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VIRTUAL MANUFACTURING AND AUGMENTED VIRTUAL MANUFACTURING IN TECHNICAL PRACTICE

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ABSTRACT
Virtual Manufacturing system is a computer system which can generate the same information about manufacturing system's structure, states and behaviours as we can observe in real manufacturing systems. Virtual manufacturing includes the fast improvement of manufacturing processes without drawing on the machines' operating time fund. 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.
Keywords: Virtual Reality, Virtual Manufacturing, Augmented Virtual Manufacturing

1. INTRODUCTION

The term virtual manufacturing first came into prominence in the early 1990s, in part as a result of the U.S. Department of Defence Virtual Manufacturing Initiative. Both the concept and the term have now gained wide international acceptance and have somewhat broadened in scope. For the first half of the 1990s, pioneering work in this field has been done by a handful of major organizations, mainly in the aerospace, earthmoving equipment, and automobile industries, plus a few specialized academic research groups. Recently accelerating worldwide market interest has become evident, fuelled by price and performance improvements in the hardware and software technologies required and by increased awareness of the huge potential of virtual manufacturing. Virtual manufacturing can be considered one of the enabling technologies for the rapidly developing information technology infrastructure [3].

2. DEFINITION AND THEORY OF VIRTUAL MANUFACTURING

There are many definitions of Virtual Manufacturing (VM). Iwata in 1990 defines VM as follows: "A virtual manufacturing system is a computer system which can generate the same information about a manufacturing system's structure, states and behaviours as we can observe in real manufacturing systems".

The report from the 1994 Virtual Manufacturing User Workshop includes an in-depth analysis of VM and its definition: "Virtual Manufacturing is an integrated synthetic manufacturing environment exercised to enhance all levels of decision and control" was annotated extensively to cover all the current functional and business aspects of manufacturing. Also the practical side of manufacturing virtuality is highlighted in this useful analysis. A comprehensive and thorough survey of literature on VM problems relating to production design and control can be found in a study done at the University of Maryland.

The definition of VM given by a Bath University project team deserves attention. According to this definition: "Virtual Manufacturing is the use of a desk-top virtual reality system for the computer

aided design of components and processes for manufacturing - for creating viewing three dimensional engineering models to be passed to numerically controlled machines for real manufacturing". This definition emphasizes the functions aiding the machining process.
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's immersiveness to achieve business manufacturing goals [2].
The combination of information technology (IT) and production technology has greatly changed traditional manufacturing industries. Many manufacturing tasks have been carried out as information processing within computers. For example, engineers can design and evaluate a new part in a 3D CAD system without constructing a real prototype. As many activities in manufacturing systems can be carried out using computer systems, the concept of virtual manufacturing has now evolved [1].
VM is defined as an integrated synthetic manufacturing environment for enhancing all levels of decision and control in a manufacturing system. VM is the integration of VR and manufacturing technologies. The scope of VM can range from an integration of the design sub-functions (such as drafting, finite element analysis and prototyping) to the complete functions within a manufacturing enterprise, such as planning, operations and control.
However, a practical VM system is highly multi-disciplinary in nature. Many of these research projects and commercial software for VM systems have restrictions in their implementation. Firstly, many machining theories and heuristics need to be modelled in a VM system. However, most VM applications are designed only for specific problems in pre-defined conditions. There is no one VM application having all the technologies necessary to model a real machining process. Secondly, each constructing process of a new VM system is akin to the reinvention of "wheels". Besides geometrical modelling of machines, analytical modelling of machining parameters, such as the cutting force, also has to be developed for every specific task. Lastly, various VM systems are developed with different programming and modelling languages, making them less flexible and scalable due to incompatibility problems. Any change in one part would require the whole system to be modified.
During a VM simulation process, 3D graphics or VR will be an enabling tool to improve human-to-human or human-to-machine communications. VM addresses the collaboration and integration among distributed entities involved in the entire production process. However, VM is regarded as evolutionary rather than revolutionary. It employs computer simulation, which is not a new field, to model products and their fabrication processes, and aims to improve the decision-making processes along the entire production cycle. Networked VR plays an essential role in VM development.

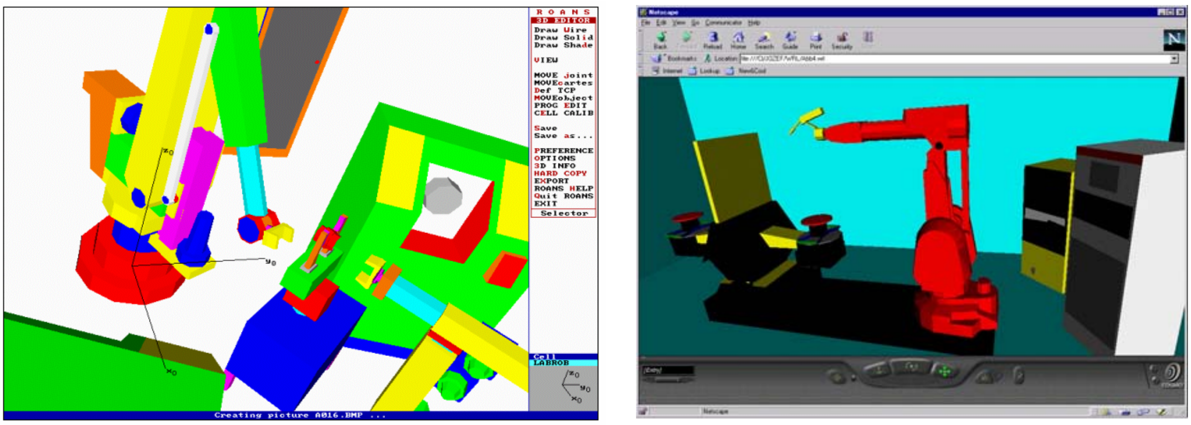

Figure 1. Simulation of virtual workplaces activity

Current VR and Web technologies have provided the feasibility to implement VM systems. However, this is not an easy task due to the following factors [1]:

- The conflicting requirements of real-time machining and rendering. Generally, a high level of detail for a scene description would result in a high complexity of the virtual scene.

• The conflicting requirements of static data structure and dynamic modelling. In the virtual machining environment, a dynamically modelled workpiece is essential.
• The requirements for a consistent environment to avoid confusion and provide navigational cues to prevent a user from getting lost in the VR environment.
• The importance of an adequate sense of immersion in the VR environment, without which even a highly detailed rendering will not help a user interact effectively in the virtual 3D environment using conventional 2D interfaces such as a keyboard.

3. AUGMENTED VIRTUAL MANUFACTURING APPLICATIONS

Augmented Reality (AR) and Augmented Virtual Manufacturing (AVM) are 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 [8].

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. 2.

Figure 2. 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 [8].

Virtual manufacturing techniques enhance our ability to understand the four dimensions described above by addressing issues such as designing products that can be evaluated and tested for structural properties, ergonomic Functionality, and reliability, without having to build actual scale models;

designing products for aesthetic value, meeting individual customer preferences; ensuring Facility and equipment compliance with various Federally mandated standards, Facilitating remote operation and control of equipment (telemanufacturing and telerobotics); developing processes to ensure manufacturability without having to manufacture the product (e.g. avoiding destructive testing); developing production plans and schedules and simulating their correctness; and educating employees on advanced manufacturing techniques, worldwide, with emphasis on safety [7].
Augmented virtual 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 virtual manufacturing application is presented real manufacturing workplace with virtual industrial robot. Application allows to test of future manufacturing system after change of manufacturing and manipulation machines realization.

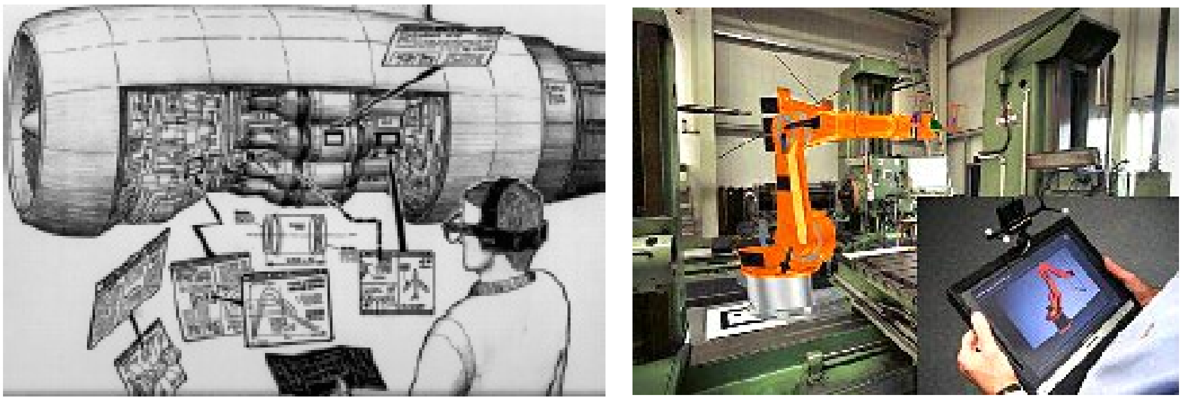

Figure 3. Augmented Reality: (a) idea of AR, (b) augmented reality manufacturing system

4. 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. Some areas that can benefit from development of virtual manufacturing include: product design, hazardous operations modelling, production modelling, process modelling, training, education. Slovak Ministry of Education supported this work, contract application research No. AV/1107/2004 and contract agency KEGA No. 3/5172/07.

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