Application of Genetic Algorithm to Supply Chain Inventory Optimization

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ABSTRACT

A key concern for global manufacturers today is to control inventory and distribution related costs and so inventory management is considered to be a very important area in Supply chain management. Efficient and effective management of inventory throughout the supply chain significantly improves the ultimate service provided to the customer. Hence, to ensure minimal cost for the supply chain, the determination of the inventory to be held at various levels in a supply chain is unavoidable. 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. The complexity of the problem increases when more agents are involved under a distribution center. In particular , we have considered a single factory manufacturing different types of products to be sent to a distribution center and only selective products as required, are sent to respective agents. 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.

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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 [11]. 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. A supply chain can also be described as a collection of numerous entities that work in unison towards 1) obtaining raw materials, (2) converting these raw materials into precise end products, and (3) delivering the end products to retailers [19].

A huge problem that a majority of the supply chains aiming to reduce the supply chains costs besides improving customer service levels face is that of the administration of the dynamic demand [10]. A variety of processes that aid the planning, implementation, control, ,manufacturing and the delivery processes originating from the raw material reserve to the point of utilization of the end product [6], are considered to be an integral part of the supply chain management. Shorter product lifecycles that lead to higher demand uncertainty and their effect on global markets accordingly increasing the supply chain complexity, results in severe problems in the management of the supply chain [11, 8]. The research proposed by Ganeshan et al[9] tends to address four problems from the operational perspective: inventory management and control; production, planning and scheduling; information sharing, coordination, monitoring; and operation tools .

The effective management of the supply chain has become unavoidable these days due to the firm increase in customer service levels [5]. 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 [3], [15], [17].

Inventory optimization application organizes the latest techniques and technologies, thereby assisting the enhancement of inventory control and its management across an extended supply network. Some of the design objectives of inventory optimization are to optimize inventory strategies, thereby enhancing customer service, reducing lead times and costs and meeting market demand [3], [15], [17]. The design and management of the storage policies and procedures for raw materials, work-in-process inventories, and typically, final products are illustrated by the inventory control[19]. The costs and lead times can be reduced and the responsiveness to the changing customer demands can be significantly improved and subsequently inventory can be optimized by the effective handling of the supply chain [8].

The inventory and supply chain managers are mainly concerned about the estimation of the exact amount of inventory at each point in the supply chain free of excesses and shortages so that the total supply chain cost is minimized. Owing to the fact that shortage of inventory yields to lost sales, whereas excess of inventory may result in futile storage costs, the precise estimation of optimal inventory is indispensable [20]. In other words, there is a cost involved in manufacturing any product in the factory as well as in holding any product in the distribution center and agent shop. More the products manufactured or held, more will be the holding cost. Meanwhile, there is possibility for the shortage of products. For the shortage of each product there will be a shortage cost. Holding excess stock levels as well as the occurrence of shortage for products lead to the increase in the supply chain cost.

This study supplements the previous study that focuses only on a single product[32]. In this paper, we have considered a single factory manufacturing different types of products to be sent to a distribution center and only selective products as required, are sent to respective agents. we have developed a novel and efficient approach using Genetic Algorithm to solve this complexity. 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 stock level should be considered in order to optimize effectively. The proposed approach of genetic algorithm predicts the optimum stock levels of the future by considering the stock levels of the past years such that the total supply chain cost will be maintained as minimum.

The remainder of the paper is organized as follows; Section 2 gives a brief review of relevant researches on inventory optimization. Section 3 gives the fundamentals of Genetic algorithm. The proposed method and methodology is presented in Section 4, results are discussed in Section 5 and conclusions are summed up in Section 6 followed by references in Section 7.

Related Works

A fresh genetic algorithm (GA) approach for the integrated inventory distribution problem (IIDP) has been projected by Abdel et al. [31]. They have developed a genetic representation and have utilized a randomized version of a formerly developed construction heuristic in order to produce the initial random population.

In [8] Pupong et al., have put forth an optimization tool that works on basis of a multi-matrix real-coded Generic Algorithm (MRGA) and aids in reduction of total costs associated within supply chain logistics. They have incorporated procedures that ensure feasible solutions such as the chromosome initialization procedure, crossover and mutation operations. They have evaluated the algorithm with the aid of three sizes of benchmarking dataset of logistic chain network that are conventionally faced by most global manufacturing companies.

A supply chain management agent comprising of predictive, optimizing, and adaptive components called the TacTex-06 has been put forth by David et al. [6]. TacTex-06 functions by making predictions regarding the future of the economy, such as the prices that will be proffered by component suppliers and the degree of customer demand, and then strategizing its future actions so as to ensure maximum profit.

Beamon et al. [19] have presented a study and 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.

A beneficial industry case applying genetic algorithms (GA) has been proposed by Kesheng et al. [27]. The case has made use of GAs for the optimization of the total cost of a multiple sourcing supply chain system. The system has been exemplified by a multiple souring model with stochastic demand. A mathematical model has been implemented to portray the stochastic inventory with demand and transportation parameters as well as price uncertainty factors

A genetic algorithm which has been proposed by Chih-Yao Lo [28] deal with the production-inventory problem with backlog in the real situations, with time-varied demand. In [29] Barlas et al., have developed a System Dynamics simulation model of a typical retail supply chain. The intent of their simulation exercise was to build up inventory policies that enhance the retailer's revenue and reduce costs at the same instant. Besides, the research was also intended towards studying the implications of different diversification strategies

A supply chain model functioning under periodic review base-stock inventory system to assist the manufacturing managers at HP to administer material in their supply chains has been introduced by Lee et al. [30]. The inventory levels across supply chain members were obtained with the aid of a search routine.

Genetic Algorithm

Genetic algorithm(GA) is a randomized search methodology having its roots in the natural selection process. Initially the neighborhood search operators (crossover and mutation) are applied to the preliminary set of solutions to acquire generation of new solutions. Solutions are chosen randomly from the existing set of solutions where the selection probability and the solution's objective function value are proportional to each other and eventually the aforesaid operators are applied on the chosen solutions. Genetic algorithms have aided in the successful implementation of solutions for a wide variety of combinatorial problems.

The robustness of the Genetic algorithms as search techniques have been theoretically and empirically proved [22]. The artificial individual is the basic element of a GA. An artificial individual consists of a chromosome and a fitness value, similar to a natural individual. The individual's likelihood for survival and mating is determined by the fitness function [20]. In accordance with the Darwin's principle, individuals superior to their competitors, are more likely to promote their genes to the next generations. In accordance with this concept, in Genetic Algorithms, we encode a set of parameters mapped into a potential solution, named chromosome, to the optimization problem [21]. The population of candidate solutions is obtained through the process of selection, recombination, and mutation performed in an iterative manner. [23].

Chromosomes refer to the random population of encoded candidate solutions with which the Genetic algorithms initiate with [22]. Then the set (called a population) of possible solutions (called chromosomes) are generated [26]. A function assigns a degree of fitness to each chromosome in every generation in order to use the best individual during the evolutionary process [25]. In accordance to the objective, the fitness function evaluates the individuals [23]. Each chromosome is evaluated using a fitness function and a fitness value is assigned. Then, three different operators- selection, crossover and mutation- are applied to update the population. A generation refers to an iteration of these three operators [24]. The promising areas of the search space are focused in the selection step. The selection process typically keeps solutions with high fitness values in the population and rejects individuals of low quality [23]. Hence, this provides a means for the chromosomes with better fitness to form the mating pool [26].

After the process of Selection, the crossover is performed. In the crossover operation, two new children are formed by exchanging the genetic information between two parent chromosomes (say C1 and C2 which are selected from the selection process) [26]. A crossover point is chosen at random by the crossover operator. At this point, two parent chromosomes break and then exchange the chromosome parts after that point. Consequently, the partial features of two chromosomes are combined to generate two off springs. The chromosome cloning takes place when a pair of chromosomes does not cross over, thus creating off springs that are exact copies of each parent [25].The ultimate step in each generation is the mutation of individuals through the alteration of parts of their genes [23]. Mutation alters a minute portion of a chromosome and thus institutes variability into the population of the subsequent generation [27]. Mutation, a rarity in nature, denotes the alteration in the gene and assists us in avoiding loss of genetic diversity [23]. Its chief intent is to ensure that the search algorithm is not bound on a local optimum [25].

Method and Methodology

The proposed method uses the Genetic Algorithm to study the stock level that needs essential inventory control. In practice, the supply chain is of length n , means having number of members in supply chain such as factory, distribution centers, suppliers, retailers and so on. Here, for instance we are going to use a three stage supply chain having four members as illustrated in figure 1.

As illustrated in figure 1, a factory is the parent of the chain and it is having a Distribution center .The Distribution center further comprises of two agents .The factory is the massive stock holding area where the stocks are manufactured as per the requirement of the distribution center From the distribution center, the stocks will be moved to the corresponding agents. As stated in our exemplary case, the factory manufactures

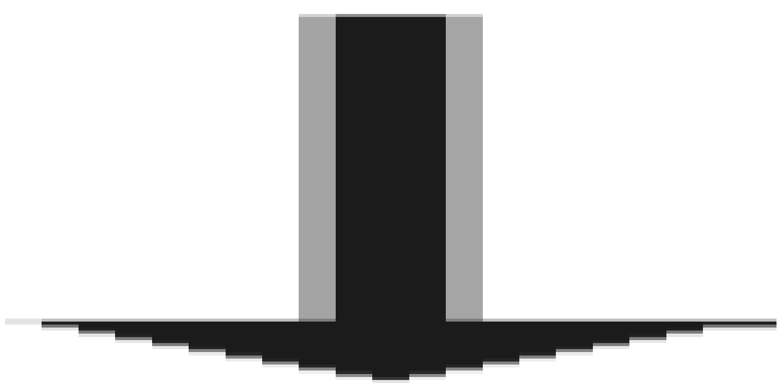

Figure 1: 3 stage-4 member supply chain

different products P1,P2,P3,P4 , 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, Agent 1 deals with products P1,P2 and Agent 2 deals with products P3,P4.

The methodology flow illustrated in figure 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, for instance, we consider a record of ten years, from Oct 1999 to Sep 2009 as past year's record set of stock levels held by different supply chain members for different products, namely P1, P2, P3, P4 . For the analysis, the stock levels for the respective products at each member of the chain throughout the ten year period are considered as data set, as shown in the Table 1.

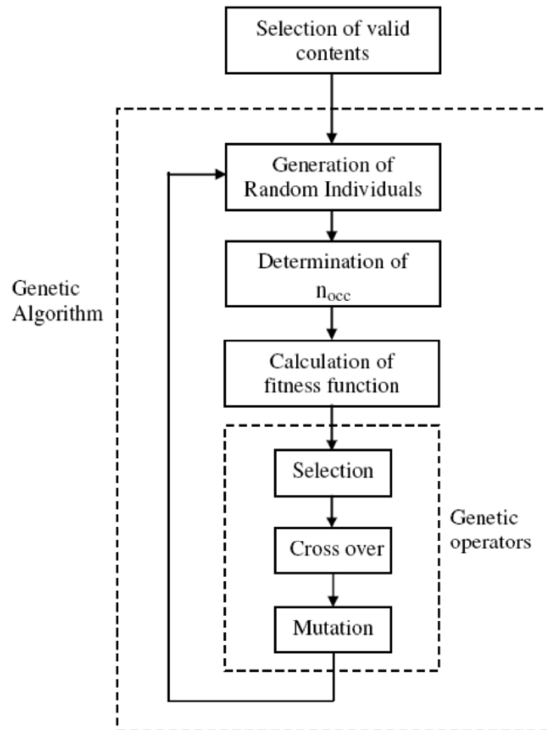

Figure2: Genetic Algorithm flow for the proposed inventory management analysis

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

Distribution			
Factory	**center 1**	**Agent 1**	**Agent 2**
P1 P2 P3 P4	P1 P2 P3 P4	P1 P2	P3 P4
100 -20 36 -65	42 25 -170 48	100 -200	289 -423

Then the data set is subjected to Genetic Algorithm and the various steps performed in the genetic algorithm dedicated for our objective work are discussed below.

Generation of Individuals

Each individual which is constituted by genes is generated with random values. Here, the chromosome of four genes where the random values occupy each gene is generated along with the product representation. A random individual generated for the genetic operation is illustrated in the figure 3.

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

Figure 3: random individual Chromosome generated to the genetic operation

These kinds of chromosomes are generated for the genetic operation. Initially, only two chromosomes will be generated and from the next generation a single random chromosome value will be generated. The chromosomes thus generated is then applied to find its number of occurrences in the database content by using a $Select\ \ count()$ function

The function will give the number of occurrences of the particular amount of stock level N_c , occurring among the members of the chain that are going to be used further in the fitness function.

Evaluation of Fitness function

Fitness functions ensure that the evolution is toward optimization by calculating the fitness value for each individual in the population. The fitness value evaluates the performance of each individual in the population.

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

where,

N_c is the number of counts of similar records that occurs throughout the period.

N_p is the total number of inventory records obtained after clustering.

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

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 shown in figure 4.

Before Crossover: C1 C2

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

C1 C2

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

After Crossover: C1 C2

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

C1 C2

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

Figure 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 illustrated in figure 5

Before Mutation :

Mp1 Mp2 Mp3 Mp4

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

After Mutation:

Mp1 Mp2 Mp3 Mp4

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

Figure 5: Chromosome subjected to mutation operation

In figure 5, we have chosen 2 mutation points Mp1 and Mp2 . The mutation is done on the particular gene present at the Mutation points. This pointing of gene is done randomly. Hence, the 2 mutation points may point to any of the twelve genes.

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. Then again the process repeats for a particular number of iteration while the two chromosomes that are going to be subjected for the process is decided by the result of the fitness function. Each number of iteration will give a best chromosome and this 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. Eventually with the help of the Genetic algorithm, the excess/shortage of stock level 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 days.

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 four 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	02	-450	-26	-144
100	-350	10	66	-120	46	-9	40	-8	20	156	-30
-62	-524	-68	-254	205	446	-469	-92	-524	-685	-25	205
-84	266	96	65	735	244	-52	-44	-282	57	-926	-414
-49	-282	77	-926	-44	-200	-743	540	-830	-35	82	-39
40	-80	-35	82	-39	768	-65	-371	-76	-299	64	448
150	-350	10	66	-120	46	-9	40	-8	20	156	-30
-78	-313	629	-60	24	-97	850	351	293	328	-732	37
155	-350	10	66	-120	46	-9	40	-8	20	156	-30
-321	2	-450	-260	-14	162	238	775	-394	-520	-72	-927
160	-350	10	66	-120	46	-9	40	-8	20	156	-30
-122	-686	-60	424	-891	-84	941	235	464	401	108	346
235	464	401	108	346	840	-934	218	-848	836	133	-554
200	-350	10	66	-120	46	-9	40	-8	20	156	-30
180	-350	10	66	-120	46	-9	40	-8	20	156	-30
190	-350	10	66	-120	46	-9	40	-8	20	156	-30
-122	-66	-60	424	-891	-824	9	775	-34	-520	-72	-927
49	409	48	850	196	851	-45	893	520	-423	-736	-78
50	108	490	-345	-26	108	-931	540	-30	-835	882	-79
200	-350	10	66	-120	46	-9	40	-8	20	156	-30

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

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

In this manner two different random chromosomes have been generated and they will be subjected to 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 a chosen iteration value of '100' , 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 Fig. 7.

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

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 initiating appropriate steps to eliminate these anticipated surplus/scarcity occurring at various members of the supply chain, we can minimize the supply chain cost. Thus by following the predicted stock levels, we can avoid the increase of supply chain cost.

Conclusion

Inventory management is an important component of supply chain management. The members of the supply chain are responsible for minimizing the costs of a supply chain by managing inventory levels in a number of production and distribution operations associated with different chain stages. We have presented a novel efficient approach using Genetic Algorithm which clearly determined the most possible excess stock level and shortage level that is needed for inventory optimization so as to minimize the total supply chain cost. The approach had been implemented in the MATLAB 7.4 to visualize its performance. As expected, the Genetic algorithm performed well and hence the work we have proposed provides us a better prediction of stock levels among different members of the supply chain for inventory control and optimization.

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