Genetic Algorithm Based Multi Product and Multi Agent Inventory Optimization in Supply Chain Management

Tarun Kumar, S. R. Singh, and C. B. Gupta

Abstract−**We propose a technique based on genetic algorithm to optimize inventory in supply chain management .We focus 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. The complexity of the problem increases when more products and multiple agents are involved in inventory management process that has been resolved in this work. We apply our method on six member of supply chain studied model for optimization**.

Index Terms**—Genetic algorithm, inventory optimization, supply chain management, base stock level, agents.**

I. Introduction

Competitiveness in today's marketplace depends heavily on the ability of a company to handle the challenges of reducing lead-times and costs, increasing customer service levels, and improving product quality. Traditionally, sourcing (procurement), production, distribution and marketing have been working independently. Unfortunately, although they seem to be working towards a common goal, these organizational units have different objectives. Marketing wants to have a high customer service level as well as high sales volume, but these conflicts with the objective of production and distribution. Sourcing decisions normally depend solely on minimizing the cost of goods, and production and distribution decisions often consider only maximizing throughput while minimizing production (unit) costs without any consideration for high inventory levels or long lead-times. Supply chain management is the effective coordination and integration of different organizations with different objectives towards a common goal. The great potential for improvement in these objectives through effective supply chain management mechanisms has recently been realized [2].

The inventory management problem is a part of maintaining an adequate supply of some item to meet an expected pattern of demand, while striking a reasonable balance between the cost of holding the items in inventory and the penalty (loss of sales and goodwill, say) of running out. There are three types of expenses associated with inventory systems. The relative importance of these will depend on the specific system. They are: (i) administrative cost of placing an order, called reorder cost or set cost; (ii) cost of maintaining an inventory, called inventory holding cost a carrying cost, which includes storage charge, interest, insurance, etc., (iii) shortage cost is a loss of profit, goodwill, etc., when run out of stock. All the above should be optimized for efficient supply chain management [3].

This paper is organized into six sections. Section II gives the introduction to genetic algorithm. Section III describes a brief review work done by researchers. The proposed analysis is presented in section IV. Section V discusses the implementation results. Finally, Section VI concludes the paper.

Manuscript received August 28, 2012; revised September 30, 2012.

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II. Genetic Algorithm

Genetic Algorithm (GA) was developed by Holland and his colleagues in the 1960s and 1970s. Genetic Algorithms are inspired by the evolutionist theory explaining the origin of species. In nature, weak and unfit species within their environment are faced with extinction by natural selection.

In GA terminology, a solution vector x€X is called an individual or a chromosome. Chromosomes are made of discrete units called genes. Each gene controls one or more features of the chromosome. In the original implementation of GA by Holland, genes are assumed to be binary digits. In later implementations, more varied gene types have been introduced. Normally, a chromosome corresponds to a unique solution x in the solution space. This requires a mapping mechanism between the solution space and the chromosomes. This mapping is called encoding. In fact, GA works on the encoding of a problem, not on the problem itself.

GA operates with a collection of chromosomes, called a population. The population is normally randomly initialized. As the search evolves, the population includes fitter and fitter solutions and eventually it converges, meaning that it is dominated by a single solution. Holland also presented a proof of convergence (the schema theorem) to the global optimum where chromosomes are binary vectors.

GA use two operators to generate new solutions from existing ones: crossover and mutation. The crossover operator is the most important operator of GA. In crossover, generally two chromosomes, called parents, are combined together to form new chromosomes, called offspring. The parents are selected among existing chromosomes in the population with preference towards fitness so that offspring is expected to inherit good genes which make the parents fitter. By iteratively applying the crossover operator, genes of good chromosomes are expected to appear more frequently in the population, eventually leading to convergence to an

DOI: 10.7763/IJMO.2012.V2.203

overall good solution.

The mutation operator introduces random changes into characteristics of chromosomes. Mutation is generally applied at the gene level. In typical GA implementations, the mutation rate (probability of changing the properties of a gene) is very small and depends on the length of chromosome. Therefore, the new chromosome produced by mutation will not be very different from the original one. Mutation plays a critical role in GA. [15].

III. Literature Review

Supply chains are a kind of network with facilities and distribution entities (suppliers, manufacturers, distributors, retailers). The supply chain performs the functions of procurement of raw materials, transformation of raw materials into intermediate and finished products and distribution of finished products to customers [1]. Chan et al. [4] implemented a multi-criteria optimization algorithm which combines GA with the decision-making technique of the Analytic Hierarchy Process (AHP). Jawahar and Balaji [5] considered a two-stage distribution problem of a supply chain that is associated with a fixed charge, and presented a GA that evolves the solution for best fitness of total cost of distribution. Feng and Zhang [6] extended the problem by involving multiple transportation modes and proposed a GA that can deal with middle-size problem instances. Pongcharoen et al. [10] proposed the Multi-matrix Real-coded Generic Algorithm (MRGA) based optimisation tool that minimizes total costs associated within supply chain logistics.. Buffett et al. [11] proposed a technique for use in supply-chain management that assists the decision-making process for purchases of direct goods. Based on projections for future prices and demand, RFQs are constructed and quotes are accepted that optimize the level of inventory each day, while minimizing total cost. The problem is modeled as a Markov decision process (MDP), which allows for the computation of the utility of actions to be based on the utilities of consequential future states. Dynamic programming is then used to determine the optimal quote requests and accepts at each state in the MDP.

Altiparmak et al. [7] proposed a GA that uses a three segment chromosome string which is decoded through a backward procedure from the third stage up to the first stage connecting suppliers and plants. They also extended their priority-based encoding in a new GA for the multi-product case in [8]. Costa et al [9] proposed a new chromosome encoding and a complementary decoding procedure able to overcome the drawbacks, and thus improve the efficiency and effectiveness of three-stage supply chains.

The distributed optimization paradigm based on Ant Colony Optimization (ACO) is a new management technique that uses the pheromone matrix to exchange information between the different subsystems to be optimized in the supply-chain. Caldeira et al.[12] proposes the use of the hybrid algorithm Beam-ACO, that fuses Beam-Search and ACO, to implement the same management concept. The Beam-ACO algorithm is used here to optimize the distributer , the supplying, and the logistic agents of the supply-chain. Beamon et al.[13] have presented a study on evaluations of the performance measures employed in supply chain models and have also displayed a framework for the beneficial selection of performance measurement systems for manufacturing supply chains. Three kinds of performance measures have been recognized as mandatory constituents in any supply chain performance measurement system. New flexibility measures have also been created for the supply chains. Singh and Tarun [16] consider inflation and apply discounted cash flow in a inventory model and formulated the total cost of the system using genetic algorithm. Singh and Tarun [17] proposed a EMQ inventory model for time dependent decaying items and selling process demand using soft computing approach.

Nowadays, it is almost inevitable that an efficient distribution network can only be achieved with the support of computer based optimization software. Lim et al.[14] show that how an evolutionary algorithm (EA) can play an effective role in this aspect. Besides being an effective and efficient optimization tool capable of handling problems of significant computational complexity, it enjoys great flexibility in coping with the constraints of typical real-life supply chain problems.

Many well-known algorithmic advances in optimization have been made, but it turns out that most have not had the expected impact on the decisions for designing and optimizing supply chain related problems. Some optimization techniques are of little use because they are not well suited to solve complex real logistics problems in the short time needed to make decisions and also some techniques are highly problem dependent which need high expertise. This adds difficulties in the implementations of the decision support systems which contradicts the tendency to fast implementation in a rapidly changing world.

IV. Genetic Algorithms Based Inventory Optimization Analysis

The inventory Control for more 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 methodology .In proposed Methodology an appropriate stock levels to be maintained in the approaching periods that will minimize the supply chain inventory cost can be arrived. Supply Chain model is divided into three stages in which the optimization is going to be performed

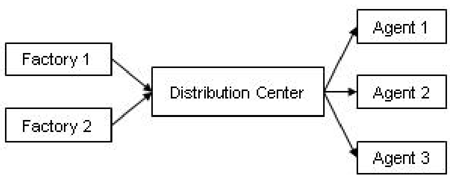

Fig. 1. Three stage supply chain (Studied model)

In Fig. 1, As shown in the supply chain example, there are 2 factories which are the parents of the chain and they are having one Distribution center 1. The Distribution center further comprises three agents, Agent 1, Agent 2 and Agetnt3. In this studied model factory 1 manufactures products P1 and P2; factory 2 manufactures products P3, P4 that would be supplied to the distribution center. From the distribution center, the stocks will be moved to the corresponding agents. In the example case, Agent 1 deals with products P1 and P2; Agent 2 deals only product P3 and Agent3 deals with product P3and P4.

The Proposed methodology is aimed at determining the specific product that needs to be concentrated on and the amount of stock levels of the products to be maintained by different members of the supply chain .

In our proposed methodology, we are using genetic algorithm for finding the optimal value. The flow of operation of our methodology is clearly illustrated in Fig. 2, which depicts the steps applied for the optimization analysis.

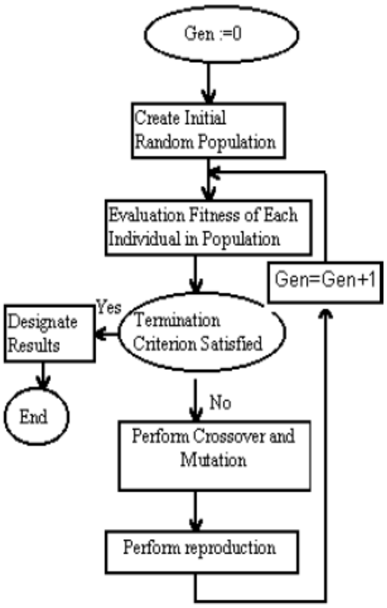

Fig. 2. Genetic algorithm structure

Initially, the amount of stock levels that are in excess and the amount of stocks in shortage in the different supply chain contributors are represented by zero or non-zero values. Zero refers that the contributor needs no inventory control while the non-zero data requires the inventory control. The non-zero data states both the excess amount of stocks as well as shortage amount. The excess amount is given as positive value and the shortage amount is mentioned as negative value.

A. Generation of Random Individual's Population

Each individual which is constituted by genes is generated with random values. Here, the chromosome of 13 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 n.umber 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.

F1 P1	F1 P2	F2 P3	F2 P4	DC P1	DC P2	DC P3	DC P4	A1 P1	A1 P2	A2 P3	A3 P3	A3 P4
400	-102	91	26	-85	24	-67	-58	-98	68	91	-84	-98

Fig. 3. Chromosome representation

B. 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.

The fitness function is given by:

$$f(j) = \log\left(1 - \frac{N_{rec}}{N_t}\right), \quad j = 1,2,3,\ldots,n$$

where

N_{rec} is the number of recurrence of records in the record set

N_t is the total numbers of the records present in records set.

n is the total number of chromosomes for which the fitness function is calculated

C. Genetic Operations

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

D. 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.

E. Crossover

As far as the crossover operation is concerned, a two point crossover operator is used in this study. The first two chromosomes in the mating pool are selected for crossover operation. The crossover operation that is performed for an exemplary case is shown in the following figure.

Before Crossover (c_1 after gene 2, c_2 after gene 9)

400	-102	91	26	-85	24	-67	-58	-98	68	91	-84	-98
300	-45	87	65	-45	42	25	-65	-36	63	99	-14	75

After Crossover (c_1, c_2)

400	-102	87	26	-85	24	-67	-58	-36	68	91	-84	-98
300	-45	91	65	-45	42	25	-65	-98	63	99	-14	75

Fig. 4. Two–Point crossover operation

The genes that are right of the cross over point in the two chromosomes are swapped and hence the cross over operation is done. After the crossover operation two new chromosomes are obtained.

F. Mutation

The newly obtained chromosomes from the crossover operation are then pushed for mutation. By performing the mutation, a new chromosome will be generated. This is done by a random generation of two points and then performing swaps between both the genes. The illustration of mutation operation is shown in Fig. 5.

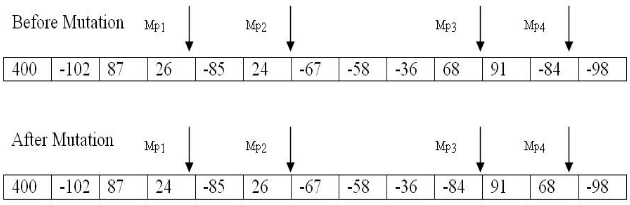

Fig. 5. Mutation

The mutation operation provides new chromosomes that do not resemble the initially generated chromosomes. After obtaining the new chromosome, another random chromosome will be generated. The process explained so far will be repeated along with the new chromosome obtained from the previous process. In other words, at the end of each of the iteration, a best chromosome will be obtained. This will be included with the newly generated random chromosome for the next iteration. Eventually, an individual which is the optimal one among all the possible individuals is obtained. This best chromosome obtained has the optimal information about stock levels of a particular product at each member of the supply chain. From the information it can be concluded that the particular product and its corresponding stock levels play a significant role in the increase of supply chain cost. By controlling the stock level of that particular product at the respective member of the supply chain in the upcoming periods, the supply chain cost can be minimized.

G. Results and Discussions

The proposed approach for the inventory optimization in supply chain management based on genetic algorithm is analyzed with the help of MATLAB. The stock levels for the three different members of the supply chain, factory, distribution center and Agent are generated using the MATLAB script and this generated data set is used for evaluating the performance of the genetic algorithm. Some sample set of data used in the implementation is given in Table I. Some 11 sets of data are given in the Table I and these are assumed as the records of the past period.

TABLE I: A SAMPLE OF DATA SETS HAVING STOCK LEVELS OF THE MEMBERS OF SUPPLY CHAIN

F1 P1	F1 P2	F2 P3	F2 P4	DC P1	DC P2	DC P3	DC P4	A1 P1	A1 P2	A2 P3	A3 P3	A3 P4
-371	-736	-199	532	445	758	952	-214	125	-124	456	254	-754
-502	379	-981	-361	214	-524	635	254	-458	-254	789	-214	524
-158	254	486	354	756	-216	-102	-98	142	521	-635	-946	-657
200	-370	35	324	-754	698	-475	-241	-854	-951	-74	325	-98
150	-350	-108	-250	-154	125	145	98	287	-268	361	-381	169
122	-66	-62	48	251	36	-98	65	-24	-89	715	-87	-78
-500	651	-851	-658	-987	-996	-214	256	367	452	-582	-98	-102
502	-984	-653	975	-69	512	-225	-265	246	-657	164	145	-98
120	-368	-652	234	264	125	215	238	486	999	722	245	-842
1000	254	-356	998	-889	-554	245	125	124	128	-268	-364	-128
138	163	-65	99	-135	-146	-185	-478	256	321	-245	-68	524

In the database tabulated in Table II, the fields are related with the stock levels of particular products that were held by the respective members of the supply chain network. Similarly, different sets of stock levels are held by the database.

As per the proposed analysis based on GA, a random initial chromosome is generated as follows.

TABLE II: INITIAL RANDOM INVENTORY GENERATED FOR THE GA BASED ANALYSIS

F1 P1	F1 P2	F2 P3	F2 P4	DC P1	DC P2	DC P3	DC P4	A1 P1	A1 P2	A2 P3	A3 P3	A3 P4
400	-102	91	26	-85	24	-67	-58	-98	68	91	-84	-98

In this manner two different random chromosomes are generated and they will be subjected to genetic operations like Selection, Crossover and Mutation. An iteration involving all these processes was carried out so as to obtain the best chromosome. For the chosen iteration value of '200', hundred numbers of iterative steps will be performed. The best chromosome obtained as result is depicted in the Table III.

TABLE III: THE FINAL BEST CHROMOSOME OBTAINED AFTER THE '200' ITERATIONS

F1 P1	F2 P2	F2 P3	F2 P4	DC P1	DC P2	DC P2	DC P4	A1 P1	A1 P2	A2 P3	A3 P3	A3 P4
300	-200	10	66	-82	54	-8	-45	30	-72	-99	40	35

The organization can decide about the quantum of iterations for running the simulation to arrive at the optimal solution. As long as minimization of the fitness function is still possible, then the iteration continues till such a time that no improvement in the fitness function value is noticeable. After a certain number of iterations, if the fitness function value is not improving from the previous iterations, then this is an indication that the fitness function value is stabilizing and the algorithm has converged towards optimal solution. This inference is useful for deciding the number of iterations for running the GA simulation as well as this may be used as the stopping criteria for the algorithm. For greater accuracy, the number of iterations should be sufficiently increased and run on the most frequently updated large database of past records.

The final chromosome obtained from the GA based analysis shown in the Table IV is the inventory level that has the potential to cause maximum increase of supply chain cost. It is inferred that controlling this resultant chromosome is sufficient to reduce the loss either due to the holding of excess stocks or due to the shortage of stocks. By focusing on the excess/shortage inventory levels and initiating appropriate steps to eliminate the same at each member of the chain, it is possible to optimize the inventory levels in the upcoming period and thus minimize the supply chain cost.

The analysis extracts an inventory level that made a remarkable contribution towards the increase of supply chain cost, and in turn enabled to predict the future optimal inventory levels to be maintained in all the supply chain members with the aid of these levels. Therefore it is possible to minimize the supply chain cost by maintaining the optimal stock levels that was predicted from the inventory analysis, and thus making the inventory management more effective and efficient [3].

V. CONCLUSION

Inventory management is a significant component of supply chain management. We have discuss a method based on genetic algorithm to optimize inventory in supply chain management we also focus 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 .we apply our methods on three stage supply chain studied model for optimization. The proposed method was implemented and its performance was evaluated using MATLAB.

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