A Semi-Automated Brokerage for a Virtual Organization of Mould and Die Industries in Brazil

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Abstract: This paper addresses a semi-automated process of brokerage for a virtual organization of mould and die industries located in the south of Brazil called VIRFEBRAS. This process is represented by a multi-agent-based decision support system that helps a human-broker in the selection of the group of enterprises within VIRFEBRAS which better fits a given business opportunity. This decision is not automated, but rather made via an agreement among the human-broker and all the members. Each enterprise will have a Production and Planning Control system that in turn feeds the whole system with updated data about its current / planned capabilities, enabling global optimizations and trust. Some implementation results are presented and next directions are pointed.

1. INTRODUCTION

The need to augment the competitiveness has been pushing most of the enterprises over the world to invest in new methods of organization and work, and in advanced manufacturing and information technologies. VIRFEBRAS – *Virtual Organization of Mould and Die Industries of Brazil* – is a Virtual Organization made up of nine mould and die SMEs in the city of Caxias do Sul, located in the south of Brazil. Caxias do Sul is nationally seen as a mould and die *cluster*. A *cluster* is seen as a group of enterprises that have the potential and the will to cooperate and therefore may become the partners in a Virtual Enterprise (VE) (Camarinha et al.,

99a). It was created as a strategic answer to face the current market needs, in the sense that the business potentialities and competitiveness of the enterprises could be increased in the global market if they behaved as a stronger coalition, gathering the sum of their individual capacities.

In the VIRFEBRAS²⁹ context, the importance of brokerage emerges in the creation phase of a virtual enterprise, when it is necessary to decide on the appropriate set of skills and resources to respond to a given business opportunity. In fact, the broker concept is wider, with its use also in the VE operation phase, when it is necessary to change a partner. Brokerage is an activity – normally coordinated by a human assistant called *broker* – that aims at searching for business opportunities over the world and to bring them into the cluster of enterprises he/she represents (Camarinha et al., 99b).

This paper presents a multi-agent-based decision support system that assists a human-broker in the selection of the team of enterprises within VIRFEBRAS that better fits a given business. This development is one of the actions of a regional industrial qualification program for the mould and die industry, lead by the Mechanical Department of the University of Caxias do Sul, regarding the problems and peculiarities of this sector.

This work represents an improvement of the first system version presented in (Rabelo et al., 2000a), developed in the scope of the INCO-DC MASSYVE project (MASSYVE, 2000). The paper is organized as follows: Chapter 2 gives a general overview of the current Brazilian scenario in the mould and die sector and the VIRFEBRAS context. Chapter 3 stresses the brokerage approach. Chapter 4 describes the brokerage scenario within VIRFEBRAS. Chapter 5 introduces the system architecture. Chapter 6 shows some results of the developed system, and Chapter 7 discusses the results and points the next steps of this work.

2. MOULD AND DIE INDUSTRY SCENARIO

In Brazil, the mould and die industry is going through a crucial moment, presenting some particularities. The mould and die sector requires specialized labor; most of the mold and die projects and manufacturing processes are based on previous experiences, sometimes without technological innovations. The customer usually decides to purchase a mould or die considering three main factors: *quality*, *cost* and *delivery time* (Santos, 97). However, another factor is emerging in importance: the *agility* in the business negotiation process.

²⁹ VIRFEBRAS companies: Indústria de Matrizes Bisol Ltda., Coprima Metalúrgica Ltda., JR Oliveira Indústria Metalúrgica Ltda., CJN Indústria de Matrizes Ltda., Elite Indústria de Matrizes Ltda., Gama Indústria de Matrizes Ltda., Tokyo Indústrias de Matrizes Ltda., Sildre Indústria de Matrizes Ltda., and Matrizes Sadel Ltda.

To be competitive a Brazilian mold and die industry must accomplish the delivery time previously agreed with the customer, with appropriate costs and the requested quality. It has been clearly seen that the biggest problem a mold and die industry has to improve its level of competitiveness is related to the quality of the Production Planning and Control systems (PPC). In this type of industry, the PPCs should be very sensible and efficient to deal with constant modifications in the schedules as the mould project uses to receive many alterations along its manufacturing. This situation also makes the process planning and scheduling very difficult considering the available resources in a certain period of time. The finite nature of the manufacture resources creates delivery priority conflicts, that become more problematic with unforeseen events, such as machine damage, employee absenteeism, delay in the delivery of materials and components, etc. (Santos, 97).

In the VIRFEBRAS scenario, one possibility to make business is when customer orders arrive via the broker. Two major problems usually occur. The first one is related to the complexity to provide a reliable answer to the customer. There can be so many possibilities of teams of members to fit a given business that it makes the broker's job extremely hard and complex, when he/she should focus on gathering new business opportunities. In this context, the importance of a brokerage, as the one being proposed here, ascends in significance as it is almost impossible for a human being to generate all possibilities of teams (i.e. possible VEs within VIRFEBRAS) and to evaluate every schedule. Thus, a non-assisted generation may imply a less profitable coalition in terms of final cost and delivery time and, in the worst case, the loss of the business opportunity. The second problem is related to the agility to provide the client with a fast but consistent answer. Regarding the complexity mentioned above, the broker should have some supporting system that helps him/her to speed up the whole process of announcing the opportunity, generating the possibilities, analyzing them, selecting one and finally giving a final answer. In this sense, a good brokerage system can offer the required agility that nowadays is a must in terms of competitiveness.

The nine mold and die industries that constitute VIRFEBRAS are on different organization and automation levels, each one having its own culture, methodologies and characteristics, some of them desirable to be kept. In spite of this, VIRFEBRAS is going to have its own / common "quality stamp" to differentiate it from other enterprises or similar clusters. Several actions have been pursued in order to have a certain degree of homogeneity in the enterprises so that, for instance, their "chances" can be equivalent and hence the trust building among the members can be reinforced. One of these actions is to provide every enterprise with a reliable – and the same – PPC & Scheduler (PPCS) system. In other words, it can be said that information technology serves to homogenize / encapsulate the differences among the enterprises from the broker's point of view.

The current implantation of the PPCS systems is extremely important to obtain in an efficient way the large volume of information that the operators and the

production manager should periodically provide. Part of the qualification methodology being applied tries to guarantee that an enterprise has the PPCS systems implanted after a process of internal reorganization. Actually, the PPCS system is viewed as crucial. The answers (bids) to be sent to the broker are based on the information the system suggests and it should reflect as much as possible the effective and planned shop-floor occupation, especially considering that a mould usually has its project modified many times along the process. Keeping the delivery time is one of the most important competitive keys in the tool and die industries.

The information about the enterprises' capacities are shared among all the members, allowing for global, cooperative and constant optimizations in the enterprises' schedules. Therefore, and using the same PPCS software, a reliable information gathering is essential to reinforce – again – the trust building, one critic aspect in the success of a virtual organization.

3. THE BROKERAGE APPROACH

An alternative to analyze business opportunities for the VIRFEBRAS is the figure of a *broker*. The broker is a human specialist who represents VIRFEBRAS and who has two main roles: to look for new business opportunities / to manage their reception, and to coordinate the process of selecting the most suitable consortium of enterprises for every opportunity.

In order to improve the agility in business management, a supporting software module is suggested. By means of a *broker agent* an acquired *business opportunity* – a set of moulds – is transformed into a distributed business process (DBP) that is split into business processes (BP), where each BP corresponds to an individual mould or die. The individual mould/die tenders are then distributed among the VIRFEBRAS enterprises. Depending on the business requirements and the available capacities and skills, it may happen that various alternatives of teams of enterprises (“internal” VEs) that can accomplish the various BPS may be found, and further the most adequate coalition should be then elected. Figure 1 illustrates the idea of having several possible VEs within the cluster to attend a given DBP, where three VEs capable to accomplish it are formed (only VE1 has BPS explicitly assigned to the enterprises). Notice that a given enterprise “E” can get more than one BP (mould) and that it can be involved in several VEs or opportunities simultaneously.

The VE life cycle involves a number of phases, basically VE creation and configuration, VE operation, VE evolution, and VE dissolution (Spinosa et al., 98), comprising the phases of business opportunity identification, and partners search and selection. This work is currently focused on the VE creation phase. It presents a multi-agent-based decision support system – the *MASSIVE Mould Broker (MMB) System* – (i) to assist the VIRFEBRAS' human broker in the decision-making process of evaluating and suggesting the most adequate consortium of enterprises for

a given package of moulds, and (ii) to support some basis to optimize the package's schedules regarding the information come from the PPCS systems. As the cluster members are potential competitors, the final decision is made by a management board and not by the broker. However, the decision is based on the broker's analysis, represented by the set of alternative consortia generated (and evaluated) by the system.

Figure 1. A VE scenario within VIRFEBRAS

4 . THE BROKERAGE SCENARIO

In the current VIRFEBRAS scenario, the enterprises receive client orders both directly (i.e. in the traditional way) and via the broker. A client order can involve an individual or a set of moulds and/or dies. The client may also indicate if the mould maker can or cannot subcontract other mould makers for each mould. A client order can arrive at the broker with a detailed specification or as a draft. In the latter case, a number of interactions among the client and the involved enterprises are required until the final proposal is agreed.

Regarding the MMB prototype being developed, the system validation and testing have been made gradually, comprising the following (partial but real) scenario for the client orders arriving at the VIRFEBRAS' broker:

1. a client order arrives as a set, i.e. as a group of individual moulds;
2. considering quality control and trust aspects required by the client, in any case an interested enterprise cannot subcontract another enterprise, even if it belongs to the cluster;
3. a client order has all information completely and precisely specified when it arrives at the broker.

A client order specifies the mould size (in *tons*), its type (*mould* or *die*), the part material (*aluminum* or *plastic*, or *die*), and the due date (for each mould or for the entire package). The mould drawing is usually sent as well, but it is not dealt with for brokerage purposes. For the broker, the technical competence of each VIRFEBRAS member is represented in terms of its *capacities*, namely the *mould size* and *type* that each one can manufacture.

Four basic steps are carried out in the VIRFEBRAS brokerage system life cycle:

1. for each business opportunity, the broker analyzes the package (DBP) and identifies who are the potential candidate enterprises for each mould or die (BP), invites them to bid, and finally distributes the client order among the enterprises whose competence fits the tender;
2. the involved enterprises should receive, analyze and bid in the case they are interested and capable to satisfy the BP's requirements. A bid requires the direct intervention of the enterprise's manager so that the price can be provided and eventually the proposed delivery date from the PPCS can be refined. Once the bid is sent to the broker, the enterprise books its agenda for that business until it receives the final decision if the BP has been assigned to it or not;
3. having positive bids, alternatives of VE for a given DBP are formed;
4. after the evaluation of every alternative and the election of the suitable VE, the VE is created and the involved enterprises are noticed about the final result, corresponding to the final commitment to the given business.

5. A MULTI-AGENT ARCHITECTURE

Multi-agent Systems (MAS) represents a suitable approach for modeling the enterprises that can participate in a VE, since they can exhibit some relevant capabilities like autonomy, interaction with other agents, decentralized and distributed decision-making, scalability, flexibility in the creation of coalitions, among many other (Rabelo et al., 98). Therefore, the MAS approach is quite suitable to support the VIRFEBRAS requirements. Applying a MAS approach to this brokerage activity implies that agents have to exchange information with each other so that a set of consortia of enterprises capable to perform a given package can be identified. Once these consortia are generated, the selection criteria are based on the *lowest global cost* and the *shortest delivery date*, in this priority order.

5.1 The MMB System Architecture

In order to cope with the VIRFEBRAS scenario requirements, four hierarchical and heterogeneous *classes* of agents have been designed:

- Mould-Broker (MB): it is the global system supervisor, acting as the more direct interface between the system and the human broker.

- Facilitator (F): it represents the logical set of enterprises that have a given technical competence. Therefore, the mould-broker agent first sends a call for tenders to the facilitators whose competence area fits the client's order *type*. This speeds up the contract process as well as avoids the unnecessary message exchange among agents that are not potential bidders.
- Enterprise-Agent (EA): it represents every enterprise of the cluster into the multi-agent community.
- Consortium (C): it is a temporary agent created to manage the process of generating VE alternatives for a certain package based on the bids received from the enterprise-agents. Once the broker and VIRFEBRAS board decide for the best schedule and awards it to the involved enterprise-agents, the respective consortium agent dismantles itself.

5.2 Control Information Flow

Figure 2 illustrates the essential control information flow among the MMB agents' *classes*. One important aspect to be highlighted in the MMB system is the direct involvement of the enterprises' representative in the negotiation process. In the mould and die sector, the *quotation* and the specification of the *delivery date* are two pieces of "lethal" information to be sent to the broker. Even small mistakes can imply a huge loss. Hence it is fundamental for the manager – at least at this stage of the system – to have these information "under his/her control". Therefore, when the enterprise-agents receive a tender and make their computation, the manager is asked to manually feed it with those information. It means that, although agents are used to give more agility in the brokerage process, humans make the decisions. It corresponds to a *hybrid* or *semi-automated* approach as the managers acts directly both in the interaction with the agents, and in the final election of the best composition of enterprises for a given package.

Figure 2. The Control Information Flow in the MMB System

5.3 Other approaches for information integration

In the figure 2 two next developments are included. The first one is the integration of the MMB system with the VIRFEBRAS Web Server. Such server can be seen as a very simple *extranet*, allowing each member to see the planned/current capacity of the other members. This information is produced by each PPCS and made available in the respective members' databases, and the enterprise manager takes it into account when he/she needs to feed the agent with the delivery date. Equivalent information integration could be done in the case of enterprises that have some supporting system for quotation, hence also helping the manager to feed the agent with the price. The second development step foreseen is the integration with a complementary partners search and selection tool (ePST tool), like the one developed in (Camarinha et al., 99b), to find the missing partners outside in case not enough resources or skills are found inside the cluster.

Related to the integration of the VIRFEBRAS Web Server, PPCSs and databases (the "internal modules") with the MMB system, some aspects should be pointed out. As mentioned above, there is no direct integration among these two entities so far (dashed line between the enterprise-agents and the other systems). One can note the simplicity or triviality of the general architecture to integrate the internal modules themselves. However, it is an approach that is very simple to be implanted at the enterprises, it does not require very specialized people in informatics, it is cheap and very easy to be understood and used by the manager and by other enterprise people. All these advantages themselves justify the approach in spite of some limitations. At this stage of maturation of VIRFEBRAS and the people involved, the most important aspect is that the system works and attends the basic requirement, which is to provide a way to share information about the members' capacities. At this

moment, very sophisticated solutions could hazard the tough work of convincing the entrepreneurs about the advantages of the whole philosophy, and trust building.

On the other hand, some more advanced directions are going to be evaluated. It will not be the case of addressing other possible frameworks for the web-based implementation solution specifically, as this would be just a matter of software engineering to some extent. But the approaches to support more efficient interoperation among agents and those internal modules as a whole deserve some comments. In this context, the problem is how an enterprise-agent can get the information about the capacities (or other information, simple or complex) of the other in an integrated way, directed communicating with the internal modules. In general, this problem can be viewed as an *agentification* process.

Agentification means to develop a wrapper around the required/involved subsystems so that their particularities and heterogeneities can be encapsulated and a transparent front-end can be established (Rabelo et al., 94). In (Rabelo et al., 2000b), for instance, an agentification was developed to support a transparent communication with a web-server, where the multi-agent system protocol encapsulated HTTP commands. In a more sophisticated approach (Rabelo et al., 2000c), the concepts of federated and distributed databases are applied in order to support agents/enterprises autonomy and privacy, and better information management and integration, where the agents can have access to the required information within the VIRFEBRAS borders no matter how and where it is stored. In the case of the integration with the PPCS, it would require some re-engineering in it in terms of developing an integration layer (an API, as open and standard as possible) to support its interoperation with the agent, like the one described in (Camarinha et al, 99b). Other different not web-based approaches are going to be investigated as well, namely workflow-based ones, which offer a more tight control and advanced coordination capabilities among the applications/agents that act as information providers and information consumers (Rabelo et al., 2000b). Summarizing, the importance of investigating more advanced approaches and effective integration mechanisms is related to the preparation of the enterprises to run in a B2B environment, a must nowadays in this era of electronic commerce.

5.4 The Brokerage Flow in the VIRFEBRAS

The interactions among agents must be coordinated in a way that the desired multi-agent system can behave properly according to the VIRFEBRAS control rules. The Contract-net protocol (Davis, 80) is used to coordinate information exchange among the agents in order to form VE alternatives. After a package is split into individual moulds (or dies), a tender of every mould is spread out over the VIRFEBRAS enterprise-agents. Once received (via Facilitators), the agents evaluate the tenders and based on their agenda and capabilities, send a positive or negative answer to the Consortium agent (specially created to collect the bids related to the

given package). After receiving the bids from all the interested enterprises, several possible coalitions of agent-enterprises are created. Each coalition represents a VE with a schedule, which can be evaluated through some objective performance metrics. The human-broker, with the results of the several Consortium-agents usually presented in the system, evaluates the most suitable coalitions for each package together with the managers of the enterprises in a board meeting.

6. IMPLEMENTATION EXAMPLE

An analogy with the VE life scenario could be made to better explain the phases necessary to run the MMB system being developed for the VIRFEBRAS cluster. Firstly the VE should be created and configured, i.e. the MMB agents should be identified and launched. Once a VE is created it can operate, i.e. once the MMB agents are launched they can execute the roles for which they have been created (see section 5.1). This section starts with the procedures to create and launch the MMB system, and after this an example is given of each of the four steps (see chapter 4).

6.1 “Derivation” of the MASSYVE Mould Broker System

The developed system corresponds to a set of instances of every MMBS agent classes, “derived” according to the VIRFEBRAS characteristics. The instantiation of the MMBS agents for VIRFEBRAS is composed of:

- 1 Mould-Broker;
- 3 Facilitators (*plastic mould, aluminum mould, and die competence areas*);
- 9 Enterprise-Agents (*one per enterprise*).

The first action the system user should do is to launch the system itself. Once the system is logically defined and all the agents are identified including the specification of on which PC (host, IP address and port), each agent will be executed. The links among agents represent the necessary (and configurable) communication possibilities. Since the consortium agents are dynamically created when a package arrives, they are not initially modeled. Furthermore, each agent has its particular graphical interface when launched, through which the respective enterprise manager can interact with. After the launching of the system, the MMB system gets ready to receive client orders from the market. In the current implementation, as the MMB system is being tested by the VIRFEBRAS broker, all the agents have been launched in the same PC, which means that the broker is the person who feeds the agents on behalf of their representatives.

6.2 Package announcement and bidding

When the broker receives a client order, it should be sent to the enterprise-agents for evaluation and further bidding. Figure 4 shows the interface of one agent and the details of the tender received. Some of the agent interfaces are “hidden” in the figure in order to allow a better visualization. Figure 5 shows the interface through which the enterprise manager is called to indicate the delivery date and price.

Figure 4. A package of moulds is received

Figure 5. Bidding, with human intervention

6.3 VE Evaluation and Selection

After the contract-net processing according to the MMBS control information flow, a set of possible VEs are created. Depending on the package characteristics and on the enterprise availability, one enterprise can get more than one mould. The set of alternatives are evaluated by the human broker who consults, following the VIRFEBRAS rules, all of its members for taking the final decision about the suitable VE for the package. The evaluation considers the global lowest cost and shortest delivery date, using the information sent by the agents in their bidding.

Figure 6 shows an interface where several VEs (with their respective schedules) were formed for a given package. In this case, only four VEs appear. However, depending on the number of alternatives generated, it is possible to see them in groups of four VEs. It is possible to zoom on each alternative and evaluate each one individually too. The performance indicators, which are the base for the decision, are provided at two levels: intra-organizational (i.e. the impact inside each enterprise) as showed in figure 6, and intra-organizational (i.e. considering the vision upon the whole VE). The broker makes a pre-evaluation on the VEs generated and takes the final decision with the VIRFEBRAS representatives.

Regarding the usual / relatively large number of possible VEs generated for a given package, the system offers to the broker the option to see / to “bring” the n best schedules firstly, ordering them according to the selection criteria price and/or delivery date. It is also possible to store these best n schedules in a historical file, organized by several “access keys”.

The MMBS system prototype has been developed in C++ / UML on a PC / Windows-NT platform, and it has used the supporting software MASSYVE KIT Tool (MASSYVE, 2000) to generate the infrastructure of the multi-agent system. Once launched, each agent takes about 2-3 MB of memory. The agents use a particular high-level protocol and TCP/IP to communicate with each other.

Figure 6. Evaluating possible VEs

6. CONCLUSIONS AND NEXT STEPS

This paper described a work being done at the VIRFEBRAS virtual organization, which is focused on the mould and die sector. A semi-automated brokerage system is proposed to assist the human broker in the selection of the most suitable team within VIRFEBRAS to accomplish a given business opportunity. The selection criteria are the lowest price and shortest delivery date. The system prototype developed – the MASSIVE Mould Broker System – is a decision-support system based on the multi-agent technology.

Initially it is intended to qualify the nine mould and die industries which currently composes VIRFEBRAS, enabling them to co-operate in the context of *Virtual Enterprises* by making them more competitive in the global market. Upon satisfactory results the intention is to transfer this work methodology to other mold and die industries of the Caxias do Sul cluster and possibly nationally. In fact, this work aims to prepare the VIRFEBRAS enterprises properly to run in a B2B scenario through the Internet.

This work is part of an ongoing initiative towards a wider and more generic brokerage tool, which is being installed for testing in the VIRFEBRAS. In this sense, and although already useful for this organization as it is now, next developments are being planned. It involves the implementation of procedures to support subcontracting as well as to refine the information models used while the enterprises gain more awareness and trust in the system. Besides that, the integration

between the agents and the enterprises PPCS is foreseen, regarding the natural evolution of the VIRFEBRAS computational environment. In the medium-term it is intended to improve the negotiation protocol among the enterprises/agents, also including some supervision capabilities during the VE operation phase.

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