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Virtual Manufacturing and Virtual Spaces

Mélissa Saadoun

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INEDIT Institute, 24 rue du Panorama - 95800 Cergy St-Christophe, France
msaadoun@aol.com

ABSTRACT

This article presents news problems linked to the increasing use of **virtual spaces** in the building of new types of manufacturing what is currently called **Virtual Manufacturing** (VM). VM has many consequences in the activity of industrial companies whatever be size, economic sector or geographical area. Particular attention is paid on virtual spaces, manufacturing and collaboration, skills matrix and manufacturability, the CAD and Virtual Prototyping case and, finally, the virtual partnerships or enterprise as a new type of organization.

Keywords: Virtual Enterprise, Virtual Manufacturing, Virtual Partnership, Virtual Prototyping, Virtual Space.

1. INTRODUCTION

Virtual Manufacturing (VM) can be defined as an integrated, synthetic manufacturing environment exercised to enhance all levels of decision and control. The vision of VM is to provide a capability to « Manufacture in the Computer ». That means, VM will provide a modeling and simulation environment so powerful that the fabrication/assembly of any product, including the associated manufacturing processes, can be simulated in the computer.

It is then a manufacturing within a computer supported on the network, having a strong links with real or physical world of manufacturing *(See Figure 1).*

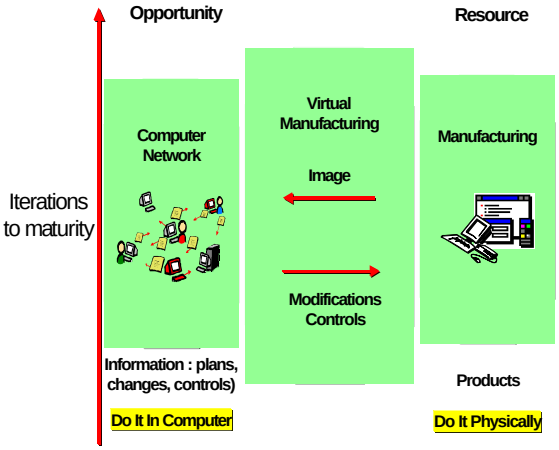

Fig.1. Virtual Manufacturing Vision

The main significants (semantics) of this definition are:

- *Synthetic or virtual working space*, mixing real and simulated objects, activities and environments of processes which supports the construction and use of distributed manufacturing simulations by synergistically providing a collection of analysis tools, simulation tools, implementation tools, control tools, models (product, process and resource), equipment, methodologies and organizational principles (culture) exercising , constructing and executing specific manufacturing simulations using the environment.
- *Enhance*: increase the value, accuracy, validity levels: from product concept to disposal, from the shop floor to the executive suite, from factory equipment to the enterprise and beyond, from material transformation to knowledge transformation decision: understand the impact of change (visualize, organize, identify alternatives).
- *Control*: predictions effect actuality.

2. IMPACTS OF VM AND NEEDS

VM affect the all industrial company activities starting from the manner in which market signal are taken into account, its relations with customers and providers until its internal reorganization or reconfiguration. In particular here are concerned the impact on the company memory, capital investment, design of production; cost estimation, risk management, client interfaces, functionality interfaces, workshop. The needs for VM are:

- Technology and development for models and simulations.
- Virtual infrastructures.
- Tools for working in the virtual spaces such as, the CAD kernel.

The scope of VM ranges from workshop to company areas. To set up a theoretical approach of this phenomenon, we propose two cases : CAD and virtual prototyping. Both will evolve more in the area of the future workshop define under this : from the « virtualisation of the real to the realization of the virtual », characterizing the new productive reality.

3. SHARED SPACES AND COLLABORATION

One of the main problems with classical forms of collaboration: they are not able to capture the knowledge generated during the collaboration process. In reality, most of the collaboration process are ad-hoc process addressed to search solutions to different emerging problems but without an infrastructure that support this process. In that case the available knowledge, generated by collaborations, is used only one time and, probably,

lost for ever [1].

We must create simple models to capture this knowledge and avoid dissipating the expertise created by collaboration [2]. Collaboration is essentially based on knowledge interaction between complementary expertise, but for becoming reality there should be a common understanding allowing creating new concepts. One of these new concepts is that of the virtual spaces. Virtual spaces have a particular nature in which problems such communication coordination or synchronisation are among the most relevants [3].

The distributed and shared infrastructure is composed of virtual spaces constituted of virtual reality models that could be manipulated by complementary expertise's of trading partners. Those virtual creations and manipulations by multidisciplinary teams enable people to reach a common understanding and to elaborate shared concepts in a better and faster way than any long discussion during meetings. Virtual spaces shared by disciplines provide a collective sense of identity and fundamental purpose as requested by the knowledge-creating company. One practical problem is to identify the rationale of any interaction need and interdependencies between entities manipulated by complementary disciplines and, to be able to manage the consistency of generated constraints. The virtual project office example of virtual shared space will be demonstrated in the, where several industrial trading partners forming a consortium will use the virtual project office as a distributed infrastructure *(see Figure 2)*.

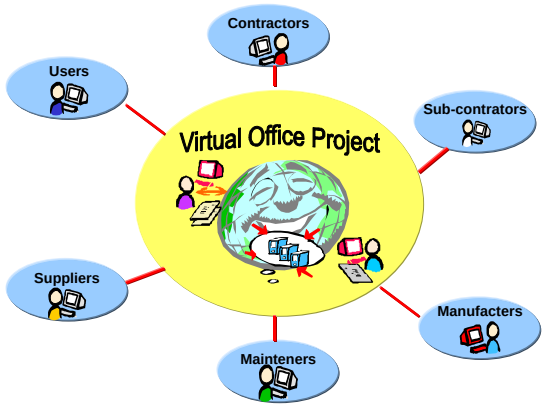

Fig.2. Example of virtual shared space : the virtual project office (Source EPICE ESPRIT project)

Expected virtual project office services to be distributed to the trading partners include the following:

- Work breakdown structure (WBS) and organization breakdown structure (OBS) management on the Web.
- Workflow management and tasks coordination.
- Requirements and constraints consistency management.
- Project progress monitoring.
- Configuration and data management.

4. VM INFORMATION BY INTERNET: THE CASE OF CAD DATA

HTML documents can be useful to send some kind VM information, transmitting design and manufacturability data to Web navigators from remote sites. Examples of this include STEP files, CAD models and textual data such as results of design or fabricability or information based on manufacturing catalog. One limit to a fluent data transmission is the large bandwidth at a given moment. For example, if we want to have a view of CAD image with a Web navigator, we need several minutes of transmission and interpretation. So the interactive operations (such as rotation of one CAD model) become impossible in a real time.

For some types of VM data, it is possible to get a larger bandwidth for transmitting data as bitmapped images but using VRML (Virtual Reality Modeling Language). One other solution of the congestion problem is to transmit only the specific code for programs to be executed in local sites. Any code must be involved but it is better to use a code written in a specific language for that purposes such as HotJava or Telescript. They are written for exchanging software components over the network. At the arrival site, it run programs and enable users to interact each other. Using these generic tools, one can compose interactive programs containing several types of documents The navigator HotJava permit to interact dynamically without congesting the network with additionnal traffic. To do it, HotJava adds a new type of markup, the HTML APP, where APP means « applet », a program wrote in Java language and running using HotJava which can link dynamically a Java code from the host and execute on the local machine.

Linked to these tools, there are the development environments of applications. These tools are used to build packaged software modules « add on » which will be coupled with other tools In CAD soft market, examples include Pro/Develop from Pro/Engineer, GRIP from EDS/Unigraphics, the Development Language (MDL) of Bentley Systems. They can be used to create software modules of network to share, execute or buy on the network starting from a simple CAD environment.

On the implementation side *(Figure 3)*, the Internet and Web-related technologies are used through Intranet (Internet tools used on an enterprise private network) and Extranet (Internet tools used on a trading partners private network). Otherwise, encryption systems and large bandwidth on the Internet must allow trading partners to avoid the use of a costly private network. The security aspect should not be underestimated as it was rated as the second greatest challenge in implementing collaboration between trading partners.

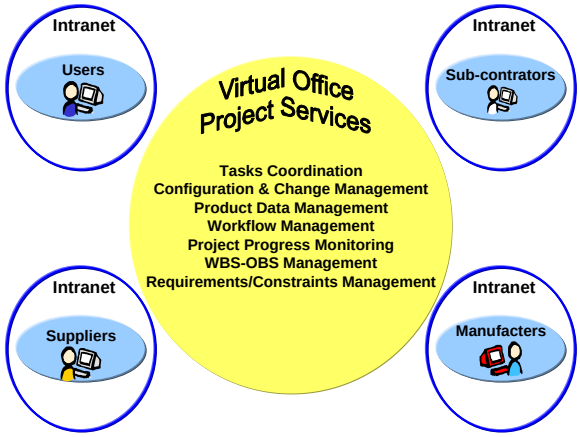

Fig.3. Example of a virtual shared space implementation

5. VM: THE CASE OF VIRTUAL PROTOTYPING

Virtual prototyping models offer an entirely new perspective in particular for the Internet trading partners and provide a strong sense of reality and the means to test the model of a product through meaningful interaction. All-digital prototypes ressemble their physical counterparts as closely as possible in terms of visual three-dimensional images, behavioral, haptic, and auditory characteristics.

An Internet virtual salesroom concept is needed to be based on a virtual three-dimensional photo realistic salesroom environment featuring a selection of virtual product models *(Figure 4)*. A particular enabling technology, virtual prototyping, in the context of consumer electronics and telecommunications industries is addressed (in Nokia case). Virtual prototyping is the application of advanced modeling and simulation techniques, user interface techniques and virtual reality techniques to support electronic commerce for customers and also business-to-business electronic commerce in the value chain that is product design, manufacturing, and sales [4].

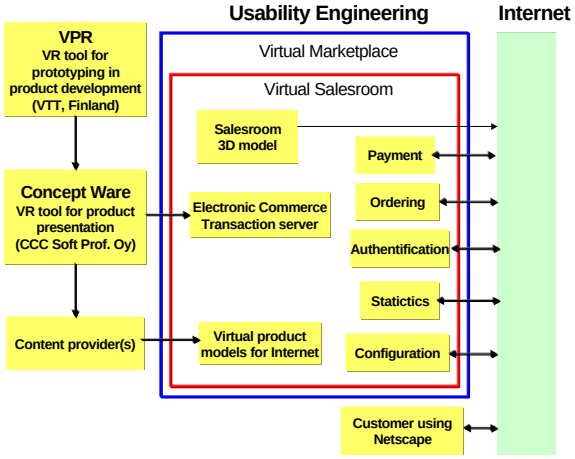

Fig.4. the proposed concept for Internet electronic commerce utilizing digital virtual product models in marketing and sales

Virtual prototyping means the process of using virtual prototypes instead of or in combination with physical prototypes, for innovating, testing and evaluating of specific characteristics of a candidate design. The following aspects are dominant:

- Functionality, created virtually, clearly defined and realistically simulated (for example product functionality and dynamic behavior).
- Human Interaction: the human functions involved must be realistically simulated, or the human must be included in the simulation (that is real-time operator-in-the-loop simulation).
- Environment: an off-line (non-real-time) computer simulation of the functions can be carried out, or a combination of computer (non-real-time) and hardware-in-the-loop (real-time) simulation can be carried out.

In virtual prototyping, a virtual world comprises both the VR model of a product under development (that is virtual prototype), and the model of the product's target environment, called virtual target environment [5]. Virtual worlds, the VR models, are highly advanced human-computer interfaces based on virtual reality techniques, providing a strong intuitive sense of reality and the means to change the world through meaningful interaction. Virtual worlds may include various levels of reality, thus enabling us to concentrate on any desired aspects of the product.

The most elementary interaction interfaces can be a keyboard and a mouse with a conventional window-based two-dimensional user interface. A more sophisticated virtual prototyping environment with a 3D user interface may include, for example a head mounted display, a 3D position and orientation tracking device, and auditory and haptic feedback devices. The type of representation in a virtual prototyping environment may be spatial, *n*-dimensional with abstract information spaces, or various combinations of video, natural and computer-generated images. During the development process, a virtual world can be seen as a model that best matches reality.

A necessary aspect of the full exploitation of the results of virtual prototyping is the requirement for the communication of the results to the interested parties. These may include persons taking part in actual product development - digital signal processing designers, software and hardware designers, and mechanical designers - or people involved in the sales and marketing of the product - marketing and sales representatives, wholesale and retail representatives, and of course customers. Quite often these persons may be quite widely geographically distributed, so solutions based on utilizing communication networks are needed.

The Internet is a viable medium for communicating of the results of virtual prototyping to parties in distributed concurrent product development. Enterprise benefits arise from the potential of the Web as a distribution channel, a

medium for marketing communications, and a market in and of itself [6]. Customer benefits arise primarily from the structural characteristics of the medium and include availability of information, provision of search mechanisms, and on-line product trial, all of which can lead to reduced uncertainty in the purchase decision. It is especially the last one where virtual prototyping would seem a superior technology.

An opportunity arises when the offering is differentiated by elements such as convenience through direct electronic distribution of software, or enjoyment through a visually appealing and exciting Web site. A visually appealing photorealistic operational virtual 3D prototype of a product would certainly fall in the same category. As evidence that this kind of behavior is already happening on the Web, consumers indicated that price was the least important product attribute when making on-line purchases [7].

6. MANUFACTURABILITY AND MATRIX OF COMPETENCIES

Industrial companies must have a virtual presentation of its kernel competencies using, for example, appropriated Internet servers as brokers of these competencies. Each company has their own competency portfolio, develop and enrich it continuously, and supplying then virtually. At this point, Manufacturability Analysis is an essential step in defining VM. This is a measure of the effort required to manufacture the part according to the design specifications (estimate the manufacturing time and cost). Given a computerized representation of the design (i.e. a solid model) and a set of manufacturing resources, the automated manufacturability analysis problem can be defined as follows: Determine whether or not the design attributes (e.g., shape, dimensions, tolerances, surface finishes) can be achieved. Two alternatives appears:

- The design is found to be manufacturable, then determine a manufacturability rating, to reflect the ease (or difficulty) with which the design can be manufactured.
- The design is not manufacturable, then identify the design attributes that pose manufacturability problems.

A VM tool, operating across the Internet, systematically generates redesign suggestions to improve the manufacturability of product designs while still satisfying the design's functional requirements. Linked to the Manufacturability Analysis, there is a Manufacturing Resource Matrix. In this case the system uses a tool for identification of potential participants for supplying manufacturing parts of virtual enterprise It identifies industrial who are able to manufacture automatically a part and have the corresponding capacity to do it. Finally, we have the Parts Characterization Matrix, an other VM tools, which must operate automatically across the distributed manufacturing network.

7. VIRTUAL PARTNERSHIPS & ENTERPRISES

VM as a powerful capability would take into account all of the variables in the production environment from shop floor processes to enterprise transactions. In other words, VM will accommodate the visualization of interacting production processes, process planning, scheduling, assembly planning, logistics from the line to the enterprise, and related impacting processes such as accounting, purchasing and management.

VM is linked to the Virtual Prototyping, the Virtual CAD and Virtual CAM made most of the time by simulation [8]. But these technical solutions need to be completed by a special attention on people working on. The first problem here is the building of the appropriated engineering teams. The second problem is that of the building of virtual partnerships forming Virtual Enterprises (VE). In both cases the manufacturability and skill matrix are the essential constituents. The constitution of VE, for example, needs an electronic presentation and qualification partners. Here's intervine virtual spaces because all this process exists only in that space.

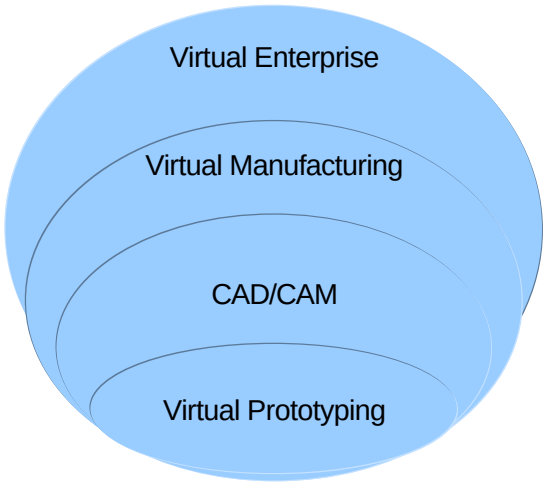

Fig.5. VM related notions

But an other double challenge is appearing: to use some techniques of virtual reality to build, evaluate and test VE, and to combine it with the ad hoc techniques developed within the framework of VE building such as, for example, the VE algebras that we can produce according to every project. We think VE exist only by project [3]. New research problems emerges, one of them being that considering communities as a virtual reality entities. The separated fields must be then integrated, creating a virtual lifecycle. *Figure 5* illustrates de relations between all these notions.

PERSPECTIVES

In the short term, the most promising fields for applying VM by Internet can fill the next criteria: to be operational on Internet, every user interaction with a remote server must respect this rule: do not use the tool frequently and

do not need of a large bandwidth. It is better to have a tool serving a large group of users because this eliminate the need for doing copies of tools to the local site users. Having this criteria in mind, we can propose as potential candidate for VM by Internet the data CAD translation, the distributed manufacturing and the design of production systems. Starting from these cases, we can build different levels of scenarios for using VM techniques by Internet.

REFERENCES

[1] M. Saadoun, Technologies de l'information et management, Hermès, 2000.
[2] M. Schrage, No More Teams ! Mastering the Dynamics of Creative Collaboration, Doubleday, 1995.
[3] M. Saadoun, Le Projet Groupware, Eyrolles, 1996.
[4] M. Sarker, B. Butler & C. Steinfeld, Intermediaries and Cybermediairies: A Continuing Role for Mediating Players in the Electronic Marketplace, Journal of Computer-Mediated Comunication, December, 1995.
[5] P. Svasta, I. Cristea & N. D. Codreanu, Virtual Proptotyping for low-cost electronic packaging, In Proceedings First International Symposium on Concurrent Enterprising Romania, ESoCE'98 4-6 June 1998.
[6] D. Hoffman, T. Novack & P. Chatterjee, Commercial Scenarios for the Web: Opportunities and Challenges, Journal of Computer-Mediated Communication, December, 1995.
[7] S. Gupta, A Research Project on the Commercial Uses of the Web, Hermès, 1995.
[8] B. Stefanescu, Coifa & H. S. Elian, Virtual Reality Systems with applications in the reconstruction of historical monuments, In Proceedings First International Symposium on Concurrent Enterprising Romania, ESoCE'98 4-6 June 1998.