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A Genetic Algorithm based Approach for Cost worthy Route Selection in Complex Supply Chain Architecture

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***Abstract*—It is always a great challenge to select an optimal route in case of a complex supply chain architecture. The challenge lies in meeting the reverse condition of quality of service and money. As time is an important factor, choosing the optimal route in supply chain architecture often becomes the most vital. To automate the route finding, in this paper, we propose a model that resemble to a modern and a complete supply chain network. We intend to solve it with the Genetic Algorithm so that a route with least cost is derived. For experiment purpose, we have implemented our model on hypothetical consideration based scenario, in which the generation, cross over and mutation process of genetic algorithm of the whole proposed model exhibits the optimized values for different routes. The algorithm was implemented in a MATLAB based environment. To show the invincibility of the Genetic Algorithm, we have also compared the computational time of this algorithm with a reward based machine learning algorithm Q-learning. Simulation result shows that Genetic algorithm takes lesser computational time.**

Keywords—supply chain; route finding; genetic algorithm

I. INTRODUCTION

The reason behind transportation's having a prime role in supply chain management is because products are never produced and consumed in the same place [1]. Transportation modes that are commonly used in moving products from one place to another are mainly air, water, rail, truck or intermodal way of transportation [2]. The entities that form supply chain architecture are retailers, distributors, carriers, manufacturers, customers. They use different modes of transportation within the network to reach each other [3]. The main goal is to achieve an optimal route with minimum cost.

Genetic algorithm is the most popular algorithm that has been used to select optimal route. Many researchers are working on it to optimize routes in supply chain networks using Genetic algorithm. They have plenty of limitations. The vital drawback they have is the incomplete design of supply chain architecture that hardly reflects the practical models of supply chain networks. Route Optimization in Supply Chain Networks is a multi-criterion complex decision making problem that has to satisfy many constrains [4]. According to the studies of [5], Genetic Algorithms work better where the traditional search and optimization Algorithms fail to avail the goal performance. Lawrynowicz *et al* also assert that GAs are efficient tools for solving complex optimization problems, highlighting the problem of minimizing the total cost for a distribution network, which presents some similar features to the problem addressed in this paper [6]. Wen *et al* proposed a Genetic Algorithm, using an integer encoding to represent the cargo item sequence to be delivered in order to solve the problem of logistics scheduling problem and optimize the total cost for a location-routing-inventory problem [7]. The proposed approach obtained good performance in terms of quality measure but the computation speed does not meet requirements. A genetic algorithm based model was proposed by Nafi *et al* that covers only 3 key components of a supply chain model [8]. They are suppliers, manufacturing plants and customers. Covering these three entities do not make a supply chain network universal. The research also lacks in experimental data that may help the readers understand the subtle issues of implying genetic algorithm. *Altiparmak et al* in their work presented mixed-integer non-linear programming model for multi-objective optimization of Supply Chain Network and a Genetic Algorithm approach to solve the problem but did not work with the uncertainty of the cost and demands which should have been dealt with [9]. Another Approach introduced by *Mortaza et al* covers the use of RPS algorithm in route optimization problem [10]. The main contribution of this research is the use of multi agent who can share their knowledge while learning the environment. The main drawback of this paper can be noted as their failure to work with the reverse condition of cost minimization and quality assurance. To overcome these limitations, we propose a fulfilled supply chain architecture with maximum possible number of nodes to be solved with Genetic Algorithm.

The rest of the paper is organized as follows: section II describes the proposed model; section III elaborates the experimental results and lastly section IV concludes the paper with possible future works.

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II. Proposed Model

For the implication of Genetic Algorithm, a network model has been designed considering supplier, manufacturing plant, distributor, retailer and customer as nodes. The entities are connected with four modes of communication such as train (t), rail (r), air (a), water (w). Fig. 1 shows the network model of the supply chain network for the implementation of Genetic Algorithm.

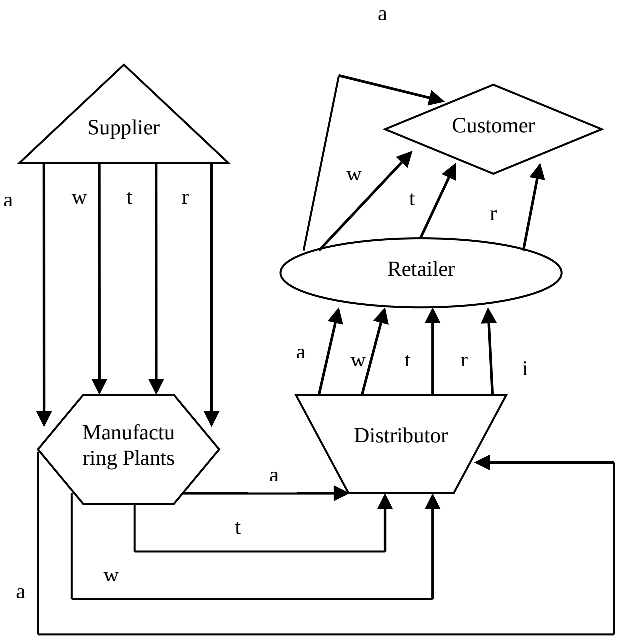

Fig. 1. Designed Network Model to implement Genetic Algorithm.

The entire process of applying genetic algorithm in our sample case scenario is described in the following diagram (see Fig. 2)

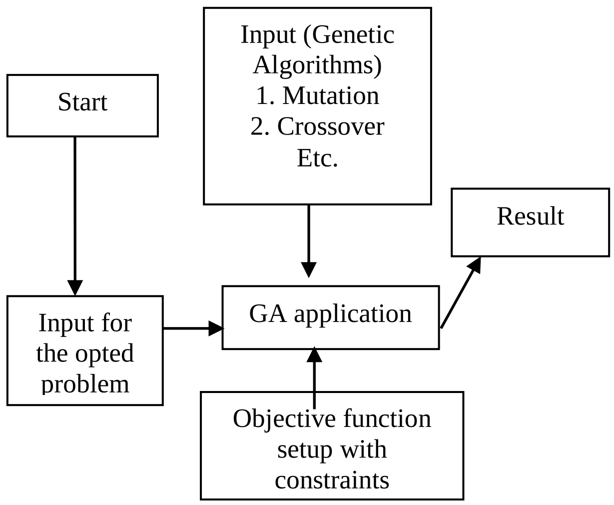

Fig. 2. Schematic Diagram for Genetic Algorithm.

Following objective function has been designed for our formulated problem:

$$F = \sum_{mij} Zmij.Dmij + \sum_{njk} Znjk.Dnjk + \sum_{okl} Zokl.Dokl + \sum_{vlc} Zvlc.Dvlc$$

Here, Parameters are described below

1. m = Set of vehicle routes from supplier to manufacturing plant.
2. i = Number of supplier, i = 1 to n.
3. j = Number of manufacturing plants, j = 1 to n.
4. n = Set of vehicle routes from manufacturing plants to distributors.
5. k = Number of distributors, k = 1 to n.
6. o = Set of vehicle routes from distributors to retailers.
7. l = Number of retailers, l = 1 to n.
8. v = Set of vehicle routes from retailers to customers.
9. c = Number of customers, c=1 to n.
10. Zmij = Binary variable whether the vehicle route to be opted is air (a), water (w), truck(t) or rail(r) from suppliers to manufacturing plants
11. Znjk = Binary variable whether the vehicle route to be opted is air (a), water (w), truck(t) or rail(r) from manufacturing plants to distributors
12. Zokl = Binary variable whether the vehicle route to be opted is air (a), water (w), truck(t) or rail(r) from distributors to retailers
13. Zvlc = Binary variable whether the vehicle route to be opted is air (a), water (w), truck(t) or rail(r) from retailers to customers
14. Dmij = Unit transportation cost from suppliers to manufacturing plants.
15. Dnjk = Unit transportation cost from manufacturing plants distributors.
16. Dokl = Unit transportation cost from distributors to retailers.
17. Dvlc = Unit transportation cost from retailers to customers.

The constraints for our case scenario of genetic algorithm are:

1. Zmij = At least one route should be open from suppliers to manufacturing plants.

2. Znjk = At least one route should be open from manufacturing plants to distributors.

3. Zokl = At least one route should be open from distributors to retailers.

4. Zvlc = At least one route should be open from retailers to customers.

Fig 3 shows the best fitness and the expectation graph of the implemented genetic algorithm in our case scenario.

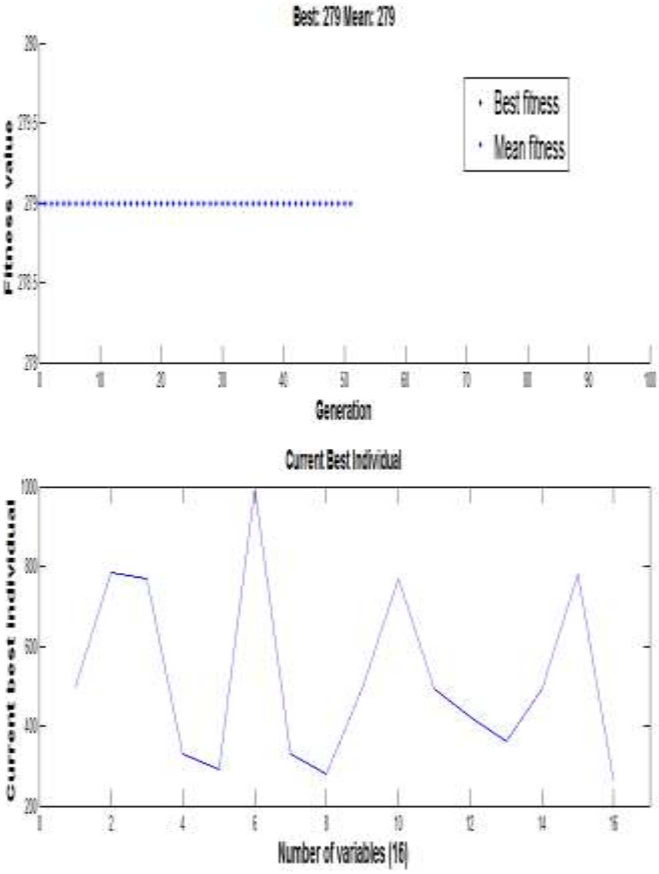

Fig. 3. Best Fitness and Expectation.

Fig. 4 shows the expectation and genealogy graph for the implemented Genetic algorithm.

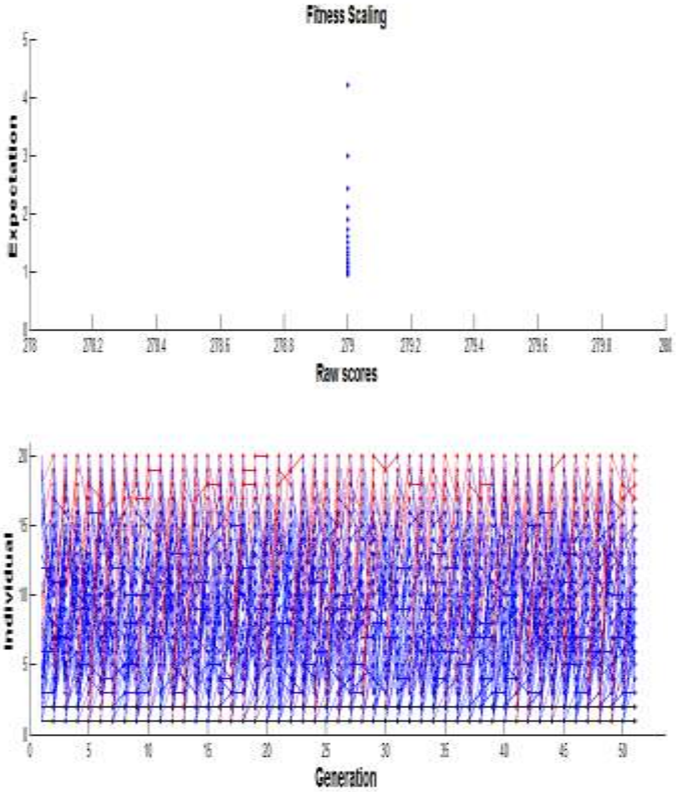

Fig. 4. Expectation and Genealogy graph.

Fig. 5 shows the distance and range graph for the implemented genetic algorithm.

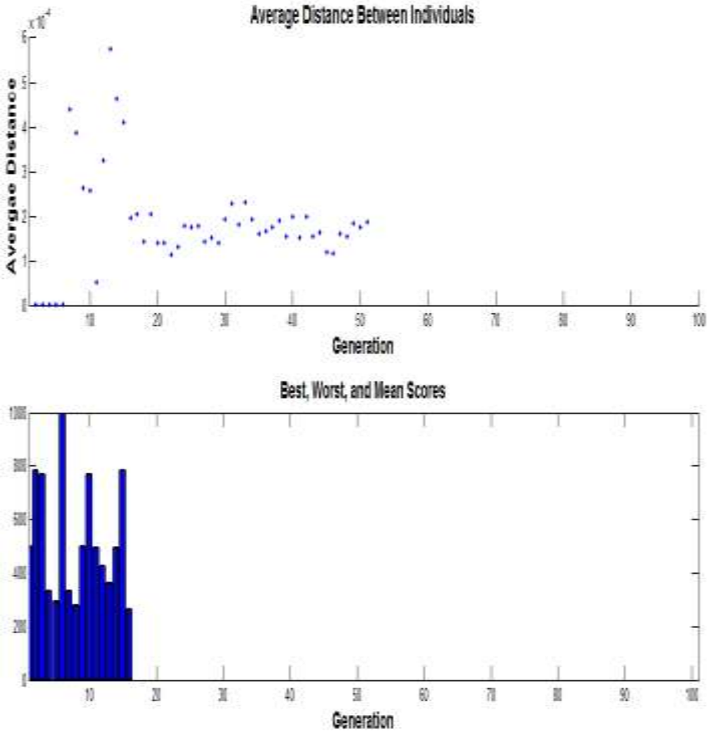

Fig. 5. Distance and Range Graph.

Fig. 6 shows the selection and maximum constraint graph for the implemented genetic algorithm.

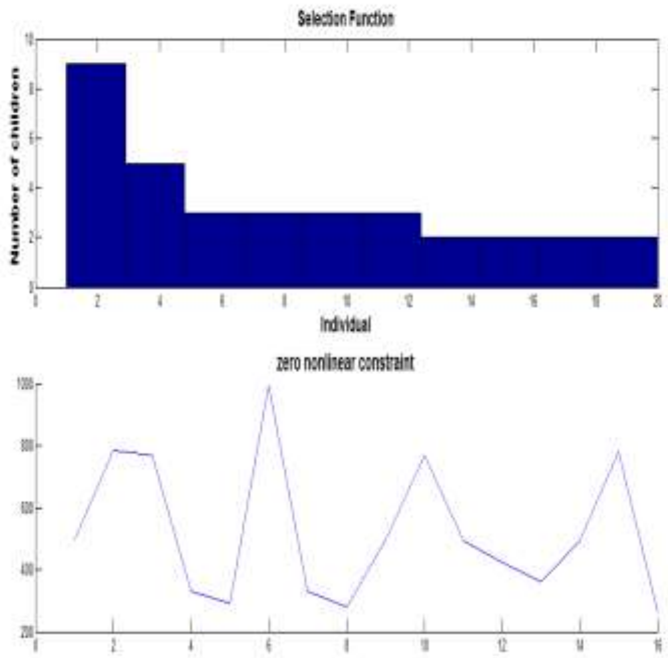

Fig. 6. Selection and maximum constraint graph.

III. Experimental Results

Approximate data range for our model is given below. The data range has been decided based on judgment and expert opinion.

- Air Transportation = 410-815 unit
- Water Transportation = 7-317 unit
- Rail transportation = 305-340 unit
- Truck Transport = 200-520 unit

Fig. 7 shows that the optimized value achieved from Genetic Algorithm.

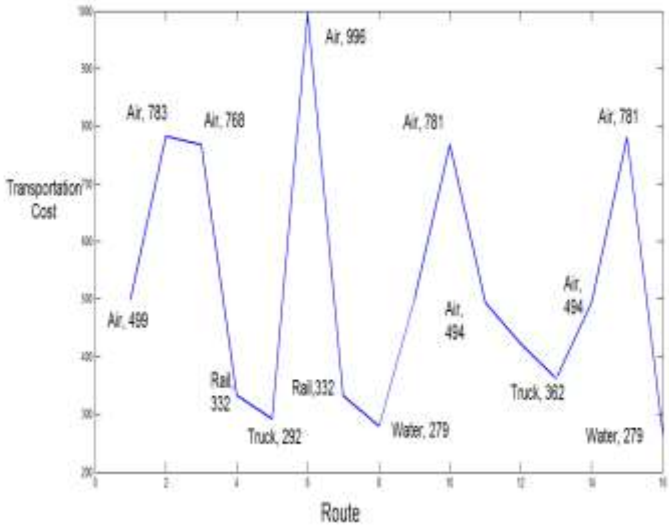

Fig. 7. Optimal value selection using Genetic Algorithm

Here,

[Rail, 332] = Rail transportation cost is close to the optimized value 279. So, rail is the optimized route from supplier to manufacturing plants.

[Water, 279] = Water transportation cost is equal to the optimized value 279. So, this route is the optimized route from manufacturing plants distributors.

[Truck, 362] = Transportation cost for truck is close to the optimized value 279. So, the optimized route from distributors to retailers is transportation via truck.

[Water, 279] = Water transportation cost is equal to the optimized value 279. So, water is the optimized route from retailers to customer.

Supply chain network that we have considered in our work has many nodes and consists of complex architecture. How fast we can get the output, is a very important issue in this case. That is why, we have counted computational time as a very important metric to measure the performance of the implied algorithms. TABLE IV shows us the lesser computation time taken by the Genetic Algorithm.

TABLE IV. COMPUTATIONAL TIME OF DIFFERENT ALGORITHMS

Algorithm	Computational Time (sec)
Q-learning	7.094
Genetic Algorithm	6.25

From the table we can see that the least computational time is taken by the Genetic algorithm. Fig. 8 shows the graph of the computational time comparison of the implemented algorithms.

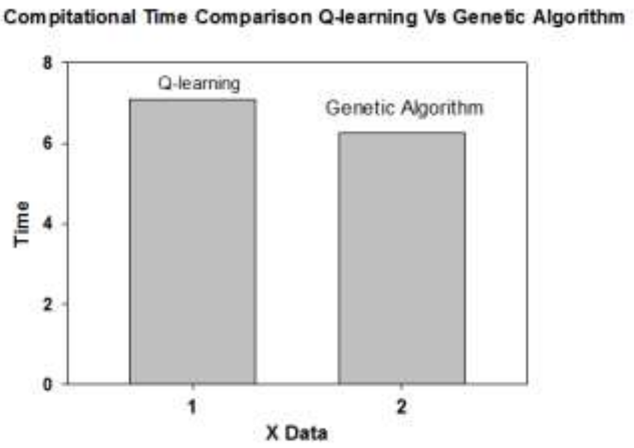

Fig. 8. Computational Time Comparison of the Q-learning and GA

IV. Conclusion and Future Work

In this paper, we have modeled universal supply chain architecture with the maximum nodes that can be added. We also compared the computational time with a very popular reinforcement learning Algorithm, Q-learning. The evolutionary learning algorithm worked faster. We still do not know if Genetic Algorithm will outsmart reinforcement learning algorithms like SARSA (State-Action-Reward-State-Action Algorithm). This reward based machine learning algorithm has not yet been used formally in this field and due to the eligibility trace parameter in the algorithm, it is quite predictable that the algorithm will take less computational time and the convergence speed will be lesser. In future, we are planning to build java based software that will help people find optimal route using simple inputs with the help of this algorithm.

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