Proceedings in Manufacturing Systems

Proceedings in Manufacturing Systems, Vol. 5 (2010), No. 1 ISSN 2067-9238

APPLICATION OF VIRTUAL MANUFACTURING IN INDUSTRIAL PRACTICE

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Abstract: *Virtual Reality (VR) requires more resources than standard desktop systems do. Additional input and output hardware devices and special drivers for them are needed for enhanced user interaction. But we have to keep in mind that extra hardware will not create an immersive VR system. Special considerations by making a project of such systems and special software are also required. As the human performs actions like walking, head rotating (i.e. changing the point of view), data describing his/her behaviour is fed to the computer from the input devices. The computer processes the information in real-time and generates appropriate feedback that is passed back to the user by means of output displays. In general: input devices are responsible for interaction, output devices for the feeling of immersion and software for a proper control and synchronization of the whole environment.*

Key words: *virtual reality, virtual manufacturing.*

1. INTRODUCTION

Virtual reality is a technology that encompasses a broad spectrum of ideas. It defines an umbrella under which many researchers and companies express their work. The phrase was originated by Jaron Lanier the founder of VPL Research one of the original companies selling virtual reality systems. The term was defined as "a computer generated, interactive, three-dimensional environment in which a person is immersed". There are three key points in this definition. First, this virtual environment is a computer generated three-dimensional scene which requires high performance computer graphics to provide an adequate level of realism. The second point is that the virtual world is interactive. A user requires real-time response from the system to be able to interact with it in an effective manner. The last point is that the user is immersed in this virtual environment. One of the identifying marks of a virtual reality system is the head mounted display worn by users. These display block out all the external world and present to the wearer a view that is under the complete control of the computer. The user is completely immersed in an artificial world and becomes divorced from the real environment. For this immersion to appear realistic the virtual reality system must accurately sense how the user is moving and determine what effect that will have on the scene being rendered in the head mounted display.

2. HISTORY AND DEFINITION OF VIRTUAL MANUFACTURING

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 [4].

Virtual manufacturing is used loosely in a number of contexts. It refers broadly to the modelling of manufacturing systems and components with effective use of audiovisual and/or other sensory features to simulate or design alternatives for an actual manufacturing environment, mainly through effective use of computers. The motivation is to enhance our ability to predict potential problems and inefficiencies in product functionality and manufacturability before real manufacturing occurs. Another term that is sometimes mentioned in the context of virtual manufacturing is agile manufacturing – sometimes defined as a structure within which agility is achieved through the integration of three primary resources: organization, people, and technologies. A way to achieve this is through innovative management structures and organization, a skill base of knowledgeable and empowered people, and flexible and intelligent technologies. Whereas agility focuses on the ability to make rapid changes in products and processes based on the voice of the customer, virtual manufacturing provides a means for doing so. One area in which virtual manufacturing has made an impact is that of rapid prototyping machines, building prototypes by precise deposition of layer upon layer of powdered metal, a process known as stereolithography. Virtual reality (VR) has been used by companies such as General Motors and Caterpillar to build elec-

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tronic prototypes of vehicles, instead of physical prototypes. This process reduces product development time significantly.

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].

3. THEORY OF VIRTUAL MANUFACTURING

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, mechanical 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 (VM) 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.

VM systems are integrated computer-based models that represent the precise structures of manufacturing systems and simulate their physical and informational behaviour in operation. VM technology has achieved much in reducing manufacturing cost and time-to-market, leading to an improvement in productivity. Much research effort to conceptualize and construct a VM system has been reported. Onosato and Iwata (1993) generated the concept of a VM system and Kimura (1993) described the product and process model of a VM system. Based on the concept and the model, a general modelling and simulation architecture for a VM system was developed by Iwata et al. (1995). Ebrahimi and Whalley (1998) developed a cutting force prediction model for simulating machining conditions in VM. A virtual machining laboratory for knowledge learning and skills training was implemented by Fang et al. (1998). In the virtual machining laboratory, both comprehensive knowledge learning and physical skills training can be achieved in an interactive synthetic environment. Using head-mounted stereo glasses and interactive gloves, students can virtually operate a lathe or set machining parameters and input CNC G-code program to cut the work-piece automatically, Machining process performance, such as machining conditions, cutting forces, cutting power, surface roughness and tool life, can also be simulated with the machining process evaluation models.

In addition, some commercial software for VM, such as Delmia's VNC, can simulate machining processes in a 3D environment and detect collision. By using a VM system, users can select and test different machining parameters to evaluate and optimize machining processes, and the manufacturing cost and time-to-market can be reduced, leading to an improvement in productivity.

However, a practical VM system is highly multidisciplinary 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 m 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.

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 [6]:

- 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.

4. FROM VIRTUAL MANUFACTURING TO VIRTUAL FACTORIES

When a single factory may cost over a billion dollars (as is the case in the semiconductor industry), it is evident that manufacturing decision makers need tools that support good decision making about their design, deployment, and operation. However, in the case of manufacturing models, there are usually no tests but the factory itself; development of models of manufacturing operations is very likely to disrupt factory operations while the models are being developed and tested.

Sophisticated computer simulations, what might be called virtual factories, call for a distributed, integrated, computer-based composite model of a total manufacturing environment, incorporating all the tasks and resources necessary to accomplish the operation of designing, producing, and delivering a product. With virtual factories capable of accurately simulating factory operations over time scales of months, managers would be able to explore many potential production configurations and schedules or different control and organizational schemes at significant savings of cost and time to determine how best to improve performance.

Since a factory model running in simulation mode would run thousands of times faster than real factory operations and would probably cost much less as well, managers would have a rapid, non-destructive methodology for testing various manufacturing strategies. Improvements suggested by real operations could be tested without risk in the simulation. Simulations could also assist in training tool operators and floor managers, who would be able to use factory models in simulation mode much as pilots use simulators to gain experience in flying real airplanes, especially under stressful or unusual conditions.

Computer-based factory models might also be coupled to real factories in what could be called control mode, in which the factory model would actually control and run the operation of the real factory through manipulation of the objects in the virtual Factory-Operating procedures and scheduling protocols would be validated in the virtual factory and then applied in or transferred to the real production facility. Control mode would enable direct electronic transfer of modularized capabilities from computer simulation to production line.

Coupled to appropriate computer-based reasoning and decision-support tools, a virtual factory operating in control mode would be capable of a significant amount of self-diagnosis. Driven by data from the real factory, the virtual factory would be able to analyze the performance of the entire factory continuously to determine the potential for optimizing operations to reduce costs, reduce production time, improve quality, or reuse materials. For example, the virtual factory would be able to use the data collected by a factory monitoring system, analyze potential and actual failures, and identify the cause of a problem. Such a system assumes the availability of a knowledge base for every piece of equipment in the factory that, given certain monitored data, can be used in conjunction with a diagnostic system and reasoning and decision-support tools to identify the source of a problem.

For monitoring and control of complex manufacturing systems, four dimensions can be conceived to express complexity [8]:

1. Space permits us to examine the physical location, layout, and flow issues critical in all manufacturing operations.
2. Time permits us to address facility life-cycle and operational dynamic issues, beginning with concurrent engineering of the production process and testing facilities during product design, extending through production and decline of the initial generation product(s), cycling through the same process for future-generation products.
3. Process allows us to study the coherent integration of engineering, management, and manufacturing processes, it permits examination of the important, yet intricate interplay of relationships between classically isolated functions. As examples, consider relationships between production planning and purchasing, production control and marketing, quality and maintenance, and design and manufacturing. Processes involve decisions ranging from long-range operational planning to machine/device-level short-term planning and control. The integration between various levels of aggregation is essential.
4. Network deals with organization and infrastructure integration. Whereas the third dimension focuses on the actions, this dimension concentrates on the actors and their needs and responsibilities. Clearly including personnel, the set of actors also includes ail devices, equipment, and workstations; all organizational units, be they cells, teams, departments, or factories; and all external interactors, such as customers, vendors, subcontractors, and partners. Issues such as contrasting hierarchically controlled networks with heterarchical, autonomous agent networks must be addressed.

5. CONCLUSIONS

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

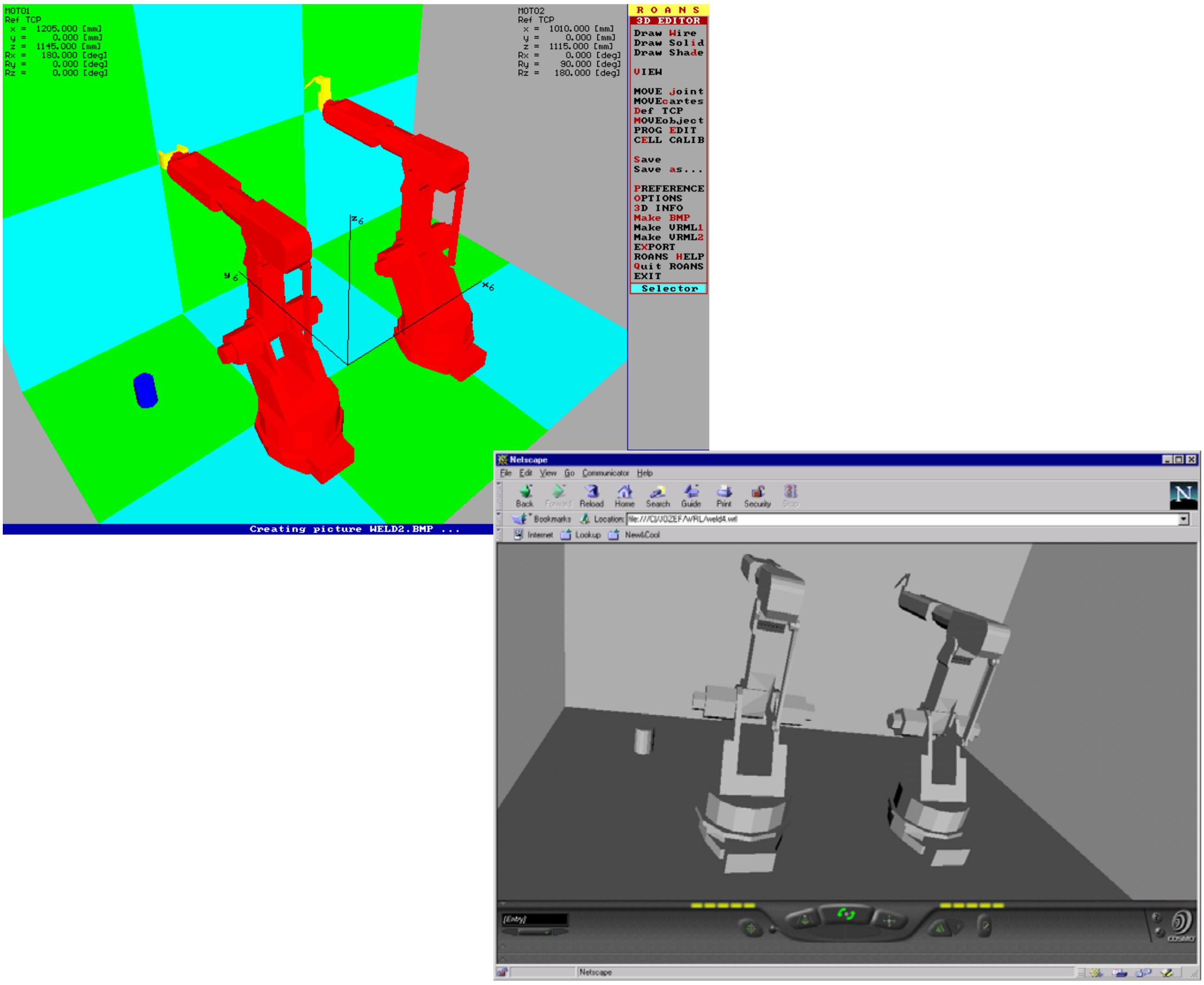

Fig. 1. Examples of virtual manufacturing.

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.

ACKNOWLEDGEMENTS: Slovak Ministry of Education supported this work, contract VEGA No. 1/0036/09 and KEGA No. 047-004TUKE-4/2010.

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