

Multi-product inventory optimization in a multi-echelon supply chain using Genetic Algorithm

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Abstract

Inventory management is very important area in the supply chain management. Excess stocks may lead to incurring holding costs while shortage of stocks lead to shortage costs. The problem becomes more complicated when several factories produce multiple products in multiple time periods and supplies to several distribution centers who in turn supply to various agents and customers. With the advances in information technology and computing methods the inventory management problem in a multi echelon supply chain can be solved reasonably well. This paper presents an approach an approach for the multi product inventory optimization in a multi echelon supply chain using Genetic Algorithm. This Paper presents an approach using genetic algorithm for inventory optimization for a supply chain employing multiple products to minimize the excess and shortage of stocks.

Key Words: - Multi product inventory, supply chain, Genetic Algorithm

INTRODUCTION

Supply chain managers' key concern is regarding the inventory levels to be maintained for all the products which are in circulation in the chain. This is very important and complex matter because excess or shortage of stock levels at one stage of supply chain (say plant) has effect not only on that stage but also on the subsequent stages (distribution centers, agents, customers). This issue becomes more complicated if stock levels at various time periods are also considered. For example excess stocks in the month of February at a particular stage of supply chain may influence the stock levels to be maintained for the month of March at the subsequent stages of supply chain.

In this paper, all the above problems have been addressed and a new decision support tool to aid the supply chain managers in predicting the probable excess or shortage in stock levels of a complex supply chain has been proposed and explained by an two plants each of which produces three products and supply to a distribution centers which in turn supplies to three agents. The time horizon considered in this model is fifty two weeks. It is assumed that the stocks will be updated every week.

P. Radhakrishnan et al (2010) have proposed predictive analytics using genetic algorithm for efficient supply chain inventory optimization. They proposed a new objective function which can be used in a genetic algorithm to predict the most probable excess or shortage stock levels at various supply chain members (suppliers, plants, distributors, retailers etc). By knowing the probable excess or shortages levels of stocks before hand, the supply chain manager can take steps to avoid the occurrence of such excess or shortages.

illustrative example. The proposed method uses Genetic Algorithm for predicting the most probable excesses or shortages in stock levels at various stages of the supply chain. The supply chain considered in this paper includes

S. Narmada et al (2010) have proposed an efficient inventory optimization of multiple product, multiple suppliers with lead times using PSO (particle swarm optimization).In addition to the stock levels at various members of the supply chain , the authors also considered the lead times of raw materials suppliers and lead times of products from one layer of supply chain to the next layer.

All the data required to solve the above problem has been organized in the form of a database. The database consists of data about the existing stock levels of all the items at various members of supply chain in one table.

This table contains fields which will give the existing stock levels at each member of the supply chain (one field for each member of the supply chain).

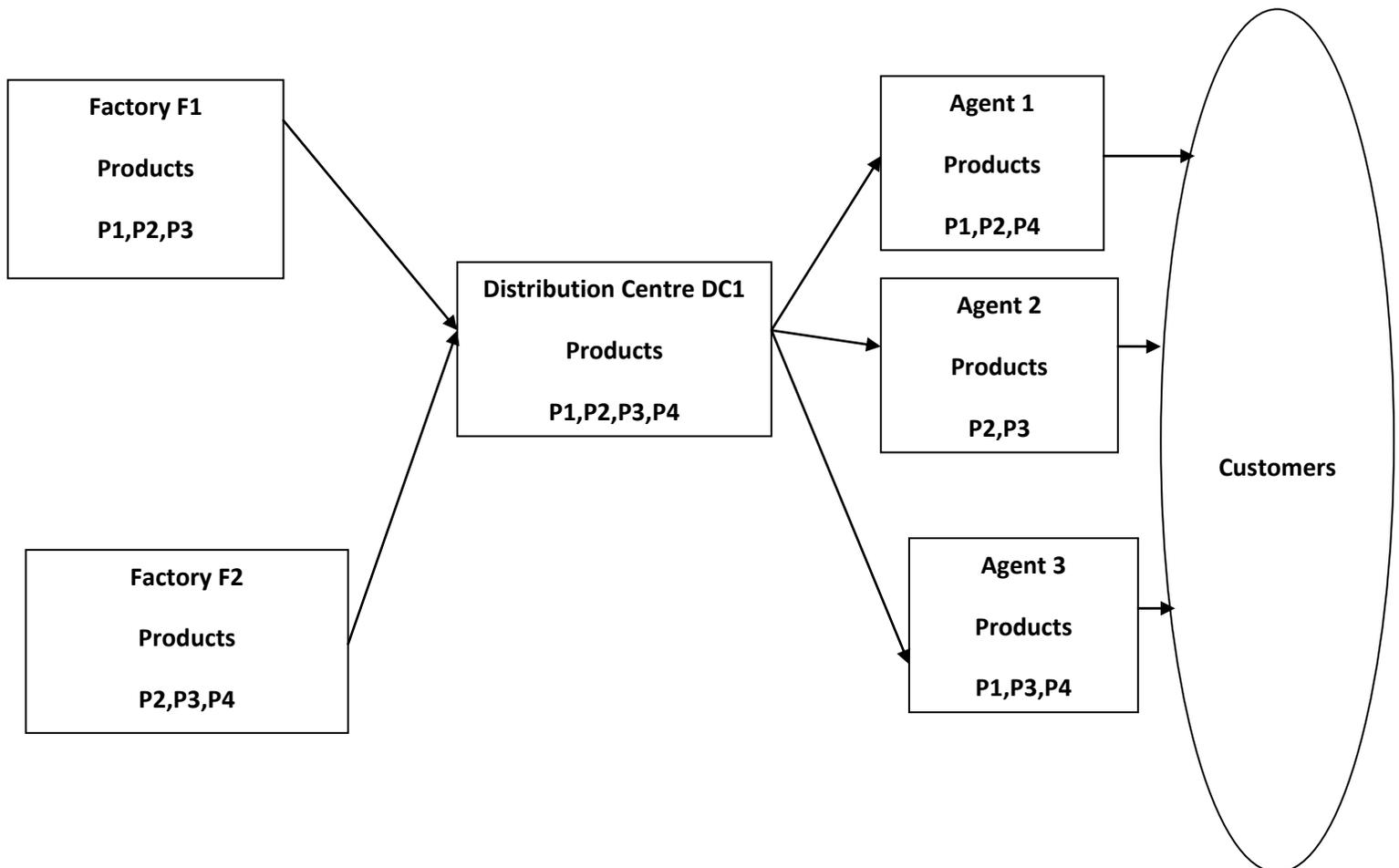


Fig.1. Multi echelon supply chain for the proposed work

LITERATURE REVIEW

T. F .Abdelmaguid et al (2006) has proposed a new genetic algorithm (GA) approach for the integrated inventory distribution problem (IIDP). They developed a new genetic chromosome representation and used a heuristic to generate the initial random population. They also developed suitable crossover and mutation operators for the GA. They have mentioned that their approach can reach within 20% of the optimal solutions on sets of randomly generated test problems.

David Pardoe and Peter Stone (2007) have proposed an autonomous agent for supply chain management. In their work, they described a TacTex-06, for predicting the winning agent in the 2006 TAC SCM (Trading Agent Competition Supply Chain Management) competition. By considering the prices that will be offered by component suppliers and the level of customer demand, they planned future actions in order to maximize profits.

J. L. Caldeira, R. C. Azevedo et al (2007) have proposed a Beam- ACO to optimize the supplying and logistic agents of a supply chain. They tested the above algorithm with three different instances of supply chains. They mentioned that their results have shown that the use of Beam- ACO improves the local and global results of the supply chain.

Chih-Yao-Lo (2008) has studied a problem, where a firm faces time-varying demand and receives product from a single supplier who faces random supply. They assumed that the supplier's availability may be affected by events such as natural disasters, labor strikes, manufacturing defects, machine breakdowns, or other events. Based on this, a model is proposed that considers the dynamic production-inventory as a NP-hard problem, which using genetic algorithm is developed to minimize the average total cost to determine the production cycles under various ordering policies. To evaluate the

S. Narmada et al (2010) have proposed a multi-product inventory optimization using uniform crossover genetic algorithm. The authors dealt with the problem of determination of base-stock levels in a ten member serial supply chain with

S. Narmada et al (2010) have proposed an efficient inventory optimization of multiple product, multiple suppliers with lead times using PSO (particle swarm optimization).In addition to the stock levels at various members of the supply

performance of the proposed algorithm, a numerical study has been conducted to compute the ordering policies under various demands in an extensive order.

K. Wang and Y. Wang (2008) have presented a successful industry case applying genetic algorithm (GA). The case has applied the GA for the purpose of optimizing the total cost of a multiple sourcing model with supply chain system. The system is characterized by a multiple sourcing model with stochastic demand. A mathematical model is developed to describe the stochastic inventory with the many-to-many demand –supplier network problem and it simultaneously constitutes the inventory control and transportation parameters as well as price uncertainty factors. Genetic algorithm is applied to derive the optimal solutions through the optimization process. A numerical example is provided to explain the method proposed.

P. Radhakrishnan et al (2010) have proposed predictive analytics using genetic algorithm for efficient supply chain inventory optimization. They discussed the key concerns that global manufacturers face today and the complexities involved in the current supply chain inventory optimization and proposed a new objective function which can be used in a genetic algorithm to predict the most probable excess or shortage stock levels at various supply chain members (suppliers, plants, distributors, retailers etc). By knowing the probable excess or shortages levels of stocks before hand, the supply chain manager can take steps to avoid the occurrence of such excess or shortages.

N. Jeyanthi and P. Radhakrishnan (2010) have considered the issues of inventory management in a multi product supply chain and proposed an approach based on genetic algorithm which will predict the most probable excess stock levels or shortage stock levels required to minimize the supply chain cost.

multiple products produced by factories using uniform crossover genetic algorithm. They considered the complexity of the problem when several distribution centers and agents and multiple products are involved.

chain , the authors also considered the lead times of raw materials suppliers and lead times of products from one layer of supply chain to the next layer.

P. Priya and K. Iyakutti (2011) have proposed a web based product inventory optimization using genetic algorithm. They presented an approach to optimize the reorder level (ROL) in the manufacturing unit taking consideration of the stock levels in the factory and distribution centers of the supply chain, which in turn helps the production unit to optimize the production level and minimizing the inventory holding cost. They used genetic algorithm for optimization in a multi product, multi level supply chain in a web enabled environment.

Tarun Kumar et al (2012) have proposed a technique based on genetic algorithm to optimize inventory in supply chain management. They focused on to specifically 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 minimized. They applied their method on a supply chain consisting of six members.

Khalili et al (2016) have proposed an uncertain centralized/ decentralized production- distribution planning problem in multi-product supply chains: Fuzzy mathematical optimization approaches. In this paper, the author has introduced uncertainty concept in the demand data of product . He solved the proposed uncertain multi product supply chain problem with centralized and decentralized models. To introduce the uncertainty in the demand data, he used two terms, core demand and forecasted demand. The core demand is the demand estimated based on firm orders and forecasted demand is the expected demand estimated. Naturally, the variation in demand for core demand is less than that of forecasted demand. In this paper, the author used fuzzy approach to solve the uncertain centralized/decentralized production-distribution planning in supply chains.

P. Radhakrishnan, V.M. Prasad and N. Jeyanthi (2010) have considered the multi-product inventory optimization in a supply chain. The authors used a Genetic algorithm approach to solve

refer to the number of occurrences of records of similar amount of stock level for the six members in the supply chain.

The data used for this work has been shown in Table.1 (Excel sheet attachment).

the inventory problem. They used two point crossover and a mutation operator for their G.A. These authors have not considered the lead times of items in this paper. N. Jeyanthi and P. Radhakrishnan (2010) have presented a Genetic algorithm for optimizing multi product inventory in a supply chain. The authors have considered, in this work, the lead times also in addition to the stock levels. S. Narmadha, V. Selladurai and G. Satish (2010) have presented a uniform crossover based genetic algorithm for multi product inventory optimization. These authors have not considered, in this work, the lead times of products. S. Narmadha, V. Selladurai and G. Satish (2010) have presented a PSO (particle swarm optimization) based approach for optimizing the multi product inventory optimization with lead times.

In order to minimize the total supply chain cost, the proposed approach clearly determines the most probable excess stock level and shortage level that are required for inventory Optimization in the supply chain. In practice, the dynamic nature of the excess stock level and shortage level over all the periods is the typical problem occurring in inventory management. The determination of the stock level that occurs at a maximum rate is the vital operation to be performed. Thus, the maximum occurrences of similar stock levels should be considered in order to optimize effectively.

The employed fitness function in this methodology is formulated in such a way that it will consider the past periods to determine the excess/shortage of stock level. The vital information of prediction of excess/shortage of stock levels at each member of the supply chain by considering the stock levels of the past years is done efficiently to maintain minimal total supply chain cost.

GENETIC ALGORITHM

Fig.2 describes the genetic algorithm procedure that is employed in this work. Each individual chromosome generated randomly 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}

Generation of individuals:- The data used for this work has been shown in Table.1 (Excel sheet attachment).where positive numbers indicate excess stock levels and negative numbers indicate shortage quantities. All the stock levels have been generated randomly to lie between minimum and maximum stock levels. This table has 18 columns and each column

represents the stock level of a particular product at a particular member.

Evaluation of fitness function: A special kind of fitness function is used in this work to determine the most probable excess or shortage quantities that are going to emerge in the next period. (see Eq.4)

$$\text{Fitness} = \log \left(1 - \frac{P_{Occ}}{T_{Periods}} \right) \quad (4)$$

Where p_{occ} = number of occurrences of the bees position string in the record set of the database. And

$T_{periods}$ = Total number of records in the record set of the database.

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, cross over and mutation comprise genetic operations

Selection:- The first operation in the genetic algorithm is the selection, where the promising chromosomes are selected for breeding the next next generation. In this work rank selection operator is used, which ranks the chromosomes according to fitness function and selects the best chromosomes for further operations like crossover and mutation.

Crossover: Crossover operation is performed on two chromosomes selected based on selection operator criteria. There are a number of crossover operators available in the literature. For our work, we used two point crossover operator because it is found to be useful for working with long chromosomes (such as the one with 18 genes used in this work).. The crossover operation performed in our analysis is pictured in fig.3. The crossover operator helps in exploitation of the search space. In crossover operation two chromosomes selected according to rank selection method will exchange portions of their chromosomes as shown in fi.3.

Mutation:. The crossover operation is succeeded by mutation operator in a genetic algorithm. The mutation operation explores

the search space. The mutation operation performed in our work is shown in fig.4. In mutation operation a single chromosome selected will undergo change in its genes i.e., a gene selected according to mutation probability will be flipped between the minimum and maximum levels as shown in Fig.4. In the fig.4 shown there are 4 mutation points and the genes at those positions will be changed and the other genes of the chromosomes remain unchanged.

The methodology proposed here will predict the optimal stock levels at each member of the supply chain by minimizing the total supply chain cost, by considering the past records of stock levels at various supply chain members. By predicting, the excess or shortages of stock levels at various members, the supply chain manager can take steps to avoid the occurrences of such excesses or shortages. The proposed methodology searches the database of stock levels for most probable excess/shortage of products that lead to maximum increase of supply chain inventory cost.

The multiple products considered among the multiple members of the supply chain considered in this work are independent that is stock levels of one product does not influence the other.

The optimization is going to be performed in the supply chain model as illustrated in the Fig.2.

The factory is manufacturing K number of products. The database holds the information about the stock levels of each product in each of the supply chain. Each and every dataset recorded in the database is indexed by a Time Identification ID..

In the fitness function, the ratio $(P_{occ}/T_{periods})$ plays the role of finding the probability of occurrence of a particular record of inventory values and $\log [1 - (P_{occ}/T_{periods})]$ will ensure minimum value corresponding to the maximum probability. Hence the fitness function is structured to retain the minimum value corresponding to various chromosomes being evaluated iteration after iteration and this in turn ensures that the fitness function evolution is towards optimization

METHODOLOGY

The exemplary problem considered in this work consists of two factories (F1, F2), one distribution centre (DC1), three agents (A1, A2, A3). The first factory (F1) manufactures three products

(P1, P2, P3), the second factory manufactures three products (P2, P3, P4). The distribution centre (DC1) stores all the four s F1 and F2 and distributed to DC1. The DC1 supplies the four products P1, P2, P3, P4 to agents A1, A2 and A3. Agent A1 deals with the products P1, P2 and P4. Agent A2 deals with the products P2 and P3. Agent A3 deals with the products P1, P3 and P4. Thus an example of the representation of a chromosome is as given below. The chromosome consists of 18 genes with

products (P1, P2, P3, P4) manufactured by factories each gene representing the stock level of that product in that level of supply chain. For example the value of 64 in the first gene in the below example represents the stock level of product P1 in Factory 1 (F1). Similarly, the value of 11 in the second position represents the stock level of product P2 in Factory1 (F1). A sample chromosome is shown in Table.1 below.

F1			F2			DC1				A1			A2		A3		
P1	P2	P3	P2	P3	P4	P1	P2	P3	P4	P1	P2	P4	P2	P3	P1	P3	P4
64	11	30	48	-18	70	46	-77	73	43	52	32	-47	52	-10	-5	38	-53

Table.1

A Sample Chromosome

The data of the stock levels at the various members of the supply chain has been generated randomly for the 52 weeks. The data generated randomly is made to lie between the Minimum and Maximum stock levels given below. The minimum stock levels at various stages of supply chain are shown in Table.2 and The maximum stock levels at various stages are shown in Table.3 In Table.2 the minus values at various stages implies maximum shortages possible at that stage. It is assumed that the stock levels will be updated weekly. Further, since all the stock levels must be integers the standard genetic algorithm solver available in the optimization toolbox of MATLAB R2009b cannot be applied straight away and a new

code for genetic algorithm for this integer restriction has been developed. The proposed methodology searches the database of stock levels for most probable emerging excess/shortages at various supply chain entities.

The data for the present work is provided in the Table named Stocks (Excel sheet attached)

F1			F2			DC1				A1			A2		A3		
P1	P2	P3	P2	P3	P4	P1	P2	P3	P4	P1	P2	P4	P2	P3	P1	P3	P4
-80	-50	-70	-60	-90	-80	-60	-80	-	-50	-70	-80	-60	-70	-90	-60	-	-80
								100								100	

Table.2

Minimum stock levels at various supply chain entities

F1			F2			DC1				A1			A2		A3		
P1	P2	P3	P2	P3	P4	P1	P2	P3	P4	P1	P2	P4	P2	P3	P1	P3	P4
80	50	70	60	90	80	60	80	100	50	70	80	60	70	90	60	100	80

Table.3

Maximum stock levels at various supply chain entities

IMPLEMENTATION

The proposed methodology has been implemented in MATLAB R2009b. The database was created in Microsoft's Access database software. The database consists of table of stock levels at various members of the supply chain. (Table named Stocks in the Excel sheet attached). Firstly, connection has been provided between the database and MATLAB by using the 'database' command. After establishing the connection, the required data can be mined from the database using appropriate commands.

In the sample data shown in Table.1, the stock levels held at each stage of the supply chain is indicated for each product. In this Table, field 1 indicates ID, which is system generated. In the experiment considered in this paper, 18 fields are created, each representing stock levels of a product in that member.

Mutation Probability = 0.1

Number of iterations =200

RESULTS

The Genetic algorithm method has been applied to optimize the stock levels of a three member supply chain consisting of two factories, one distribution centre and three agents. Three products are manufactured by factory 1 and three products are manufactured by factory 2. These details are explained in the Methodology section. The algorithm has been run for two hundred iterations and the best value obtained is as follows. The Best Cost obtained is -0.044792. These stock levels are the stock levels that contribute to maximum supply chain cost. Positive stock levels mean excess quantity and negative stock levels means shortage

Parameters of the Genetic algorithm:-

Population size = 100

Crossover operator = Two point crossover

Crossover Probability = 0.8

Mutation operator = Integer Mutation.

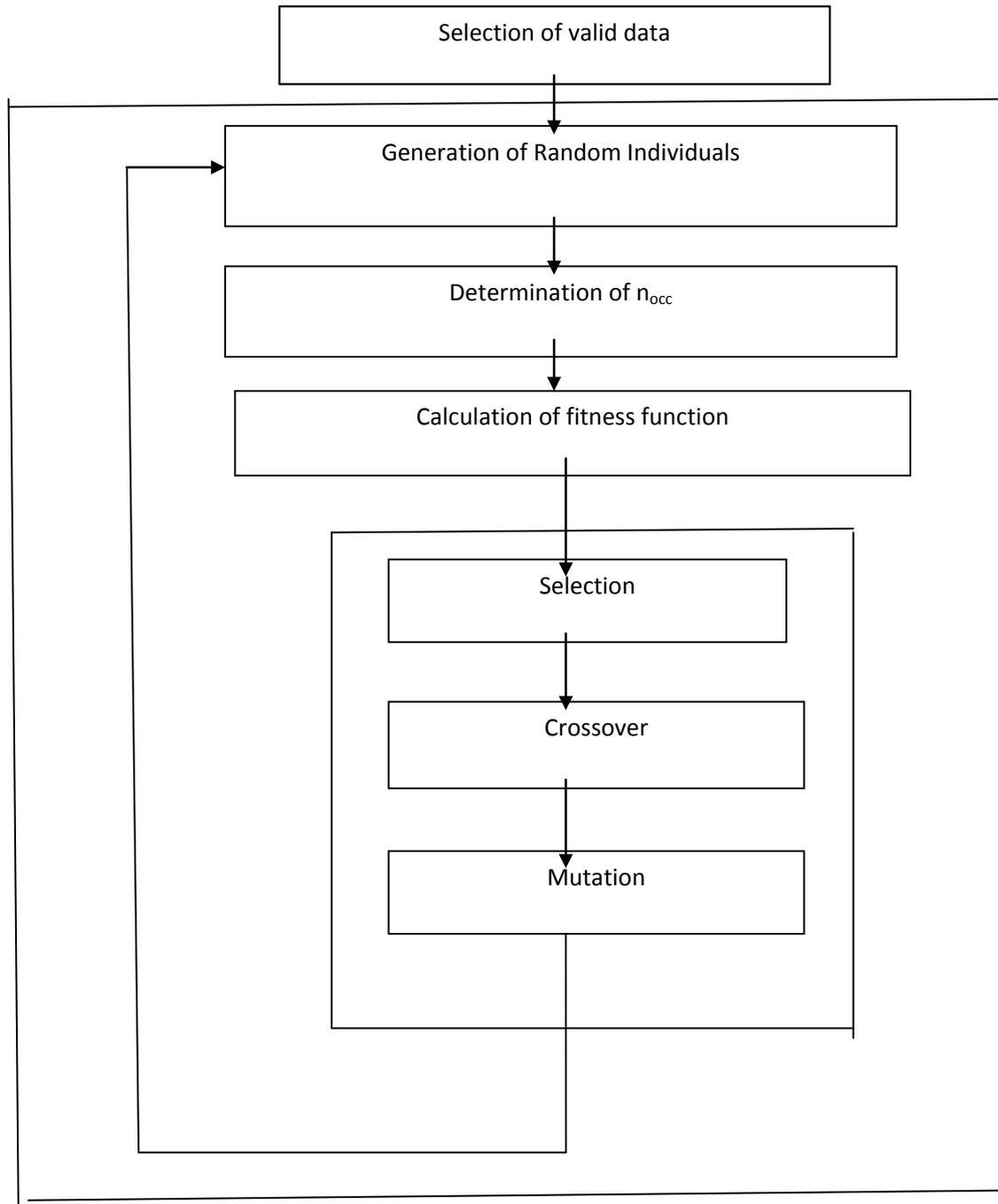


Fig.2. Genetic Algorithm for the proposed work.

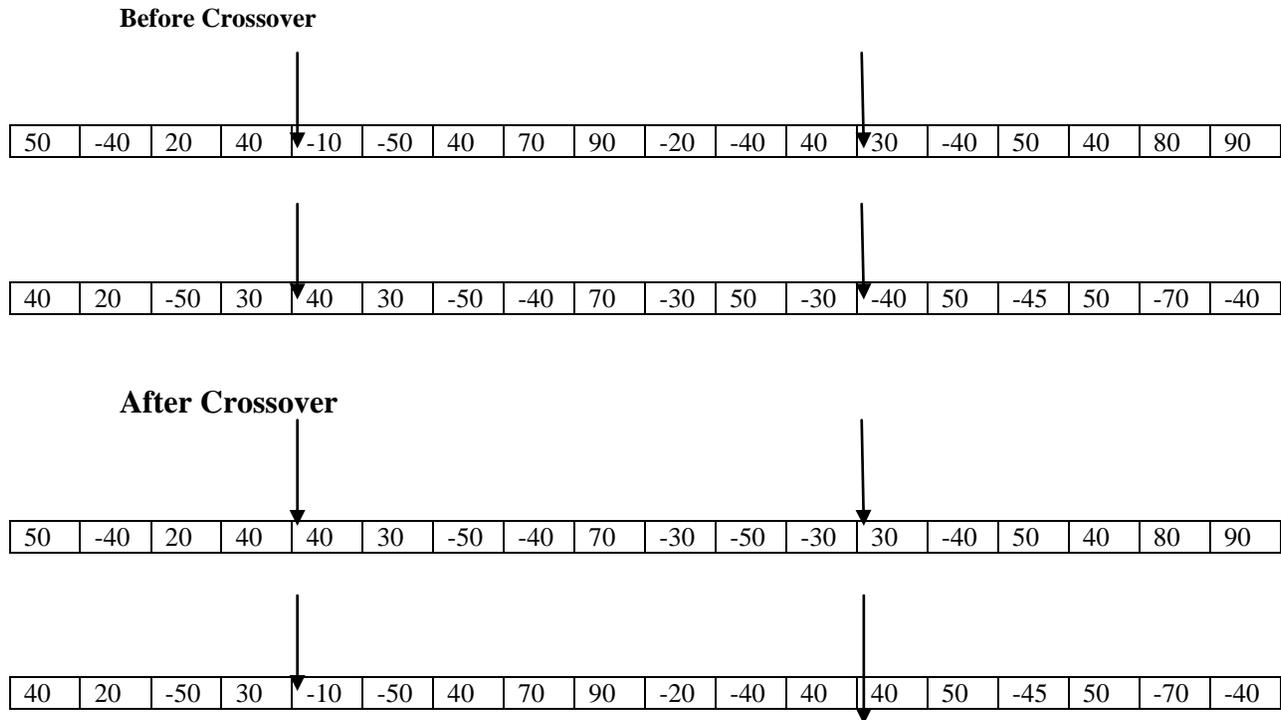


Fig.3. Two Point Crossover operation of the Genetic Algorithm.

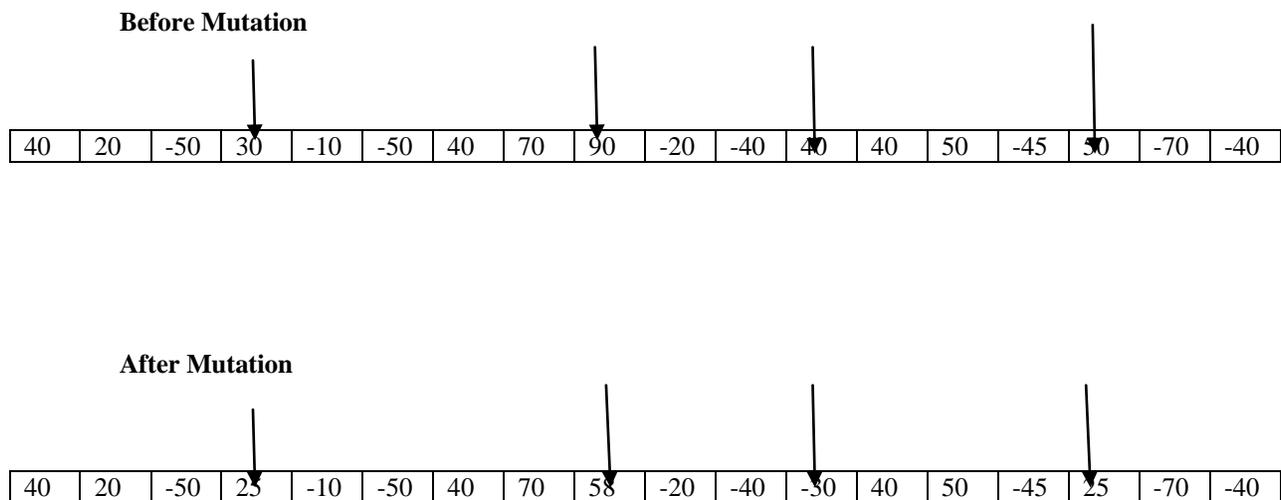


Fig.4. Mutation operation of the Genetic Algorithm

quantity. For example the stock level of product P1 in factory 1 in the optimal result shown below means that an excess of 56 units in the stock level of product P1 at F1 leads to maximum increase of supply chain cost. Hence by decreasing

the stock level of P1 in F1 by 56 units for the next period, the supply chain cost can be minimized. Similarly, the stock level of product P3 in factory F2 in the optimal chromosome shows a stock level of 44. That is an excess

quantity of 44 of product P3 in factory F2 leads to an increase of cost. Hence by decreasing the stock of product P3 in Factory F2 by 44 units for the next period, the supply chain cost can be decreased. The same logic can be applied to all the products (P1, P2, P3, and P4) at all levels (F1, DC1, A1, A2, and A3) to optimize their stock levels.

The final chromosome obtained after 200 iterations is given in Table.4 below. This combination of stock levels leads)

to maximum increase of supply chain inventory cost. Hence by taking steps to avoid the occurrence of those stock levels, the total supply chain inventory cost can be minimized. Stock levels with positive values and negative values in the final best bee's position shown below represent the excess and shortage of stocks. If there is a stock level with a positive value, the stock position of that level should be decreased by the respective value and vice versa.(if there is a negative value

F1			F2			DC1				A1			A2		A3		
P1	P2	P3	P2	P3	P4	P1	P2	P3	P4	P1	P2	P4	P2	P3	P1	P3	P4
56	30	-2	-24	44	71	-16	-43	92	-34	-25	60	2	-34	-61	49	-96	67

Table.4

Best chromosome obtained after optimization

CONCLUSION

The multi product inventory optimization problem has been explained in this paper. A genetic algorithm methodology to solve this problem has been proposed in this paper. The problem has been solved by taking the data generated randomly representing the stock levels of various products at different supply chain members. The database is created using Microsoft Access database. The proposed algorithm has been implemented in MATLAB R2009B. The algorithm has been run for two hundred iterations and the best solution obtained is reported.

The methodology proposed in this paper is very useful and can be more accurate for large datasets. This methodology can be applied to real world inventory optimization problems involving several products at different supply chain levels for multiple periods.

The following table (Table.5) summarizes the actions to be taken about the stock levels of products at factories, distribution centre, and agents for the next period to minimize the total supply chain cost.

Product	Supply chin member	Increase/Decrease	Quantity to increase/Decrease
P1	Factory 1	Decrease	56
P2	Factory 1	Decrease	30
P3	Factory 1	Increase	2
P2	Factory2	Increase	24
P3	Factory 2	Decrease	44
P4	Factory 2	Decrease	71
P1	Distribution centre1	Increase	16
P2	Distribution centre1	Increase	43
P3	Distribution centre1	Decrease	92
P4	Distribution centre1	Increase	34
P1	Agent1	Increase	25

P2	Agent 1	Decrease	60
P4	Agent1	Decrease	2
P2	Agent2	Increase	34
P3	Agent 2	Increase	61
P1	Agent 3	Decrease	49
P3	Agent 3	Increase	96
P4	Agent 3	Decrease	67

Table.5

Actions to be taken about the stock levels for the next period.

The convergence graph of the artificial bee colony algorithm for the proposed problem has been shown at fig.3.(see the attachment)

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