Predictive Analytics using Genetic Algorithm for Efficient Supply Chain Inventory Optimization

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Summary
A key concern for global manufacturers today is to reduce inventory and inventory driven costs across their supply and distribution networks. Efficient and effective management of inventory throughout the supply chain significantly improves the ultimate service provided to the customer Minimizing the total supply chain cost refers to the reduction of holding and shortage cost in the entire supply chain. Efficient inventory management is a complex process which entails the management of the inventory in the whole supply chain. The dynamic nature of the excess stock level and shortage level over all the periods is a serious issue when implementation is considered. In addition, consideration of multiple factories, multiple products leads to very complex inventory management process The complexity of the problem increases when more distribution centers and agents are involved. In this paper, these issues of inventory management have been focused and a novel approach based on Genetic Algorithm has been proposed in which the most probable excess stock level and shortage level required for inventory optimization in the supply chain is distinctively determined so as to achieve minimum total supply chain cost.

Keywords:
Supply Chain Management, Inventory control, Inventory Optimization, Genetic Algorithm, supply chain cost.

1. Introduction

Global competition, shorter product life cycles, dynamic changes of demand patterns and product varieties and environmental standards cause remarkable changes in the market scenario thereby thrusting the manufacturing enterprises to deliver their best in order to strive [1]. Decrease in lead times and expenses, enrichment of customer service levels and advanced product quality are the characteristics that determine the competitiveness of a company in the contemporary market place [4]. The above mentioned factors have made the business enterprises to contemplate about their supply chains. An ensemble of organizations providing products and services to the market may be called as a supply chain.

The effective management of the supply chain has become unavoidable these days due to the firm increase in customer service levels [3]. The supply chain cost was immensely influenced by the overload or shortage of inventories. Thus inventory optimization has transpired into one of the most recent topics as far as supply chain management is considered [2], [5], [6].
This paper supplements the previous study that focuses only on a single factory and single product[7]. Here, we are considering the situation of multiple Factories, multiple products and multiple agents of the supply chain. The determination of the stock level that occurs most frequently over a period under consideration is an essential information for inventory optimization.
The proposed approach of genetic algorithm predicts the most emerging stock levels of the future by considering the stock levels of the past periods such that the total supply chain cost can be minimized.

2. Method and Methodology

The inventory control for more number of products along with different levels of supply chain is a complex task. 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 here through the and the methodology we have proposed. to estimate the level of stocks of the particular products to be maintained by the respective members of the supply chain in the upcoming period. For instance, we are taking a three stage supply chain having six members and it is depicted in Fig. 1.
As shown in Fig. 1, there are 3 factories which are the parents of the chain and they are having one distribution center. The Distribution center further comprises of several agents but as stated in our exemplary case, the Distribution center is having two agents.

Manuscript received March 5, 2010
Manuscript revised March 20, 2010

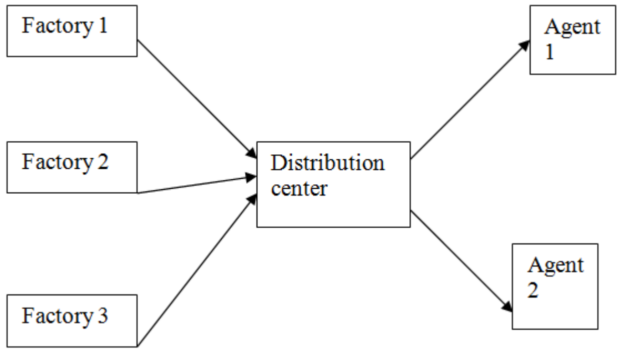

Fig. 1: 3 stage-6 member supply chain

Also in our exemplary case, we assume that factory1 manufactures products P1 and P2, factory2 manufactures products P1, P2, P3 and factory 3 manufactures products P2 and P3 that would be supplied to the distribution center.

From the distribution center, the respective stocks will be moved to the corresponding agents. In our exemplary case, we make further assumption that Agent 1 deals with products P1,P2 and Agent 2 deals with products P2,P3.

Our analysis will determine whether the stock level of the particular product to be maintained by the different members of the supply chain needs to be in abundance in order to avoid shortage of the product or needs to be held minimal in order to minimize the holding cost.

The methodology flow as shown in Fig. 2 would analyze the past records very effectively and thus facilitate efficient inventory management with the contribution of Genetic Algorithm. The analysis flow is initiated by the selection of valid records. The validation of records are done over the records of past periods.

The stock levels for the respective products at each member are considered as data set as shown in the Table 1. In the valid record set selection, records having nil values are neglected and the records having positive or negative values are selected for the analysis. This can be done by means of clustering algorithms, extraction algorithms or by any of the data mining functions. Hence the extraction function results in data sets having either positive or negative values.

Figure 2 describes the Genetic algorithm procedure that each random individual chromosome will go through genetic operators selection, cross over and mutation and with each iteration the best chromosome will be included for consideration in subsequent iterations. Here n_{occ} refers to the number of occurrences of records of similar amount of stock level for the six members in the supply chain.

The numbers in the Table 1 having positive values represents excess stock levels of the product and the negative values represent shortage level of the product in the respective members of the supply chain. Then the data set is subjected to Genetic Algorithm and the various steps performed in the genetic algorithm are discussed below.

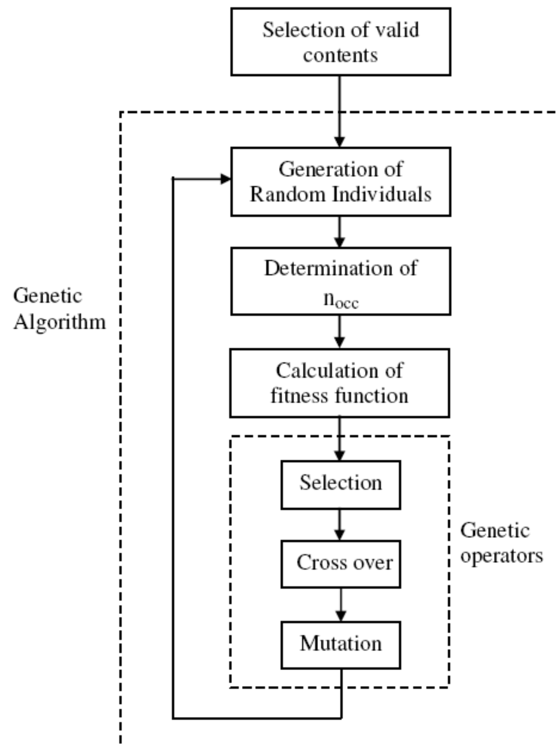

Figure 2. Genetic Algorithm flow for the proposed inventory management analysis

Generation of individuals: Each individual which is constituted by genes is generated with random values. Here, the chromosome of 14 genes where the random values occupy each gene is generated along with the product representation. A random individual generated for the genetic operation is shown in the Fig. 3.

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 respective product in all the members throughout the period under consideration.

Evaluation of 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 the other chromosomes is known as Fitness function.

Optimal chromosomes, or at least chromosomes which are near optimal, are permitted to breed and merge their datasets through one of the several techniques available in order to produce a new generation that will be better than the ones considered thus far.

Table 1. The dataset format for the analysis taken from the past periods

Factory1		Factory2			Factory3		Distribution center 1			Agent 1		Agent 2	
P1	P2	P1	P2	P3	P2	P3	P1	P2	P3	P1	P2	P2	P3
100	-20	36	-65	42	25	-170	48	23	-79	100	-200	289	-423

300	-35	100	67	-87	45	-90	84	-84	90	200	-300	72	-90

Fig. 3: Random individual generated for the genetic operation

The fitness function is given by:

$$f(i) = \log\left(1 - \frac{n_{occ}(i)}{n_{tot}}\right), \ i = 1,2,3,\cdots,n$$

Where:

$n_{occ}(i)$ = The number of occurrences of the chromosome i in the record set

n_{tot} = The total number of records that have been collected from the past or total number of data present in the record set

The fitness function mentioned ranks the randomly generated chromosome. Then, the chromosomes are subjected to the genetic operations.

Genetic operations: Once fitness calculation is done, Genetic operations are performed. Selection, Crossover and mutation comprise Genetic operations.

Selection: The selection operation is the initial genetic operation which is responsible for the selection of the fittest chromosome for further genetic operations. 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.

Crossover: Among the numerous crossover operators in practice, for our complex operation, we have chosen two point crossover. From the matting pool, two chromosomes are subjected for the two point crossover. The crossover operation performed in our analysis is pictured in Fig. 4.

Before Crossover:

C1 (after gene 4), C2 (after gene 10)

300	-35	100	67	-87	45	-90	84	-84	90	200	-300	72	-90

C1, C2

200	-350	10	54	-27	29	-96	8	-820	30	-200	30	720	583

After Crossover:

C1, C2

300	-35	100	67	-27	29	-96	8	-820	30	200	-300	72	-90

C1, C2

200	-350	10	54	-87	45	-90	84	-84	90	-200	30	720	583

Fig. 4: Chromosomes are subjected to two point 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. In the mutation, a new chromosome is obtained. This chromosome is totally new from the parent chromosome. The concept behind this is the child chromosome thus obtained will be fitter than the parent chromosome. The performance of mutation operation is shown in Fig. 5.

Before Mutation :

Mp1 Mp2 Mp3 Mp4

300	-35	100	67	-87	45	-90	84	-84	90	200	-300	72	-90

After Mutation:

Mp1 Mp2 Mp3 Mp4

300	-35	-87	67	100	45	-90	84	200	90	-84	-300	72	-90

Fig. 5: Chromosome subjected to mutation operation

As in Fig. 5 we have chosen four mutation points Mp1, Mp2, Mp3 and Mp4. The mutation is done on the particular gene present at the Mutation points. This pointing of gene is done randomly. Hence, the four mutation points may point any of the fourteen genes.

After obtaining the best chromosome from the 1st iteration, another random chromosome will be generated and these 2 chromosomes will be used for the 2nd iteration. Similarly, the process repeats for a particular number of iteration while the two chromosomes that are going to be subjected to the process is decided by the result of the fitness function. Each number of iteration will give a best chromosome and this is will be considered to find an optimal solution for the inventory control. When the number of iterations is increased then the obtained solution moves very closer to the accurate solution. The iterations will continue as long as improvement in the objective function is possible as determined through the fitness function evaluation. Eventually with the help of the Genetic algorithm, the best stock level to be maintained in the members of the supply chain could be predicted from the past records and so that the loss due to the holding of excess stock level and shortage level can be reduced in the upcoming periods for supply chain inventory optimization.

3. Results and Discussions

The approach we have suggested for the optimization of inventory level and thereby efficient supply chain management has been implemented in the platform of MATLAB (MATLAB 7.4). The database consists of the records of stock levels held by each member of the supply chain for every period. In our implementation we have utilized three different products and these products are in circulation to the appropriate member of supply chain network we have considered. The sample database which consists of the past records is shown in Table 2.

Table 2: A sample data set along with its stock levels in each member of the supply chain

-12	-686	-620	42	-891	-824	941	-32	902	-450	-26	-144	6	238
-407	37	-81	-64	-391	99	-196	-146	-4	443	74	-56	-73	445
-62	-524	-68	-254	205	446	-469	-92	-524	-685	-25	205	46	-46
-84	266	96	65	735	244	-752	-44	-282	57	-926	-414	-200	-743
-49	-282	77	-926	-44	-200	-743	540	-830	-835	82	-39	78	-65
40	-80	-835	82	-39	768	-65	-371	-76	-299	64	448	76	340
-371	-736	-299	634	448	756	340	-778	-313	629	-690	824	-927	850
-78	-313	629	-60	824	-97	850	351	293	328	-732	37	-56	685
500	108	490	-345	-236	108	-931	844	-728	286	740	686	-421	424
-321	2	-450	-260	-14	162	238	775	-394	-520	-72	-927	-89	-50
794	932	-584	307	-171	-529	-503	-122	-686	-620	424	-891	-824	941
-122	-686	-60	424	-891	-84	941	235	464	401	108	346	40	-34
235	464	401	108	346	840	-934	218	-848	836	133	-554	-939	-834
489	09	148	50	196	851	-45	-422	638	66	-112	59	107	-40
893	20	-423	-736	-778	63	-335	540	-830	-35	882	-379	768	-635
-778	-313	629	-90	84	-927	80	844	-728	286	40	686	-1	424
-122	-66	-60	424	-891	-824	9	775	-34	-520	-72	-927	-89	-57
49	409	48	850	196	851	-45	893	520	-423	-736	-78	863	-35
50	108	490	-345	-26	108	-931	540	-30	-835	882	-79	78	-65
-449	-22	577	-926	-44	-200	-743	-371	-76	-299	634	48	756	340

In the database we have tabulated in Table 2,the fields in a record row are related with the stock levels that were held by the respective members of the supply chain network. Similarly, different sets of stock levels occurring are held by the database.

As per the proposed analysis based on GA, we have generated the random initial chromosome as

300	-35	100	67	-87	45	-90	84	-84	90	200	-300	72	-90

Fig. 6: Random inventory generated initially for the GA based analysis

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 processes was carried out so as to obtain the best chromosome. Here for instance, we have chosen the iteration value as '100' and so hundred numbers of iterative steps will be performed. The best chromosome we have obtained as result based on a simulated data set is depicted in the Fig. 7.

200	-350	10	66	-120	46	-9	40	-8	20	156	-30	48	10

Fig. 7: The final best chromosome obtained from the analysis

The final chromosome we have obtained from the GA based analysis shown in the figure 7 is the inventory level that caused maximum increase of supply chain cost. By focusing on the excess/shortage inventory levels and initiating appropriate steps to eliminate the same at each member of the chain, we can minimize the supply chain cost. Thus by following the predicted stock levels, we can avoid the increase of supply chain cost.

4. Conclusion

Inventory management is an important component of supply chain management. We have proposed an innovative and efficient methodology that uses Genetic Algorithms to precisely determine the most probable excess stock level and shortage level required for inventory optimization in the supply chain such that the total supply chain cost is minimal. The proposed approach was implemented and its performance was evaluated using MATLAB 7.4. The performance of Genetic Algorithm was well as predicted. By following the proposed genetic algorithm based approach for inventory management, we determined the products due to which the members of the supply chain incurred extra holding or shortage cost in the whole supply chain regardless of the number of products and the number of members in the supply chain. The proposed approach of inventory management has achieved the objectives which are the minimization of total supply chain cost and the determination of the products due to which the respective supply chain members endured either additional holding cost or shortage cost which is a vital information for supply chain inventory optimization.

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