THE DESIGN AND DEVELOPMENT OF A DISCRETE EVENT SIMULATION SYSTEM TO SUPPORT VIRTUAL INDUSTRY ACTIVITIES

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The evolution of the organisational design has been moving towards the use of physical structures and virtual mechanisms in a hybrid manner, involving industries, distributors and customers, with a wide margin of independence. The vast majority of real systems are complex, with many boundary conditions, and discrete-event simulation can be used to model such systems. Described within this paper is the concept of a software for business management between virtual enterprises. It is composed of many integrated modules, and some of these modules have been developed. One of these modules is the shop floor simulation module, whose objective consists of maximising the utilisation of shop floor resources, and being able to inform customers the product's due date with statistical confidence.

1. INTRODUCTION

The globalisation of the world economy is a factor that leads enterprises to the need to become more competitive. Another consequence consists of the steady increase in the use of the Internet, due to the reduction to the prices of telephone calls and computers. The number of users of such technologies will increase from 130.6 million in 1999 to 350 million in 2003 (Ecommerce, 1999). This represents a growth both in the amount of available information and in the quantity of people that will have access to the information.

The emergence of the Internet as an important global access to information carries with it a new business concept. Fifteen years ago nobody predicted the electronic commerce, which is causing deep transformations (a) in economy, markets and structures of entire industries; (b) in the product, services and in their flows; (c) in the values and behaviour of customers; (d) in the labour and employment markets (Druker, 2000). The absence of access limits to information

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has eliminated the distance between the potential customer and the enterprise, which exposes all of its production lines in a virtual display window, at a relatively low cost compared with real shopping locations. The industries that sell their goods through the Internet spend less with distribution, and cash in the profit margin of the resellers. But in the virtual shops prices are not necessarily lower, since it is necessary to avoid bankruptcy of the traditional distribution channels (Fruet, 1999).

Conceptually, the electronic commerce can be divided into two areas: business to customer, and business to business. Analysts estimate that in 1999 the business to customer commerce reached approximately US\$ 17,000 million, and business to business reached US\$ 68,000 million (Pombo, 1999). With regard to business to business e-commerce, it is important for traditional enterprises to realise that in order to do e-commerce, they will have to (a) reinvent themselves; (b) place themselves in a virtual value chain; (c) operate in a digital economy; (d) shift paradigms so as to achieve good results with much greater order of magnitude.

Based on the above scenario, it is necessary for industries to aim at permanent progress. The prosperity of enterprises in this scenario depends on their capacity of self-knowledge, in order to predict and react quickly according to the market conditions. It is necessary thus that reliable pieces of information are continuously shared between enterprises that compose the value chain, which increase the level of confidence of decision-making and the capacity of integration between those enterprises. Information technology (IT) can be used to support achieving this objective.

The influence of IT on productivity and enterprise organisation can be more significant, since it affects the production and management tasks, besides expanding the organisational memory (Durand, 1994). Consequently, the development of specific and integrated software that answers questions such as "What if?" reaches new dimensions regarding strategic levels. If such software systems are capable of simulating, controlling and monitoring this value chain integration scenario, generating reliable results, and allowing a better understanding of the current state of the real system, they will increase the level of efficiency of the decisions made.

There are software systems available that aim at increasing the speed and ensuring the correct communication between suppliers and distributors, improving the operations of the production chain. These systems help suppliers and distributors to perform transactions in a dynamic data chain, which connects partners around the world in real time. The objective of these activities is to help enterprises to become more efficient through the ease in the management and exchange of business documents, independent of the document format (e.g. EDI, XML) or transportation means (e.g. Internet, e-mail), and to integrate these pieces of information with operating systems.

The implementation of this kind of software results in a higher level of integration between the many partners of the chain, allowing the analysis of the current situation of the enterprises. This is a significant improvement, since previously they used to produce for a non-updated demand, which many times was found to be inaccurate. However, simulation techniques can be used effectively in such a scenario, considering (a) the potential demand that could be met with satisfactory cost and time; (b) each partner in the value chain. Since the enterprise is exposing its products in a global environment, it should use methods with rapid response, which would help in situations such as the case when the enterprise would

need to withdraw its products from the virtual display window due to its insufficient capacity to produce them in a lower cost and time. Thus this enterprise would preserve its image before the customer, offering products only according to the capacity of its value chain.

The objective of this work is to present the structure of an integrated computer system to manage business between virtual enterprises, including suppliers and distributors, using discrete event simulation modelling analysis techniques. The system has a modular structure, and the Module for Manufacturing Integration with Statistics and Simulation (SIMES) (Ribeiro, 1999) will be described in this paper.

2. THE STRUCTURE OF THE BUSINESS MANAGER BETWEEN VIRTUAL ENTERPRISES

When developing a virtual environment, it is important to provide customers with adequate browsing tools. In the proposed system, the customer will have to access a web site, where he/she will register to a customer database. With this registration the customer will have an identity and a history, where the past negotiations will confer him/her a rank among the other customers. Thus it will be possible to identify preferential customers, and to these will be given an even better treatment. After registering, the customer will receive the Personal Access Browser (PAB), which will allow the navigation to be performed according to the specific needs of that customer.

When executing the PAB module, connections will be established between the customer and the Virtual Shopping Centre (VSC), which will function as a Centralised Business Unit (CBU). For the customer, the CBU will be a large consultation and purchase window available on the web, capable of supplying technical information on each product reliably, and the date when the product will be in the customer's hands, as well as its cost.

For the associated partners in the value chain, this VSC will work as a large customer that uses only the idle capacity of the manufacturing resources of each partner, capable of monitoring and scheduling new orders. This module would thus be capable of integrating the partners in value chain, ensuring that the due dates are met, and in the case of unpredicted situations it would generate new manufacturing alternatives between the partners.

In this work, a Virtual Industry is represented by a simulation model that was verified and validated according to its real equivalent. It performs electronic communication with the real industry, in order to update the input parameters, ensuring statistical confidence to the results obtained.

The CBU has the role of creating a neutral space between the many partners, also giving statistical confidence to the transactions, based on the virtual industries that compose it. Different suppliers of the same component may be considered, but they should be registered and technologically prepared to manage the pieces of information.

Simulation runs will be performed in order to verify which of these partners will meet the needs considering reliability, cost and time. If the sale is confirmed, the order is expedited. Before performing the simulation, the CBU communicates electronically with each registered partner involved in the manufacture of this

product, in order to extract and update the value of the state variables of the resources in each of the enterprises involved.

The modules that compose the software system proposed are the following:

- a) Module of Exposition of the Virtual Display Windows;
- b) Module for Creating and Updating the Virtual Display Windows;
- c) Module of Consultation of Specific Products;
- d) Module for Manufacturing Integration with Statistics and Simulation (SIMES);
- e) Module of Communication with the Real Equivalent;
- f) Module of Optimisation of the Simulated Hypotheses;
- g) Module of Potential and Confirmed Sales;
- h) Module of Alternatives for Unpredicted Situations;
- i) Module of Customer Registration and Ranking;
- j) Module of Distribution of Sales Percentages;
- k) Module of Memory of Consultations Performed;
- l) Module of Partner Evaluation and Ranking;
- m) Module for Building Models of Real Systems;
- n) Module of Communication with the Customer Partner.

It is important to mention the Module for Partner Monitoring and Scheduling (PMS). This module aims at monitoring the state of the resources currently involved, verifying the production previously scheduled in the real enterprise. It may decide to include new service orders, and also to communicate with the Module of Communication with the Real Equivalent (CRE), whenever any significant event occurs. The information exchange will take place through the Internet using encrypted protocols.

It is important to point out that the partnership does not mean dependence, since each partner will keep its sales independent of the CBU's authorisation, since as soon as a new order is scheduled, the PMS module informs automatically the presence of a new schedule. Thus, the Virtual Industry uses the idle capacity of the partners in order to increase its virtual production capacity.

The customer of the VSC can be:

- An Internet user (i.e. business to customer e-commerce);
- A real reseller shop, that could be registered or not as a partner. If it is registered, it will be considered as a "customer partner", and when its inventory reaches a minimum level, the inventory management system informs the need to purchase more material.
- An industry outside the partner network, that wants to order a batch of components, with confidence of delivery, and good product quality (i.e. business to business e-commerce).

Consequently the potential sales of the VCS becomes wider. The business to customer transaction is performed many times without triggering the simulation, since the customer will be served by the Module of Communication with the Customer Partner, checking its inventory, and redirecting sales to the most capable customer partner in terms of availability and distance.

The proposed structure leads to benefits to partners that manufacture for a certain demand, allowing them to achieve zero inventory. The deliveries planned according to the real need of each distributor or partner result in the following advantages: (a)

lower inventory; (b) supply of products within the validity period; (c) reduction and/or elimination of mistakes in the order made by the customer.

The CBU has a wide manufacturing potential, and it can respond efficiently to demand peaks, since it considers the capacity of many of its partners in order to manufacture a product, generating reliable results in a short time.

3. WHERE TO INSTALL THE VIRTUAL INDUSTRY?

It is important to consider where to install the Virtual Industry. We point out the following possibilities: (a) an IT enterprise without links with the partners in the value chain; (b) an IT research centre is created, which is not always possible due to cash flow limitations; (c) an association with industries that have research centres is made, but this is difficult due to the reduced quantity of those enterprises that have a research centre that is adequate to the needs of the value chain partners; (d) universities.

We believe that one of the main roles of the University is to give support to Manufacturing Enterprises, working as a research centre integrated with industries. However the integration process between University and Industry is slow and gradual, since mutual confidence is many times hindered by human factors. On the other hand, the rapid and continuous transformations occurring in the world are leading to more aggressive scenarios, increasing even more the industries' concern with improving continually its methods and processes. Thus, the association with universities becomes likely.

Both Universities and Industries gain with such an association. With regard to the University, more investment could be obtained from government agencies. Concerning the Industries, a team of doctors, engineers, and post and under-graduate students would be available in a relatively low cost, compared with the cost the enterprise would have to pay for a similar team. Thus the cost of installation and maintenance of the Virtual Industry's structure would be significantly reduced.

4. THE DEVELOPMENT OF THE SOFTWARE SYSTEM

Due to the complexity of the proposed modules, the development of the software system was structured so as to allow in a first phase the implementation of the SIMES module. The SIMES module is responsible for assessing the current virtual capacity of the Virtual Industry, exploring the idle capacity of the registered partner, and generating manufacturing cost and time information. The SIMES module aims at integrating many areas, such as: manufacturing systems; statistical methods; discrete event simulation; group technology; production planning; costing systems, etc.

With regard to this integration, one of the main difficulties for the preparation of the case study was that there was no previous work on the integration of the above areas that would generate cost and time results associated with a statistical confidence considering shop floor attributes.

We consider that simulation is a tool that will increasingly be used by enterprises. The advantages of using simulation include (a) a model representing the

shop floor can be created; (b) many evaluations of different proposals can be made. This can be done because the simulation models allow the analysis of almost any conceivable metric, as opposed to the analytical models. Simulation also allows the identification of bottleneck resources in the manufacturing system, and thus such situation can be changed in order to increase productivity.

The proposed approach aims at eliminating some disadvantages that are usually assigned to simulation, which include (a) the need of special training to elaborate the model; (b) the difficulty of interpreting the results of simulation. Thus it is possible to reduce the time involved in all simulation stages, besides promoting the integration of other concepts.

The development of the simulation software that analyses the global performance of the enterprise, including the scheduling of orders and dynamic monitoring of the state of the resources, would be very beneficial to the enterprise. The proposed work represents the initial steps towards this goal.

The SIMES module was developed in Borland Delphi and runs on a Pentium microcomputer. Details of the implementation, which includes cost and time calculations, can be found in (Ribeiro, 1999). The simulated enterprise is based on classical data found in the literature (Burbidge, 1988), although no information regarding costs and times is included in that reference.

5. CASE STUDY

The example proposed by Burbidge considers the manufacture of 43 types of components in 16 different machines (see table 1).

Table 1 – Machines available in the shop floor

<i>Code</i>	<i>Type</i>	<i>No. in the Incidence Matrix</i>	<i>Quantity</i>
PRE-211	Press	5	2
PRE-412			
PRE-120		2	1
PRE-130		3	1
PRE-340		7	1
FUR-211	Drilling machine	15	2
FUR-412			
FUR-320		10	1
FUR-130		16	1
FUR-140		14	1
FRE-311	Milling machine	1	2
FRE-412			
FRE-120		9	1
FRE-230		4	1
FRE-340		13	1
TOR-210	Lathe	11	1
TOR-121			
TOR-222			
TOR-323		6	4
TOR-424			
RET-111	Grinding Machine		
RET-212			
RET-313		8	4
RET-414			
RET-220		12	1
Total number of machines =			25

These machines should be initially grouped into cells, so as to optimise production. An incidence matrix 16x43 represents the above production, where rows correspond to machines, and columns correspond to components. Each field in this matrix can have the values "1" and "0", where the value "1" characterises the need for the component (column) be processed by the machine (row), as shown in Figure 1. The value "0" means that that component does not need to be processed at that machine. It is assumed that these components are small in size.

In a manufacturing system, the engineer responsible for the layout must take into consideration the following factors: number of resources involved; amount of traffic between them; area needed; geometric constraints imposed by each resource, as well as by the available area. Another important factor to be determined is the quantity of cells to be installed. A module was implemented to do that, which creates and associates component families to machine cells, and the results from this module were used to form the shop floor layout.

Figure 1 – Given incidence matrix

This module applies a version of the branch-and-bound method (Kattan, 1990; Kattan, 1997), which analyses the incidence matrix aiming at grouping components into families and machines into cells simultaneously. After inputting the 16x43 incidence matrix to this module, the result obtained was the formation of three component families, each being processed by a distinct machine cell, represented by the codes "C-1", "C-2" and "C-3", as shown in Figure 2.

Figure 2 – Rearranged incidence matrix for cell clustering

Figure 3 illustrates the adopted layout, which includes 25 machines. It can be noticed that 9 of the 25 machines correspond to duplications. These are arranged in three distinct cells. The module described above outputs the first three cells, and this module also duplicates the busiest machines. This is the case of machines "6" and "8", which have three copies each, resulting in 20 machines instead of 16. Besides, other five machines were duplicated, resulting in 25 machines.

Figure 3 – Resulting incidence matrix, with family and cell groupings

One can imagine the situation in which a customer consults the sales department about the possibility of anticipating a delivery (to 16 hours), and increasing the size of a certain batch previously scheduled (from 100 to 175 components). Assume that this customer uses each ordered component in product assembly.

This anticipation is motivated by the possibility of a demand increase in the regional market. The prompt supply aiming at satisfying the demand increase is strategic, so as to keep the share of the market. The customer needs to know how flexible his supplier can be with regard to time and production volume.

The FMS model described above considers the change of priority a very important factor. In order to perform the analysis, a higher priority is assigned to this batch, and the batch size is increased from 100 to 175 components. The main and alternative routings for the manufacture of this batch are shown in table 2. The simulation is then run for 100 components, and the total time needed to manufacture this batch was calculated as 12.8 hours, with a cost of US\$ 579.50.

Then another simulation run is made for 175 components, resulting in a total time of 23.4 hours. The time obtained is still beyond the one desired by the customer (i.e. 16 hours). Thus, a new production strategy must be implemented.

After analysing the results of many simulation runs, the batch size range that meets the desired time of the customer can be determined, and in this case this range lies between 125 and 150 components. Then a new simulation run is executed for a batch size of 130 components, resulting in a manufacturing time of 15.8 hours, with a cost of US\$ 5.29. This solution meets the time requested by the customer, but it still below the quantity ordered, which is equal to 175 components.

In order to increase the number of components to be manufactured during the time requested by the customer, new main and alternative routings are planned. When analysing the simulation run for 130 parts, it is possible to identify among alternative machines which ones effectively participate in production. In this way,

the used machines can become part of new routings that may manufacture components in parallel. Although the new layout has a lower performance compared with the previous one, it can become an option towards increasing the total number of manufactured components in the prescribed time, and this situation can be evaluated using simulation. Table 2 shows the new situation.

Table 2 – Main and alternative routings in the modified plan

Initial Plan Routings					Modified Plan Routings				
Main	Number of the Alternative				Main	Number of the Alternative			
	1	2	3	4		1	2	3	4
PRE-120	PRE-130	-	-	-	PRE-340	PRE-211	-	-	-
TOR-121	TOR-210	-	-	-	TOR-323	TOR-222	-	-	-
FRE-120	-	-	-	-	FRE-311	-	-	-	-
FUR-130	FUR-140	-	-	-	FUR-320	FUR-211	-	-	-
RET-111	RET-212	RET-414	-	-	RET-313	RET-220	-	-	-

This new strategy decreases the flexibility of the original plan, since the number of alternative machines is reduced for the creation of a modified plan that will process another batch of the same type, but with less components.

Another factor that should be noticed is that the machines in the main routing in the modified plan belong to cell "C-2". Thus, cells "C-1" and "C-2" operate in parallel in order to meet the desired target. Despite cell "C-2" was originally grouped to manufacture components in family "2", and the component being manufactured belongs to family "1", the duplication of resources (i.e. there are some identical machines in both cells) enables the manufacture of these parts.

After performing a simulation run for the main routing shown in table 2, the time to manufacture a batch of 120 components was equal to 14.9 hours, with a cost of US\$ 5.42. The simulation for the manufacture of 100 components using the modified plan resulted in a time equal to 14.6 hours, with a cost of US\$ 6.14. Notice that with the modified plan, the manufacturing time of each batch, which are produced in parallel, satisfies the due date requested by the customer.

By using the developed simulation software, it is possible to simulate in a few minutes different arrangements so as to arrive at a strategy that responds efficiently to the proposed scenario. The solution obtained consists of dividing the total batch in two, where the first is composed of 120 components, and the second of 100 components. For this production strategy, it is possible to ensure the supply of a batch of 220 components within the desired time, at a cost of US\$ 5.78.

The case study shows that the proposed software system can be used to help increase the flexibility of the enterprise, exploring the potentialities of the machines so as to absorb quantitative and qualitative fluctuations on demand. It is important to mention that the software does not perform optimisation.

A similar situation can be the one where a customer orders a batch of products that is above the production capacity of the customer partners. In this case, the amount of products that exceeds the capacity is produced in the following manner: the CBU, after receiving the consultation from the Personal Access Browser (PAB), determines the batch size and triggers a dynamic update process of the status of the resources involved in manufacturing, by contacting the Partner Monitoring and Scheduling (PMS) module. The PMS module then returns the requested statuses. Based on this consultation, many simulation runs will be performed, so as to provide information to the Module of Optimisation of the Simulated Hypotheses (OSH), which will rank the possibilities according to the selection criteria, such as the largest profit margin, shortest manufacturing time and due date, performance of

previous sales, etc. Then the CBU will present to the PMS module information regarding the product price and due date, and this will allow the customer to make a decision whether or not to do the transaction. If the customer decides for the transaction, the CBU contacts the PMS module of the sales partner in order to schedule the sale process. The CBU monitors the manufacturing phases, receiving periodically information from the PMS module until the end of the sale process, i.e. the success of the transaction.

6. CONCLUSIONS

The structure of the system presented in this paper attempts to avoid problems related to increase in demand due to globalisation, since it is possible to gather information on the real potential of each partner in the value chain. For instance, this information can be used to determine the quantity of each product, and based on that to limit its sales in the virtual display window. As a rule an enterprise must not violate the due dates, which would lead to the customer's lack of trust.

We consider strategic to integrate and to model each partner in the value chain, and to simulate them with the help of the computer, so as to obtain information with a degree of statistical confidence. This eases the business of each part involved, be it customers, suppliers, distributors or producers. The implementation of the SIMES module, as well as the other modules, is important to achieve these objectives.

It is important to point out that the association between Universities and Industries, with regard to the proposed system, would lead to a continuous development of the system in a research centre with high quality personnel. These researchers would be responsible for activities such as shop floor modelling; possible improvements to the model; software maintenance; and development of new versions. These centres, through its servers, would allow access to registered industries that would have available an advanced module for data input. They would then inform the centre's server- the situation of the shop floor resources, and also the attributes of the new batch. As a result of this partnership, the aggregated cost for acquisition, training and maintenance of such system would be significantly reduced, which is beneficial to both.

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