Path Planning for Multiple AGV Systems Using Genetic Algorithm in Warehouse

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Abstract—**Path planning problem in multiple automated guided vehicle (AGV) system has been proven to be NP-Hard problem by many researchers. This complex task is being done using various mathematical techniques traditionally. This paper proposes an optimal path planning method for the multiple AGV system based on genetic algorithm. The constraint in the optimization task is that, each AGV starts and returns to transfer center, travelling to a unique set of pick-up stations, each pick-up station is visited by exactly one AGV for goods picking up. The Cost Function is to search for the shortest path i.e. the least distance needed for each AGV to travel from the start location to individual points and back to the original starting place. The experimental results shows the solution in this paper is effective which provide a reference for practical applications.**

Keywords—pathing planning; genetic algorithm; multiple AGV; optimization; warehouse

I. INTRODUCTION

Automated guided vehicle (AGV) systems are frequently used for transporting material within a manufacturing, warehousing, or distribution system [1]. AGV is a portable robot that follows markers or wires in the floor, or uses vision, magnets, or lasers for navigation. Running 24/7, AGV are increasing the productivity while reducing labour costs. They are most often used in industrial applications to move materials around a manufacturing facility or warehouse. With many advantages, AGV has been widely used as the core equipment of modern logistics system.

Nowadays the dispatching problem of the multiple AGV system is one of the most worthy questions to study. Finding the optimal path for each AGV can improve the whole efficiency in practical situations of the factory [2-4]. Picking problems concern optimization problems of this procedure in relation with the design of the warehouse. Different path planning algorithms are suited for different warehouse layout. The proposed scheme applies to one particular type of layout.

Genetic Algorithms (GA) are adaptive heuristic search algorithm on the basis of evolutionary ideas of natural selection and genetics [5]. As such they represent an intelligent exploitation of a random search used to solve optimization problems. Although randomized, GA are by no means random, instead they exploit historical information to direct the search into the region of better performance in the search space. The basic techniques of the GA are designed to simulate processes in natural systems necessary for evolution, specially those follow the principles first laid down by Charles Darwin of "survival of the fittest". Since in nature, competition among individuals for scanty resources results in the fittest individuals dominating over the weaker ones.

In this paper, the genetic algorithm was utilized to finding the optimal path for multiple AGV in the warehouse. As shown in the experimental results, modified genetic algorithm is superior than the original one.

The remainder of the paper is organized as follows. The related work is list and discussed in section 2. Section 3 described the proposed algorithm. The experimental results and discussion are presented in section 4 and section 5 concluded the whole work.

II. RELATED WORK

The path planning is an important research area of artificial intelligence and robotics which has been proven to be NP-Hard problem [6]. Various algorithms have been applied to the path planning.

Latombe [6] mentioned in the paper that the traditional methods are mainly graphical and analytical methodologies. Graphical method includes road map method, grid method etc. Analytical methods including Genetic Algorithm, Ant Colony Optimization (ACO), Taboo search intelligent algorithm and its hybrid form are also used to solve the path planning problem.

The famous Dijkstra algorithm searches for the global space without considering the target information. It causes that the solving time is long and difficult to meet the need of fast path planning [7]. Another path planning method named a star algorithm frequently used when the global environmental information is already known [8]. The process flow of the algorithm is complex and a big amount of mathematical calculations are required.

Many researches utilize genetic algorithm to find an optimal path [9, 10]. For instance, Nallusamy dealt with generating of an optimized route for multiple vehicle routing problems by first clustering the given cities depending upon the number of vehicles and each cluster is allotted to a vehicle [11]. Then the Genetic Algorithm were applied to the cluster and iterated to obtain the most optimal value of the distance after convergence. The final results show that genetic algorithm gave better performance on optimal path planning.

Each algorithm has its own advantages and disadvantages. So it's very important to choose the suitable algorithm for different situations.

III. PROBLEM DESCRIPTION AND MODELING

The mathematical formulation of the presented problem use the following notation:

n - the number of stations in the warehouse to be visited; and the number of nodes in the route network;

i,j,k - Indices of stations that can take integer values from 1 to n;

t-The time period, or step in the route between the stations;

x_{ijt} - 1 if the edge of the network from i to j has been used in step t and 0 otherwise;

d_{ij} - the distance calculated from station i to station j;

The linear programming formulation of this problem can be exampled as:

The objective function is to minimize the total distance of all of the selected elements of the tour:

$$F = \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{t=1}^{n} d_{ij} x_{ijt}$$

The constraints are as following,

$\sum_{i} \sum_{j} x_{ijt} = 1$ for all t; For all values of t, AGV is running in one segment.

$\sum_{j} \sum_{t} x_{ijt} = 1$ for all i; For all stations, at certain time there is just one other station which is being reached from it;

$\sum_{i} \sum_{t} x_{ijt} = 1$ for all j; For all stations, at certain time there is one station from which it is being reached;

When a station is reached at time t, it must be left at time t+1, in order to exclude disconnected sub-tours that would otherwise meet all of the above constraints. These sub-tour elimination constraints are formulated as:

$$\sum_{i} x_{ijt} = \sum_{k} x_{ik(t+1)} \quad \text{for all j and t}$$

In addition to the above constraints the decision variables are constrained to be integer values in the range of 0-1:

$$0 \leq x_{ijt} \leq 1$$

As a computational intelligence method, genetic algorithm aim to find the approximate solutions to combined optimization problems. It contains the algorithmic idea of survival of the fittest. That is to guess solutions first, and then combining the fittest solutions to create a new generation of solutions that should be better than the previous generation.
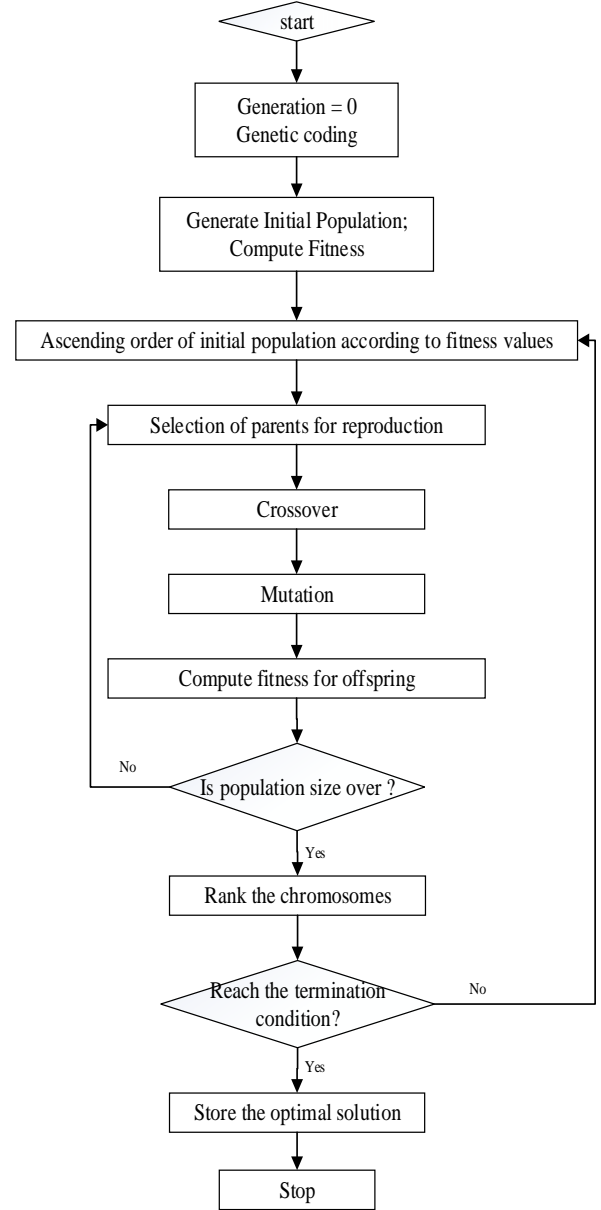

FIGURE II. FLOWCHART OF GENETIC ALGORITHM

A. Genetic Algorithm

Figure 2 shows flowchart of the genetic algorithm. The genetic algorithm uses three main types of rules at each step to create the next generation from the current population:

- Selection rules which select the individuals, called parents that contribute to the population at the next generation.

- Crossover rules combine two parents to form children for the next generation.

- Mutation rules apply random changes to individual parents to form children.

Details of the algorithm including:

1) Encoding: A suitable encoding is found for the solution to our problem so that each possible solution has unique encoding and the encoding is some form of a string.

2) Evaluation/Selection: The initial population is then selected, usually at random though alternative techniques using heuristics have also been proposed. The fitness of each individual in the population is then computed that is, how well the individual fits the problem and whether it is near the optimum compared to the other individuals in the population.

3) Crossover: The fitness is used to find the individual's probability of crossover. Crossover is where the two individuals are recombined to create new individuals which are copied into the new generation.

4) Mutation: Some individuals are chosen randomly to be mutated and then a mutation point is randomly chosen. The character in the corresponding position of the string is changed.

5) Decoding: A new generation has been formed and the process is repeated until some stopping criteria has been reached. At this point the individual who is closest to the optimum is decoded and the process is repeated until we get an individual with high fitness value.

In the warehouse, there are m AGV travelling in a set of workstations, and suppose there are n workstations calls the AGV for pick-up jobs at same time. All the AGV are defined to start and end at the transfer center (as shown in figure 1).
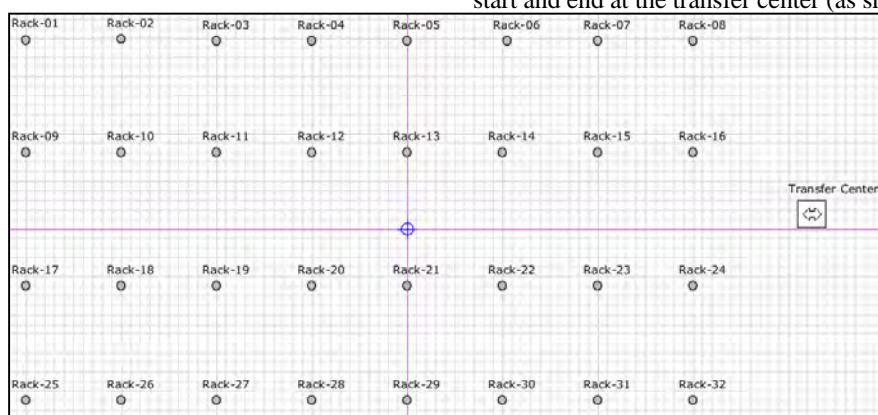

FIGURE I. FLOWCHART OF PATH PLANNING FOR MULTIPLE AGV USING GENETIC ALGORITHM

In simulations, each pick-up point must be visited exactly once by only one AGV and its objective is to minimum total distances travelled by all the AGV.

B. Modified Genetic Algorithm

The proposed algorithm modified the traditional genetic algorithm by using one chromosome. In this method, the stations are represented by of the integers from 1 to a, and the permutation is divided into b sub-tours by the insertion of b negative integers (from 1 to b), thus the total length of the single chromosome is a+b.

A modified crossover operator is proposed based on the order crossover operator. In this crossover operation, a randomly chosen crossover point divides the parent strings in left and right sub-strings. The right sub-strings of the parents are selected. The order crossover randomly selects several points in a parent tour while the modified crossover selects all the right of positions.

In the mutation step, two points are randomly chosen in the string, and sub-string is reversed between these two cut points.

This algorithm employ a local search technique to obtain a better solution as compared to previous iterations. The search tries to improve route by replacing its two non-adjacent edges by two other edges. It should be noted that there are several

routes for connecting nodes and producing the tour again, but the tour should satisfy all the constraints.

Under the premise of satisfying all constraints, if the new tour produces a better value for the problem than the previous solution then only the unique tour will be accepted. The process is repeated until the termination condition is met.

IV. EXPERIMENTS

The proposed algorithm is implemented and tested in MATLAB. To reveal the performance of the algorithm we test a case of certain number of AGV traveling in the warehouse to pick-up parts or goods delivering to the transfer center. The first step is to calculate the distance matrix. As shown in figure 2, the input data is the coordinates of the transfer center and the pick-up points, which contains 33 stations in total. The final task is to find the optimal path for each AGV using the proposed algorithm under the condition of each AGV is allowed to travel a minimum of 5 pick-up points. The illustrative result is presented here in the figure 3.
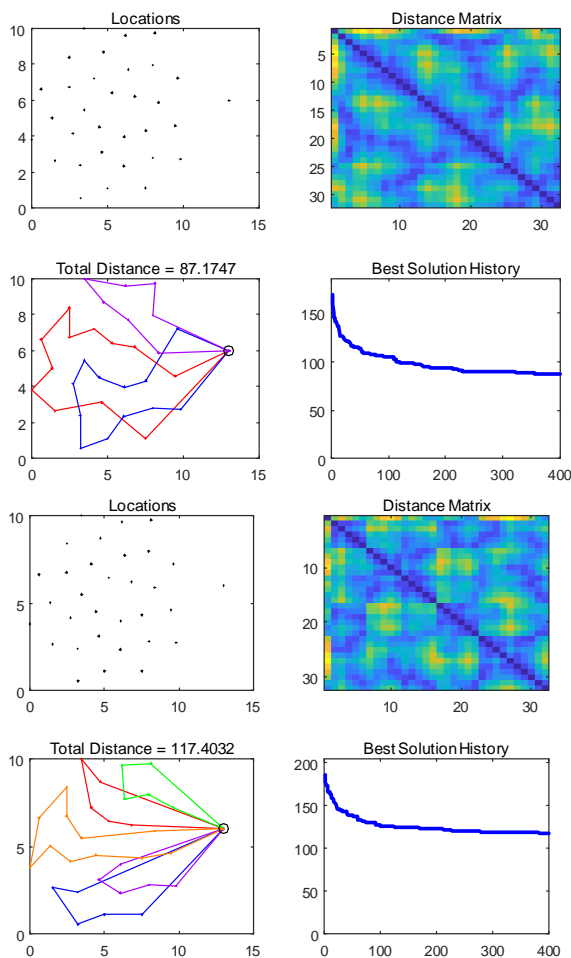
FIGURE III. THE RESULTS OF THE SIMULATION EXPERIMENTS

The parameters selected in the simulation are as follows:

- Population size: population size affects the performance and efficiency of genetic algorithm, the number is set 80 in this work;

- The minimum tour length is set 5, not including the transfer center.

- The number of stations (pick-up points) is 32.

With the above parameter settings, figure 3 shows the simulation results of modified genetic algorithm. The figure shows the simulated stations (pick-up points) and distance matrix. During the entire optimization process, the shortest path of each iteration is calculated. In the initial stage of optimization, the convergence speed is very fast, and the further it goes, the slower it becomes. When reaches around 400 iteration, it can be considered that the optimization result is close to the optimal value. Table 4 lists experimental results of the traditional genetic algorithm and modified genetic algorithm for specific circumstance presented in this work. The modified genetic algorithm obtain better results than the traditional genetic algorithm in most cases. This improvement becomes more obvious while the problem becomes larger.

TABLE I. EXPERIMENTAL RESULTS OF DIFFERENT ALGORITHMS

AGV number	Algorithms			
	Genetic Algorithm		*Modified GA*	
	Iteration	Total distance	Iteration	Total distance
3	352	104.65	231	87.17
5	400	121.53	327	117.4

V. CONCLUSION

This study is focused on the optimal path finding algorithm of multiple AGV transfer goods in the warehouse using genetic algorithms. The proposed scheme is also appropriate for a variation in the number of workstations and a variation in the number of AGV. The proposed algorithm shows excellent performance for solving such small-scale problems illustrated in this work. Further research can be done by considering the scheduling and collision problem between AGV to promote the total performance in warehouse.

REFERENCES

[1] L Sabattini, V Digani, M Lucchi, et al. Mission Assignment for Multi-Vehicle Systems in Industrial Environments [J]. Ifac Papersonline, 2015, 48(19):268-273.

[2] Y Xing, K Yin, B X Wang, et al. Dispatch Problem of Automated Guided Vehicles for Serving Tandem Lift Quay Crane[J]. Transportation Research Record Journal of the Transportation Research Board, 2012, 2273(2273):79-86.

[3] T Leanh, M B M De Koster. Multi-Attribute Dispatching Rules for Agv Systems with Many Vehicles [J]. Social Science Electronic Publishing, 2004.

[4] R Olmi, C Secchi, C Fantuzzi. Coordination of multiple AGVs in an industrial application[C]// IEEE International Conference on Robotics and Automation. IEEE, 2008:1916-1921.

[5] G. Nagib, W. G. Ali, "Network Routing Protocol using Genetic Algorithms", International Journal of Electrical and Computer Sciences IJECS, vol. 10, No. 02, 2010, pp. 40-44.

[6] J. C. Latombe, "Robot motion planning", Kluwer Academic Publishing, Norwell, MA, (1991).

[7] E A Shaikh, A D Dhale. AGV routing using Dijkstra's Algorithm – A review [J].

[8] R Yuan, T Dong, J Li. Research on the Collision-Free Path Planning of Multi-AGVs System Based on Improved A* Algorithm [J]. American Journal of Operations Research, 2016, 06(6):442-449.

[9] M R Panda, R Priyadarshini, S Pradhan. An Optimal Path Planning for Multiple Mobile Robots Using AIS and GA: A Hybrid Approach[C]// Mike. 2015.

[10] F A Afsar, M Arif, M Hussain. Genetic Algorithm Based Path Planning and Optimization for Autonomous Mobile Robots with Morphological Preprocessing[C]// Multitopic Conference, 2006. INMIC '06. IEEE. IEEE, 2006:182-187.

[11] R Nallusamy, K Duraiswamy, R Dhanalaksmi, et al. Optimization of Multiple Vehicle Routing Problems using Approximation Algorithms[J]. International Journal of Engineering Science & Technology, 2009, 1(3).