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Article

The Cloud Manufacturing Resource Scheduling Optimization Method Based on Game Theory

Xiaoxuan Yang* and Zhou Fang

Heilongjiang Province Cyberspace Research Center, Heilongjiang Province Harbin, 150090, China
*Corresponding Author: Xiaoxuan Yang. Email: xiaoxuanyang@126.com
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Abstract: In order to optimize resource integration and optimal scheduling problems in the cloud manufacturing environment, this paper proposes to use load balancing, service cost and service quality as optimization goals for resource scheduling, however, resource providers have resource utilization requirements for cloud manufacturing platforms. In the process of resource optimization scheduling, the interests of all parties have conflicts of interest, which makes it impossible to obtain better optimization results for resource scheduling. Therefore, a multithreaded auto-negotiation method based on the Stackelberg game is proposed to resolve conflicts of interest in the process of resource scheduling. The cloud manufacturing platform first calculates the expected value reduction plan for each round of global optimization, using the negotiation algorithm based on the Stackelberg game, the cloud manufacturing platform negotiates and mediates with the participants' agents, to maximize self-interest by constantly changing one's own plan, iteratively find multiple sets of locally optimized negotiation plans and return to the cloud manufacturing platform. Through multiple rounds of negotiation and calculation, we finally get a target expected value reduction plan that takes into account the benefits of the resource provider and the overall benefits of the completion of the manufacturing task. Finally, through experimental simulation and comparative analysis, the validity and rationality of the model are verified.

Keywords: Cloud manufacturing; resource scheduling; optimal allocation of resources; conflict of interest; stackelberg game

1 Introduction

With the development of the national economy and the times, my country's manufacturing industry, as the main force of economic development, has also accelerated the pace of development. However, the imbalance of manufacturing resources has seriously affected the efficiency improvement of the manufacturing industry. For this reason, people have combined the characteristics of idle resources of large enterprises and the inability of small enterprises to complete tasks independently, and gradually developed manufacturing in the direction of networking and service. The development model of cloud manufacturing-as-a-service came into being. Cloud manufacturing [1–3], as a new manufacturing model, uses information technology to achieve a high degree of sharing of manufacturing resources, connects huge social resource pools, and provides a public platform for various resource services. Users and enterprises no longer need to purchase expensive equipment resources or waste idle resources. These are leased or leased through the public platform of cloud manufacturing. How cloud manufacturing can be carried out quickly and efficiently has always been a problem that people have been paying attention to and have been studying. The problem of resource scheduling is the first consideration. The resource can be accurately and quickly scheduled where needed, which not only saves manufacturing costs but also speeds up the completion time of tasks.

Therefore, as one of the key steps of cloud manufacturing, the pros and cons of resource scheduling methods determine whether cloud manufacturing services can proceed smoothly [4]. Many scholars have conducted a lot of research on resource scheduling. The initial research has many problems that need to be solved. The cloud manufacturing scheduling model cannot fully adapt to the normal operation of the cloud manufacturing platform, and the second is the lack of consideration of the possibility of scheduling. Constraint, the third is that some applied algorithms are inefficient for the established scheduling model. These problems have seriously affected the efficiency of manufacturing services.

Game theory [5] is that the two sides of the game use the other's strategy to change their own strategies in an equal game to achieve a win-win situation. At first, it was only used for winning or losing in chess, chess, and gambling. Now it has gradually developed into a branch of modern mathematics, which is the study of mathematical theories that have the nature of struggle or competition. The conflict between multi-party interests such as total manufacturing cost and service quality with cloud customers [6], we proposed a multithreaded auto-negotiation method based on the Stackelberg game to resolve conflicts. The contribution of this paper can be summarized into the following points:

- We deeply study the process of manufacturing resource optimization allocation in the cloud manufacturing environment and propose that the minimum manufacturing cost, the highest quality of service, and the most balanced load are the optimization goals for resource optimization scheduling.
- In the process of resource scheduling, we use the group intelligent negotiation algorithm based on the Stackelberg game to negotiate and mediate with each participating agent to ensure the maximization of the overall interests while ensuring the interests of each participant.

The rest of the paper is organized as follows: In Section 2, we present the process of the cloud manufacturing platform operating scenario. In Section 3, we describe the mathematical model of resource allocation in detail. In Section 4, we present case studies. In Section 5, we review the relevant literature. Finally, we conclude the paper.

2 Related Works

After continuous research and improvement, the current research only considers the time, quality, and cost issues related to manufacturing tasks, and uses the ant colony algorithm, genetic algorithm, etc. to solve the model by converting it into a unit target optimization problem. At present, research on the optimal allocation of cloud manufacturing resources is mainly focused on multi-objective optimal allocation. Literature [7,8] has studied the measurement methods of the flexibility factors of resource services in the cloud manufacturing environment, established a flexible management framework, and designed the CMfg service portfolio The management framework studies the flexible management of resources. Literature [9] proposes an optimized configuration method for cloud manufacturing resources to optimize the impact of dynamic changes in manufacturing tasks and manufacturing resources on cloud service composition and execution and uses service quality and service flexibility combination as an evaluation system to establish cloud resource-oriented resources. The two-level programming model is optimized, and the proposed model is solved by an improved multi-objective genetic algorithm. Literature [10] proposed a resource scheduling model with the lowest completion time, the lowest service cost, and the highest service quality as the goal, and an improved genetic algorithm combining a variety of cross-mutation strategies was used to solve the model. Literature [11] studies the service optimization resource allocation scheme centering on the content of the Internet of Things, focusing on resource allocation in the Internet of Things. Literature [12] focuses on the problem of dynamic resource scheduling and takes the shortest time for resource providers to find resource users for task packaging as the optimization goal. A dynamic resource scheduling algorithm based on the ant colony algorithm is proposed, and the original resources are optimized through Matlab. Dynamic service model. Literature [13] established a multi-objective optimization scheduling model based on service completion time, service cost, service quality and service satisfaction, and used a non-dominated sorting particle swarm algorithm to calculate the model problem. Literature [14] according to the problem of resource scheduling in the cloud manufacturing environment, a dynamic scheduling technology was proposed to deal with emergencies, and a scheduling algorithm based on a genetic algorithm was used to calculate the model. Literature [15] has the potential to scale up or down virtual resources through web application providers in an on-demand cloud environment to achieve cost-effective results. Literature [16], in order to solve the problem of cloud manufacturing resource scheduling falling into local optimality and slow convergence speed, a resource scheduling method based on adaptive multi-objective differential evolution was proposed and a multi-objective optimization scheduling model with timing and cost constraints was established. Literature [17] studied flexible operations in the cloud manufacturing environment and took many methods to solve the problem of how to allocate equipment resources reasonably for the tasks of the workshop and cloud manufacturing platform, and used an improved ant colony algorithm to solve the model. However, it lacks consideration of the constraint relationship between tasks and does not have a good grasp of logistics costs and transportation time. The flexibility of cloud manufacturing services, the relevance of manufacturing services, and the individual needs of users require people to continuously innovate in manufacturing resource scheduling models and scheduling strategies. Literature [18] considers the complex structure of multiple tasks and the high individual requirements of users and proposes a multi-objective optimization scheduling based on the shortest processing time, preparation time, and transfer time, the lowest service cost, and the best service quality. Model, designed a multi-objective algorithm based on ACO and a multi-objective meta-heuristic algorithm based on NSGA-II. By applying the two algorithms to different scheduling instances, the multi-objective algorithm based on ACO can get more after verification and comparison. The sample Pareto solution provides more choices. Literature [19], in order to meet the constraints of resource type matching, task priority, resource occupancy and logistics factors in the resource scheduling process, an artificial neural network is constructed to predict the task completion status of candidate resources, and an ANN-based scheduling method is used to optimize scheduling Objectives such as total service cost, service satisfaction and manufacturing span in the process.

3 Operation Scenario Description of Cloud Manufacturing Platform

The cloud manufacturing system is composed of three parts: manufacturing resource providers, manufacturing task demanders, and cloud manufacturing platform. Manufacturing resource providers can be mapped to multiple companies with manufacturing resources. The company has local users' needs for manufacturing resources. After completing the local manufacturing tasks, the remaining manufacturing resources and manufacturing capabilities are packaged, and the cloud manufacturing platform can be described in a standardized manner. The accepted resource form is virtualized and uploaded to the cloud manufacturing platform. The cloud manufacturing platform then converts these uploaded virtualized resources into sellable manufacturing services, so that the cloud manufacturing platform can be unified into a virtual resource pool. The cloud user group is the demand side of the manufacturing service of the cloud manufacturing platform. They publish manufacturing tasks on the cloud manufacturing platform through the network. The cloud manufacturing platform allocates suitable manufacturing resources to the virtual resource pool for resource services based on the manufacturing tasks. As the core of the cloud manufacturing system, the cloud manufacturing platform plays three roles: On the one hand, unified and standardized management of the manufacturing resources and manufacturing capabilities provided by resource providers is required to transform virtualized manufacturing resources into a form of service; On the other hand, it provides a platform interface for the demander of manufacturing resources so that they can release manufacturing tasks to the cloud manufacturing platform. In the third aspect, cloud manufacturing matches the manufacturing tasks released by the resource demander with appropriate manufacturing services. The operating scenario of the cloud manufacturing platform is shown in Fig. 1.

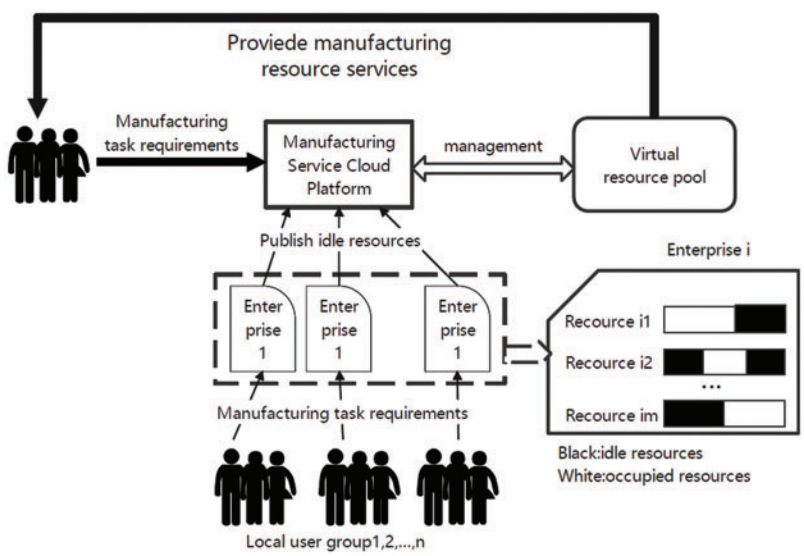

Figure 1: Operating scenario of cloud manufacturing platform

4 Mathematical Model of Resource Allocation

There are many types of manufacturing resources in the cloud manufacturing environment, and the resources are widely distributed. Cloud manufacturing connects a huge social resource pool. Enterprises that cannot complete manufacturing tasks independently can obtain the manufacturing resources they need through the cloud manufacturing system. Due to the large number of enterprises and manufacturing resources involved, the method of resource scheduling has become one of the key issues of the cloud manufacturing service platform. The provider of manufacturing resources is no longer a single department of a single enterprise, but a multi-enterprise, cross-regional cooperation process, so we need to consider transportation factors in addition to the traditional resource scheduling constraints.

4.1 Objective Function

Manufacturing task demanders issue manufacturing task requirements through the cloud manufacturing platform. There are many factors that need to be considered in the matching of manufacturing resources and the scheduling process, including service completion time, service cost, service completion quality, transportation time, transportation cost, etc. This section will optimize the resource scheduling model with the largest load balancing index, the lowest service cost, and the best service quality as the objective function. Within the range of available resources, select a better processing route to complete the manufacturing task.

Each element in the matrix (1) is a 2-dimensional vector $O_{(s,k)} = \langle subtask, trcost_{s,k} \rangle$, subtask Represents a group of subtasks to be processed at the resource trcost$_{s,k}$ Represents the transportation cost from resource s to resource k.

$$\boldsymbol{O}_{m\times m} = \begin{bmatrix} \boldsymbol{O}_{11} & \boldsymbol{O}_{12} & \dots & \boldsymbol{O}_{1m} \\ \boldsymbol{O}_{21} & \boldsymbol{O}_{22} & \dots & \boldsymbol{O}_{2m} \\ \dots & \dots & \dots & \dots \\ \boldsymbol{O}_{m1} & \boldsymbol{O}_{m2} & \dots & \boldsymbol{O}_{mm} \end{bmatrix}_{m\times m} \tag{1}$$

$$\boldsymbol{O}_{3\times 3} = \begin{bmatrix} <\{N_{2,3}\}, 0> & <\{N_{3,3}\}, 13> & <\{N_{2,1}\}, 25> \\ <\{N_{1,1}\}, 10> & <\{N_{2,3}\}, 0> & <\{N_{1,3}\}, 12> \\ <\{N_{3,2}\}, 13> & <\{N_{3,1}\}, 11> & <\{N_{1,2}\}, 0> \end{bmatrix}_{3\times 3} \tag{2}$$

Matrix (2) means: $\mathrm{O}_{1,1} = \langle \{\mathrm{N}_{2,3}\} \rangle, 0$ Represents the task process The manufacturing resources required for completion are in manufacturing resource 1, and are transported from manufacturing resource 1 to manufacturing resource 1. No transportation is required, and the transportation cost is 0.

$O_{1,2} = \langle \{N_{3,3}\} \rangle, 13$ Represents the task process The manufacturing resources required for completion are in manufacturing resource 2, which needs to be transported from manufacturing resource 1 to manufacturing resource 2 for processing, and the transportation cost is 13.

Explain the mathematical symbols used in the following formula:

There are N manufacturing tasks $N_1, N_2, \dots, N_n$, Each manufacturing task has its own manufacturing subtasks, $N_{i,j}$ Represents the $j-th$ subtask of the $i-th$ task $(i = 1, 2, \dots, n, j = 1, 2, \dots, a_i)$ a_i represents the number of subtasks in i manufacturing tasks. There are m manufacturing resources that can provide resources for manufacturing tasks. $c_{i,j,e}$ Represents the manufacturing cost of the j-th subtask of the i-th manufacturing task on resource e. $c^t_{i,j,e}$ Means from $N_{i,j-1}$ Transported to the manufacturing resource processing office of $N_{i,j}$ The transportation cost of the manufacturing resource processing office $c^t_{i,j,e}$ From the matrix $O_{m\times m}$ Search in it.

1. Load balancing index F

Load balancing refers to balancing the manufacturing tasks and apportioning them to various resource providers, but not evenly, but also according to the manufacturing capacity of the manufacturing unit and the equipment resources. Here we use the variance of the load rate of each resource to describe the load balancing state. The smaller the variance, the more balanced the distribution of manufacturing tasks and the rational use of resources. The expression is:

$$F = \max\left(1 - \frac{\sum_{e=1}^{m}\left(\theta_e - \overline{\theta}\right)^2}{m-1}\right) \tag{3}$$

Among them, $\theta_e = \frac{L(e)}{A(e)} \times 100\%$ Represents the load rate e of the resource, A (e) Represents the total working hours at resource e, L (e) Available work hours at resource e.

$\overline{\theta} = \frac{1}{m}\sum_{e=1}^{m}\theta_e$ Represents the average load rate at all resources.

2. service quality Q

Service cost is a concern of manufacturing resource demanders and resource providers. The level of cost is also a measure of the demand side's choice of manufacturing resources. The service cost in the cloud manufacturing environment has also undergone major changes. On the one hand, it is the cost of completing the manufacturing task, and on the other hand, the cost of the transportation of the manufacturing task. The expression is:

$$C = \min(C_a + C_b) \tag{4}$$

Formula (2) is the total function of cost, which represents the completion cost of manufacturing tasks, and is the cost incurred during transportation.

$$C_a = \sum_{i=1}^{n}\sum_{j=1}^{a_i}\sum_{e=1}^{m}\left(c_{i,j,e}\right) \tag{5}$$

$$C_b = \sum_{j=1}^{a_i}\left({c^t}_{i,j,e}\right) \tag{6}$$

3. Service cost C

Service quality is another measure for the demander of manufacturing resources to choose manufacturing resources. The level of service quality will also affect the length of service time and the size of service costs. The quality of service is calculated by the quality qualification rate of the subtasks completed by the manufacturing resources.

$$Q = \max\left(\frac{\sum_{i=1}^{n}\left(\sum_{j=1}^{a_i}\sum_{e=1}^{m} w(j)\right)}{n}\right) \tag{7}$$

4.2 Constraint Condition

There are too many uncertainties in the completion of manufacturing tasks in the cloud manufacturing environment. The traditional workshop tasks are transformed into virtual online tasks, in order to better complete resource scheduling and successfully complete the manufacturing tasks. The following constraints are given:

(1) At the same time, the same manufacturing resource can only process one manufacturing task.
(2) The subtasks in the manufacturing task are in order, and the next subtask can only be processed after the previous subtask is processed.
(3) The load balancing index should be greater than the minimum load balancing index required by local customers, namely

$$1-\frac{\sum_{e=1}^{m}\left(\theta_e-\overline{\theta}\right)^2}{m-1}\geq F\min \tag{8}$$

(4) The total service cost of manufacturing tasks cannot be greater than the total cost required by cloud customers, namely

$$\sum_{i=1}^{n}\left(\sum_{j=1}^{a_i}\sum_{e=1}^{m}c_{i,j,e}\right)+\sum_{j=1}^{a_i}\left(c^{t}{}_{i,j,e}\right)\leq C_r \tag{9}$$

(5) The service quality of manufacturing tasks cannot be less than the minimum service quality required by cloud customers, namely

$$\frac{\sum_{i=1}^{n}\left(\sum_{j=1}^{a_i}\sum_{e=1}^{m}w\left(j\right)\right)}{n}\geq Q_{\min} \tag{10}$$

4.3 Conflict Description in Resource Allocation

The completion of manufacturing tasks in the cloud manufacturing environment requires multiple resource providers to provide manufacturing resources for joint completion. Each resource provider expects resource utilization and obtains additional benefits through the full utilization of idle resources. However, in the process of resource allocation, the cloud manufacturing platform takes the smallest manufacturing cost, the highest quality of service, and the most balanced load as the optimization goals to achieve its own revenue goals and complete manufacturing tasks. Cloud users will also have low manufacturing costs when choosing manufacturing resources. High service quality requirements, so in the configuration process, manufacturing resources with lower manufacturing costs and higher service quality will be selected first, and then some service providers will have low utilization of idle resources and cannot achieve their own resource utilization. Therefore, the requirements of resource providers for resource utilization and the requirements of cloud manufacturing platforms and cloud users for manufacturing costs and service quality conflict with each other, that is, conflicts of interest between multiple parties.

As shown in Fig. 2, the cloud manufacturing platform, resource providers, and resource demanders are all participants in the completion of manufacturing tasks. In order to resolve conflicts, an automatic negotiation method for multi-party conflicts of interest is used. The concession of the expected value of various indicators is negotiated and mediated. After the concession, the various indicators can meet all the constraints of the cloud manufacturing platform, resource providers, and resource demanders and achieve their respective revenue goals. At this time, the conflict resolution is completed.

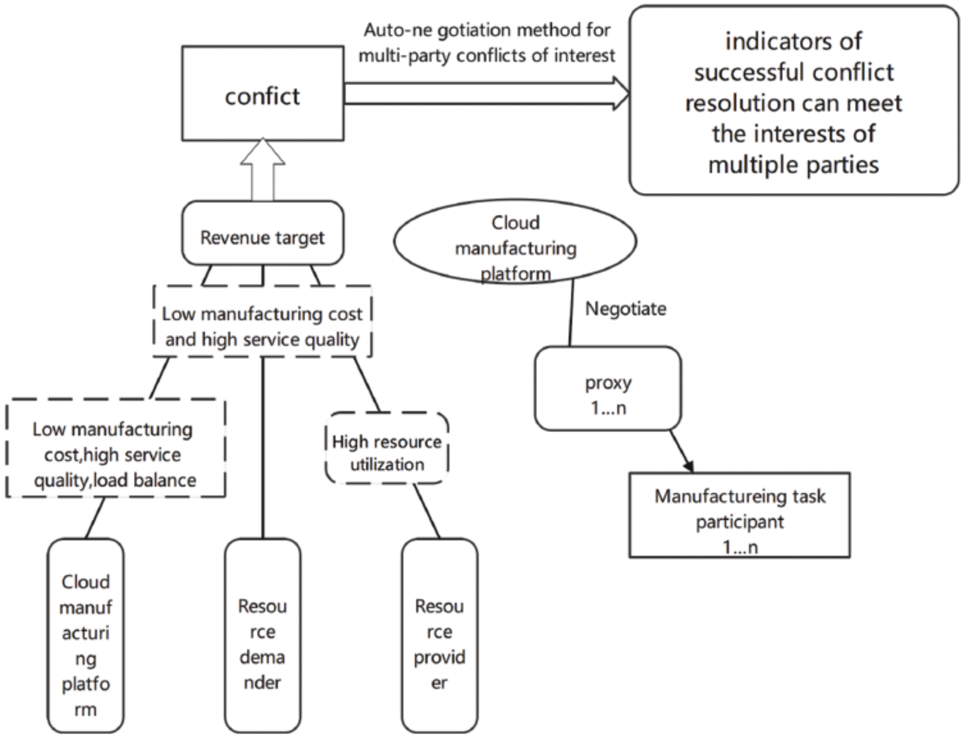

Figure 2: Conflict and resolution in the process of resource allocation

4.4 Framework and Process of Conflict Resolution

According to the conflict of interest that appeared in the process of resource allocation, we analyzed and established the detailed process of the conflict resolution framework. The Cloud Manufacturing Platform (CMP) is proposed as a negotiation agent. It is not only a negotiator of conflicts of interest, a participant in the negotiation, but also a coordinator who minimizes the overall concession of the expected values of various indicators during the negotiation process. In the process of negotiation and regulation, it represents the interests of the cloud manufacturing platform, and it also represents the overall interests of all participants in the entire service process.

At the beginning of conflict resolution, CMP uses the planning method to calculate and generate a globally optimized concession plan and the bottom line value of the concession plan of various indicators. According to the generated concession plan and the bottom line value of the concession, CMP negotiates with the agents involved in the conflict process one by one, and makes a concession through the negotiation agent. At this time, a local optimization plan is obtained, and the first round of negotiation ends. At this time, feedback on the negotiation result to CMP, CMP according to the negotiated concession plan, verify whether the current optimization plan can meet the profit goals of all parties. If it succeeds, it means that the conflict resolution is successful. Output the concession plan with the expected value of various indicators and complete the process of resource allocation according to the optimization plan. The conflict resolution ends. If the profit target of all parties cannot be met, the concession plan obtained from the current negotiation is retained, and the agent that has already concession will not be required to make a concession in the subsequent negotiation process. Based on the current situation CMP recalculates the global optimization concession plan, conducts a new round of negotiation according to the concession plan, and sends the negotiation result to the CMP for verification until the configuration is successful. When the result of negotiating concession is close to the bottom line value expected by various indicators, and the number of negotiation rounds has reached the threshold, if it still fails, there is no need to negotiate again, and the resolution fails.

In the process of concession of the expected value of various indicators, it is not that the more the expected value of each indicator concession, the better, only the concession that is truly meaningful can help resolve conflicts. Therefore, we calculate the minimum value of the expected value of each indicator as the CMP negotiation bottom line value, that is, the minimum value of the agent yield that the CMP can accept. If the bottom line value of the concession cannot be reached during the negotiation process, the conflict must fail to resolve.

In the process of conflict resolution, it is not enough for a few agents to give in. In order to ensure the fairness of concession, each agent must make a certain degree of concession. CMP must ensure the overall index expectation value in the process of calculating the global optimization plan. The minimum back-off means that the global optimization back-off plan is generated with the minimum overall performance loss as the objective function during the service process. The objective function for calculating the concession plan is:

$$\min \sum_{e=1}^{m} \alpha_i \times n_i \times v_i \tag{11}$$

α_i represents the expected concession value of the i-th indicator n_i represents the expected weight value of the i-th indicator v_i indicates the normalization factor expected by the i-th indicator, because the units of each indicator are different. Therefore, at this time, we only need to calculate the minimum value of the i-th indicator's expected return to ensure that the overall performance loss is minimized.

4.5 Swarm Intelligence Negotiation Algorithm Based on Stackelberg Game

Based on the existing actual scenarios, a negotiation model is established for the resolution of conflicts of interest in the resource scheduling process, which is defined as a multi-group form: $\left(CMP, agent_i, S, \alpha_i, \overline{\alpha_i}, \underline{\alpha_{CMP}}, \alpha^S_{CMP}, \alpha^S_i, v\left(s\right)\right)$

1. CMP stands for cloud manufacturing platform and represents the overall interest coordinator of the negotiation process.
2. $agent_i$ Representing the agent expected for the $i - th$ index, the negotiation parameters in the negotiation process are set by the relevant manufacturing task participants.
3. S represents the maximum number of negotiation times. When the number of negotiation times S is reached, no negotiation plan is generated, and the negotiation fails.
4. α_i It indicates the expected concession value of the $i - th$ index when the CMP calculates the global optimization plan before the negotiation starts.
5. $\overline{\alpha_i}$ Indicates the maximum concession value that can be accepted by itself, and the minimum concession value suggested by the CMP negotiation can be accepted $\underline{\alpha_{i=}}\alpha_i - \overline{\alpha_i}$.
6. $\underline{\alpha_{CMP}}$ Indicates that the CMP can accept the minimum compromise value from the $agent_i$ negotiation proposal.
7. α^s_{CMP} It represents the concession value of the CMP proposed in the $S - th$ negotiation or the counter proposal α^s_i it represents the concession value of the $agent_i$ in the proposal or counter proposal in the sth negotiation.

8. v (s) It means that during the negotiation process, the satisfaction of multiple parties to the compromise of the expected value of the indicator is negotiated. During the negotiation process, participants are divided into active negotiators and passive negotiators. By calculating the satisfaction of both parties, the party with low satisfaction is the active negotiator.

$$v_{CMP}(s) = \min\left(\frac{{\alpha^s}_i - \underline{\alpha_{CMP}}}{\alpha_i - \underline{\alpha_{CMP}}}, 1\right) \tag{12}$$

$$v_i(s) = \min\left(\frac{\overline{\alpha_i} - \alpha_i^s}{\overline{\alpha_i}}, 1\right) \tag{13}$$

The negotiation process of conflict resolution is itself a game process in which both parties are constantly pursuing the maximization of their own interests. Without knowing the bottom line value of the other party, the negotiating parties continue to test the bottom line of each other through negotiation and concession to the expected values of various indicators, and finally reach a negotiation. A negotiation plan that is acceptable to all parties and maximizes the interests of all parties will complete the resolution of conflicts. And use the group intelligence negotiation algorithm based on Stackelberg game to speed up the negotiation process, so that the negotiation can be completed quickly and minimize the overall efficiency loss. The pseudo code of the algorithm is shown in Table 1:

Table 1: The resolution process of the group intelligence negotiation algorithm based on Stackelberg game

Algorithm 1: Swarm intelligence negotiation algorithm based on Stackelberg game
begin
1: Initialize multiple threads
2: Generate negotiation parameters vi = (di, wi, qi, ei), i = 1, 2 . . . , N
3: **for** (r = 1; r < R; r++)
4: **for** (s = 0; s < S; s++)
5: Multiple threads start negotitation
6: Calculate v(CMP), v(agent)
7: **if** (v(CMP) = v(agent) = 1)
8: output negotiation results and save
9: **else if** (v(CMP)) > v(agent))
10: agent is native negotiator
11: **else**
12: CMP is active negotiator
13: **if**(s > S)
14: Negotiation failed and end
15: s = s + 1
16: Active negotivator calculate $\alpha_{\eta\delta}$
17: Calculate ad = $(\alpha_i - {\alpha^*}_\eta, \overline{{\alpha^*}_\eta)}$ and send to passive negotivator
18: Passsive negotivator calculate cad = $({\alpha^*}_\mu, \alpha_i - {\alpha^*}_\mu)$
19: **return** 4

(Continued)

Table 1: Continued

Algorithm 1: Swarm intelligence negotiation algorithm based on Stackelberg game

if(r < R)
  Multi-threaded negotiation results for leaning
else
  output optimal negotiation result
end for
end for

The specific implementation steps of the algorithm: initialize the thread and randomly generate N groups of CMP negotiation parameters within the value range corresponding to multiple threads $v_i = (d_i, w_i, q_i, e_i), i = 1, 2, \ldots, N$ the value range of the negotiation parameters is set by the cloud manufacturing platform according to the actual situation, and the expected return plan and the bottom line value of the indicator obtained by the initial calculation of the CMP are input into the thread. Conflicts of interest may not be resolved through negotiation at one time. The agent will record by itself, and adjust its own bottom line value according to the initial expected value of the index that has already backed down. At this time, the number of times to search for the best result. Multiple threads start to negotiate at the same time. The initial default CMP is the active negotiator and the agent is the passive negotiator. The satisfaction of both parties is calculated according to the current concession plan and the satisfaction formula of the negotiating parties. If the satisfaction of both CMP and agent is both When it is 1, the two parties negotiate successfully, output the negotiation result, and save the optimal negotiation result in each thread. Otherwise, based on the satisfaction of both parties, the party with low satisfaction becomes the active negotiator and takes the initiative to negotiate with the other party. When the number of negotiations s > S the number of negotiations exceeds the threshold, indicating that the two parties did not succeed in the negotiation within the specified time and ended. In the new round of negotiation, if the active negotiator is still the active negotiator at this time, and the negotiation parameters are too small at this time, adjust $d = \min(d + 0.01h, 1), h$ represents the number of times as an active negotiator. During the negotiation, the active negotiator estimates the minimum value that the passive negotiator may accept according to the actual situation. $\underline{\alpha_{\eta\delta}}$

$$\underline{\alpha_{\eta\delta}} = \frac{\alpha_\eta}{1+\eta} + h_\delta \times N, \delta \in [1, q] \tag{14}$$

q represents the quality index in the entire service process, N represents a constant, α_η represents the concession value of the active negotiator in the current plan, and η is actually an adjustment parameter, and its size affects the change range of the game process method and strategy, and The size of the value will also continue to change with the number of negotiations. The default normal distribution calculates the probability of the estimated bottom line value.

$$f\left(\underline{\alpha_{\eta\delta}}\right) = \exp\left(\frac{-\left(\underline{\alpha_{\eta\delta}} - \frac{\alpha_\eta}{1+\eta}\right)}{2\sigma^2}\right) \tag{15}$$

5 Case Analysis

This chapter will use the actual case of the cloud-manufacturing platform to schedule manufacturing resources to complete the manufacturing tasks to verify the method proposed in this article. Before the manufacturing resource scheduling, the cloud-manufacturing platform configures the quality indicators according to the expected values of the indicators of all parties. First, each participant declares the expected indicators, as shown in Table 2. The size of the concession value is determined by all participants, but it is only disclosed to the own agent.

Table 2: Statement of expected values of various indicators

Various indicators and symbols	Load balancing index F	Service cost C	Service quality Q	Resource utilization U
Expected value	>0.90	<240 (Ten thousand yuan)	>0.85	>0.75
Bottom line value	0.40	70 (Ten thousand yuan)	0.35	0.30
Weights	0.15	0.20	0.35	0.30

According to the service capabilities of all resource providers involved in the manufacturing task, the relevant quality indicators is given as shown in Table 3.

Table 3: Quality index statement

Quality parameter name	Quality parameter value range
Total working hours	[12 h, 24 h]
Available working hours	[1 h, 12 h]
Service cost per unit time	[15 yuan, 20 yuan]
Transport cost per unit time	[10 yuan, 15 yuan]
Quality qualification rate	(0, 10]

When calculating the constraint conditions based on the data in Tables 2 and 3, the feasible region appears to be empty, which indicates that there is a conflict of interest in the resource scheduling process, and the conflict of interest needs to be resolved. We use the Stackelberg game-based group intelligence negotiation algorithm (Group Intelligence Negotiation Algorithm Based on Stackelberg Game, TS_VCR) to resolve conflicts.

Different manufacturing resources will have different concession values according to their capabilities and costs. Therefore, the average values are obtained during the experiment. The results are shown in Fig. 3. It can be seen that the proposed algorithm in this paper does not require multiple rounds of negotiation and can be completed in only 4 rounds, and the negotiation can achieve the desired result faster and is more implementable.

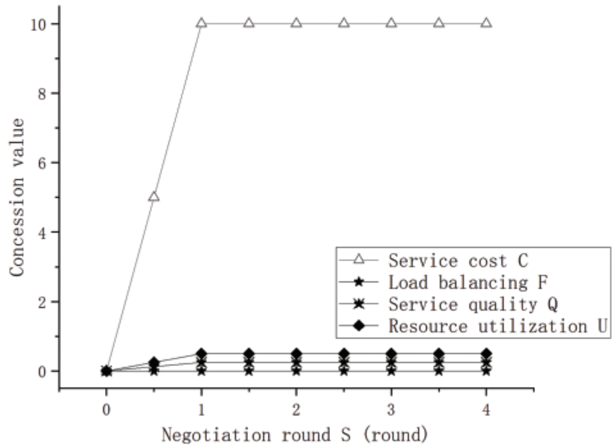

Figure 3: TS_VCR negotiation and concession result

6 Summary

This article combines the new characteristics of resource scheduling in the cloud manufacturing environment to study the resource allocation process in the cloud manufacturing environment. For the conflict of interest that appears in the optimization process, it fully considers the impact of the resource allocation environment and risk objectives on the model. Based on this, a multi-thread auto-negotiation model oriented to multiple targets is established. Using the stackelberg game-based group intelligence negotiation algorithm iteratively seeks the negotiation plan that minimizes the overall performance loss and improves the overall benefits. In order to ensure the fairness of the negotiation, each resource provider must make a certain degree of concession to the expected value of the index during the negotiation process, and at the same time ensure the personal interests of the service participants. After the conflict resolution is completed, the cloud manufacturing platform successfully completes the resource scheduling process according to the optimization goal, and the manufacturing task is completed under the service of multi-party manufacturing resources. Through experimental simulation design, it is verified that the established model can effectively solve the conflict problem in the service process and optimize the existing methods. During the negotiation process in this paper, the negotiation parameters are fixed. In future research, variable negotiation parameters can be introduced and the negotiation of service quality improvement can be added to cope with complex and changeable application scenarios. The continuous development of the cloud manufacturing model will also be a research direction to accelerate the development of manufacturing in the future. The research in this article will also lay the foundation for future development. Future research will also continue to improve resource scheduling models and experimental parameters to better respond to the development of cloud manufacturing services and better serve the cloud manufacturing platform.

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