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Research Article

Modeling and Optimization of Food Cold-chain Intelligent Logistics Distribution Network

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Abstract: Aiming at improving the efficiency of food cold-chain logistics network, shortening the logistic time of food and reducing the logistics cost of food, this study analyzes the optimization strategy and various cost factors of the supply network of food cold chain and establishes and expands a kind of logistics network model adapting to the food cold-chain logistics. We use an improved genetic algorithm to solve the model and design an effective coding scheme, through the modified adaptive crossover probability and mutation probability, we integrate them into the elitism strategy, which has effectively avoided the prematurity of the algorithm and improved the operation efficiency of the algorithm. In the same instance, compared with the simple genetic algorithm, this study puts forward that the average running time and the average iteration number of the improved genetic algorithm have reduced nearly 50%, which has proved the feasibility and the effectiveness of the model and the algorithm.

Keywords: Elitism strategy, food cold chain, genetic algorithm, logistics network

INTRODUCTION

Cold chain is a kind of supply chain to control temperatures and a complete cold chain including a series of activities such as processing, storage, transportation, logistics, retail, until consumption, which are all conducted in a given environment temperature. Cold chain can ensure the quality safety of perishable products, cut down the consumption of products, prevent product contamination and extend the shelf life of products (Jiao *et al*., 2014).

Cold chain is mainly applied to the food industry, such as: agricultural products including fruits, vegetables, meat products, eggs, dairy products, aquatic products etc., (Laguerre *et al*., 2013); it also can be used in the pharmaceutical industry, for example: the supply of vaccines. The process of cold chain is the extension of a good supervision system and specification, (Montanari, 2008) so for the construction of cold chain logistics, we need to consider the problems in all links of the process such as production, transportation, sales, economy and technicality as a whole and coordinate the relationship among all links to ensure the safety of perishable food in the process of cold chain and it is a cryogenic systems engineering with high technology content (Van Donk *et al*., 2008).

Logistics network optimization is an important part of supply chain management and the planning and design to logistics network is the foundation of the implementation of enterprises' strategic decisions (Hoang *et al*., 2012). In the face of the increasingly fierce market competition and diversified market demands, enterprises' focus has turned from the traditional procurement and manufacturing to provide products and services through logistics network to meet users' demands and more and more attention has paid to the logistics links, therefore, the reasonable construction of logistics network is significant and meaningful to enterprises. In the supply chain, logistics is an important means to improve the economic efficiency of enterprises through middlemen to play their sales function and establishing a good and stable logistics network is an important method for enterprises to improve competitiveness. Through the research of the value distribution in the supply chain (Jens and Gine, 2011). We can find that logistics cost occupies a considerable proportion. Therefore, designing and running a reasonable and efficient logistics network can make enterprises to improve the customer service level, enhance enterprise competitiveness and production flexibility, increase the ability to penetrate into new markets and achieve an effective balance between costs and services to further improve enterprise competitiveness (Liu *et al*., 2013).

In this study, we use an improved genetic algorithm to solve the model and design an effective coding scheme, through the modified adaptive crossover probability and mutation probability, we integrate them into the elitism strategy, which has

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effectively avoided the prematurity of the algorithm and improved the operation efficiency of the algorithm.

MATERIALS AND METHODS

The logistics model of food cold chain: Food cold chain is formed by different sizes and different number of participants, including suppliers of food raw materials, food manufacturers, catering service providers, food wholesalers and retailers, consumers, the provider of food cold chain logistic services, (Fig. 1) etc. and from the figure, we can know that different participants of the food cold chain have close relationship, so they can form different structural forms of food cold chain. Food processing manufactures also can directly provide food to consumers and food manufactures can provide food to consumers through catering service providers, while the provider of food cold chain logistic services can run through the whole food cold chain to establish the circulation bond of food among all participants. These participants of cold chain that can directly provide food including suppliers of food raw materials and food manufacturers can boil down to suppliers and the participants of cold chain that provide food to consumers but not directly produce food including food wholesalers and retailers and catering service providers can come down to sellers, as a result, food cold chain can be simplified to be composed of food suppliers, food sellers and consumers.

Food cold chain logistics is a special supply chain system: One is the particularity of objects. The objects of food cold chain logistics are perishable fresh food; the second is the particularity of operating environment. The storage and operating environment of cold chain logistics must be limited to appropriate low-temperature environment. According to the particularities, we also can define food cold chain logistics as: a set of comprehensive facilities and management means that use certain technological means to make fresh food kept incessantly under certain suitable conditions and furthest keep the quality of fresh food during the whole process of harvest, processing, packaging, storage, transportation and sales and the logistics system formed by all logistics links under complete low temperature environment is called food cold chain logistics.

The general chain structural model of the logistics of cold chain food is shown in Fig. 2.

Raw material acquisition of cold chain food: This is the first link of food cold chain. And in this link, the supply of goods of cold chain food can be got through artificial cultivation or from the nature (Kuo and Chen, 2010).

Initial processing: Food raw materials need sorting and simple processing firstly, for example, the fish captured by catching should be sorted and simply processed according to different market demands before

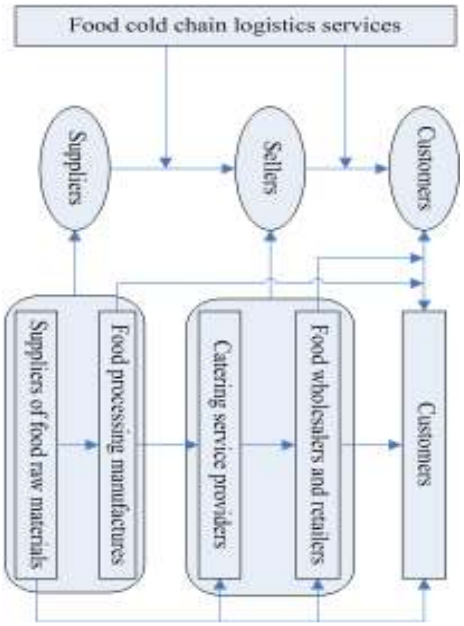

Fig. 1: Formation of food cold chain

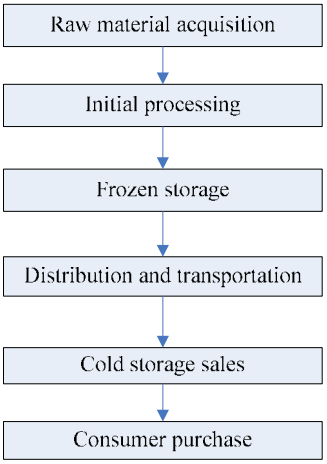

Fig. 2: Chain structural model of the logistics of cold chain food

they are sold in the market and the food raw materials cultivated by suppliers themselves also need the similar process, such as beef, cattle should be slaughtered first and the beef should be sorted and so on according to different parts, the cooling and freezing of meat and poultry, fish and eggs, the pre-cooling of fruits and vegetables, etc. and then after simple package of various quick-frozen food, the packaged food can be sold by bulk to suppliers for production or subsequent process (Xu, 2013).

Freezing processing/storage: It is the processing operation process of freezing processing under low temperature condition, including the low temperature processing of all kinds of quick-frozen food and diary products, etc., (Aung and Chang, 2014). Through

cooling and freezing equipment, quick-freezing plants and so on, the temperature in the manufacturing process can be effectively controlled.

Transportation and handling: Cold chain logistics is a logistics process, goods is in a constant flow condition and all logistics nodes need loading and unloading and handling, for example, in pork processing enterprises, the process of pork from the processing workshop to the storehouse, or the process form the warehouses of the processing enterprises to the third-party logistics center. This process is in the early position of the cold chain logistics, so it also needs to control temperatures well.

Refrigerated transport: The biggest characteristic of this link is that it runs through the whole cold chain, connects different links of cold chain and puts other links together to form a complete cold chain logistics. Refrigerated transport can ensure that food can always be in low temperatures in such logistics links as intermediate and long-distance transport and short-distance distribution.

Frozen sales: After cold chain food is out of distribution centers, it enters the stage of frozen storage and sales of the link of wholesale and retail, it generally will be sold at retail counters and this link is jointly completed by manufacturers, wholesalers and retailers.

The network structure of food cold chain logistics transportation: In a broad sense, the network system of food cold chain logistics transportation includes a comprehensive use of many links of the procurement, washing and processing, storage, transportation and sales of food enterprises' materials and raw materials. In a narrow sense, it refers to a circulation process that take the acquisition of food materials and raw materials as a starting point, continue and pass the procedures and links such as sales, transportation, distribution processing of middlemen (including food packaging and sorting) and transfer and finally deliver the food to end-users for consumption (Bertolini and Romagnoli, 2012).

The network structure of food cold chain logistics transportation is a complex transportation network structure that is composed of many starting points and end points, multiple transportation routes, a variety of modes of transportation and transportation facilities that cross each other (James and James, 2010). A kind of network expression in "graph theory" can be introduced into the food cold chain logistics transportation system, abstract out the common characteristics of the transportation network formed by various modes of transportation and express them with symbols of the network graph theory (Lou *et al*., 2013).

Here, we describe the definition of food cold chain logistics transportation network as follows:

$$G = \{N,\ V,\ W\}$$

Among them:

G = Food cold chain logistics transportation network
N = All nodes in the food cold chain logistics transportation network
V = Sides in the food cold chain logistics transportation network
W = The weight of the sides in the food cold chain logistics transportation network in the whole food cold chain logistics transportation network

Logistics network is a network system composed of more than one member enterprises; its total cost minimization is not only the minimization of the cost of a single enterprise, but the minimization of the cost of the whole logistics network system. As the proportion of the expenses of facilities, inventory and transportation in the cost system is very large, we need to have a systematic and comprehensive analysis. The total cost includes: the fixed cost FC of logistics centers j, the ordering cost CO of logistics centers j, inventory holding cost CH and shortage cost CL; freight transport cost C T1 from production plants to logistics centers and freight transport cost C T2 from logistics centers to logistics points.

The intelligent optimization strategy of logistics network: Genetic Algorithm (GA for short) was proposed by American Michigan University's Professor John Holland in 1960s and it is a kind of adaptive artificial intelligence technology that simulates biological evolution process and mechanism to solve problems. Its core idea originates from such a basic understanding: the biological evolution process itself from simple to complex and from low level to high level is a natural and steady optimization process occurring in parallel, whose purpose is the adaptability to the environment and biotic population achieve the goal of evolution through the "fittest" and genetic variation. This algorithm is a global optimization method formed on the basis of natural genetic and natural optimization mechanism. Genetic algorithm is to express problem-solution as "chromosome", place them in the "environment" of questions, according to the principle of survival of the fittest, select and replicate the "chromosome" that adapts to the environment, namely reproduction and through the two kinds of genetic manipulation of crossover and mutation to produce a new generation of "chromosome" complex that adapts to the environment better, thus, generations and generations continue to improve, until the convergence to an individual that is most suitable to the environment (of course, there are other convergence criteria) to obtain the optimal solution of problems.

Coding scheme: The primary problem and key step of genetic algorithm is how to encode solutions of problems to chromosomes. At present, the encoding scheme can be divided into binary encoding, real number encoding, integer or alphabetical order, general data structure encoding, etc.

Population size and initial population: The scale of the population size greatly affects the performance of GA and is the key factor for GA ability of solution. The larger the scale is, the more solutions the algorithm can deal with, the smaller the risk of falling into local solutions is, so it is easy to find the global optimal solution, but the calculated amount also will increase significantly and the search time will become long. If the population size is too small to make GA searching space limited, more iterations are needed to search for better solutions or the optimal solution and sometimes it is easy to cause prematurity of the algorithm (Jedermann *et al*., 2009).

Fitness function: GA expresses the problem space as chromosome bit string space and in order to implement the principle of survival of the fittest, the adaptability of individual bit string must be evaluated (Joshi *et al*., 2010). The evaluation of fitness function is the basis of choosing operation and the design of fitness function directly affects the performance of genetic algorithm. A good chromosome bit string structure has a good value of fitness function, namely it can obtain higher evaluation and has strong survival ability and the ability of reproduction.

Selection: Essentially speaking, the principle of GA is based on Darwin's theory of natural selection, selection provides the driving force of GA, the purpose is to achieve survival of the fittest and the operation of choosing the winners from groups and eliminating inferior individuals is called selection.

Crossover: It is the crossover operator that plays a core role in GA. GA crossover operator is to imitate the genetic recombination process of sexual propagation of nature and the function is to pass the original good genes on the next generation of individuals and generate new individuals with more complex genetic structure.

Mutation: According to Darwin's theory of evolution, individuals in the population may have the phenomenon of mutation. Introducing the idea of mutation when proposing genetic algorithm can effectively prevent the occurrence of premature convergence and improve GA's local searching efficiency and for the usual binary encoding, mutation operator usually flips genetic values, for example, invert 0 to 1, or invert 1 to 0.

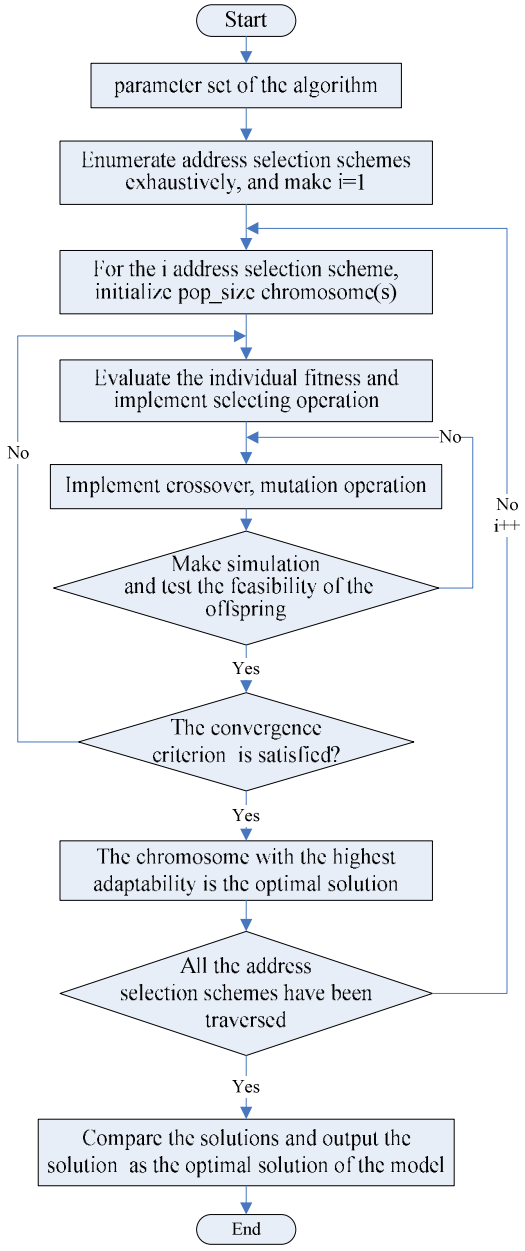

Fig. 3: Flow chart of the optimization algorithm

Elitism strategy: In order to ensure that each generation of excellent individuals will not be destroyed, the elitism strategy is adopted. The so-called elitism strategy is: if the best individual adaptive value is less than that in the current population, the best individuals in the current population or the adaptive value that is greater than the best individual adaptive value of the next generation will be directly copied to the next generation to randomly replace or replace the corresponding number of individuals in the worst next generation.

The flow diagram of the network optimization design based on genetic algorithm in this study is as shown in the Fig. 3.

Table 1: Comparative analysis between the two algorithm

Algorithm	Comparative item	Logistics center/logistics point p = 6/q = 16
Basic genetic algorithm	Average running time (sec)	16.2
	Average number of iterations	68.0
Improved genetic algorithm	Average running time (sec)	8.2
	Average number of iterations	36.0

RESULTS AND DISCUSSION

There is a pig-breeding enterprise with the monthly pig slaughter of over 30000 and the pigs are sold throughout the country. The logistics network of the enterprise includes 3 slaughter houses (A, B and C), 6 alternative logistics centers and 16 logistics points. The daily maximum slaughter capacity of slaughter house A, B and C is respectively 400, 350 and 400 heads/day, respectively the expense of transporting raw pork from the slaughter houses to the logistics centers is 0.36 Yuan/km and the expense of transporting raw pork from the logistics centers to the logistics points is 0.78 Yuan/km.

In the situation that all other parameters are the same, the performance of the improved genetic algorithm and the basic genetic algorithm is compared as Table 1.

By comparing the results of the two kinds of optimization algorithms, we can find that under the condition with the same parameter setting, the improved genetic algorithm has a fast arithmetic speed, good convergence and strong stability and it especially has obvious advantages when calculating large scale problems. Through instance analysis, it has been proved that the algorithm has better optimization effect on the logistics network optimization model based on inventory control proposed in this study.

CONCLUSION

Aiming at improving the efficiency of food cold-chain logistics network, shortening the logistic time of food and reducing the logistics cost of food, a genetic operator is designed reasonably and an improved genetic algorithm is used to solve the model in this study through adaptive crossover probability and mutation probability. Comparing the improved genetic algorithm with the basic genetic algorithm, we have found that the improved genetic algorithm has advantages such as the prevention of premature convergence and the slowness of the late searching stage, fast arithmetic speed, good convergence and strong stability (Ruiz-Garcia and Lunadei, 2011). Through the research on logistics network optimization of typical cold-chain enterprises and applying the systematic theoretical method to conduct empirical analysis, the feasibility and the effectiveness of the model and the algorithm have been proved.

As some variables of logistics network may be vague, such as the fuzziness of considering customers' demands and the uncertainty of production capacity of sub plants, we can consider to use the fuzzy mathematical method to deal with and handle the problems of logistics network optimization and use the method of the combination of a variety of optimization algorithms to solve the model so as to further improve the solution efficiency of the model.

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