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Intelligent Control of Robotized Workcell by Augmented Reality Application

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***Abstract*—**The computer aided for design, analysis, control, visualization and simulation of robotized workcells is very interesting in this time. Computer Aided Robot Control (CARC) is a subsystem of the system CIM including the computer aided systems of all activities connected with visualization and working of robotized workcells. There are three basic ideas: current CAD/CAM/CAE systems for design and 3D visualization, special PC based control and simulation systems and Augmented Reality Aided Manufacturing (ARAM) systems. This paper describes example of Open Source software application that can to be utilized at planning of the robotized workcells, visualization and off-line programming the automated processes realized by authors.

***Keywords*—**Intelligent control, augmented reality, robot.

I. Introduction

COMPUTER AIDED ROBOT CONTROL (CARC) started as an off-line-programming tool for robotized manufacturing workcells. Its prime purpose was to program robots off the shop floor, thereby providing the operators with a safer working environment, an efficient tool to perform trial-and-error routines, a reduction in maintenance and troubleshooting efforts, and better use of the production equipment for real manufacturing purposes rather than preparation work. Last development in area of robot workcell simulation and visualization is application of virtual and augmented reality in this area with out in new scientific branch titled Augmented Reality Aided Manufacturing (ARAM).

Soon the benefits of using CARC tools upstream became clear. Why use Computer Aided only for programming equipment, why not use it up-front, for designing the whole workcell? ARAM tools enabled manufacturing engineers to design the complete workcell in a faster, optimized and error-free fashion. The ability to view the equipment working in a manufacturing environment allowed for much tighter designs with less error margins, as well as more accurate time and flow calculations.

This paper deals with concrete idea of simple but effective form of augmented reality application in today's very important area of mechanical manufacturing technologies oriented to area of robot and automated devices control. It brings the information on present time of augmented reality technologies development. It describes proposed algorithm of AR application and example of AR utilization in design and control process of robot workcell. In the main part it also deals with utilization of Open Source Application for programs realization, realization of the position sensors device and algorithm of Open Source application realization in laboratory of Faculty of Manufacturing Technologies. It considers further improvements and reserves in area of developing the applicability of programs in preparation phase for robot workcell visualization and control [1].

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II. Augmented Reality Theory

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. Either these worlds are very simplistic such as the environments created for immersive entertainment and games, or the system that can create a more realistic environment has a million dollar price tag such as flight simulators. 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. 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 cannot 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 [2].

The discussion above highlights the similarities and differences between virtual reality and augmented reality systems. A very visible difference between these two types of systems is the immersiveness of the system. Virtual reality strives for a totally immersive environment. The visual, and in some systems aural and proprioceptive, senses are under control of the system. In contrast, an augmented reality system is augmenting the real world scene necessitating that the user maintains a sense of presence in that world. The virtual images are merged with the real view to create the augmented display. There must be a mechanism to combine the real and virtual that is not present in other virtual reality work. Developing the technology for merging the real and virtual image streams is an active research topic.

Milgram describes a taxonomy that identifies how augmented reality, augmented virtuality and virtual reality

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work are related. He defines the Reality-Virtuality continuum shown as Fig. 1 [3].

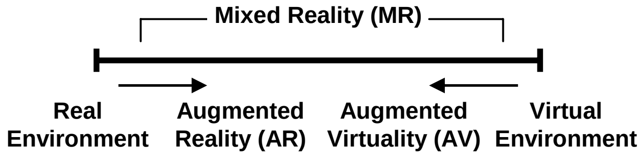

Fig. 1 Milgram's Reality-Virtuality Continuum [3]

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 further defines a taxonomy for the Mixed Reality displays. The three axes he suggests for categorizing these systems are: Reproduction Fidelity, Extent of Presence Metaphor and Extent of World Knowledge. Reproduction Fidelity relates to the quality of the computer generated imagery ranging from simple wireframe approximations to complete photorealistic renderings. The real-time constraint on augmented reality systems forces them to be toward the low end on the Reproduction Fidelity spectrum. The current graphics hardware capabilities cannot produce real-time photorealistic renderings of the virtual scene. 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. Immersion in that display comes from simply having your eyes open. It is contrasted to systems where the merged view is presented to the user on a separate monitor for what is sometimes called a "Window on the World" view.

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. In some domains these relationships are well known which makes the task of augmenting reality easier or might lead the system designer to use a completely virtual environment. The contribution of this thesis will be to minimize the calibration and world knowledge necessary to create an augmented view of the real environment [4].

III. Augmented Reality Application

As mentioned in introduction, an AR system generates a complex view where the virtual areas are covered by real environment and offers the basic working place for the user. It is a reciprocal combination of the real scene observed by the camera and a virtual scene generated by the computer logical core that mixtures the both scenes. Based on the previous information it is easy to say that possibilities of AR find the utilization in many industrial spheres like as aeronautics, automobile industry, manufacturing etc. [5].

The entire structure of this part of paper is focused on basic steps and advances which are necessary and needy to know for the engineer in the processes of creation of the robot workcell structure. During the realization of this process the engineer can be surprised by many obstacles which are suitable for next examining. Whereupon, it is easy to say that the correct result has a main impact on final workcell structure. The main task of creating an AR scene is to get an understanding of the position and orientation of the implemented devices.

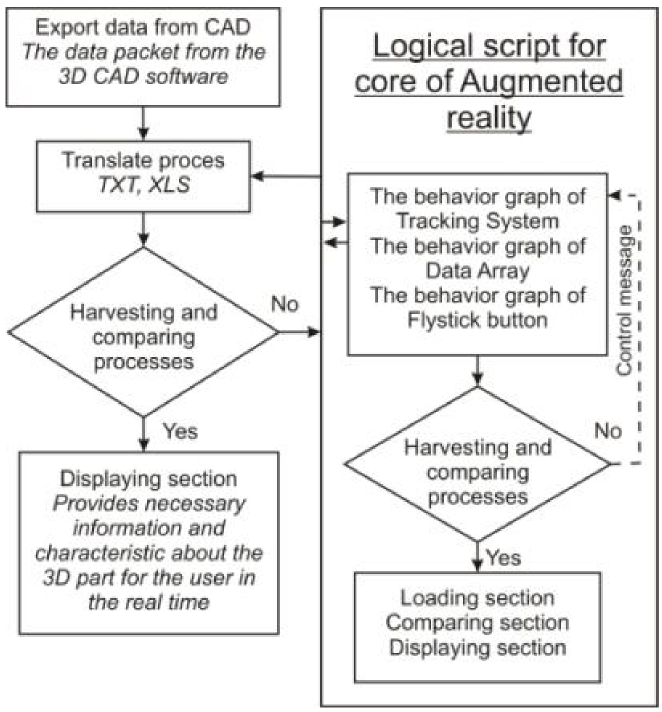

Fig. 2 Logical algorithm of AR application

In the first point of this mentioned process the single 3D objects (entries from workcell plan) need to be created and defined by tools of CAD system. These applications are using special modules which are implemented in the logical core of high CA systems. The 3D model comprises necessary information about its own properties (geometrical value and shape of 3D objects, orientation and position of all 3D objects, mass properties and other characteristics). These data packets are continually sending in the special comparing section of the programming core. By means of it the 3D CAD model will be filled with necessary information about geometry and structural condition [5].

The result of these processes, the data packet is ready to exports on entry area of systems of AR. The single virtual 3D objects needs to obtain information about its own position and orientation value which is used for fixing process on the particular place of the auxiliary model in the real environment. The result of all mentioned steps is logical algorithm which allows seeing a data flow between single blocks. These blocks are collected and presented on Fig. 2.

IV. AR Robot Workplace Programming and Control System

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 was robotic device from Swedish producer ABB - compact robot IRB 140.

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 software philosophy (Fig. 3) [6].

Fig. 3 Real robot workcell in the Blender software

A. Application of the Color Tracking

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 or 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 programmed on the base of real one.

Other possibility to apply the color tracking is to use it for detection of workplace objects and also the task objectives. With a camera suitably located near the end of robot reach zone we can monitor the working area and achieve the location of bodies that are supposed to be handled. Blender integrates the ARToolkit features so it can perform even upgraded level of color tracking - shape detection. On Fig. 4 is presented model of a robot inserted into the live video sequence on the base of the data acquired from combination of Kinect sensing and color tracking [7].

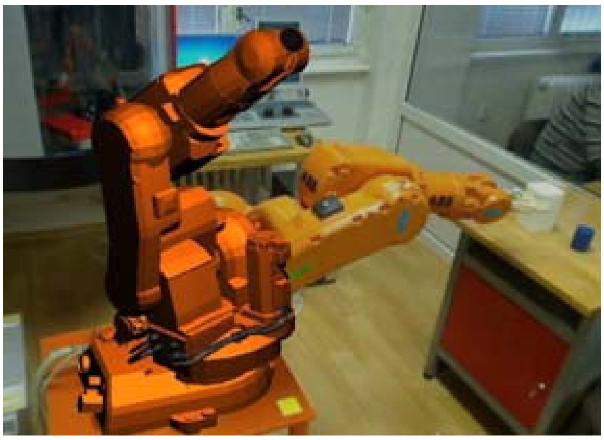

Fig. 4 Virtual model of robot in real environment

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B. AR Displaying of the Robotized Workcell through the Special Glass

New perspective possibility of displaying the environment of augmented reality is using of special visualization unit created on the Faculty of Manufacturing Technologies, which utilizes the principle of combined glass-mirror medium [7].

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 we are able 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 Fig. 5 is presented use of the half-silvered mirror for presentation of virtual model of industrial robot activity in comparison with real robot workcell activity.

Fig. 5 Displaying of AR environment using the half-silvered mirror

C. Augmented Programming and Control

Programming of the robot with use of above mentioned elements and techniques of AR is possible thanks to the programming character of Blender software. User can control the real robot and its virtual model in the same environment using the half-silvered glass or the interface of PC monitor or eventually glasses for VR (offline mode). Either way he controls the virtual robot in the AR environment, while all the key positions and motions desired between them are stored in the graphical form of 3D Blender data. This data are then using the simple scripts of objects programming translated into the syntax code of robot control system [7].

V. Conclusion

This paper is focused to improvement of important features of robot workcell control. It concerns both design verification and control area. Details of research and related concept are explained on the example of experimental robotic workcell situated at the Faculty of Manufacturing Technologies of TU of Kosice with a seat in Presov, Slovakia.

An idea is based on utilization of newly created displaying unit that is based on the principle of half-silvered glass, fixed in frame that is situated between programmer and workcell, which reflects and simultaneously transmit the light. This means that looking to the workplace through this glass, the programmer can see real objects behind it in combination with virtual ones inserted in software environment of application created in Blender. This can be considered as new approach among the methods of robot workcell control.

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