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Application of Genetic Algorithm in Optimization of Supply Chain Inventory

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Abstract: *In this paper developing a novel and efficient approach using Genetic Algorithm which clearly determines the most possible excess stock level and shortage level that is needed for inventory optimization in the supply chain so as to minimize the total supply chain cost has been discussed.*

Keywords: *Genetic Algorithm, Supply chain, Crossover, Mutation*

INTRODUCTION

Genetic algorithms were formally introduced in United States in the 1970s by John Holland at University of Michigan. The continuing price and performance improvements of computational systems have made them attractive for some types of optimization. In particular Genetic Algorithm work well on mixed (continuous and discrete), combinatorial problems.

Optimization is the methodology for improving the quality and desirability of a product or product concept. It is the process of finding function extrema to solve problems and finding an alternative with the most cost effective or highest achievable performance under the given constraints, by maximizing desired factors and minimizing undesired ones. In design, construction and maintenance of any engineering system, engineers have to take many technological and managerial decisions at several stages. The ultimate goal of all such decisions is focused on the benefit.

Supply Chain

A supply chain encompasses all activities in fulfilling customer demands and requests. These activities are associated with the flow and transformation of goods from the raw materials stage, through to the end user, as well as the associated information and funds flow. A typical supply chain network is shown in Fig. 1

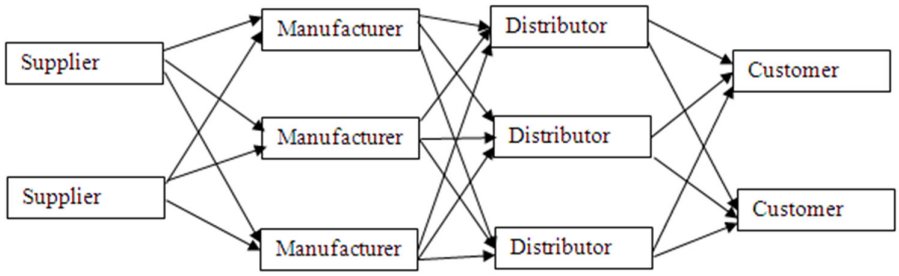

Fig. 1: Typical Supply Chain Network

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That is a supply chain incorporates multiple entities that work in coalition towards,

- Obtaining raw materials,
- Converting these raw materials into precise end products and
- Delivering the end products to retailers.

Each manufacturer or distributor has some subset of the supply chain that it must manage and run profitably and efficiently to survive and grow. Managing the entire supply chain becomes a key factor for the successful business. The minimization of the total supply chain cost can only be achieved when optimization of the base stock level is carried out at each member of the supply chain.

Genetic Operator and Algorithm

A simple Genetic Algorithm largely uses three basic operators which are

1. Reproduction
2. Crossover
3. Mutation

The individuals likelihood for survival and mating is determined by the fitness function. In accordance with the Darwin's principle individuals superior to their competitors, are more likely to promote their genes to next generation. Thus, the first operator applied on a population selects good chromosomes in a population which is usually referred as **Reproduction**.

Crossover is a recombination operator, which proceeds in three steps:

- The reproduction operator selects at random a pair of two individual strings for mating.
- A cross site is selected at random along the string length and
- The position values are swapped between two strings.

There are basically five types of crossover. They are

1. Single-site crossover
2. Two-point crossover
3. Multi-point crossover
4. Uniform crossover
5. Matrix crossover

Single-site and Two-point crossover are most commonly used in GA.

Genetic Algorithm for Optimization of Single Factory, Multiproduct Supply Chain

The type of supply chain discussed is three stage seven member supply chain as shown in Fig. 3

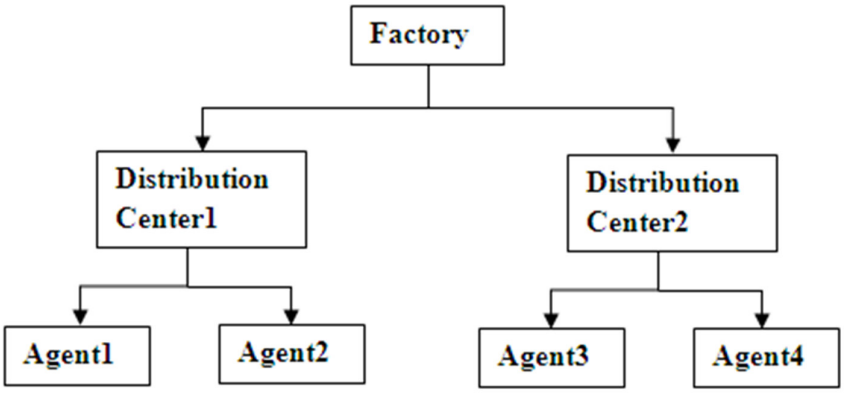

Fig.3 : 3 stage 7 member supply chain

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As shown in Fig.3 a factory is the parent of the chain and it is having two distribution centers i.e., Distribution center1 and Distribution center2. Each distribution center further comprises of several agents but as stated in this exemplary case, each distribution center is having two agents. So, in aggregate there are four agents, Agent1 and Agent2 for Distribution center1, Agent3 and Agent4 for Distribution center2.

The factory manufactures different products that would be supplied to the distribution centers. From the distribution center, the stocks will be moved to the corresponding agents. To make the inventory control effective, the most primary objective is to predict where, why and how much of the control is required. Such a prediction is to be made through Genetic Algorithm.

The analysis flow is initiated by the selection of valid records. The validation of records is done over the records of past periods. In the valid record set selection, records having positive and negative values are selected for the analysis. This can be done by means of Clustering algorithm, Extraction algorithm or by any of the data mining functions. Hence the extraction function results in data sets having either positive or negative values. Then the data set is subjected to GA.

Generation of Individuals

Each individual which is constituted by genes is generated with random values. Here, the chromosome of seven genes where the random values occupy each gene is generated along with the product representation. A random individual generated for genetic operation is shown in Fig.4

P1	200	700	-400	600	-800	-100	600
P2	600	-100	-500	400	-300	600	-700
P3	500	300	-600	400	900	-800	600

Fig. 4: Random individual generated for the genetic operation

Each gene of the chromosome displayed in Fig. 4 is the stock level of the product with that particular number. Three individuals, Individual1 deals with product1, Individual2 deals with product2 and Individual3 deals with product3. So the first individual P1 represents 200 excess stocks in factory, 700 excess stocks in Distribution center1, and shortage1 400 stocks in Distribution center2 and so on. In such a manner the other individuals represent the product P2 and the product P3.

After the generation of the individuals, the number of occurrences of the individual in the past records is determined. This is performed by the function count ( ) and the total number of occurrences of that individual for the particular product is determined. This is equivalent to the number of occurrences of such situation of stock levels for the particular product in all the members throughout the period.

Fitness Function

A specific kind of objective function that enumerates the optimality of a solution in a Genetic Algorithm in order to rank certain chromosome against all other chromosomes is known as fitness function. Optimal chromosomes, or atleast chromosomes which are near optimal, are permitted to breed and merge their data sets through one of the several technique available in order to produce a new generation that will be better than the once considered thus far.
The fitness function is given by,

$$f(k) = \log\left(1 - \frac{N_c}{N_{tot}}\right), \quad k = 1,2,3 \dots \dots \dots \dots m$$

where,
N_c is the number of occurrences of the chromosome k in record set.
N_{tot} is the total number of inventory values obtained after clustering.
m is the total number of chromosomes for which the fitness function is calculated.

The fitness function mentioned ranks the randomly generated chromosome. Then, the chromosomes are subjected to genetic operations. Genetic operations comprises of selection, crossover and mutation.

Genetic Operators

Selection

The selection operation is the initial genetic operation which is responsible for the selection of the fittest chromosome for further genetic operation. This is done by offering ranks based on the calculated fitness to each of the prevailing chromosome. On the basis of this ranking, best chromosomes are selected for further proceedings.

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Crossover

Among the numerous crossover operators in practice, for this complex operation, two point crossover is chosen. From the mating pool, two chromosomes are subjected for the two point crossover. The crossover operation performed in this analysis is pictured in Fig. 6

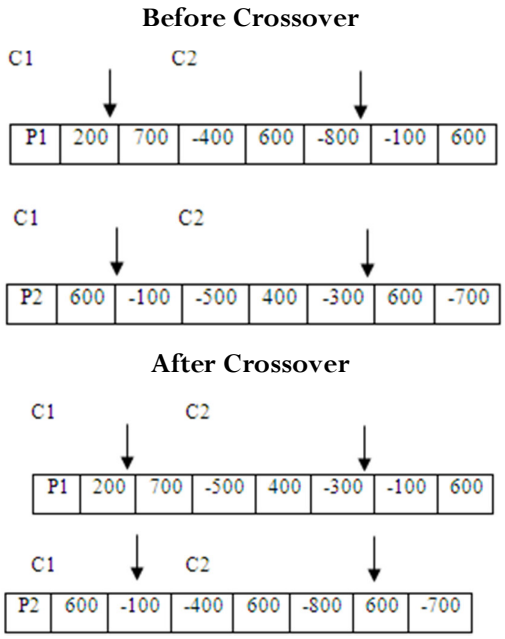

Fig. 5: Chromosomes are subjected to crossover operation

As soon as the crossover operation is completed, the genes of the two chromosomes present within the two crossover points get interchanged. The genes before the crossover point C1 and the genes beyond the crossover point C2 remain unaltered even after the crossover operation.

Mutation

The crossover operation is succeeded by the final stage of genetic operation known as Mutation. A new child chromosome is obtained by this process which is fitter than the parent chromosome. Four mutations Mp1, Mp2, Mp3 and Mp4 points are selected randomly which points any four genes of a particular chromosome as shown in Fig. 6

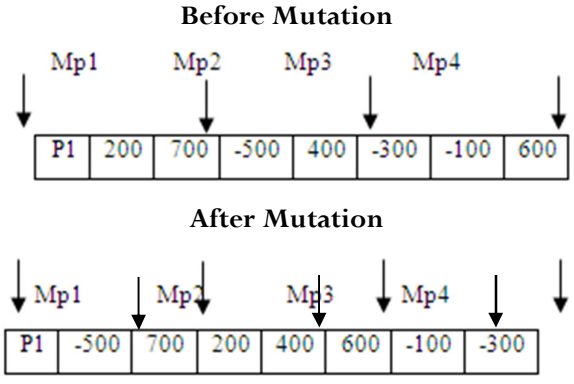

Fig. 6: Chromosomes subjected to Mutation operation

The process explained so far will be repeated along with the new chromosome obtained from the previous process. Eventually an individual which is the optimal one among all the possible individuals is obtained.

Experimental Result

The approach suggested for the optimization of inventory level and thereby efficient supply chain management has been implemented in the platform of MATLAB. The database consists of the records of stock levels held by each member of the supply chain for every period.

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The five different products and these products are in circulation in the seven member supply chain network is considered. The sample database which consists of the past records is shown in Table 1.

Table 1: A sample dataset constituted by the product identification along with its stock levels

PI	F	Distribution center1	Distribution center2	Agent1	Agent2	Agent3	Agent4
5	-407	379	-981	-864	-391	999	-196
2	-146	-604	443	746	-561	-734	445
4	-962	-524	-685	-254	205	446	-469
3	-834	266	969	965	735	244	-752
3	-449	-282	577	-926	-414	-200	-743
4	540	-830	-835	882	-379	768	-635
4	-371	-736	-299	634	448	756	340
3	-778	-313	629	-690	824	-927	850
2	351	293	328	-732	357	-566	685
1	500	108	490	-345	-236	108	-931
5	844	-728	286	740	686	-421	424
4	-321	902	-450	-260	-144	162	238
3	775	-394	-520	-792	-927	-879	-507
4	794	932	-584	307	-171	-529	-503
2	-122	-686	-620	424	-891	-824	941
3	235	464	401	108	346	840	-934
5	218	-848	836	133	-554	-939	-834
4	489	409	148	850	196	851	-495
3	-422	638	676	-112	539	107	-440
5	893	520	-423	-736	-778	863	-335

In the database tabulated in Table 4.1, the first field comprises of the Product Identification (PI) and the other fields are related with the stock levels that were held by the respective seven members of the supply chain network. For example, the first attribute and first field of the database is '5' which refers the PI 5. The corresponding fields of the same attribute denote the stock levels of the product ID '5' in the respective members of the supply chain. Similarly, different sets of stock levels are held by the database.

As per the proposed analysis based on GA, the random initial chromosome [4 895-732 485 -213 -270 314 -850] is generated. This will represent the database content as shown in Fig.8

PI	F	Distribution center1	Distribution center2	Agent1	Agent2	Agent3	Agent4
4	895	-732	485	-213	-270	314	-850

Fig. 8: Random individual chromosome representation

In this manner two different random chromosomes have been generated and they will be subjected for genetic operations like Fitness evaluation, Selection, Crossover and Mutation. An iteration involving all these process was carried out so as to obtain the best chromosome. Here for instance, the iteration value is chosen as 100 and so hundred iterative steps will be performed. The best chromosome obtained is, [1 697 -906 304 257 849 -444 -845].

This final chromosome that has been obtained from the GA based analysis is the inventory level that caused maximum increase of supply chain cost. By maintaining the inverse of these kinds of stock levels, that is [-1 -697 906 -304 -257 -849 444 845] supply chain cost can be minimized. This is the optimal stock level that needs to be maintained in order to make the supply chain cost minimum. Thus by following the predicted stock levels, increase of supply chain cost can be avoided.

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