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Research and Application of Production Planning Model Based on Multi-Agent

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Abstract: - Integrating multi-agent system, the plan assignment model base on multi-agent is proposed to solve the assignment problem of production plan among some parallel shops with geographic distribution. The advantages and disadvantages of Contract Net Protocol (CNP) applied in production plan was analyzed, and the improved negotiation mechanism of CNP is developed. Through the negotiation of Management Agent, Shop Agent and Plan Agent, it realized the optimization assignment of production plan. Finally, the simulation example shows that whole interaction of multi-agent and proves the validity of the model.

Key words: - multi-agent system, production plan, CNP, negotiation mechanism, task assignment

1 Introduction

In Computer Integrated Manufacturing System (CIMS), as the chain of management decision-making and production scheduling, production plan can provide not only guidance for production but also basis for management and decision-making. The main task of production plan is to confirm the products produced in a certain period and resources (such as material, equipments, manpower, finance and energy sources) for the products. Based on the market requirement of products, supply of material, examination and repairs of equipments, and the producing cost of finished products and semi finished articles, the method such as heuristic method is applied to optimize the production management of the enterprise for various production states and plan models. Then it can assist the planning persons to form annual production plan, quarter production plan and month production plan, provide the manager with information about forecast and decision-making to assure a maximum profit the enterprise [1].

Based on the resources of various shops with geographic distribution, the plans established must be distributed to the shop and realized reasonable optimization assignment [2, 3]. At the same time, because the resources continually change with the progress of production, the plans must continually be made adjustment in the course of assignment [4,5]. For the management system of production plan, its reaction to the resources and the harmony between the resource and the resource are very important

With the development of Distributed Artificial Intelligence (DAI) and the appearance of the concept of multi-agent, it is possible to solve the dynamic and complicated problems in virtue of the autonomy and cooperation of multi-agent [6]. In addition, the wide application of computer network, especially Internet/Intranet, can provide manufacturing corporations with the communication mechanism and realize the repeat use and spare of the resources. It is more important that the cooperating work environment with distributed and isomerous characteristic is created [7, 8]. It just provides mutual harmony and cooperation among distributed shops with the conditions.

Aiming at the parallel shops of the enterprise, their plan assignment was studied in this paper. For the popular contract net protocol, its advantages and disadvantages were analyzed. And then an improved model of contract net protocol was presented, which could realize the optimization assignment of the plans through the mutual cooperation of Management Agent, Shop Agent and plan agent. Considering the fact that the production environment was not unchangeable, registration and logging out was used to realize enter and exit for Shop Agent in the bidding. Finally, the detail realization of the model was given and simulation proved the validity of the model.

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2 Production Plan Optimization Model of Multi-Agent based on Improved Contract Net

2.1 Production Plan Optimization Model of Multi-Agent

According to the order production mode, the order product can be decomposed to distribute to the shop in production plan management, which can mainly form and manage main production plan, material requirement plan, capacity requirement plan and shop plan. Because there are generally many parallel shops with geographic distribution in the enterprise, it is very important how to arrange the shop plan established in the level of the enterprise and how to harmonize the processing among the shops.

To reinforce the rationality and feasibility of production plan management, and increase the ratio of delivery of the orders on time, the production plan optimization model of multi-agent is presented in Fig. 1. Through analyse, balance and adjustment of capacity requirement of the shops, it can achieve the tasks of shops with geographic distribution and the harmony work among the shops. Thus the production process can be controlled beforehand and in the event. The reaction speed and the ability meeting an emergency are increased for production plan and scheduling management.

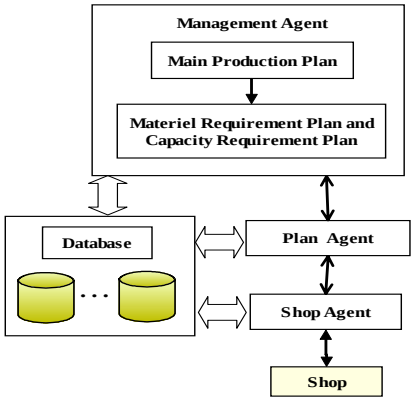


Fig.1. Optimization Model of Product Plan based on Multi-Agent

In Fig.1, the assignment model of production plan includes Management Agent, Shop Agent and Plan Agent. With mutual harmony and cooperation among many agents, the production plans decomposed are distributed to the shops. Here, Management Agent can form main production plan, material requirement plan and capacity requirement plan in term of the order. If an urgent order arrives, Management Agent will give the higher PRI to the order in term of rules in the knowledge base. As a role of production planning person, Plan Agent can decompose the above plans into sub plans, distribute the sub plan to the shop and form shop plan. As a role of shop scheduling person, Shop Agent can receive the shop plan, dispatche the jobs and record the accomplishment of the plan.

2.2 Negotiation Mechanism of Multi-Agent based on Improved Contract Net

Smith and Davis [9] presented Contract Net Protocol (CNP) in 1980. In the field of distributed artificial intelligence and distributed problem solving based on multi-agent, CNP has played the important role. CNP is easy to understand and define, so it is very fit to solve the problem of task assignment[10]. For the distributed and stochastic system, it is very difficult to set up the accurate mathematic model. In addition, the realization of algorithm is very complicated and the ratio of execution is also very low. So Multi-Agent System (MAS) based on CNP becomes into a scheme to solve the problem [11].

In CNP, if an agent has a task that need be solved by the other agents, it will broadcast the information about task, namely invite public bidding. Agent received the information can examine its capacity solving the task and emit its value of bid. Then it can become into the bidder. Finally, the agent broadcasting invitation can estimate the bids, select the most appropriate bidder and arrange the task to it. The whole process is accomplished based on the market mechanism of inviting bidding, bidding and hitting bid. However, there some disadvantages in the model of multi-agent based on the above contract net, such as a big traffic, low negotiation efficiency and large data of the plans. To avoid readjusting the plan assigned as soon as possible, an improved negotiation model based on contract net is developed in this paper.

In the improved model, Management Agent can set the PRI of the order, form some plans in term of the rules and supervise the execution of the whole plan. Plan Agent can find the corresponding shops for the sub plan and then invite bidding. Based on the resources of the shop, Shop Agent can compute its profits and form the tender book.

2.2.1 Improved Negotiation Mechanism of CNP

Generally, Shop Agent belongs to a group or many various group. Each Shop Agent can record its group information, which includes the name of the other shops in the same group and the global and uniform sign. Considering communication load and negotiation efficiency, the improved negotiation mechanism is adopted. Namely, each Shop Agent can not passively receive the invitation, but voluntarily

inform Plan Agent when its resources are available. When Plan Agent invites public bidding, it firstly can check which Shop Agents have submitted the requisition in the group in term of the group information. Then it can invite the shops to bid the task. The improved negotiation mechanism can largely decrease communication of the system and improve negotiation efficiency. At the same time, the state of shop voluntarily is sent to Plan Agent, so, the system is provided with more quick reaction to abnormity.

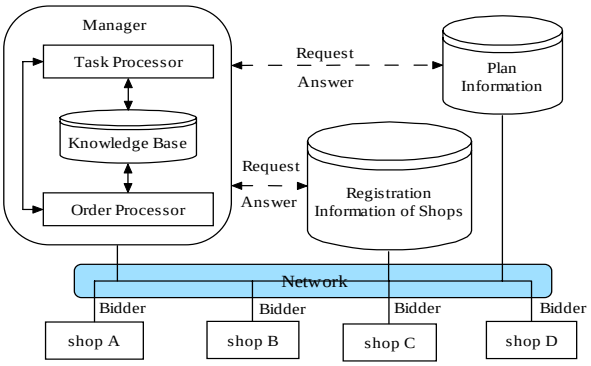


Fig.2. Negotiation Model of CNP

Based on Fig. 2, the improved negotiation mechanism is realized in detail as follow.

Step 1 Initialization. When the system starts up, each Shop Agent can write its information into the database of shop registration information, such as the state, address, machining capacity and group information of the shop. When a new order arrives, Management Agent can set the PRI in term of the urgency of the order and form main production plan, material requirement plan and capacity requirement plan. Then Plan Agent can decompose the plan into machining plans according to the rules in the knowledge base, which can be put into the database of plan information. Finally, Plan Agent can wait for inviting public bidding.

Step 2 Releasing Plan. If Plan Agent finds the undistributed machining plan in database of plan information, then it can invite public bidding. Based on database of shop registration information, Plan Agent firstly can send the bidding information to Shop Agent in the same group waiting for the bidding according to the assignment probability. Then it can wait for the bid of Shop Agent.

Step 3 Bidding. When Shop Agent receives the invitation information, it can compute a general bid according its status, such as the ratio of resources utility, machining cost and finishing time. Then it send the bid to Plan Agent.

Step 4 Choosing Bid. Plan Agent waits till it receives the bids of all Shop Agent invited bidding or the deadline of bidding reaches to the given date. Then it can choose the shop of the biggest bid and send information of hitting bid to the Shop Agent. At same time, it can send information of failing bid to the other shop agents that don't hit the bid.

Step 5 Signing Contract. If Shop Agent receives the information of hitting bid from Plan Agent, Plan Agent and it will be signed a contract. According to the number of hitting bid, Shop Agent can read the plan from the database of plan information and write it into the machining queue. Then the plan will wait to be processed.

2.2.2 Award and Penalty

When the k th machining plan is finished in the shop, Management Agent can compute and update the global reward parameter R_k and the assignment probability P_k of Shop Agent in term of the accomplishment of the plan and historical records.

$$R_k = R_{k-1} + C_1 T_a + C_2 T_p + C_3 P_e,$$

$$P_k = \frac{R_k}{\sum_{j=1}^{k} R_j}, \qquad (1)$$

$$R_0 = 0,\ P_0 = 0,\ k = 1,2,...$$

Where T_a and T_p are the number of days for earliness and tardiness, respectively. P_e is the number of unqualified products. $C_i (i = 1,2,3)$ is the coefficient of performance and it can be adjusted to adapt the various objective requirement.

Based on the past accomplishment of Shop Agent, Plan Agent can invite Shop Agent to bid the $k+1$th plan according to the assignment probability P_k. It can be seen in the equation (1) that if Shop Agent excellently fulfills the plan, then Management Agent gives a bigger coefficient denoting award to it, namely, there is more chance that Plan Agent can invite it to bid next time. Or else, Management Agent gives a smaller coefficient denoting penalty to it, consequently, the chance receiving the tender book will be decreased next time.

2.3 Computing Rules of Bids

In the course of bidding, Shop Agent can judge that whether it can accomplish or join the plan according to its capacity. If it can do, it will voluntarily ask Plan Agent for bidding. If Shop Agent receives the inviting information, it will make a general estimate in term of the finishing time, delivery deadline and machining cost of the plan, and return the general bid to Plan Agent. Then Plan Agent can select the shop of the biggest general bid as the person of hitting bid.

The general index is computed as follow,

$$E = \lambda_1 \cdot f(T) + \lambda_2 \cdot g(C) + \ldots + \lambda_n \cdot l(X) \quad (2)$$

where $\lambda_i (i = 0,1,\cdots n)$ is the weight coefficient of each item. $f(T), g(C) and \quad l(X)$ are the index function, respectively.

The weight coefficient is decided by experience. Or it is random decided and then optimized step by step. The method computing the general index can be dynamically changed to fulfill with the requirement of various scheduling objective.

3 Realization of Production Plan Assignment Model based on Multi-Agent

The negotiation model of improved CNP is realized in C/S (Client / Server) mode in this paper. Plan Agent lies in Server and Shop Agent is regard as Client. The assignment of the plan is realized by the negotiation of Client and Sever. At the same time, Management Agent takes charge of the execution of the plan. If the plan is completed, Management Agent will compute the reward coefficient and the assignment probability. The interaction of Plan Agent and Shop Agent is introduced as follow.

3.1 Plan Agent

If the database of plan information are not empty, then Plan Agent can inform each Shop Agent in the group and invite them to bid. The concrete flow is shown in Fig. 3.

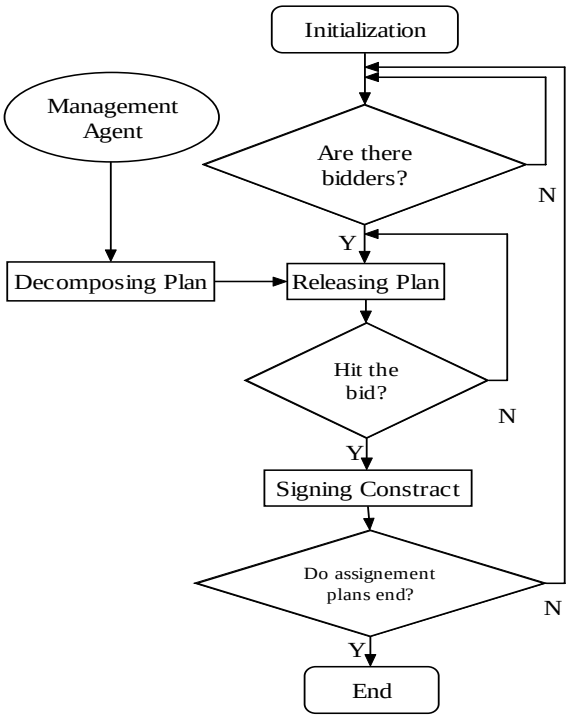


Fig.3 Negotiation Flow of Plan Agent

In the initialization, a registration table is provide with each Shop Agent and tell Plan Agenta bout a few basic state information of the shop and the assignment probability of the plan. Plan Agent can search which shop joins the bidding through the registration table. In the Table 1, there are the number of shop (Shop_id), the name of shop (Shop_name), the registration time (Registration_time), the group number of shop (Group_id) and the assignment probability (Assign_prob).

Table 1. Table of Registration

Shop_id	Shop_name	Registration_ time	Group _id	Assign _prob
0001	Job Shop	05-12-22	0001	1
0002	Job Shop	05-12-22	0001	1
0003	Fitting Shop	05-12-22	0002	1

When Plan Agent checks the shop applying for bidding, it must send the plan to the table of plan issuance and inform Shop Agent to read the plan. The table of plan issuance includes the number of the plan (Plan_id) and the due date of the plan(Due_date) as shown in Table 2.

Table 2. Table of Plan Issuance

Plan_id	Due_date	Remark
0006	05-12-28	

After Plan Agent sends the plan, it must collect the bid of Shop Agent, which is saved to the table of bids. According to the bids, it can decide that which shop and it can be signed a contract. The table of bid consists of the number of shop(shop_id), the number of the bid (bidnumber) and the value of the bid (bidvalue) as shown in the follow table.

Table 3. Table of Bid Value

Shop_id	Group_id	Bidnumber	Bidvalue
0001	0001	1	1243
0002	0001	1	1457

After Plan Agent and Shop Agent are signed the contract, the information about the order must be saved in order to manage the production. So the table recording the contract signed is provided in the Plan Agent, which comprises the number of shop, the sequence of the bidding and the name of the plan as shown in Table 4.

Table 4. Results of Bid

Shop_id	Group_id	Bidnumber	Plan_id	Bidvalue
0001	0001	1	0001	1243
0003	0002	2	0002	1254

3.2 Shop Agent

Once Shop Agent registers, it just waits for the notice of bidding from Plan Agent. If it receives the invitation, then it can read the plan information in the

table of plan issuance and read the whole plan according to the number of the plan in the database of plan information. It can make the estimate of the whole plan and compute bid value. Then it can send the bid value to Plan Agent. The flow in detail is shown in Fig.4.

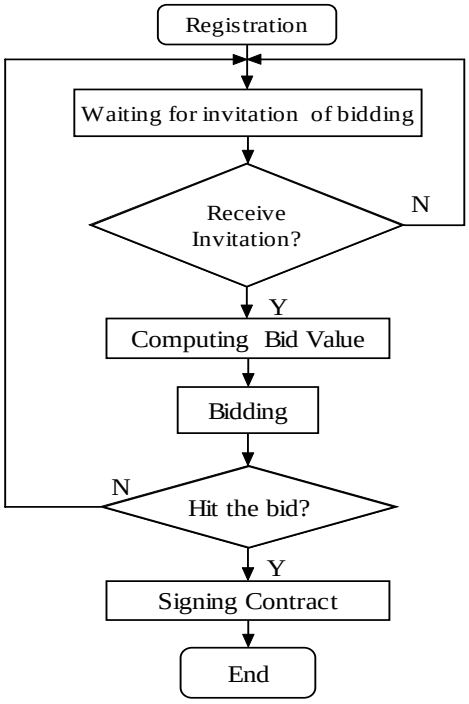


Fig.4. Negotiation Flow of Shop Agent

After Shop Agent and Plan Agent are signed the contract, it can call the scheduling algorithm in the shop and schedule the plan, namely, each task is distributed to the machine. After the plan is completed, Shop Agent can apply for the bidding again in order to obtain new machining plan. Through the interaction of Shop Agent and Plan Agent, the machining task is accomplished at last.

4 Simulation

To validate the validity of the model, a 4-shops and 10-plans problem of plan assignment is given in this paper. There are 3 job shops and 1 fitting shop and it is supposed that all plans must be processed in job shop. Through the negotiation of Plan Agent and Shop Agent, the assignment of 10 plans is realized.

Because the real system is more complicated, the example is made a certain simplification. It is emphasized to show the whole process that the model how to negotiate to realize the plan assignment. For the value of bid, this paper mainly considers the finishing time. When Shop Agent receives the notice of inviting bidding from Plan Agent, it can read the plan from the database of plan information to the shop according to the number of plan. Then the plan is scheduled to obtain the finishing time as the bid value. The more shorter the finishing time is, the more better it is. So Plan Agent can choose the shop with the shortest finishining time and then they are signed a contract.

The finishing time is computed as follow,

$$T_c = T_0 + T_{pc} \tag{3}$$

where T_0 is the starting time of the plan and T_{pc} is the processing time of the plan. In the example, the starting time of the first plan is 0 in the shop, namely, $T_0 = 0$. At the same time, the shop of hitting bid can still join the next bidding.

Shop Agent must register before the negotiation of the plan and tell Plan Agent about a few basic information of the shop. The initial assignment probability is set 1. The table of registration information is shown in Fig. 5.

Parameters Set | Bidding Results | Registration Information | Negotiation Process

Shop Number	Shop Name	Registraion Time	Group Number	Assignment Pbobability
0004	Fitting Shop	2005-12-15	0002	1
0001	Job Shop	2005-12-15	0001	1
0002	Job Shop	2005-12-15	0001	1
0003	Job Shop	2005-12-15	0001	1

Fig.5. Registration of Management Agents

If the shops entirely register, then Plan Agent begins to invite bidding. Here, the plan has been sorted by PRI. The plan of the highest PRI is firstly invited bidding as shown in Fig.6.

The whole of negotiation is shown in Fig.7 and the final result of the negotiation is obtained as shown in Fig.8.

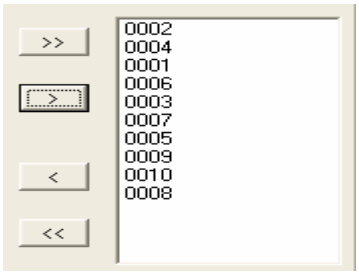


Fig.6. PRI of Plans

5 Conclusion

Based on the negotiation model of CNP, an improved CNP is applied in the plan assignment in this paper. Through the negotiation of Management Agent, Shop Agent and Plan Agent, the improved model based on CNP realized the plan assignment of shop with geographic distribution. Finally, the simulation example proves the validity of the model.

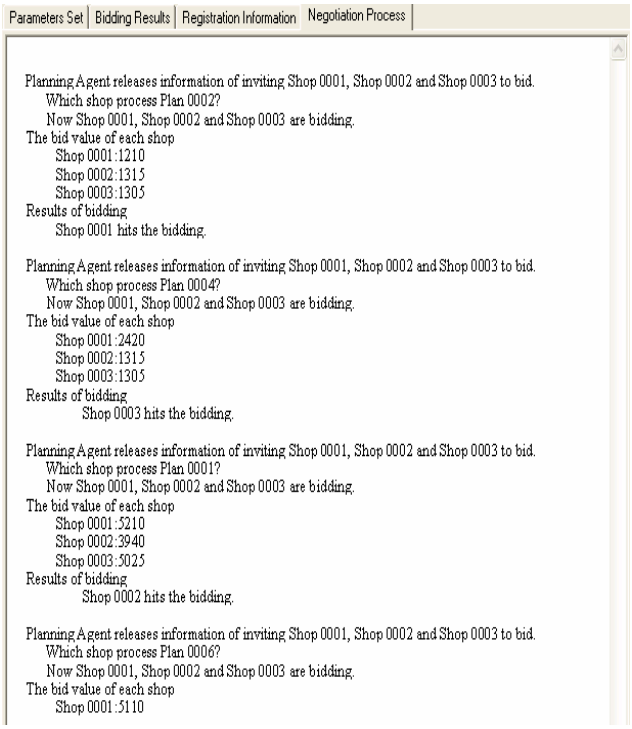
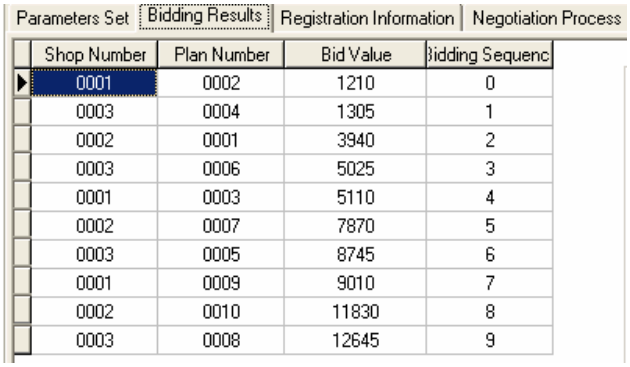


Fig.7. Negotiation Process of Multi-Agent



Shop Number	Plan Number	Bid Value	Bidding Sequenc
0001	0002	1210	0
0003	0004	1305	1
0002	0001	3940	2
0003	0006	5025	3
0001	0003	5110	4
0002	0007	7870	5
0003	0005	8745	6
0001	0009	9010	7
0002	0010	11830	8
0003	0008	12645	9

Fig.8. Bid Results

Acknowledgement

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