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Design and Research on Logistics Tracking System of Supply Chain Based on Multi-Agent

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Abstract

The technology in the design and research of agent-based supply chain logistics tracking system has effectively solved the schematic diagram that caused the vacancy through application realizability. Other solutions for logistics tracking cannot effectively solve the path tracking and real-time monitoring of items. The successful development of the agent-based supply chain logistics tracking system design and research has achieved the tracking of logistics paths and intelligent logistics tracking through negotiation algorithms.

Keywords: *Supply Chain, Logistics Tracking, Multi-agent System, Negotiation;*

1. Introduction

Supply chain is a network system of supply and demand composed of manufacturing, supply and distribution, which is formed by multiple jobs[1-3]. In the current environment, the competition among enterprises is fierce, and then many enterprises will develop business according to their own strengths, and then outsource non-core business, so the distribution of the entire supply chain is particularly important[4-6]. The design of the multi-Agent supply chain logistics tracking system maximizes the interests of enterprises, and the enterprises in the entire supply chain can achieve coordination and mutual assistance. The logistics tracking of the multi-agent supply chain solves the effect of real-time coordination and communication to create Greater good.

2. Formal description of the problem

The logistics tracking problem discussed in this paper is the logistics tracking between a group of autonomous agents (representing different node enterprises) in a supply chain environment. In this case, there is no global controller, and there is no global consistent knowledge and global shared goal. It is impossible for any agent to have complete information of other agents. For the same task, these Agents can complete all or part of it, but due to the limitations of resources and capabilities, the price (i.e., cost) paid for completing the task may be different, so some Agents are required to form alliances and cooperate with each other. , So that under the premise of self-profit, the formed bidding alliance can be favored by the task issuing party, and thus obtain the right to complete the task.

In general, any task can be represented by a four-tuple, namely <T, N, P, C>, the specific meaning is as follows: ① T is a task set that cannot be completed by a certain agent, T=(t1, t2,…,tm}, each of the subtasks tj(j=1,2,…,m) can be decomposed; ②N is the set of Agents with potential and resources to complete the task set T, N={A1,A2, …, An}; ③P is the reward that the Agent gets for completing task T, P={(pij)}, where pij is the reward that Ai gets for completing the subtask tj. If the subtask tj cannot be completed, then pij=0;④C The cost required for the Agent to complete task T, C={(cij)}, where cij is the cost spent by Ai to complete task tj.

According to the above description, from the point of view of the logistics tracking publisher, it is hoped that through the distribution of tasks among multiple agents, the tasks can be completed and the rewards paid are the least, which can be described by the following formula:

$$G_b = \min \sum_{i \in N} \sum_{j \in T} p_{ij} \quad (1)$$

From the point of view of the task performer, hoping to obtain the greatest profit can be described by the following formula:

$$G_c = \max \sum \sum \left(p_{ij} - c_{ij} \right) x_{ij} \quad x_{ij} \in \{0,1\} \quad (2)$$

Among them, xij=1 means task tj is assigned to Ai to complete, xij=0 means task tj is not assigned to Ai.

In the supply chain system, there is no authority for logistics tracking, and there is no common goal among Agents. The relationship between Agents is both competition and cooperation. Competition is inevitable and unconditional, and cooperation is temporary and conditional. Therefore, it is obviously not feasible to optimize the assignment of tasks through the authority. The goal of logistics tracking is to balance the partial goals of the task bidder and the task performer, and seek the most balanced and satisfactory logistics tracking result among the Agents.

3. Negotiation protocol and algorithm among multi-agent

This article follows the basic idea of the contract network proposed by Smith[1], and regards logistics tracking in the supply chain as a process of bidding-bidding (including negotiation)-winning the bid. In the negotiation process, the task tenderer is responsible for task assignment, task execution monitoring and execution result processing, and task bidder is the potential performer of the task. Both task bidders and task bidders are dynamically formed in the process of logistics tracking. Sometimes the same Agent is both the bidder for this task and the bidder for another task. In order to realize the negotiation between task bidders and task bidders and between task bidders, the following two negotiation agreements can be used.

3.1. Tenderer-bidder negotiation agreement

The bidder of the task is unable to complete the task or cannot complete the task more effectively than other agents or agent alliances. Therefore, the job of the bidder is to select a certain (some) Agent or agent alliance from the bidders to complete the task. The task, the selection criterion is the lowest pay. In order to effectively achieve this goal, this article improves the contract network agreement proposed by Smith, so that the tenderer and the bidder can achieve task allocation through two communications. The specific process is as follows:

(1) The task tenderer receives the task set $T^m = \{t_1^m, t_2^m, \cdots, t_k^m\}$, first analyzes the type of Agent required to complete the task set Tm, and publishes the task set Tm to the relevant Agent in a broadcast manner (using the broadcast method can save communication time and communication Cost), and pass the deadline of bidding and the condition information of winning the bid to the relevant Agent. In this way, the release of the task can be described by a five-tuple <TMIDS, MA, Tm, CTm, DL>, where TMIDS is the identifier of the manager of the task Tm, MA is the tenderer of the task Tm, and CTm is the set of completed tasks DL is the deadline for bidding.

(2) After the relevant bidders receive the information, in order to win in the competition, they will make relevant bidding decisions based on their own situation and the relevant information of other bidders. In the agreement, there are three kinds of responses to the information received: rejection, not understanding and bidding. The bidding information is described by a five-tuple, <TMIDB, Bidderi, Ti, Pi, CTi>, TMIDB is the identifier of the task tenderer, Bidderi is the bidder or the alliance formed by the bidders, and Ti is the bidding agent or the alliance of the agent For the set of tasks that can be completed, Pi is the remuneration required to complete the task set Ti, and CTi is the condition met by the bidder to complete the task set Ti.

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(3) During the deadline for bidding, the tenderer receives all bids

According to the information received, the tenderer makes three responses: accept a bid from a certain bidder, reject all bidders, or suggest that certain bidders form an alliance to bid.

(4) If the bidder receives a proposal from the bidder to form an alliance, there are three types of information returned to the bidder: reject the proposal, accept the proposal, and pass the new bid information to the bidder.

(5) If the information received by the bidder from the bidder is a new bid information, the bidder can accept or reject the new bid information.

(6) If the bidder's bid is accepted by the tenderer, the logistics will be tracked to the bidder, then the bidder will feed back the result of its completion to the task tenderer.

3.2. Bidder-bidder negotiation agreement

In order to win the bid, every bidder has two choices: participate in the bid alone or form an alliance with other bidders to participate in the bid. In this article, the negotiation between bidders adopts the random proposal agreement, which evolved according to Rubinstein's rotating proposal agreement. The random proposal process is described as follows: ①Any bidder can form an alliance with related parties according to the tasks issued by the tenderer. The Agent puts forward a proposal to form an alliance; ②Every bidder who receives a proposal can choose to accept the proposal, reject the proposal and withdraw from the negotiation process. If the proposal is accepted by all relevant bidders, that is, all bidders who have received the proposal choose to accept the proposal, then the negotiation process ends and the proposal is accepted. If none of the bidders withdraw from the negotiation process, but one or several bidders reject the proposal, the negotiation process will continue until a certain bidder's improvement proposal can be approved by other bidders and meet the negotiation process. End the conditions so that the negotiation ends and an alliance is formed. If one of the relevant bidders withdraws from the negotiation, the negotiation process ends and no alliance can be formed.

3.3. Negotiation algorithm of bidders

In the negotiation-based logistics tracking process, task bidders and task bidders have very different goals, so bidders and bidders have different negotiation algorithms.

The tenderer is responsible for the issuance of the tasks and the assignment of the final tasks, but it does not have absolute authority to force other bidders to complete the tasks assigned by it. Instead, the assignment of tasks is achieved through negotiation. The corresponding negotiation algorithm is as follows:

(1) When the task of a certain agent needs the help of other agents, that is, when there is a task set Tm that needs to be allocated to other agents to complete, the agent becomes the tenderer of the task set Tm. The tenderer first relates the task set and the completion of the task. The conditions and deadlines are announced by broadcast, namely <TMIDS, MA, Tm, CTm, DL>.

(2) After the task is released, the tenderer starts to receive the corresponding bidder's information, <TMIDB, Bidderi, Ti, Pi, CTi>, i=1,2,...,l, and will not stop receiving until the deadline.

(3) If $\bigcup_{i=1}^{l} T^i$, go to (4), otherwise it means that Tm cannot be completed by these bidding agents.

(4) If each sub-task of Ti can be completed by a bidder alone (represented by T_a^m), then the logistics tracking problem becomes very simple. The goal of the bidder is to T_j^m (j=1, 2,...,k) are looking for the smallest payment p_j^{m*} , then the bidder's goal is obtained by the following formula:

$$G_m = \sum_{j=1}^{k} 1 \min_{i=1}^{l} p_{ij} = \sum_{j=1}^{k} p_j^{m*}$$
$$s.t. p_j^{m*} \le v_j^m \tag{3}$$

In the formula, v_j^m is the value of subtask t_j^m to the task tenderer.

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If $p_j^{m*} > v_j^m$, the bidder refuses the bidder to complete the task. If Ti cannot be completed by a certain agent alone, the subtask set (represented by T_p^m) needs some agents to form an alliance to complete. Therefore, the manager divides the assignment problem of the task set Tm into two problems, namely the assignment problem of T_a^m and the assignment problem of T_p^m, $T^m = T_p^m + T_a^m$. The distribution of T_a^m is relatively simple, as explained above. For the allocation of T_p^m, the tenderer will feed back the bidder's information (<Bidderi,{tr,r=1,2,...},{pri,r=1,2,...},CTi>) to the relevant bidder , It is recommended that they form an alliance to jointly complete the tasks in the subtask set T_p^m.

(5) After a period of waiting, the tenderer receives the result of the bidder's negotiation. Finally, the tenderer chooses the alliance with the lowest cost to complete $T_j^m\left(t_j^m \in T_p^m\right)$ as the winning bidder.

3.4. Tenderer's negotiation algorithm

The bidder first monitors the task release information of the bidder, and after receiving the information, bids according to the task completion deadline specified by the task bidder and their own resources. After bidding, the bidder will receive information from the bidder. If it is to track the logistics to the bidder, the bidder who finally accepts the task will feedback the execution result of the task to the bidder; if the information received by the bidder is a suggested bid To form an alliance to complete a task, the relevant bidders enter the negotiation process and notify the tenderer of the negotiation result. Finally, the successful agent or agent alliance will notify the tenderer of the execution result of the task. The specific negotiation algorithm is as follows:

(1) Bidder i received feedback from the tenderer<Bidderi,{ti=λitm,tm∈Tm,0<λi<1,r=1,2,...},{pr,r=1,2,... },CT>, for subtask $i\left(A_i^j = \left\{A_1^j, A_2^j, \cdots, A_h^j\right\}\right)$, search for all potential alliances A_e^j that can complete subtask $i\left(A_e^j = \left\{A_{h+1}^j, A_{h+2}^j, \cdots, A_s^j\right\}\right)$.

(2) From the perspective of bidder i, divide all the searched potential alliances Aj into two parts: one part contains bidder $i\left(A_i^j = \left\{A_1^j, A_2^j, \cdots, A_h^j\right\}\right)$ and the other part does not contain bidder $i\left(A_e^j = \left\{A_{h+1}^j, A_{h+2}^j, \cdots, A_s^j\right\}\right)$. First, find the smallest reward p_e^{j*} that can complete t_j^m from the set A_e^j, namely

$$\begin{aligned} p_e^{j*} &= \min_{A_{h+1}^j \in A_e^j} \min\left(\sum x_k^l p_k^j / \lambda_k^l + \left|A_{k+1}^j\right| \beta\right) \\ s.t. &\sum_{k \in A_{h+1}} x_k^l = 1 \\ & x_k^l \geq 0 \end{aligned} \tag{4}$$

In the formula, β is the cost required by each bidder in forming the alliance.

Then, search for all potential alliances smaller than p_e^{j*} in the set A^j, and put it into the negotiated alliance list in ascending order of the rewards received by bidder i Anc=(Anc(1),Anc(2),...,Anc(q)}.

(3) If Anc=∅, bidder i will search for the alliance A* in A_i^j with the lowest payment required to complete task t_j^m, and suggest that the Agents in A* form an alliance, and then wait for answers from other bidders . If all Agents in A* agree, then an alliance is formed to re-bid for task t_j^m, and the negotiation process is over.

(4) If there is and at least one bidder in A* does not agree to form an alliance, then an alliance cannot be formed to re-bid for task t_j^m.

(5) If Anc≠∅, then let k=1.

(6) Bidder i suggests that the Agents in Anc(k) form an alliance, and propose a task allocation plan, and then wait for answers from other agents.

(7) If all Agents in Anc(k) agree to form an alliance and the corresponding logistics tracking plan, then re-bid to the tenderer and the negotiation process ends. If there are bidders who disagree with

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the logistics tracking plan in Anc(k), the random proposal agreement is used for negotiation. If an agreement can be reached, an alliance will be formed to re-bid the task. If no agreement can be reached and k≤q, then let k=k+1 and return to (6). If a consensus cannot be reached and k>q, then no alliance will be formed for re-bidding, and the negotiation process will end.

4. Run the example

Through the system simulation of the transportation logistics tracking prototype system developed on the JADE (Jave Agent devocopment framework) platform, the negotiation protocol and algorithm proposed in this paper are verified. The prototype system consists of a bidding company (manager of the task) and bidders (executor of the potential task). The bidding company is mainly responsible for the release of the transportation task, and selects one or more qualified bidders from the bidders to complete the transportation task; and the bidders participate in the bidding based on the task information, and strive to obtain the task. At that time, it can form an alliance with other bidding companies to complete the task together. In order to simplify the analysis of the problem, this paper takes freight rate as the only consideration factor in choosing a transportation company, and does not consider other factors such as delivery time, reliability, and assumes that each transportation company has the same delivery time in the same transportation interval.

4.1. Transport logistics tracking prototype system structure

The supply chain logistics tracking system is based on the realization of dynamic enterprise alliances and information sharing, through the combination of multi-agent, information technology, business intelligence and other technologies to provide logistics tracking solutions for business modeling and quantitative analysis, thereby achieving knowledge Management and decision-making support. Its core strategy is to establish a reconfigurable and reusable dynamic organization integration method for multiple companies based on the principle of complementary advantages to support multiple applications in the supply chain, and to meet the diversification and individualization of customer needs, and to achieve rapid response integration Supply chain logistics tracking system.

The basic idea of intelligent supply chain integration is to treat the internal mechanism of the supply chain management system as a network composed of cooperative intelligent agent modules. Each agent module implements one or several functions of the supply chain. Coordinate with other agent modules to realize the solution of decision-making problems. A more typical study is based on the functions of the supply chain and divides the multi-agent system into supplier agents, purchasing agents, raw material inventory agents, production planning agents, manufacturing agents, product inventory agents, order processing agents, transportation agents, and distributor agents, etc. . Taking into account the characteristics of the above-mentioned supply chain decision support system, this paper presents a multi-agent-based logistics tracking framework for supply chain enterprises (Figure 1).

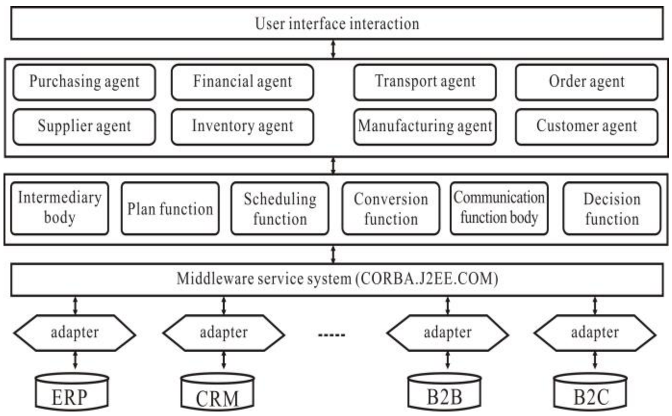

Figure 1. Logistics tracking framework for supply chain companies.

In order to strengthen the analysis function of the supply chain, in the construction of the actual system, the multi-agent system of the supply chain adopts a multi-layer structure in function: realize the storage

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of data, information and knowledge at the supply chain resource layer, and the legacy system As well as access to B2B and B2C systems; basic management intelligence and business intelligence are integrated in the business logic layer and basic service layer. According to the actual needs of the enterprise, multi-agent dynamically maintains regular management knowledge and business knowledge; and it is implemented in the interface layer Real-time interaction and operation between the system and the user.

4.2. System operation example

In this example, a supplier sells products to 4 distributors located in Beijing, Shanghai, Shenzhen, and Guangzhou. According to the contract, the supplier is responsible for delivery, and the supplier uses third-party logistics to complete the delivery of the goods. There are 4 transportation companies (A, B, C, D) to compete for these transportation tasks. In this case, the supplier is the bidder for the transportation task, and four transportation companies are the bidder for the task.

The specific task in the example is T=(t1,t2,t3,t4), where t1 represents a transportation task with a destination of Beijing and a total of 100t; t2 represents a transportation task with a destination of Shanghai and a total of 100t; t3 It means the transportation task whose destination is Shenzhen and the total amount is 100t; t4 means the transportation task whose destination is Guangzhou and the total amount is 100t. The specific allocation process is as follows:

(1) The bidding company first obtains the information of the related transportation companies on the JADE platform, and then releases the task T={t1,t2,t3,t4} and the deadline for bidding to the 4 transportation companies. Within the deadline, the bidding enterprises shall submit bids to the bidding enterprises according to their own operating conditions. In this example, B company chose to give up because of its own business and insufficient transportation capacity. For example, the information of A company is {(100,80000),(80,60800),(50,45000),(100,90000)), which means that A company can complete: 100t to Beijing transportation task, total freight rate 80,000 yuan; 80t to Shanghai, the total freight rate is 60,800 yuan; 50t to Shenzhen, the total rate is 45,000 yuan; 100t to Guangzhou, the total rate is 90,000 yuan. Others and so on: C enterprise information ((50,43000), (100,80000), (80,68800), (80,64000)); D enterprise information ((40,35000), (60,60000) ,(40,38400),(100,75000)}.

(2) According to the bid information, the bidding company assigns the subtasks t1 and t4 to A and D, which can be completed independently and with the lowest freight rate, respectively, that is, to issue a bid winning notice to A and D, and wait for A and D to return the results of the task execution . Merchants form an alliance to complete t2 and t3. After the three bidding companies receive the information from the bidding company, they will, according to their own conditions, negotiate and negotiate with the bidder to achieve the goal of minimum cost, and announce the bidding information of A, B, and C to the three companies. It is recommended that three bidding companies Enterprises strive for tasks through collaboration. The following takes bidding company A as an example to illustrate the negotiation process between bidders: all potential alliances that can complete subtask t2 are divided into two parts, namely $A_i^2=\{\{A,C\},\{A,D\},\{A,C,D\}\}$ and $A_e^2=\{\{C\},\{C,D\}\}$; similarly, potential alliances that can complete subtask t3 can also be divided into Two parts, namely $A_i^3=\{\{A,C\},\{A,C,D\}\}$ and $A_e^3=\{\{C,D\}\}$. Since the allocation process of subtasks is the same, take the allocation of subtask t2 as an example. Equations (3) and (4) can get $p_e^{2*}=80000$ yuan, p_e^{2*} is the cost required by enterprise C to complete it alone. According to formula (4), Anc={A,C} can be obtained. Therefore, Bidder A will strive to negotiate with Bidder C to form an alliance. If Bidder C agrees, A and C will form an alliance and jointly bid <t2,{A,C},76800}>

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from the bidding company. The distribution plan of and C is x=0.8, pc2=60800 yuan, x=0.2, pc2=16000 yuan.

If C disagrees with this allocation plan, two strategies may be adopted: one is to propose other allocation plans, and conduct multiple rounds of negotiation with A to strive for more profit, such as the plan <{A,40,30400},(C, 60,48000}>; The other is that enterprise C can bid alone, because enterprise C can complete the task alone, but this does not have an advantage in price and may not necessarily obtain the task. What kind of strategy is adopted, and how to propose a new allocation plan. The system mainly adopts human-computer interaction, that is, directly soliciting opinions from decision makers through dialog boxes.

(3) After receiving the new bid information, the tendering company will select the alliance that can complete the task and requires the lowest remuneration. From this example, the final completion of the subtask t2 will be the alliance formed by A and C, namely <t2,{A,C},76800>. At this point, the entire logistics tracking process is over.

5. Conclusion

This paper uses multi-agent technology to study the logistics tracking system in the supply chain, improves the contract network agreement, and proposes the corresponding negotiation algorithm, which realizes the assignment of tasks and the cooperation between bidders. According to a practical example, the proposed negotiation algorithm was used to simulate the entire logistics tracking process.

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