A Study on Partners Selection in Food Traceability System: Perspective Based on Improved Constriction Factor Particle Swarm Optimization Algorithm

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ABSTRACT: *An improved Constriction Factor Particle Swarm Optimization (CFPSO) algorithm is proposed and used to solve the optimization problem through establishing multi-objective decision-making model, which is applied to choose the best coalition partners association in food traceability system. The results of simulation by standard CFPSO and improved CFPSO shows that: in comparison with those of the standard CFPSO, the improved CFPSO can be well used to find the decision of multi-objective decision-making model, and it avoids trapping into the local optimal solution prematurely, increases search speed and enlarges the probability of converging to a global optimal solution. Simulation by improved CFPSO is better to explain the running logic of traceability system in theory, and provide theoretical basis for executive decision making in food traceability system.*

Keywords: Food traceability system, Particle swarm optimization algorithm, Constriction factor

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1. Introduction

In the world wide, the crucial reason of frequent food risk incident lie in market failure, which caused by asymmetric information and un-traceable responsibility [1,2]. Food traceability system effectively solve information asymmetry and enable quick trace of food producer responsibility, through technical method to form a reliable and continuous flow of information on the food supply chain with traceability. Thus, food traceability system as an effective control of food quality and safety has been implemented in many countries [3]. On the other hand, practice shows that food traceability system not only can reduce food risks, but also can promote diversification of food by trust attributes. Furthermore, food traceability system meet consumer demand, improve added value of products, and finally get more revenue for all involved in the subject [4,5]. China started to build food traceability system since the year of 2000, but only on a few of cities and limited categories. Food traceability system of china mainly driven by government, and implemented by voluntary enterprises, the coverage of beneficiaries needs to be improved and further expanded [6,7].

Supply Chain Partnership refers to the protocol relationship of information sharing, risk-sharing and joint profit agreement among supply chain companies formed in a given period. The relationship of supply chain partnership developed from initial experience of pure trade relationship, the logistics related to operational level and technical level, and then toward the high-level, wide-ranging strategic partnership [8]. In other words, the core issue of supply chain operations is no longer manufacture or distribution of the product, but how to choose the right partners to improve the ability to adapt environment and market change of the entire supply chain. Meanwhile, improvement of supply chain performance is also dependent on the partnership which could enhance coordination and management capabilities [9]. Partner selection of core enterprise, especially high value added manufacturer in supply chain, has become one of the focal issues [10,11].

On the basis of the general supply chain, the concept of the food supply chain was creatively put forward, which has been widely recognized for academia [12]. Food traceability system is involved in all producers, processors, logistics providers, retailers (included supermarkets) and other participators, which together to form the "network chain", there is not only the contract between each main constraint on market interest but also with a full two-way or multi-way flow of information security among partners. Therefore, food traceability system a higher level of the food supply chain system [13], which is a typical collaborative "symbiotic chain" with process effects [14]. Furthermore, food traceability system that based on general guidelines for the food supply chain formation is established in the basis of interdependence and mutual support of partners alliance system, the characteristic of partners behavior inevitably affected by other subjects behavior in food traceability system, the overall performance of food traceability system (includes the realization of added value) not only depends on the individual behavior, but also more dependent on synergies between each main subject behavior generated by the combined effects. So far, Selection and combination of partners has become one of the fundamental and critical issues in food traceability system construction. However, little is known on how to solve this issue by scientific methods. In investigation of this issue, after introducing the theoretical background and research methodology, the paper analyses how to choose the best coalition partners association in food traceability system through establishing multi-objective decision making model by improved constriction factor PSO algorithm.

2. Problem Descriptions and Mathematical Modeling

2.1 Problem Definition

Performance and hierarchy of food traceability system depends on the level of breadth, depth and precision which derived from system itself. Breadth refers to the scope of security information recorded by system, depth refers to the distance can be traced forward or backward of security information, while, accuracy refers to the ability to trace the source of the issue [15]. Moreover, the breadth, depth and accuracy inherently rest with the collaborative degree of partner behavior in food traceability system in fact. Therefore, design a scientific, effective optimization algorithm to solve how to choose the best coalition partners association in food traceability system is essential. The standard PSO algorithm is improved in this research, aims to solve this question, and attempt to explain the mechanism of the traceability system.

2.2 Multi-Objective Optimization Model

Partner selection problem of the traceability system is considered as the traceability system has n sub-tasks or core abilities. That is

$$Task = r_1, r_2, \cdots, r_n,$$

Where sub-task r_i is presented as a node in the traceability system network. For a designated task, there is more than one partner willing to complete the task, that is to say, each node has m_i candidates subject. We choose the optimized candidate subject of each node. Comprehensively considered with every factor, we get a set contains all the optimized candidates subject of partners in the traceability system, which effectively achieve system-breadth, depth and precision of multi-objective optimization.

Let the optimized candidate set, which can complete sub-task r_i as:

$$E_i = \{e_{ij} \mid 1 \le j \le m_i, j \in N\}, (i = 1, 2, 3, \cdots, n)$$

t_{ij} is the time of j_{th} candidate subject to complete the task i. c_{ij} is the cost of jth candidate subject to complete the task i. q_{ij} is the quantity of jth candidate subject to complete the task i. S_{ij} is the satisfaction of jth candidate subject to complete the task i. p_{ij} is the price of produces which are produced during the jth candidate subject to complete the task i. T, C, Q and S individually present the total time, total cost , total profit and total satisfaction[16].

If the sub-tasks in the supply chain execute in order, we have:

$$\mathrm{T} = \sum_{i=1}^{n} \sum_{j=1}^{m_i} t_{ij} u_{ij} \tag{1}$$

$$C = \sum_{i=1}^{n} \sum_{j=1}^{m_i} c_{ij} u_{ij} \tag{2}$$

$$Q = \sum_{i=1}^{n} \sum_{j=1}^{m_i} (p_{ij} - c_{ij}) q_{ij} u_{ij} \tag{3}$$

$$S = \sum_{i=1}^{n} \sum_{j=1}^{m_i} (-S_{ij}) u_{ij} \tag{4}$$

Where,

$$u_{ij} = \begin{cases} 1, \textit{ candidate } e_{ij} \textit{ is selected to complete sub - task } r_i \\ 0, \textit{ candidate eij is not selected to complete sub - task } r_i \end{cases} \tag{5}$$

If the sub-tasks combination execute in parallel, the parallel section should take maximal executing time when calculating the total time by formula (1).

The budget of this problem is picking up a set of candidate $B = (b_1, b_2, \cdots, b_n)$, where $B \cap E_i = \{b_i\} (i = 1, 2, ..., n)$. It makes T and C getting minimal values, Q and S getting maximal values. This is a multi-objective optimization problem, that using the weighted average method to build multi-objective optimization problem into the following single objective optimization problem [17]:

$$\min f = w_1 T + w_2 C + w_3 (-Q) + w_4 (-S) \tag{6}$$

$$\text{s.t. } 0 \leq u_{ij} \leq 1, u_{ij} \in Z, 1, 2, ..., n; j = 1, 2, ...m_i; \sum_{k=1}^{4} w_k = 1 .$$

$w_k (k = 1, 2, 3, 4)$ is the sub goal weight. It can be determined by Expert scoring method or analytic hierarchy process.

2.3 Coding Solution

In multi-objective optimization model of the traceability system, we set $x = \{x_1, x_2, ...x_n\}$ as one selecting solution. n is the number of the tasks. x_i is the identifier of ith sub task's candidate, which is an arbitrary integer between 1 and m_i.

Let the food traceability system contains 10 sub tasks. Each sub task has 4 candidate subjects. The solution {3,2,4,2,2,4,3,1,4,3} presents 1st sub task is completed by 3rd candidate subject; 2nd sub task is completed by 2nd candidate subject; 3rd sub task is completed by 4th candidate subject and so on. Determining the optimal solution is a combination optimized problem. If the number of sub tasks and the candidate is huge, there is a time-consuming and huge workload work using exhaustive method. Therefore, it is necessary to choose or select a faster convergence of the optimization method.

Each partner in the traceability systems can be compared to Particle Swarm Optimization Algorithm (PSO). At present, some scholars have already used basic PSO algorithm for solving such combinatorial optimization problems [18]. In this paper, Constriction Factor Particle Swarm Optimization Algorithm, (CFPSO) is improved and applying for solving partner selection problems of food traceability system.

3. Algorithm Design

3.1 PSO

Similar to other evolution algorithm, PSO is an intelligent optimization algorithm. It was originally build by imitating birds, fish and other swarms of animals looking for food. PSO is simple and easy to achieve [19] . In PSO, each particle represents a feasible solution in the search space. All particles have a fitness value determined by the objective function. The speed and location of the particle determines its flying distance and direction. The particle updates itself by tracing two extreme values. One is the optimal solution the particle experienced, which is called person-best $(pbest^t_i)$. The other is the optimal solution the whole swarm currently found, which is called global-best $(gbest^t)$. Assume in a m dimensional search space, there is an particle swarm consist of n particles. The spatial location of ^{i}th particle is $X_i = (X_{i1}, X_{i2}, ..., X_{im})$. The speed is $V_i = (V_{i1}, V_{i2},..., V_{im})$ $(i = 1,2,3,...,n)$, where X_i is a potential solution of the optimization problem. It can be measured by corresponding fitness values, which is obtained when substituting X_i into the objective function.

In order to solve the problem, that is elementary particle swarm is difficult to ensure convergence, this paper improved the Constriction Factor Particle Swarm Optimization (CFPSO) proposed by M. Clerc and his partner [20]. The new speed and location function of CFPSO is:

$$v^{k+1}_{id} = \theta \ (v^k_{id} + c_1R_1 \ (pbest^k_{id} - x^k_{id}) + c_2R_2 \ (gbest^k_d - x^k_{id})) \quad (7)$$

$$x^{k+1}_{id} = x^k_{id} + v_{id}^{k+1} \quad (8)$$

Where $\theta = \dfrac{2}{\left| 2 - \phi - \sqrt{\phi^{2-4}\phi} \right|}$

is the compress factor , $\phi = R_1 + R_2$, and $\phi > 4.1$. c_1 and c_2 are acceleration factor, which are positive constant. R_1 and R_2 are two random number Uniformly distributed uniformly in the interval [0,1], which are used to ensure the particle swarm's diversity and randomness of searching.

Due to the clever parameter setting, CFPSO ensures the particles have stronger search ability and faster convergence speed, CFPSO can not only guarantee the convergence of the algorithm, but also get faster convergence speed. However, if the particle which has high fitness appears in the iterative process, it is easy to fall into premature convergence or local optimum. The algorithm would not find the global optimal solution. Therefore, it is necessary to improve CFPSO. Innovative idea of this paper is to filter the particle swarm, that is removing the particles have excellent or poor fitness. Using fitness scaling technology to transform fitness, fitness transformation function is set as:

$$Fitness = \frac{1}{objv(x) + F(x)} \quad (9)$$

Fitness is the individual particle fitness, *objv(x)* is the budget function, $F(x)$ is the penalty function when x beyond the scope of constraint.

The basic idea of improved CFPSO is filtering the swarm to avoid excellent fitness particle appeared untimely in the swarm, which would cause the algorithm into a premature. First, use fitness transformation function (9) to transform fitness. Filter the particles have high or low fitness. Shrink particles search space and increase the proportion of effective particles. Secondly, choose the particles has nice fitness from effective ones and copy them, and randomly generate some new particles, make sure copying and newly generated is equal to the number of particles filtered out, so that the number of particles remains the same. Cross between particles to increase the diversity of the population. In this way, the particles with unsuitable fitness are substituted by ones with fine particles. It will increase the proportion of particles with suitable fitness, and enhance the vitality of the swarm. It will also ensure CFPSO convergence speed while avoiding the search process prematurely trapped in local optima and increases the probability of convergence to the global optimal solution.

3.2 Improved CFPSO

Step1: Randomly produce a original swarm with *popsize* particles. Calculate each particle's fitness, which is the optimal value of the supply chain's partner in food traceability system. Set the $pbest^t_i$ of particle i as current location, the $gbest^t$ is as the location of the global optimal particle.

Step2: Initialized algorithm's parameter.

Step3: Update particle by formula (7) and (8), and produce new generation swarm.

Step4: Calculate the optimal supply chain's partner selected value of each particle in food traceability system. Filter swarms by fitness transformation function and filter out particles with unsuitable fitness. Choose some particles has nice fitness and copy. Generate some new particles randomly, cross substituted, and keep the swarm's size (*popsize*) as the same.

Step5: If fitness of particle i is better than its' ($pbest^t_i$), its' ($pbest^t_i$) is updated to current location. If one particle's fitness is better than ($gbest^t$), the ($gbest^t$) is updated to the current location of the particle.

Step6: Determine whether the algorithm has reached the requirement of error or achieve the maximum number of iterations. If satisfied, turn to Step 7. Or go to Step 3.

Step7: Output the optimal global fitness and its' location. This location is the optimal solution of supplier selected in traceability system.

3.3 Convergence Analysis

Let particle i's best experienced position coincides with the swarm's best experienced position and the swarm's best experienced position would not be changed after that. Set this moment as the initial time, the speed is v^i_o, the location is x^i_o, where

$$\phi = R_1 c_1 + R_2 + c_2$$

$$v_k = v^i_{d,k},$$

$$y_k = g_d - x^i_{d,k},$$

By formula (7), we get

$$\begin{bmatrix} v_{k+1} \\ y_{k+1} \end{bmatrix} = \begin{pmatrix} \theta & \theta\phi \\ -\theta & 1-\theta\phi \end{pmatrix} \begin{pmatrix} v_k \\ y_k \end{pmatrix} = \begin{pmatrix} \theta & \theta\phi \\ -\theta & 1-\theta\phi \end{pmatrix}^{k+1} \begin{pmatrix} v_0 \\ y_0 \end{pmatrix} \tag{10}$$

M. Clerc and J.Kennedy(2002)have improved that the above iteration process is convergent [20]. When the number of iteration tends to infinity, the particle's speed is 0. In the end, it will convergent to the global best position g_d.

$$\lim_{k \to \propto} \begin{pmatrix} v_{k+1} \\ y_{k+1} \end{pmatrix} = 0, \quad \lim_{k \to \propto} x^i_{d,k} = g_d \tag{11}$$

In CFPSO, if the global optimal solution has not been found when the best position is no longer updating, the algorithm will fall into premature convergence through endless iterations. The improved CFPSO in this paper adds the fitness scaling technology and particle swarm cross operations, filtering out the undesirable particles and ensuring the swarm's activity. The improved CFPSO doesn't change the swarm's size and the main framework of the algorithm. According to the convergence of CFPSO [21], the improved algorithm in this paper is also convergent.

3.4 Simulation And Result

Design a multiple budget partner selection simulation program of a food traceability system in MATLAB According to the necessary of simulation, the program can generate different number of task, candidate enterprise of each sub task, and time, cost, profit and satisfaction of each candidate enterprise. Then use the improved CFPSO to get the best solution of finding *gbest*^{t}.

The size of swarm is 50. The maximum The maximum allowable number of iterations is 500. The food traceability system consists of 10 sub tasks. Individually, the sub tasks have 3, 5, 4, 3, 2, 4, 3, 5, 2, 4 candidates. The weight of budget function sets as w_1 = 0.28, w_2 = 0.29, w_3 = 0.21, w_4 = 0.22. Apply CFPSO and improved CFPSO in the partner selection model. Figure 1 shows the convergence of budget function when applying two algorithms. Figure 2 and 3 shows the trends of partners' profit and satisfaction when applying improved CFPSO in the system.

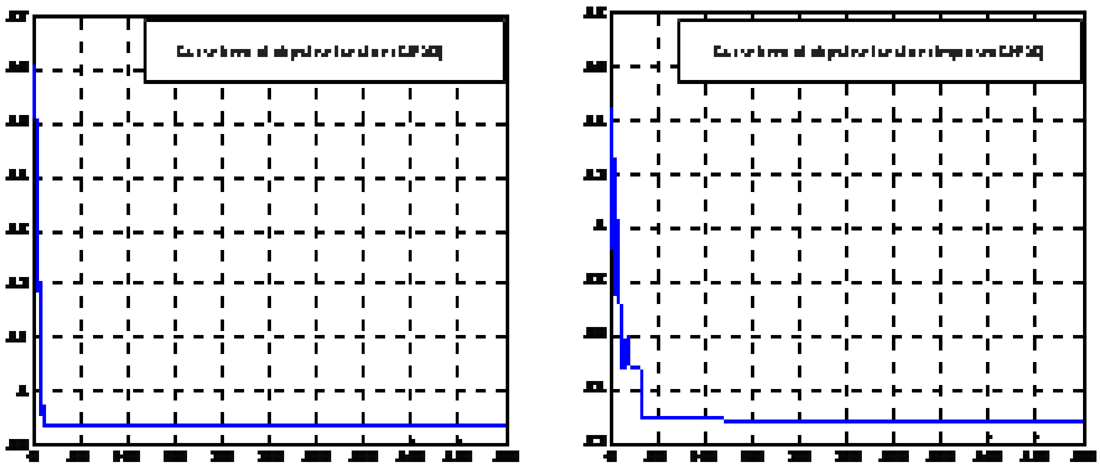

Figure 1. Comparison optimal curve between CFPSO and improved CFPSO

From the simulation result of Figure 1, when the number of iteration is between 0 and 50, it will fall into premature (local optimal solution) when finding best partner by CFPSO. The improved CFPSO solves the problem. It improved swarm's updating strategy, helping the swarm jumping out the local optimization. The improved CFPSO algorithm does not only ensure convergence speed and stability, but also improve the ability to jump out of the local solution.

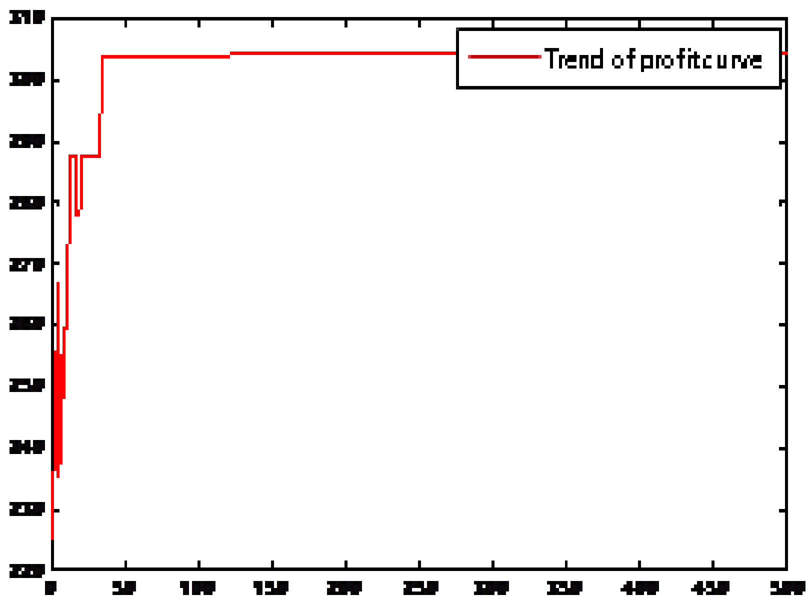

Figure 2. Profit curve with iteration

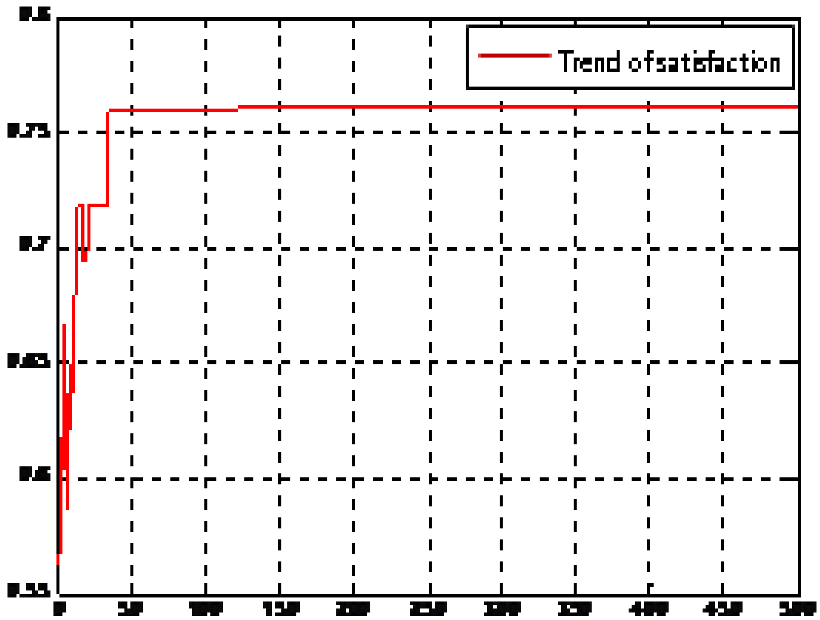

Figure 3. Satisfaction curve with iteration

From Figure 2 and Figure 3, the food traceability system achieves best overall profit by using improved CFPSO. At every node, the enterprises' satisfaction is above 75%. It basically realized the budget to maximize the profit.

4. Conclusions

For partner selection optimization problem of food traceability system, this paper proposes an improved Constriction Factor Particle Swarm Optimization Algorithm with filtering mechanism. In order to weed out the appropriate number of particles which has excellent or poor fitness, the particle swarm of the improved algorithm transforms the fitness in the evolution process firstly. Then copy the fitness of some individuals more desirable and intersect with certain number of new randomly generated individuals. It will increase the proportion of the best individual in the system, and decrease the excellent or poor individuals, while ensuring the number of the population in the system remains the same.

Simulation results using Matlab show that, in general, the proposed improved CFPSO can avoid premature local optimum solution, improve search speed, and increase the probability of convergence to the global optimal solution.

Applying improved algorithm in the food traceability system can shorten the response time of the system, reduce the total cost of the entire system, increase the total output of the entire system as well as improve the overall satisfaction of the whole system. It will also conducive to food traceability systems to maximize synergies in revenue in each subject, conducive to ensuring food safety, and improving the competitiveness of the whole process of the food traceability symbiotic chain.

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