scan of the real environment and to use this real data while creating the virtual one. Entities from the scan serve as the references for generation of spatial links between computer models and real things, such as machines, tables, robot base. Secondly, the ability of sensing the workplace with depth sensors in real time provides us with direct calibration of the environment and all included devices. This generation of mixed space and co-calibration of its both parts is realized in the software environment of Blender application. This powerful and widely complex graphical solution offers many useful tools, libraries and sub-routines for object programming with excellent level of graphical overview, everything based on the principles of open source philosophy.

For real-time detection of position of important objects we use the technique of color markers. Thin paper stripes of different colors are stick on the surfaces of the robot and other devices (table, milling machine). They are either easily locatable by the camera and also suitable from the viewpoint of robot motion description. Color stripes are monitored in pairs, while each pair consists of two stripes which are one to other in upright direction. This way the stripes of equal color create a graphical marker which can be used for monitoring of exact position of each robot axis. Next the relevant command line called in the Blender environment activates the procedure of color tracking checking the position of real robot and recalculating the coordinates of individual motion axis in software environment. Position and orientation of robot model can be then adjusted or proposed (programmed) on the base of the real one. This means that the programmer can create the sequences of a new program also while proceeding from the positions used in old one or from actual robot position (possible program creation in mixed online/offline mode).

New perspective possibility of displaying the environment of augmented reality is using of special visualization unit, which utilizes the principle of combined glass-mirror medium.

The surface of the glass is either half-silvered or there is a half-leaky foil stick on it that creates a reflection and at the same time allows a view to the working environment with no obstacle or decrease of view quality. This commonly available kind of mirror is often used in gaming, medicine or business presentations. By optical connection of two seemingly different views it creates an ideal platform for the creation of a realistic spatial effect. Displaying is a reversed emission of the view to the reflex surface. It can be provided by computer monitor or classical projector placed over the working area.

With a development of the projectors and their displaying technologies is possible to use the advantages of LED projecting. In comparison to the classical light projector the LED technology does not generate the luminous cone that would reflect in the form of light spot on the displaying glass. The setting up of whole scene becomes easier as you can mount the devices in the necessary displaying angles without the need to prevent the direct light reflection. On the Fig. 2 is presented use of the half-silvered mirror for presentation of virtual model of industrial robot activity in comparison with real robot workcell activity [11].

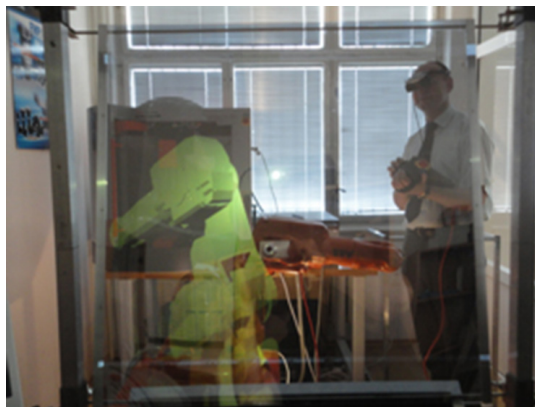


Fig. 2. Augmented reality environment with industrial robot IRB 140

#### 4. Augmented reality aided assembly

One example of teaching with use of augmented reality can be found in following text. Main objective of the system is teaching disassemble/assemble procedure of automatic transmission of a vehicle to students of automotive engineering. System includes vehicle transmission, set of tools and mechanical facilities, two video cameras, computer with developed software, HMD glasses and two LCD screens. Developed software gives instructions on assembling and disassembling processes with the help of AR objects on the video stream. Overlaying of 3D instructions on the technological workspace can be used as an interactive educational material. Mechanical parts which should be disassembled are augmented on video stream from video cameras. Animation and other visual effects are applied for better indication of the current instruction. During training, student can see the parts and their order. Required tools and technological operations are displayed as well. As a result, the system guides a student step-by-step through an assembly/disassembly sequence. Developed augmented reality system makes educational process more interesting and intuitive [12].

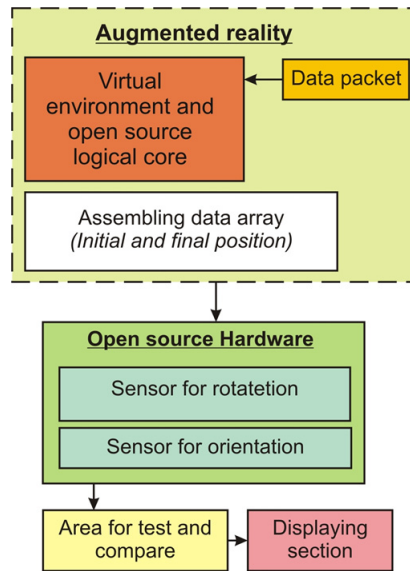


Fig. 3. Basic logical algorithm of application of augmented reality built on open source idea

A process called visual scripting was used for developing procedures and programming orders for the work with logical behavior loops in open source virtual environment. By using these tools, the application allows engineer to manage an entire data flow between different logical cores of the application (Fig. 3).

Next section provides more detailed view on the single logical areas where the necessary data are collected and compared with values from virtual arrays and then they are sent to the displaying section of the augmented reality. In the following phase the general processes and logical steps of new application are described in the theoretical level. The application consists of the 4 main logical levels where the data packets come not only from inner computer elements but also from outer devices such as sensors and measuring devices.

First of these loops observes the button section which gives information about the confirming processes. By means of these buttons the logical loop called displaying section starts viewing process (initial and final position).

Next loop consists of two basic areas (area for testing and comparing, area for position setting). Data packet from these mentioned areas include information about the names of all virtual items and their relevant values of initial vectors together with information about final parameters of position. Then the collected data from outer sensors are sent to the area for testing and comparing with each other and also to area for setting of position (initial, final one).

On the basis of these processes, all new information of position and orientation are sent again into the logical core of the application where the newly received parameters are tested, compared and evaluated between each other. After that, the displaying section is able to see the motion process of virtual item according to its trajectory. The entire process of AR assembling is presented on the Fig. 4 where the 3D part is moved on the virtual trajectory and offers exact value about final position for each part (real and virtual part in the same environment). For better understanding the Fig. 4 gives view on improvement elements of application where each part has different color and it allows to create assembly more clearly without mistakes.



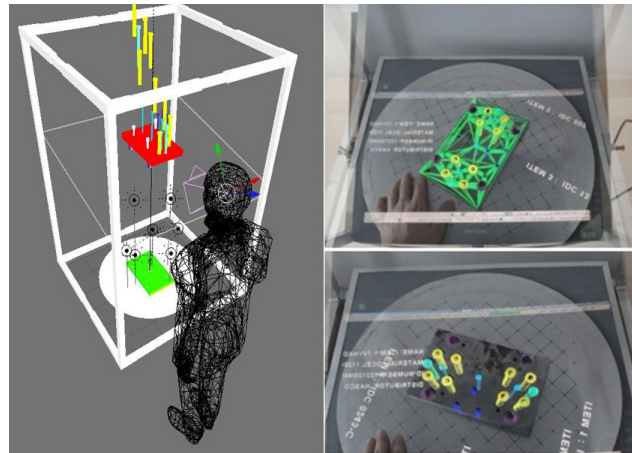


Fig. 4. Worker realizing the assembly task and his working view through

Existing method of application of augmented reality elements was based on visual taking of real environment (using the standard camera) and its overlaying managed by the logical core of software application. Despite to its efficiency, there is the disadvantage present in the form of necessary monitoring the view field situated out of the space of actual assembly what can result in negative synchronization issue. To prevent the problem, new visualization unit was created based on the philosophy of independent working environment, which increases the interactivity of the application together with user's comfort. The unit exploits the half-silvered surface situated directly in the view field of the worker. In principle it is special glass with surface that is half-silvered or has a semi-pervious, (reflex) foil on it which provides necessary reflection but at the same time allows to see through the glass directly to the working area. Thanks to this characteristic the mirror reflects the half of the image while it allows seeing through it. This is an ideal platform for generation of deep spatial scenes. Entire imaging process can be explained as reversed emission of the image realized by the LCD display situated above the mirror, out of the view field of the user. After realization of these imaging process, the major disadvantage was found, as the displaying and quality of the image was suitable but limited with single condition – the user has firmly set viewing point and does not move during the task realization. Example of augmented reality aided assembly system developed on the Department of Computer Aided Manufacturing Technologies in Presov (Slovakia) is on Fig. 4.

This unwanted state was removed, as into the application created in Blender system we implemented the script for face tracking that uses the libraries and program elements of free accessible database known as OpenCV. Face tracking used in AR application offers the possibility to set the relations and programming orders, that handle the adjusting of created virtual environment according to the position and orientation of the user's face in the real time. This means that the user can freely moves with his head or body without the risk of losing the AR image or separate it from the image of real video sequence [13].

This part of the paper mentions three main areas of application of specific features that are utilized in application for realization of assembly process with use of elements of AR. Purpose of these effective improvements lies in increase of user comfort and total quality and complexity of realized assembly activities.

*1. Audio Support of Assembling Process:* One of most expected utilization of the application is realization of assembly in training mode, eventually the effort to build the whole assembly with no mistakes on first attempt. Suitable solution for better prospect and information awareness of the user and thus for assuring mistake prevention is enhancement of application with information in the form that is acceptable with use of so far unused senses. Program includes audio signals in the form of short informational inputs and beeps or recorded verbal instructions.

2. *Better Text Info*: More usable working environment is achieved also with better quality of informational input from text files, eventually with better integration of text data in virtual working environment. Text information are displayed in the form of wider interactive text menu, where after clicking to particular entries the additional information are displayed.

3. *Interactivity of Working Environment Supported by Evaluating Unit*: Idea of user comfort in the form of monitoring and evaluating unit is built on logical cycle of the program based on colour tracking techniques used in real time while comparing ordinal number of assembling cycle and according to the predefined initial conditions it evaluates the propriety of actual part for every moment of the working cycle (Fig. 13). Combination of these tools allows observing of working environment and its surroundings together with realized assembling process in 3D virtual application. Condition for such feature lies in managing and harmonization of programming and settings section in Open Source software environment. Main programming task here is to assure the proper monitoring and comparing processes between real video sequence and virtual objects in real time.

Utilization of the application combines all the advantages of usual text and graphical assembly instructions, while all provided information are presented in form easy to accept and understand with the use of the tools of AR. 3D instructions can be even enriched of sound tracks, additional text-visual information and animation effects. Augmented reality application for assembling processes concerns software issues regarding open source tools that can be used for creation of augmented working environment. It also deals with hardware matters, especially with positioning device that was constructed for the purposes of assembly realization. In environment of Blender programming interface there was a new application created that presents a practical bridge connection between the real working table and elements of AR generated in the computer [14].

## 5. Conclusion

The implementation of elements of AR in the areas of technical praxes connected to the field of manufacturing technologies can be improved to the satisfactory level with every single development and improvement of any factor of these processes. Research and realization of experiments from this area therefore belong to key steps for reaching the limits of efficiency and productivity while assuring the user's comfort on highest possible level. Usual methods for imaging realized in AR systems are displaying using the LCD monitor or head-mounted display. Paper presents new attitude in imaging of combined working environment and its practical realization based on the principle of utilization of half-silvered surface, which provides the advantages thanks to displaying of the AR objects directly in the working view of the user and free motion and user's comfort without hardware device connected to the user. The interactivity of the application is assured by software application exploiting the Blender core and also by construction of working box for fixation of displaying glass and emitting monitor, together with application of face tracking technique.

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## References

- [1] Marcincin JN. Selected applications of virtual reality in manufacturing, *Journal for Technology of Plasticity* 2011; **36**(1):25-34.
- [2] Marcincin JN, Barna J, Torok J, Marcincinova LN. Definition of computer aided manufacturing engineering and its place in CA systems chain, in Proceedings of the SAMI 2013 - IEEE 11th International Symposium on Applied Machine Intelligence and Informatics, art. no. 6480989, 2013, p. 263-266.
- [3] Jedrzejewski J, Kwasny W. Remarks on state-of-the-art Virtual Manufacturing. *Virtual Manufacturing*. Wroclaw: Wroclaw University of Technology, 2001.
- [4] Lederer G. Virtual Manufacturing - Manufacturers Challenge of the 1990s. *CIME - Computer Integrated Manufacture and Engineering* 1996; **1**(2): 44-46.
- [5] Ong SK, Nee AYC. *Virtual and augmented reality applications in manufacturing*. London: Springer-Verlag; 2004.
- [6] Ong SK, Pang Y, Nee AYC. Augmented reality aided assembly design and planning, innovation in manufacturing systems and technology. *Annals of the CIRP* 2007; **56**(1).
- [7] Vallino J, Kutulakos KN. Augmenting reality using affine object representations. In: Barfield W, Caudell T, editors. *Fundamentals of wearable computers and augmented reality*. Mahwah: Lawrence Erlbaum Assoc. Publ., 2001, p. 157-182.
- [8] Vallino J. *Introduction to Augmented Reality*. Rochester: Rochester Institute of Technology, [www.se.rit.edu/~jrv/research/ar/](http://www.se.rit.edu/~jrv/research/ar/), 2002.
- [9] Marcincin JN, Barna J, Janak M, Marcincinova LN, Fecova V. Production process with integration of CA data in augmented reality environment, in Proceedings of the IEEE 16th International Conference on Intelligent Engineering Systems, art. no. 6249806, 2012, p. 77-80.
- [10] Marcincin JN, Janak M, Barna J, Torok J, Marcincinova LN, Fecova V. Verification of a program for the control of a robotic workcell with the use of AR. *International Journal of Advanced Robotic Systems* 2012; **9**(54): 1-7.
- [11] Marcincin JN, Janak M, Fecova V, Marcincinova LN. Utilization of augmented reality elements for visualization of operational states of manufacturing devices. *Applied Mechanics and Materials* 2013; **308**:111-114.
- [12] Marcincin JN, Fecova V, Marcincinova LN, Torok J, Barna J. Verification of machine position in production plant with use of virtual reality technology. *Applied Mechanics and Materials* 2013; **308**:171-174.
- [13] Marcincin JN, Barna J, Janak M, Marcincinova LN, Fecova V. Utilization of open source tools in assembling process with application of elements of augmented reality, in Proceedings of VRCAI 2011: ACM SIGGRAPH Conference on Virtual Reality Continuum and its Applications to Industry, Hong Kong, 2011, p. 427-413.
- [14] Marcincin JN, Barna J, Janak M, Marcincinova LN, Torok J. Visualization of intelligent assembling process by augmented reality tools application, in Proceedings of the LINDI 2012 - 4th IEEE International Symposium on Logistics and Industrial Informatics, art. no. 6319505, 2012, p. 33-36.