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AUGMENTED VIRTUAL REALITY APPLICATIONS IN MANUFACTURING SYSTEMS

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Abstract: *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 augmented reality 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.*
Key words: *Virtual Reality, Augmented Virtual Reality, Manufacturing Systems Design*

1. INTRODUCTION

In virtual manufacturing have significant impact areas such as facility layout and work-cell management, real-time exact collision detection, motion modelling and virtual-real environment interaction in training. There are connections between virtual reality (VR) and computer vision (especially camera self-calibration and stereo vision) in the context of depth recovery in virtual manufacturing. Some of the automation techniques resulting from these concepts can potentially reduce a lot of time and boredom for users involved in manually creating CAD-based virtual environments. Lately, with the emergence of complementary areas of VR such as augmented reality (AR), one can address crucial problems of registration between virtual and real worlds.

2. VIRTUAL REALITY

Historically, virtual reality has entered into the public awareness as medial toy with equipment „helmet-glove“, which was preferentially determined for wide public and the price of this system had also to correspond to this fact, so price could not be very high. As follows, the producers of virtual reality systems have aimed at developing and providing of the systems for data collecting and analysing and systems supporting economic modelling. It is obvious that, from among areas, where virtual reality systems can be most frequently used are applications based on 3D-space analysing and physical dimension visualisation. Virtual reality with ability to show data 3D and attach sounds and touch information increases extraordinarily data comprehensibility. Along with increasing the number of data are increased the effects from virtual reality too [6].

At the beginning of 1990s the development in the field of virtual reality became much more stormy and the term Virtual Reality itself became extremely popular. We can hear about Virtual Reality nearly in all sort of media, people use this term very often and they misuse it in many cases too. The reason is that this new, promising and fascinating technology captures greater interest of people than e.g., computer graphics. The consequence of this state is that nowadays the border between 3D computer graphics and Virtual Reality becomes fuzzy. Therefore in the following sections some definitions of Virtual Reality and its basic principles are presented.

Virtual Reality (VR) and Virtual Environments (VE) are used in computer community interchangeably. These terms are the most popular and most often used, but there are many other. Just to mention a few most important ones: Synthetic Experience, Virtual Worlds, Artificial Worlds or Artificial Reality. All these names mean the same [1]:

- "Real-time interactive graphics with three-dimensional models, combined with a display technology that gives the user the immersion in the model world and direct manipulation."
- "The illusion of participation in a synthetic environment rather than external observation of such an environment. VR relies on a three-dimensional, stereoscopic head-tracker displays, hand/body tracking and binaural sound. VR is an immersive, multi-sensory experience."
- "Computer simulations that use 3D graphics and devices such as the DataGlove to allow the user to interact with the simulation."

Although there are some differences between these definitions, they are essentially equivalent. They all mean that VR is an interactive and immersive (with the feeling of presence) experience in a simulated (autonomous) world – and this measure we will use to determine the level of advance of VR systems.

VR systems could be divided by ways of communication with user to such groups:

1. *Window on World Systems* – for displaying the virtual world are used conventional computer monitors. This system is also called Desktop Virtual Reality, but usually it is called as Window on World (WoW).

2. *Video Mapping* – This system is modification of WoW system, where the siluetes of human body could be displayed in 2D. User could see himself or herself on monitor in interaction with environment.
3. *Immersive Systems* – basic VR systems, which enables user to be in virtual environment. The feeling to be in is created by Head Mounted Displays (HMD). This HMD could be with or without limitation of moving. Example of HMD application is on Fig. 1. On Fig. 2 are presented special gloves with sensors for VR.

Fig. 1. *Special Head Mounted Display for VR*

Fig. 2. *Gloves with sensors for VR*

4. *Telepresence* – Attached to a high – speed network, VR takes telepresence to next level. Participants can be thousand of kilometres apart and yet feel as if they are all standing in the same virtual office or laboratory, with their product, design, or experiment right in front of them not only talking about it, but interacting with it, change it etc. This technology connects sensors, which are apart in real world. Sensors could be placed on robot or on presented tool.
5. *Mixed reality* – This system is created by connecting of telepresence and Seamless Simulation Systems. Computer generated data are connected with telepresence entries and with user sight on real world.
6. *Fish Tank Virtual Reality* - System created in Canada. It is a combination of stereoscopic monitors and tracking system measures position and orientation of a hand.

Augmented reality (see Fig. 3) offers the enhancement of human perception and was applied as a virtual user's guide to help completing some tasks: from the easy ones like laser printer maintenance to really complex ones like a technician guide in building a wiring harness that forms part of an airplane's electrical system. An other example of augmented reality application was developed at the UNC: its goal was to enhance a doctor's view with ultrasonic vision to enable him/her to gaze directly into the patient's body.

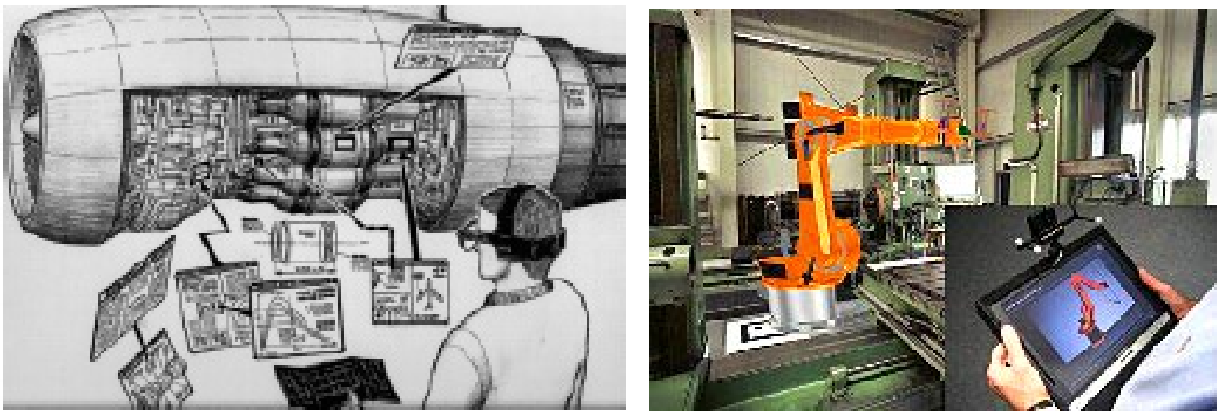

Fig. 3. *Augmented Reality: (a) idea of AR, (b) augmented reality manufacturing system*

3. AUGMENTED REALITY

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 augmented reality 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 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 [4].

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.

The computer generated virtual objects must be accurately registered with the real world in all dimensions. Errors in this registration will prevent the user from seeing the real and virtual images as fused. The correct registration must also be maintained while the user moves about within the real environment. Discrepancies or changes in the apparent registration will range from distracting which makes working with the augmented view more difficult, to physically disturbing for the user making the system completely unusable. An immersive virtual reality system must maintain registration so that changes in the rendered scene match with the perceptions of the user. Any errors here are conflicts between the visual system and the kinesthetic or proprioceptive systems. The phenomenon of visual capture gives the vision system a stronger influence in our perception. This will allow a user to accept or adjust to a visual stimulus overriding the discrepancies with input from sensory systems. In contrast, errors of misregistration in an augmented reality system are between two visual stimuli which we are trying to fuse to see as one scene. We are more sensitive to these errors.

Milgram describes a taxonomy that identifies how augmented reality and virtual reality work are related. He defines the Reality-Virtuality continuum shown as Fig. 4.

Fig. 4 *Milgram's Reality-Virtuality Continuum*

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 can not 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.

4. AUGMENTED REALITY SYSTEM

A standard virtual reality system seeks to completely immerse the user in a computer generated environment. This environment is maintained by the system in a frame of reference registered with the computer graphic system that creates the rendering of the virtual world. For this immersion to be effective, the egocentered frame of reference maintained by the user's body and brain must be registered with the virtual world reference. This requires that motions or changes made by the user will result in the appropriate changes in the perceived virtual world. Because the user is looking at a virtual world there is no natural connection between these two reference frames and a connection must be created. An augmented reality system could be considered the ultimate immersive system. The user can not become more immersed in the real world. The task is to now register the virtual frame of reference with what the user is seeing. This registration is more critical in an augmented reality system because we are more sensitive to visual misalignments than to the type of vision-kinesthetic errors that might result in a standard virtual reality system. Fig. 5 shows the multiple reference frames that must be related in an augmented reality system [9].

The scene is viewed by an imaging device, which in this case is depicted as a video camera. The camera performs a perspective projection of the 3D world onto a 2D image plane. The intrinsic (focal length and lens distortion) and extrinsic (position and pose) parameters of the device determine exactly what is projected onto its image plane. The generation of the virtual image is done with a standard computer graphics system. The virtual objects are modeled in an object reference frame. The graphics system requires information about the imaging of the real scene so that it can correctly render these objects. This data will control the synthetic camera that is used to generate the image of the virtual objects. This image is then merged with the image of the real scene to form the augmented reality image.

The video imaging and graphic rendering described above is relatively straight forward. The research activities in augmented reality center around two aspects of the problem. One is to develop methods to register the two distinct sets of images and keep them registered in real time. Some new work in this area has started to make use of computer vision techniques. The second direction of research is in display technology for merging the two images.

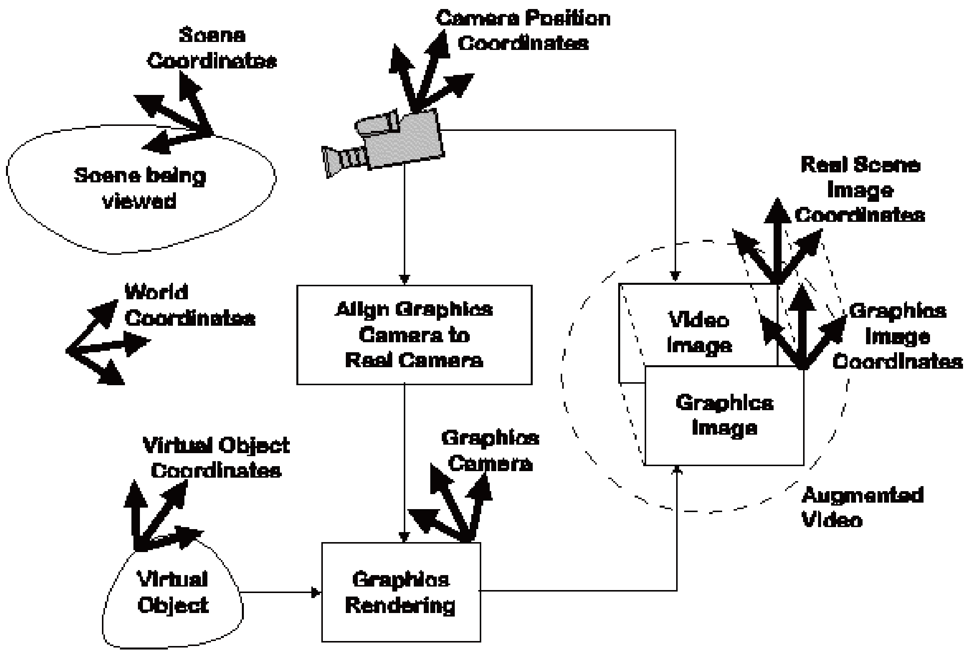

Fig. 5 *Components of an Augmented Reality System*

Augmented reality systems are expected to run in real-time so that a user will be able to move about freely within the scene and see a properly rendered augmented image. This places two performance criteria on the system. They are [8]:

• Update rate for generating the augmenting image,

• Accuracy of the registration of the real and virtual image.

Visually the real-time constraint is manifested in the user viewing an augmented image in which the virtual parts are rendered without any visible jumps. To appear without any jumps, a standard rule of thumb is that the graphics system must be able to render the virtual scene at least 10 times per second. This is well within the capabilities of current graphics systems for simple to moderate graphics scenes. For the virtual objects to realistically appear part of the scene more photorealistic graphics rendering is required. The current graphics technology does not support fully lit, shaded and ray-traced images of complex scenes. Fortunately, there are many applications for augmented reality in which the virtual part is either not very complex or will not require a high level of photorealism.

5. CONCLUSION

Virtual reality and virtual manufacturing often concentrate on an interface between VR technology and manufacturing and production theory and practice. In this thesis we concentrate on the role of VR technology in developing this interface. It is our belief that the direction of evolution of manufacturing theory and practice will become clearer in the future once the role of VR technology is understood better in developing this interface.

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