

ON SOME ASPECTS OF THE VIRTUAL MANUFACTURING CONCEPT

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1. INTRODUCTION

The term *virtual manufacturing* is relatively newer and has an even less agreed upon definition. Even the semantics in virtual manufacturing is not completely agreed yet¹. The general idea behind most of definitions, however, is that virtual manufacturing is nothing but manufacturing in the computer. This definition is the shortest one but comprises two key elements of virtual manufacturing notion—the process (*manufacturing*) and the environment (*computer*).

Many current definitions limit significantly the scope of the virtual system. Some authors restrict the scope of the virtual manufacturing system only to the structure of the real manufacturing system² or a real factory³, while others⁴ narrow the scope only to a single manufacturing operations or to a sequence of operations.

The role of virtual reality (VR) is overemphasized in some of the current definition. Virtual manufacturing is often times defined as an application of VR in manufacturing.^{3,5} Our understanding is that VR is only a tool for visualization in virtual manufacturing, not a core element. There are some examples^{6,7} of computer graphics simulations (essentially a virtual machining processes) of the metal cutting process, which are not VR-based.

One of the most comprehensive discussions on virtual manufacturing is available in the Internet at the Institute for Systems Research web site.¹ The definition proposed states that virtual manufacturing is an integrated, synthetic manufacturing environment exercised to enhance all levels of decision and control.

From the analysis of current definitions, it is evident that there is still confusion in the common understanding of what exactly virtual manufacturing is, which are its scope and objectives, which is the role of VR technology, *etc.*

For the purpose of the present paper, a new definition of virtual manufacturing concept has been synthesized⁸, defining virtual manufacturing as *a system, in which models of manufacturing objects, processes, activities, and principles evolve in a computer-based environment to enhance one or more attributes of the manufacturing process.*

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2. THE SPACE AND SCOPE OF VIRTUAL MANUFACTURING

In the present paper, the virtual manufacturing is considered as an initiative, which provides a modeling and simulation environment to evaluate and optimize *a priori* manufacturing processes for a specific process attribute. The concept of virtual manufacturing could be expanded to encompass activities, processes and objects both along the production stage and across the enterprise hierarchy (Fig. 1).

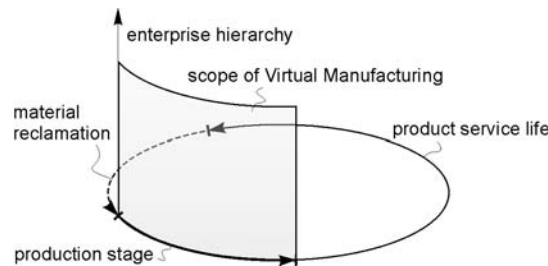


Figure 1. The space of Virtual Manufacturing.

Object-oriented taxonomy is proposed to define and to categorize the different implementations of this concept.

A comprehensive virtual system (referred to as a *Virtual Production System*) will cover the entire production stage. The Virtual Production System is a composition of a number of smaller-ranging, overlapping, and interrelated virtual components, which span on particular phases of the production stage, e.g. the *Virtual Prototyping System*, which focuses on the evaluation of the manufacturability of a proposed virtual prototype design and may include simulations of the planned manufacturing process, or the *Virtual Manufacturing System (VMS)*, which deals with the virtual prototype production but may also include an iterative cycle through the virtual prototype design.

Across the enterprise hierarchy, VMS is again developed systematically at different levels. At the lowest level, it is the underlying *Virtual Process*, which forms the kernel for the *Virtual Manufacturing Operation*. The Virtual Manufacturing Operation is developed independently from the other components of the VMS and possesses an interface to communicate with them. It is an encapsulated object of the system, because the Virtual Process in the Virtual Manufacturing Operation is hidden from the rest of the VMS. Now, the *Virtual Manufacturing Process* can be defined as a partially ordered sequence of a number of Virtual Manufacturing Operations (Fig. 2).

The principle of inheritance of the object "Virtual Manufacturing Operation" means that a new object of the VMS can be built at the next level of hierarchy based on an existing Virtual Manufacturing Operation(s). For example, a *Virtual Manufacturing Cell* inherits the characteristics of the lower level base objects plus those of some extra objects (for instance, a *Virtual Robot* for material handling). Subsequently, at a shop floor and factory level, the virtual systems are derived from all relevant sub-systems. Thus, the entire VMS can be considered as a system with *object-oriented architecture*.

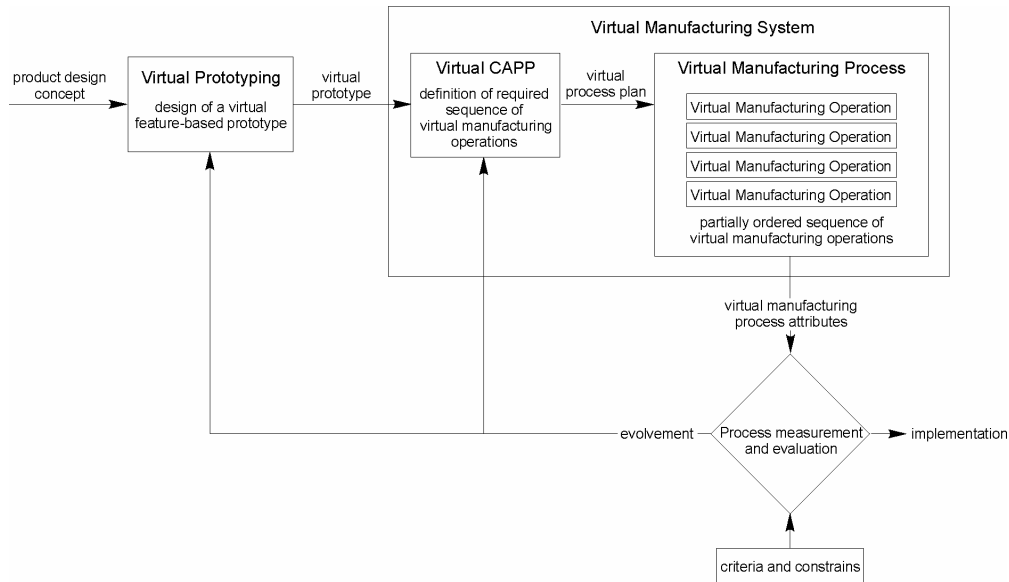


Figure 2. Virtual Manufacturing System for part production.

3. ADEQUACY OF A VIRTUAL SYSTEM

Making decisions based on a VMS demands a confidence that the impacts of those decisions on the real manufacturing process will be realized as predicted. That confidence is measured by the model *adequacy*.

The adequacy is generally defined as the agreed degree of accuracy and precision between the responds of the virtual and the real systems under the same conditions, in all points of the modeling space. *Accuracy* determines the deviation of the results obtained by the VMS from the results produced by the real system under the same conditions, while *precision* defines the spread of modeling results due to the stochastic character of the VMS. The problem in precision is how to increase the spread of simulation results rather than to reduce it. The virtual system often exhibits a "perfectly precise" behavior, producing repetitive constant responses at a point of the modeling space, something that is quite far from the real situation. To embed a stochastic character to the virtual system, methods of the imitation modeling should be employed, in which the principal factors are modeled as stochastic to emulate a stochastic real system behavior.

To acquire better model adequacy, the usual way is to further increase the model complexity, *i.e.* the model *depth*. But the experience shows that modeling deeper and deeper complicates extremely the model with little if any benefits. We should agree that enhancing the virtual system has to come to an end when a tolerable value of the modeling error, perhaps around 10%, is achieved. This value seems reasonable taking into account the precision and accuracy in the real process measurements.

Now, if we include the model depth as an additional coordinate axis in Fig. 1, a three-dimensional virtual modeling continuum could be proposed, depicted in Fig. 3.

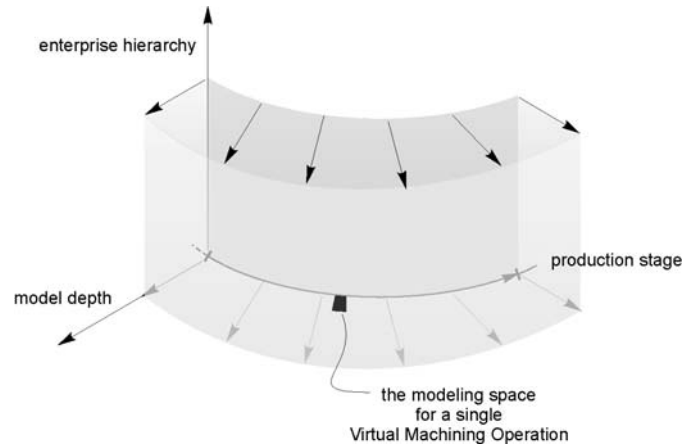


Figure 3. Three-dimensional modeling continuum in virtual manufacturing.

4. CONCLUSIONS

1. New definition and object-oriented taxonomy are advanced to characterize virtual manufacturing as an initiative, which provides a modeling and simulation environment to evaluate and optimize manufacturing processes for a specific process attribute.
2. In modeling for virtual manufacturing, model precision has to be “decreased” by stochastic modeling tools to account for the behavior of the real system.
3. The model adequacy could be improved by increasing the depth of modeling but enhancing the model should come to an end when the tolerable value of the model error is achieved.
4. A new concept of a three-dimensional virtual modeling continuum is proposed, which includes the modeling depth as a coordinate axis.

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