

Artificial Bee Colony Algorithm Based on Complex Network

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Abstract—The research in this paper includes the supply chain of complex structures of multiple manufacturing centers and multiple products, and the total cost and total response time are used as two major indicators to optimize the supply chain decision problem of this three-tier structure. The complex network theory is introduced into the solution structure, and the artificial bee colony algorithm is used in the subsequent solution process. The algorithm shows excellent performance in solving the global POS solution set of the three-layer complex supply chain network structure.

Keywords—complex network, artificial bee colony, supply chain network, optimization

I. INTRODUCTION

Nowadays, with the rapid changes in the business environment, enterprises must evaluate and configure the supply chain network to achieve the demand for products or services that better meet customer needs at the lowest cost[1,2,3,4]. The manufacture, processing and transportation of products constitute a complex supply chain network(supply chain network, SCN),The process model managed in the SCN involves both the selection of materials (raw materials, intermediate products, finished products) and the screening of information (requirements data, delivery date, delivery time, assembly costs and delivery dates)[5,6].A number of different literatures have now proposed a variety of different models to solve optimization problems in multi-target supply chains. For example, Shaw et al. [7] proposed an integrated supplier selection strategy based on fuzzy analytic hierarchy process and fuzzy multi-objective linear programming, but did not consider the importance of the complex network structure of the supply chain. Moncayo-martinez et al.[8] proposed an ant colony optimization algorithm to minimize total supply chain costs while reducing product response time to ensure product delivery without delay.Although they noticed that the ant colony algorithm can solve the multi-objective problem in some aspects, its research does not improve the search speed.

Optimization in supply chain network (SCN) management refers to finding the best process model for product manufacturing (ie, resource selection) [9]. The process model managed in the SCN involves both the selection of materials (raw materials, intermediate products, finished products) and the screening of information (requirements data, delivery dates, delivery time, assembly costs and delivery dates) [10,11].

II. MODEL ESTABLISHMENT

A. Problem Description

The three-tier supply chain model can be seen as a complex network. This paper cites a three-tier supply chain model for multiple products: Product A, Product B, and Product C, as well as multiple manufacturing centers. As shown in Fig.1, different nodes represent different processing processes. (a) The black node of the dotted line represents the collection and processing of raw materials or intermediate products; (b) The black node of the thin line represents the configuration process of the most end product; the black line of the thick line indicates the transportation process of the product to the target market. The directed line segments between the nodes represent the supply relationships of the various parts, and the dashed lines in each node indicate their respective selectable options). The black points in each node in this supply chain network are an option for the node in which they are located, and each has its own cost value and response time. The directed line segments connecting the black points represent the relationship between the upper and lower levels in the supply chain network. With the continuous improvement of network technology, the number of suppliers has increased dramatically, and more nodes will be added to form a more complex three-tier supply chain network.

A node is the main subcomponent of three products (A, B, and C), node a_2 is a common subcomponent of two products (B and C), and node a_3 is a subcomponent of a product (A). Abstract the above supply chain network into a complex network structure. It consists of a number of independent node sets $\{a_1, a_2, a_3, \dots, a_n\}$. The black point contained in each node is represented by $a_{ij}(j = 1, 2, \dots, N_i)$, where N_i represents the total number of black points contained in the a_i node. The total cost and total response time are used to represent the satisfaction indicators of the company and the customer, respectively, and the following formula is used to describe the problem:

$$Z = \omega_1 \times PC + \omega_2 \times LT \quad (1)$$

Equation (1) is the subject objective function, where PC represents the total cost on the supply chain and LT represents the

total response time. ω_1 and ω_2 are weights used to balance the total cost and total response time to measure the importance of the two and add up to 1.

$$PC_i = \mu_i \sum_{j=1}^{N_i} C_{ij} \times y_{ij} \quad (2)$$

$$PC = \delta \sum_{i=1}^N PC_i \quad (3)$$

Equations (2) and (3) are used to solve the total cost of the supply chain. δ represents the monthly or weekly interest rate of the cost of node a_i , and μ_i represents the average demand per unit time. The cost per unit product in a_{ij} is expressed as C_{ij} , and if the black point a_{ij} is selected for delivery, its corresponding y_{ij} value is 1, otherwise it is 0.

$$LT_i = \sum_{j=1}^{N_i} T_{ij} \times y_{ij} + \max_{\alpha_k \in S_i} LT_k \quad (4)$$

Where T_{ij} is the response time required by the j th material provider manufacturing process in node a_i . S_i is a set of black points that provide material for a_i , α_k is the manufacturing process in all S_i and LT_k is the response time accumulated by α_k .

$$LT = \sum_{i=1}^N LT_i \quad (5)$$

Where LT_i is the response time of node a_i and LT is the total response time on the supply chain.

$$y_{ij} = \begin{cases} 1 & \text{if choose } j \\ 0 & \text{otherwise} \end{cases} \quad \forall i \in N, j \in N_i \quad (6)$$

$$\sum_{j=1}^{N_i} y_{ij} = 1 \quad (7)$$

For $a_i (i = 1, 2, \dots, N)$, equations (6) and (7) ensure that only one black point in each node can be selected.

$$\sum_{i=1}^N T_{ij} + \max_{\alpha_k \in S_i} LT_k - LT_i = 0 \quad (8)$$

Equation (8) verifies the correlation of response times between nodes.

B. The expression of solution

In Fig.2, each node represents a manufacturing process, and we can express the supply chain network structure in some subnets, as shown in Figure 2.

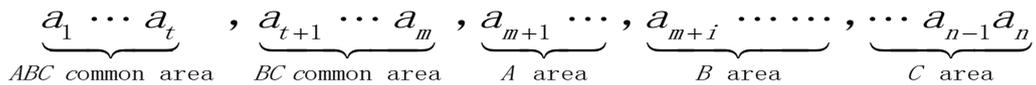


Figure.2 Visual representation of the supply chain network

As a combinatorial problem, the solution of the artificial bee colony algorithm can also be expressed in the form of $A_i = (a_1, a_2, a_3, \dots, a_n)^T$. According to the different node combinations formed by different products, a complete supply chain is formed. Similarly, the node $a_i = (a_{i1}, a_{i2}, a_{i3}, a_{i4}, a_{i5})^T$ is a 5-dimensional vector including the node number, the number of black points, the response time of the black point, the cost of the black point, and the probability that the black point is selected.

III. ARTIFICIAL BEE COLONY ALGORITHM BASED ON COMPLEX NETWORK

The subnetwork is detected and extracted from the supply chain network, as in step 2.1. Shown as Fig.3.

Outbound of Node A (Out Degree): The number of directed segments leading from Node A to other nodes.

Single out node: A node with an outbound value of 1.

Multi-exit nodes: Nodes with an out-of-range value ≥ 2 and support assembly ≥ 2 products.

Terminal node: Finished product node with an exit ≥ 2 pointing to the target market.

The use of parallel computing and greedy principles in algorithms greatly improves the speed of global POS solution sets. The specific algorithm flow is shown as Fig.3.

The global optimal solution of the sub-network is combined into the global optimal solution GlobalParams of the SCN, and the optimal cost GlobalBestCost and the optimal response time GlobalBestLeadtime are calculated.

IV. ANALYSIS AND SUMMARY OF ALGORITHM RESULTS

The solution to the complex network in the supply chain network management decision can greatly improve the search speed of the global POS solution set of the multi-objective optimization algorithm. When a large, complex supply chain network is extracted into a combination of small, relatively simple subnetworks, the complexity of problem solving is greatly reduced.

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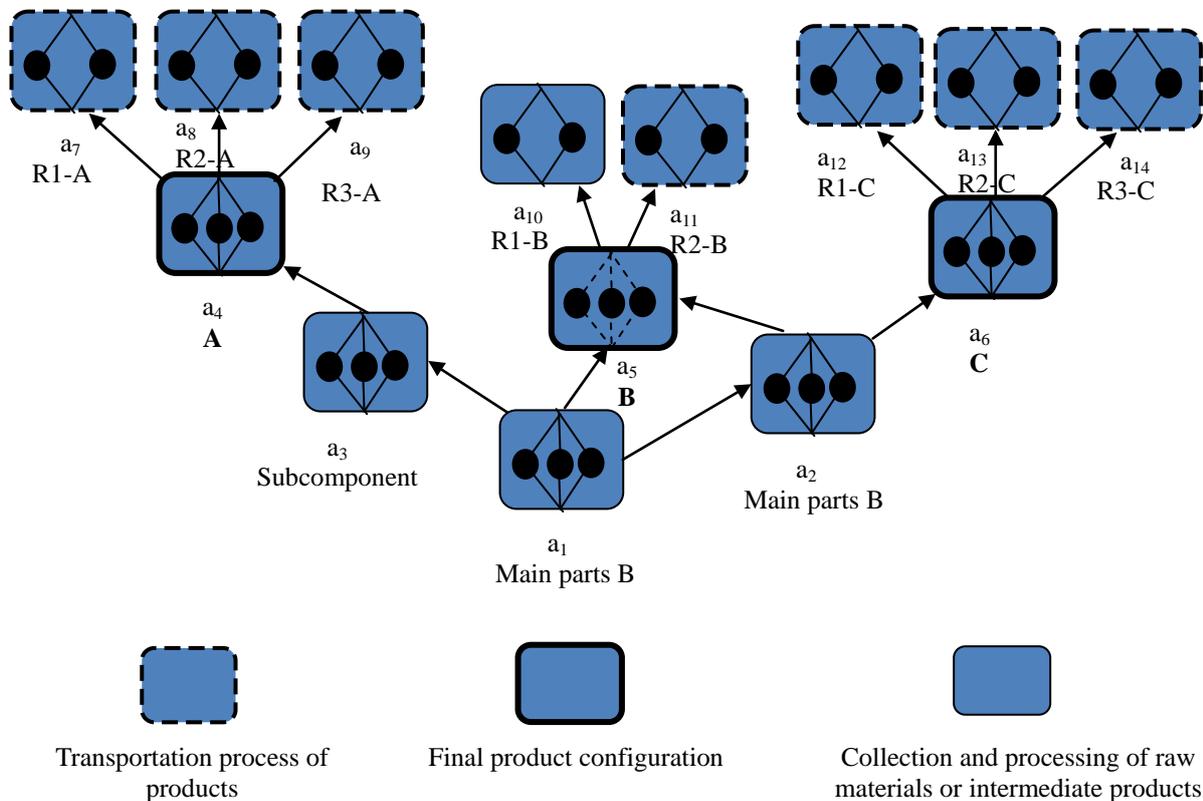


Fig.1 Three layers of the supply chain network

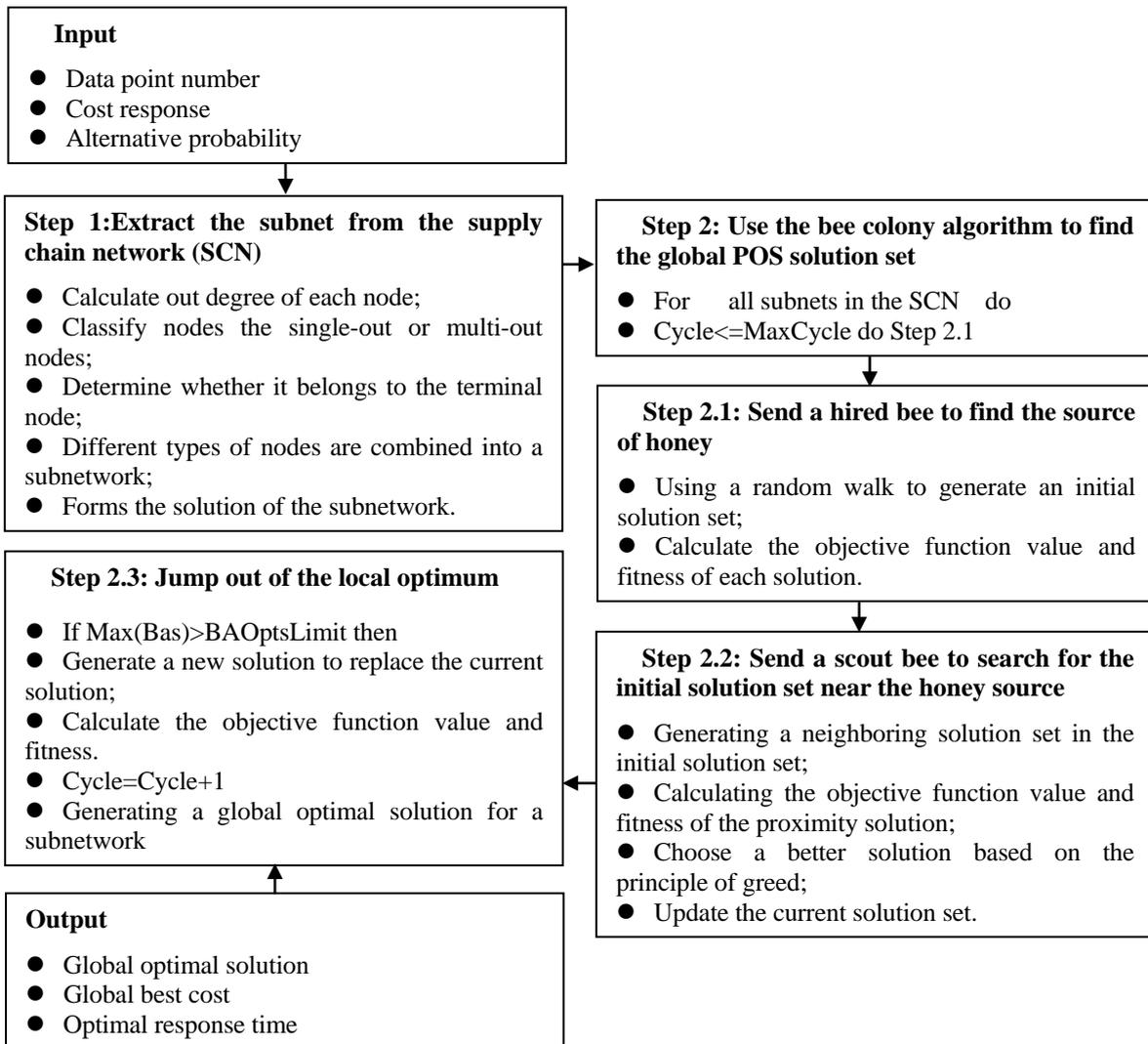


Figure.3 Visual representation of the supply chain network