A Review of the Negotiation Protocol for Agent based Manufacturing System Control

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Abstract :

An investigation in traditional approach to manufacturing system control based on centralized or hierarchical control structures presents good characteristics in terms of productivity due to its inherent optimization capabilities. However, it does not possess the dynamic and adaptive response to change which is currently the key to competitiveness in global market. Agent-based manufacturing system control fits into this gap left by the traditional approach and it is potentially beneficial due to the need for automated decision-making, reaction to disturbances and the parallel computation. This paper reviews the negotiation protocol in agent based manufacturing systems control and also explore negotiation mechanisms. While there are other interesting artificial intelligence techniques that have already been employed in manufacturing system controls for more than two decades, however, recent developments in multi-agent technique will bring new and interesting possibilities.

Keywords - Manufacturing system control; Multi-agent system; Negotiation protocol; generative functions; reactive functions

I. INTRODUCTION

An investigation in traditional approach to manufacturing system control based on centralized or hierarchical control structures presents good characteristics in terms of productivity, due to its inherent optimization capabilities. However, it does not possess the dynamic and adaptive response to change which is currently the key to competitiveness in global market. The traditional approach typically falls into monolithic software packages that are developed and modified, making it insufficient to support the current requirements introduced on contemporary manufacturing systems in terms of flexibility, expansibility, agility and re-configurability [1]. Agent-based manufacturing system control fits into this gap left by traditional approach, and it is potentially beneficial due to the needs for automated decision-making functions, reaction to disturbances, parallel computation, and better fault tolerance [2]. Agent based manufacturing control is able to act without the supervision of human beings or other agents, and possesses control over its own actions and internal states.

According to Jennings and Wooldridge, an agent is a computer system situated in some environment, and that it is capable of autonomous actions in its environment in order to meet its design objectives. While an agent-based system is a system in which the key concept used is that of an agent [2]. Hence, agents are loosely coupled or distributed network of problem solvers that work together to solve problems that are beyond their
individual capabilities. This paper reviews the negotiation protocol in agent based manufacturing system control and explore the negotiation mechanisms.

II. MULTI-AGENT SYSTEMS PARADIGM

In an agent-based manufacturing system control, the multi-agent system (MAS) paradigm is derived from the distributed artificial intelligence (DAI) field. It is being characterized by decentralization and parallel execution of activities based on autonomous entities, called agents. There are several agent architectures ranging from reactive agents to deliberative agents. The reactive agents operate in a stimulus-response manner while the deliberative agents are characterized by pro-active reasoning and goal-oriented behavior [3].

In most literatures, the negotiation protocol and application of multi-agent systems (MAS) can be found in various areas of manufacturing researches

III. MULT-AGENTS NEGOTIATION PROTOCOL

Negotiation in multi-agent systems (MAS) is an interesting form of cooperation. The information flow is multidirectional and each agent can make an informed choice whether to participate or withdraw from the negotiation activity. Given the complexity of contemporary manufacturing processes, MAS decision making and negotiation mechanisms becomes a powerful solution. When it comes to planning process decisions and global decisions making each agent retains its autonomy. In negotiation mechanisms, each agent can exercise influence power and mainly because it can deal with uncertain transactions and asymmetric knowledge typical of a negotiation process [12]. The designing of negotiation model for each level of production planning comprises of the definition of the agents involved in the negotiation process and also the definition of the negotiation mechanisms. Fig. 1, exhibits an overview on some negotiation variables for the planning level.

![Figure 1. Negotiation models for Production Planning level](image)

Just as Smith proposed in the contract net protocol, in Fig. 1, the agents involved in the negotiation are separated by a dashed line and the bilateral communication channels among agents are bidirectional arrows. When an agent makes an announcement to other agents that some task must be performed. The announcement contains (1) a brief task description, (2) an eligibility specification which specifies the criteria that must be satisfied by the potential bidders, (3) a bid specification which describes the expected form of the bid and (4) the expiration time which specifies the submission deadline for bids [11].

During the negotiation, the bidders respond to the announcement individually by submitting bids that contain a description of their capabilities and why they can and should perform the task. The job agent adjudicates the bids after the expiration time is reached and makes an award. The successful agent, otherwise
known as the contractor, acknowledges the award by sending either an acceptance or refusal message. The latter case may result from the inability of the successful bidder to honour the contract. Awards can either be announced or directed. An announced award is the result of a negotiation process while a directed award occurs when a manager assigns a task to a particular agent without negotiating. It combines the announcement, bid and award stages into a single stage. Once an award has been accepted, a contract is said to be concluded.

IV. MANUFACTURING SCENARIO

Considering that a manufacturing system produces $X$ product families. Each product families associated to a group and are produced in $Y$ plants, where the plants are geographically dispersed and reconfigurable in order to produce all of the different product families. The reconfiguration is allowed once every three months and in every three months the $Y$ plants are assigned to the $X$ groups for accomplishing the annual quarter production of the associated product family. The fig. 2, exhibits the negotiation models for the production planning level.

![Figure 2. Negotiation models for higher Production Planning level](image)

At this planning level, if $Z$ is the production capacity of each plant and $W$ is the annual quarter capacity ownership, it results

$$W_{tot} = \sum_{x=1}^{X} w_x = Y.Z \quad (1)$$

From the above equation, it can be deduced that the association of group-plant is accomplished by negotiation. This association can be interpreted as an internal transaction among a given group and a given plant. In fig. 2, the group is requested to bid to a certain amount to the plant in order to receive the needed service. Such amount can be said to be money, where the money is the sum $b_{xy} \cdot v_{xy}$ that the group $x$ bids to the plant $y$ at the end of the quarter. $v$ is the volume of family $x$ that will be produced by the plants $y$ while $b_{xy}$ is the negotiated transaction bidding [4].

V. THE MULTI-AGENT SYSTEM NEGOTIATION MODEL

Considering an annual quarter capacity ownership ($W_x$), being assigned to each group as an outcome of the higher planning level, the Group Agents (GAS) negotiate with the Plant Agents (PAS) in order to gain enough number of plants for supplying the required $W_x$. Since the negotiation is bilateral and simultaneous; in every three months, all of the GAS currently submits their offer to the PAS. The GAS make offers based on their generative functions to the PAS during the negotiation, and based on their reactive functions these offers are evaluate and then decided whether they want to sign the contract with a given group or to ask for a new proposal. The negotiation is being concluded for a fixed number of rounds, $r_{max}$. If at the end of $r_{max}$ some of the plants are not allocated to any group, then they are automatically allocated to the groups that in the last round proposed the best offer [11]. Following the service oriented negotiation notation, a given plant can be assigned...
only to one group. The negotiation issue is the bidding \( b_{xy} \) that the group \( x \) offer to the plants \( y \) at each round \( r \).

The groups' agent generative functions for the price offer computation and the plants' agent reactive functions for the price offer evaluation are described as follows. The generative function can be represented mathematically as:

\[
\frac{r-1}{c_x} - call_i \xi_i
\]

\[
b'_{xy} = b_{xy}^i + (b_x^{xy} - b_{xy}^i)^* r_{max} - 1 * c_x
\]

It is deduced in (2), the price the group \( x \) offers to the plant \( j \), increases according to the round of the negotiation (time dependent) while it decreases according to the capacity already allocated to the group itself (resource dependent). The reactive function is represented in (4) where:

\[
\begin{align*}
þ_{xy} &= b_{xy}^i + b_{xy}^j + a_{xy} + Cr \\
\end{align*}
\]

- \( b_{xy}^j \) is a constant, \( þ_{xy} \) is the reactive function utility threshold. The plant \( y \) accepts the offer of group \( x \) if \( b'_{xy} \geq þ_{xy} \).

- \( Cr \) is the reconfiguration cost of plant \( y \) when this is allocated to a group \( x \) which is different from the one allocated in the antecedent quarter;

- \( a_{xy} \) is a measure of the efficiency of plant \( y \) in producing products for group \( X \); it represents the plant \( y \) variable costs \( cv_{xy} \) for producing \( x \)

\[
\begin{align*}
\phi_{xy} &= \frac{r-1}{\phi_{xy}^i} \\
b_{xy}^i &= b_{xy}^i \theta (1 - \theta) \cdot r_{max} \theta, \quad \phi_{xy} = \sum X' \\
X &= 1, 2, \ldots, X \\
\theta_{xy} &= b_{xy}^{r-1} \phi_{xy} \\
\phi_{xy} &= b_{xy}^{r-1} \phi_{xy} \\
\end{align*}
\]

The equations represent the risk attitude of plant \( y \) at round \( r \); it increases according with the round itself (time dependent method) and decreases with the average gradient (imitative method) between the prices that the groups’ offer at the round \( r \) and \( r-1 \). \( X' \) is the number of groups that are still negotiating at round \( r \), while \( b_y \) is a constant. The plants that are allocated lastly have a higher risk to remain under-loaded \( (V_{xy} < A) \). Equation (3) shows that the utility threshold of the plant agents increases according with their risk attitude (agent state), their efficiency in producing product \( x \), and the reconfiguration cost.

VI. CONCLUSIONS

In this paper, the authors believe that successful assessment of negotiation protocol and mechanisms in agent based manufacturing systems control is very necessary and beneficial to the contemporary manufacturing system control. The review of negotiation protocol conducted in this paper confirms some benefits promised by negotiation and also yielded some interesting and unusual observations.
REFERENCES


