Developing the manufacturing value chain through simulation - The Finnish Enterprise Simulation Laboratory project

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Abstract

The paper describes the Simulation Laboratory concept for business process prototyping, which is based on the application on virtual reality, computational and conceptual models for group mode simulations. The modeling and simulation methods and their research challenges are discussed, and the first steps of the pilot companies' process development projects are presented.

Keywords

**process innovation, simulation models, virtual reality,
manufacturing processes**

1 INTRODUCTION

In today's turbulent competitive environment, enterprises are continuously developing their structures and strategies. New management principles like Just-in-time, Lean Production, Activity Based Costing, Value Management, Agile Manufacturing, or organizational forms like Process Organization, Team Organization, Network Organization, Virtual Organization etc. have been created by innovative companies at an accelerating speed, and thereafter eagerly

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benchmarked by the followers - as well as explained and theorized by the academia.

The common "platform" for these strategic innovations has been a shift from structure to **process** in management thinking: the interpretation of the business enterprise as a dynamic system of processes that transcend the organizational boundaries and create dynamic networks. The basic process in these networks is the manufacturing value chain from suppliers and subcontractors to the main contractor, and further through the distribution channels to the customer.

To remain competitive in this rapid development, the whole organization has to be capable of process innovation and learning. However, trial and error is a slow and ineffective way of innovation, and errors in real life can be fatal. For product innovations, scale models and even virtual prototypes are used for testing out different product concepts before expensive realization. Analogically, for process innovations, simulation models are needed that allow "enterprise prototyping", the experimentation of an enterprise's operational processes, strategies, management principles and potential performance, before final design and implementation. **Simulations on enterprise models** are needed to connect practice and theory, doing and thinking, into an efficient spiral of innovations and learning in companies. (Smeds 1996, 1997, Riis *et al.* 1998)

The Finnish Enterprise Simulation Laboratory project SimLab (1998-2000) aims to create a visual learning and experimentation environment for groups to enhance innovations and organizational learning in enterprises. (Smeds 1998)

2 MODELING AND SIMULATION IN THE SIMLAB PROJECT

2.1 Basic principles

The aim of the business process simulations is to assist the whole organization to learn and innovate its processes. Therefore, the simulations are built to create a joint understanding and experience of the process (holistic knowledge), and also to support human interaction for innovation (hologram structure). The implementation of new process structures requires the acceptance and also creativity and enthusiasm of the affected personnel, thus the requirement of broad participation in the simulations is crucial (empowerment).

To uncover and utilize the strategic potential of the process innovations, also management should be present in the simulation sessions. A joint experimentation through simulations opens the dialogue between operational solutions and strategic possibilities, which is crucial for process-based strategic reorientation and can even change the strategic vision itself (umbrella strategy).

The principles of holistic knowledge, hologram structure, empowerment and umbrella strategy build the basis for the SimLab simulations. These generic

principles of evolution management support the development of the enterprise towards a continuously learning organization. (Smeds 1996, 1997).

In the SimLab project, enterprises are designing, building and testing business process prototypes as parts in systematically managed **process development projects** (cf the Softmatch method, Haho and Smeds 1997, Haho 1998). (Figure 1)

Figure 1 Rapid prototyping for process innovations (elaborated further from Haho and Smeds 1997).

2.2 Process modeling for SimLab simulations

Conceptual models and social simulation

The present state business process is first conceptually modeled as a flow chart (process map) of activities and flows, together with some performance data (typically time, cost, quality, resources, tools). The model information is gathered in team discussions with company personnel. The SimLab project applies a process modeling software with a visual flow chart user interface, which supports performance analyses and what if experiments.

For knowledge work systems, where the flows mainly consist of information, or in cases where the main emphasis in the simulation is on organizational development, the process map serves as a sufficient basis for the so called **social simulations or tailored simulation games**. (e.g. Smeds and Haho 1995, Piispanen *et al.* 1996, Smeds 1996, 1997)

Following the process map, a rough model of the present process is constructed by furnishing a seminar room as a "scale model" of the process. In the game itself, the players act in their own work roles and fill in the missing details and dynamics of the model by explaining their activities in the process. Thus, the composition of the game team is an important part of the simulation model. The players "talk through" the activities, the information and material flows of the process, following the route of a concrete historical case example, e.g. a specific customer order, and using supporting case material.

The social simulation games are concrete and interactive, and reach excellent learning and innovation results especially in present state simulations. Through the human interaction and discussion in the game, the players' tacit knowledge about the process is externalized and shared, and a common understanding is created. Development ideas, problems and open questions concerning the process are awakened and written down for further use in smaller process development teams. The teams refine the ideas into a new process design to be tested in a prototyping manner in the subsequent simulation games. Sometimes, the first simulation game becomes itself an important method to clarify and define the strategic objectives for the process re-engineering project. (cf Figure 1)

However, social simulation games are inefficient in what-if considerations and testing of alternative process solutions. Each simulation model is unique and has to be manually constructed, and it is not possible to run many rounds of the simulation at accelerated speed to test future alternatives.

Computational models for technical systems simulation

When technical systems such as manufacturing chains with material flows are the target of development, also computational models are needed. In the SimLab project, manufacturing and logistic processes are modeled as stochastic queue-

server systems (Lehtonen 1998). The discrete event simulation model used in the SimLab project has limited visualization capabilities, but is efficient in computation.

The computational models enable accelerated simulations based on numerical data. They can be used to simulate alternative processes structures and control principles quickly and efficiently. But they do not create concrete "hands-on" experience for groups of participants (only the model expert gains experience in the process experiments), nor do they support human interaction during the simulation.

Visual models to simulate socio-technical systems

Business processes in general, and especially the manufacturing processes, are complex socio-technical systems. Thus the interaction of human actors and the functioning of the technical subsystems should both be incorporated in a correct simulation model. Also successful process innovation and evolution management require the inclusion of the human knowledge and interaction in the simulations.

In the SimLab project, the core features of both conceptual and computational models are further visualized for group mode simulation (Table 1). In these visualized simulations, a group of people can together experience, experiment, discuss and innovate enterprise processes in a **virtual reality "enterprise space"**.

Table 1 Characteristics of different process simulation models in SimLab

<i>Model</i>	<i>Simulation experience</i>	<i>Learning Human interaction</i>	<i>Simulation efficiency</i>	
conceptual	social	concrete	strong	low
computational	technical	abstract	none	high
visual	technical & social	concrete	strong	high

3 VIRTUAL REALITY FOR PROCESS SIMULATIONS

The interactive social simulation of business processes is achieved through the combination of existing conceptual models, computational models, and virtual reality. The virtual reality applications are created through the **virtual wall** concept (Takala 1997) On one wall of the laboratory, a huge three-dimensional picture of the simulated system is projected from a computer display. This picture can be

flexibly modified applying computer graphics and e.g. video picture. Every player can simultaneously see the wall, which enables a shared simulation experience.

The virtual wall gives almost unlimited possibilities to visually model the enterprise "space", from the simple furnishing of the simulated room (e.g. applying animation) to the visual presentation of data, and even to the telepresence of the players in the virtual space (immersive virtual reality):

- Simulation data can be projected to the wall, for every player to see: e.g. the layouts and process charts, performance measures, economic analyses of the processes; also outputs from computational simulations.
- The physical simulation environment can be visualized in a two- or three-dimensional form: e.g. the future layout of the new company, the workshop with its machines, the material flows and even the movements of virtual actors in the workshop. - The game facilitator can change these images flexibly and quickly on the screen, even during the simulation.
- The players can interact directly with the virtual wall model, e.g. change the layout of the factory and the location of the machines in the workshop.
- The players can immerse themselves into the virtual reality, e.g. into the planned future factory, and experience the its functioning from "within".
- Even players at different geographical locations can participate in the same simulation through telepresence, if the virtual wall picture is transmitted via interactive broadband telecommunication networks simultaneously to several locations. The players can interact applying CSCW technologies and video, and meet as virtual actors in the "enterprise space".

The two first applications can already be realized with existing multimedia software, hardware, and simulation game methods, but the latter three require multidisciplinary research and development effort to create software and equipment for an appropriate user interface for the virtual "enterprise space".

4 THE SIMLAB PROJECT

The Enterprise Simulation Laboratory SimLab is being developed in a three year project 1998-2000 at Helsinki University of Technology, TAI Research Centre, as a multidisciplinary effort of three laboratories: Industrial Economics, Industrial Psychology, and Telecommunication Software and Multimedia (TLM). It is funded by national R&D funds and has been physically built into a laboratory with advanced IT and telecommunication technology, video projectors for the virtual wall, and a local network of PCs for simulation interface purposes. Six researchers are currently working in the laboratory, and several students work in the development projects of the pilot companies on special assignments or on their Masters' theses.

The project proceeds in a "concurrent engineering mode" with three cutting edge Finnish industrial companies representing machine industry, telecommunications and medical industry:

- Pilot company A needs a generic, modular simulation game to train its whole personnel in understanding the operations, strategies and economic performance of a typical customer-driven manufacturing company.
- Pilot company B is growing rapidly, and is moving to a new factory. It needs tailor-made technical and social simulation support to re-engineer its layout, production lines, material flows, and later its global logistic chains.
- Pilot company C is re-organizing its highly complex, knowledge intensive R&D process of medical drugs, and needs interactive social simulation games to be able to dramatically decrease the lead time of new product development.

The pilots proceed in parallel, and are currently in the modeling phase of the present state. All of them aim to realize a test simulation round with the first model prototypes in SimLab in the summer 1998.

Pilot A is applying the computational discrete event simulation model to build up the simulation "engine" of a generic model company. The engine is the basic manufacturing process model, into which also monetary flows and performance measures will be included. Existing manual simulation games have been benchmarked, and the company is currently setting the educational objectives for the new SimLab simulation games

Pilots B and C are enterprise specific process development projects in high technology companies. Pilot B is the prime example of a manufacturing chain development project. It is currently in a phase of extensive modeling. The manufacturing process is modeled with the computational discrete event simulation model. Also the material suppliers are analyzed, and a separate project on demand forecasting is going on. All these analysis efforts feed to the conceptual model, to the process map of the manufacturing system, which is also needed for the first simulation session, to combine the social and technical simulations.

Pilot C has started with the conceptual modeling of its target R&D process, and is preparing the first social simulation session. The development project has a clear structure and strong management support, and has been communicated throughout the enterprise effectively from the start. The process model is extremely complex, and puts increased visualization requirements on the conceptual process modeling tool.

The visual modeling in all pilot cases is only in its beginnings, and the first simulation sessions in SimLab will be important research opportunities to get "demanding customer requirements" for the visual support of group simulation. Pilots A and B apply in the first simulation session in addition to the social simulation also computational simulations, and the interfaces between the computerized simulations and the social simulation in the same simulation session is an important topic for research.

With each pilot company simulation session, the simulation model prototypes themselves are developed and tested. The prototypes' validity, usability, learning effects, and effects on process innovations are evaluated in each simulation.. Also

the technical requirements concerning the software and graphics, and the pedagogical requirements concerning the facilitators' roles in the group simulations are important development issues both for the simulation sessions, and for the whole Enterprise Simulation Laboratory concept.

5 SIMLAB IN THE FUTURE

After the development project, SimLab will continue it functioning as a multidisciplinary research and teaching laboratory at Helsinki University of Technology, and as an "enterprise clinic" for companies.

SimLab can be used for computer supported experimental learning in many Industrial Management courses. The combination of the virtual wall and advanced telematics creates new possibilities for students also to engage in distant learning in the "virtual university".

Practitioners from industry can be invited for training simulations to SimLab. But secondly, and more importantly, they can use SimLab as an "enterprise clinic" for their specific problem solving and process development tasks. Development groups can attend simulations, which are tailored to the enterprises' needs. Even global manufacturing chains can be jointly experimented and developed through the virtual meeting of players in the same "enterprise space".

The multidisciplinary research teams of SimLab will have excellent possibilities to develop and study virtual reality supported group simulations of enterprise processes, as well as their innovation and learning effects. As "patients" of the SimLab clinic, the enterprises will provide rich empirical research data in a laboratory setting. The implementation success of the SimLab assisted process innovations can also be followed up later through real life case research.

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7 BIOGRAPHY

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