Best Path Planning Algorithm for Mobile Robot Based on Modified Genetic Algorithm

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ABSTRACT

In this paper a best path planning for mobile robot based on modified Genetic algorithm is introduced. The proposed algorithm read the map of the environment which expressed by grid model and then attempts to create an optimal or near optimal collision free path. No mutation operator is used in the proposed algorithm and modified generations of population size with modified selection operator are used. The proposed approach is implemented in five different environments. Four of these environments are implemented in different range of space. The fifth environment is very large size. The simulation results show that the proposed method can give good results in terms of minimizing distance and executions time in comparison with the other Genetic algorithms and with other kinds of soft computing (Neural Networks and Fuzzy) when they applying with different environments and cutter environments.

Keywords: Modified Genetic Algorithm, Path Planning, Modified Selection Operation.

خوارزمية تخطيط افضل مسار لروبوت متحرك اعتمادا على خوارزمية الجينات المطورة

الخلاصة

في هذه البحث تم عرض أفضل مسار للروبوت المتحرك على أساس الخوارزمية الجينية المعدلة. الخوارزمية المقترحة تقوم بقراءة خريطة البيئة والتي عرضت على شكل نموذج شبكة وثم تحاول انشاء أمثل أو قرب مسار لتجنب التصادم. لم يتم استخدام عامل الطفرة في الخوارزمية ألمقترحة وتم استخدام عامل اختيار معدل. النموذج المقترح تم تنفيذه على خمس بيئات مختلفة , اربع منها نفذت على مساحات مختلفة والبيئة الخامسة ذات مساحة كبيرة جدا. نتائج المحاكاة تبين أن الطريقة المقترحة تعطي نتائج جيدة من حيث حساب اقصر مسافة و اقل وقت تنفيذ مقارنة مع الخوارزميات الجينية الأخرى وأنواع الحوسبة .

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INTRODUCTION

It is well known that there are various definitions of the term robot, but they generally revolve around this:

A robot is a machine with abilities of perception, decision and action which can act autonomously in their environment based on the perception. Autonomous mobile robots must have many skills. First, it must be able to see its environment and the location in it .To do this, a robot has sensors such as sonar and a laser scanning device laser to measure distances between itself and the obstacles nearby .Once located in its environment, the robot must be able to move from one point to another by finding safe and effective ways to avoid collisions with obstacles. In addition, a robot is often able to communicate with people or other agents nearby. This can be done in different ways, for example by voice or via a graphical interface [1].

In addition to generally perceive their environment, a robot must often be able to identify objects, recognize people, read signs, and able to identify graphic symbols.

Evolutionary computing based on evolutionary algorithms, such as genetic algorithms, represents an excellent alternative to the single-point methods. Genetic algorithms are inspired by the natural selection and evolution processes. They operate on a population of possible solutions to produce a better solution [2].

Path planning for a mobile robot is defined as determining a route from the start to the goal for successfully maneuvering the robot around obstacles in some optimal manner. Generally, some optimization criteria with respect to time, distance, or energy must be satisfied. Distance is a commonly adopted criterion. It is difficult to obtain the optimal path solution between the start and target position using conventional methods, such as gradient search methods, because of the difficulties of Optimization very huge number of possible solutions in acceptable time. Many approaches have been proposed to solve this problem. One can categorize these approaches on the basis of model considerations; mainly sensor based model (online) and map based model (offline).Sometimes they called local path planning and global path planning or online and offline [3].

Local path planning acquired information about its environment from the sensors (that scan the area within a certain range). Global path planning determines the paths between the start point and the target after a complete survey of the whole environment [4].

Soft computing such as fuzzy logic, Neural Networks and Evolutionary computing (in particular, Genetic algorithms (GA)) are very often used in the fields of path planning. However it is useful to mention that genetic algorithms are more efficient than the fuzzy logic and Neural Networks. This is due to the capability of genetic algorithms to optimize both discrete and continuous mappings. They are easily distinguished from the conventional single-point based Optimization techniques, such as gradient search methods, by the fact that their search mode is performed based upon multiple points in the search space rather than upon a single point [5].

Many researchers have been worked in the field of path planning using genetic algorithm

Yong Z. et al. 2008 [6], presented an unknown environment robot path planning algorithm using Hybrid Genetic Algorithm. This technique improved the traditional genetic algorithm, the planning can be achieved satisfactory results and the speed of convergence and shows that the genetic algorithm strong environmental adaptability.

Shijie D. et al. 2009 [7], Proposed a rough set genetic algorithm to optimize the robot path planning speed and improve the precision. The simulations are performed under group test conditions to the initial population of Genetic Algorithm simplified by rough sets and generated randomly respectively, the results of this suggest is significant at optimizing the robot path panning speed, especially in the complicated environments.

Soh C. et al. 2010 [8], proposed a modified genetic algorithms of optimum path planning for mobile robot navigation. An Obstacle Avoidance Algorithm (OAA) and a Distinguish Algorithm (DA) are designed to generate the initial population in order to improve the path planning performance to select only the feasible paths during the evolution of genetic algorithm. Crossover, mutation, refinement and deletion operators are specifically designed to fit path planning for mobile robots. The proposed genetic algorithms feature unique, simple path representations, simple and effective evaluation methods. Real time implementations are carried out to prove and validate the effectiveness of the proposed algorithms.

I. Engedy and G. Horváth 2010 [9], presented an artificial neural network based motion and path planning system of a wheeled mobile robot navigating among stationary and moving obstacles. The artificial neural network is used as a controller, and it is trained using a back propagation through time algorithm.

Cen Z. et al. 2011 [10], Investigated a genetic algorithm and A* algorithm for mobile robot Global path planning. Simulation results indicate that the proposed algorithm is more efficient than Dijkstra algorithm in term of both solution quality and computational time, and thus it is a viable approach to mobile robot path planning.

Hachour O. 2011 [11], proposed an artificial neural network based navigation for intelligent autonomous mobile robots. The proposed algorithm deals with unknown static obstacles. The simulation results appear the ability of the neural networks to providing autonomous mobile robots with capability to navigate in several environments.

Marko A. Et al. 2011 [12], divided the path planning problem into several simpler problems. Firstly is generating collision free path from starting to target point, which is solved by using Particle Swarm Optimization (PSO) algorithm. Secondly interpolates the obtained collision free path, which is solved by using Radial Basis Function Neural Network (RBFNN).

THE MODIFIED GENETIC ALGORITHM

The most traditional genetic algorithms of path planning use one of the two below procedure for carrying out a Genetic algorithm .These are shown in Figure (1) and Figure (2) [8]. These approaches although they have rapid search and high search quality in the existing algorithm, there are four problems associated with this method. **First**, the initial population of solutions with fixed population size takes very long times in some condition especially in cutter environment and sometimes fail generate the population size finally, which have negative influence on the performance of the genetic algorithm. **Secondly**, after a generation, off springs may contain infeasible paths and the population size decreased so need either go back to the initial population step or repeat perform the genetic operators until get population number equal to population size. **Thirdly,** it required complex selection operator and test function to discover the infeasible paths. **Fourthly,** it required binary encoding/decoding which consume the time [8].

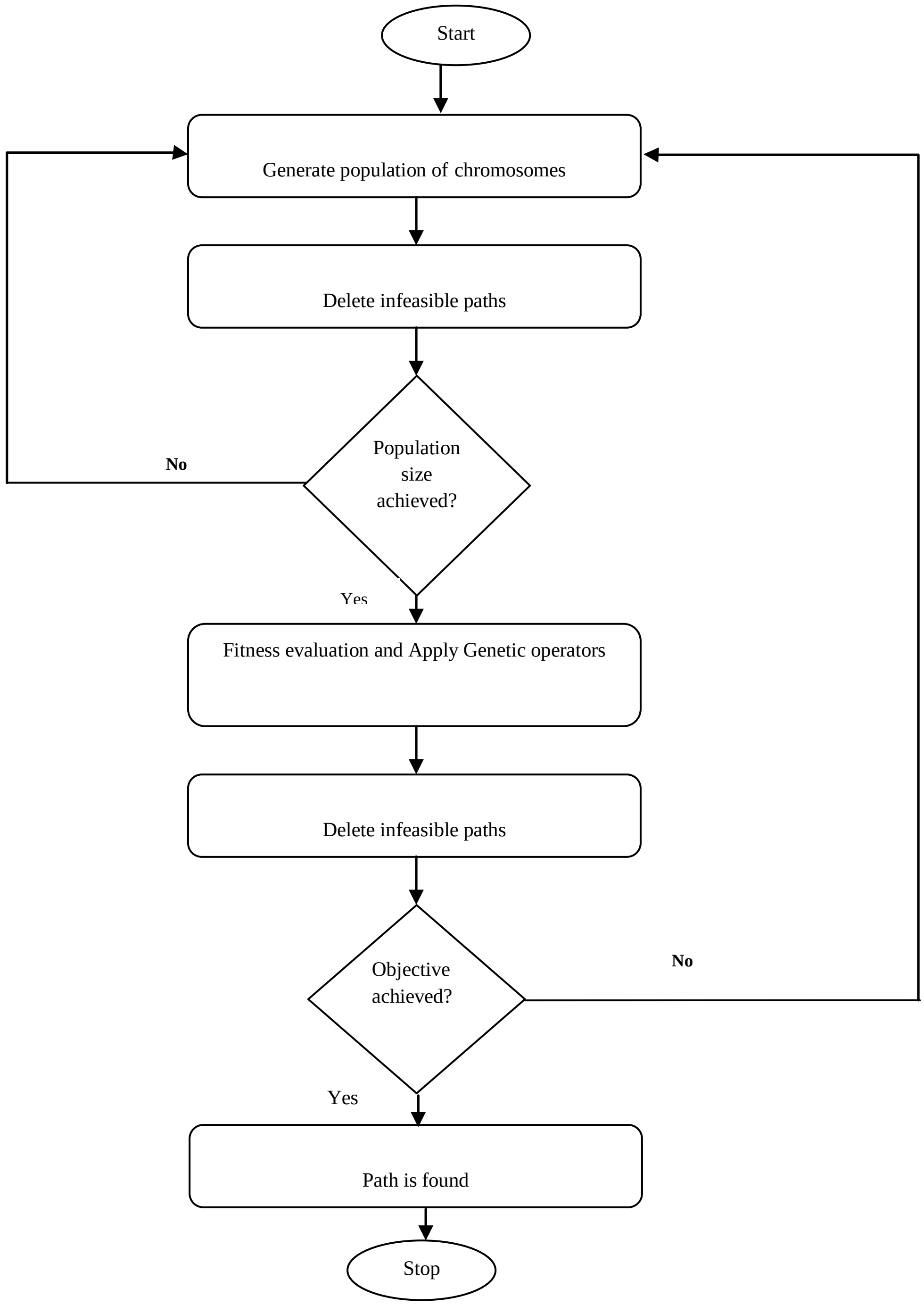


Figure (1) Flowch… …ic Algorithm

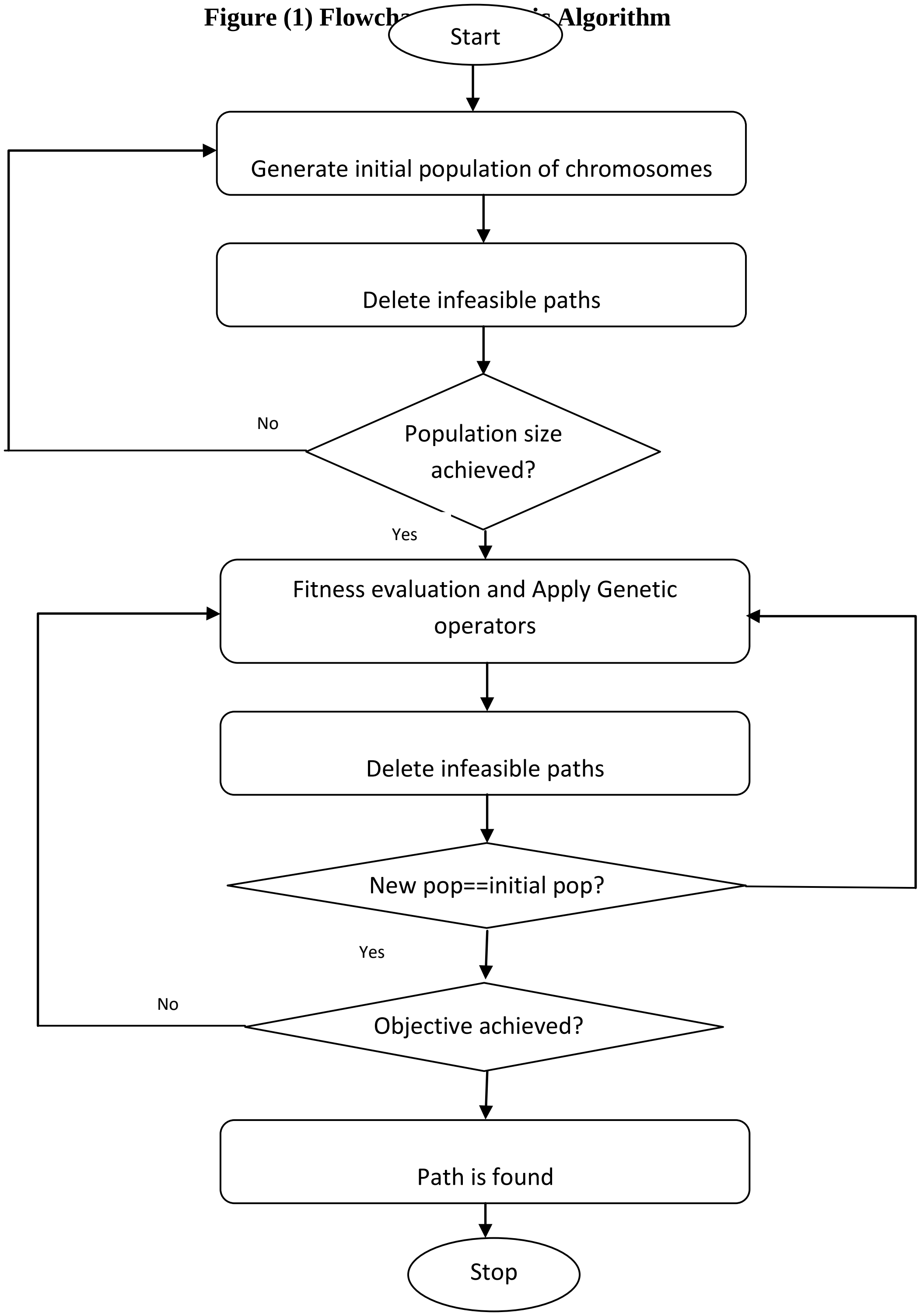


Figure (2) Flowchart of Genetic Algorithm (2).

The proposed Modified Genetic Algorithm (MGA) path planning does not required any encoding scheme because it use the real representation .No time is required for encoding and decoding population.

A potential path is formed by line segment connecting the nodes falling on the grids with different numbers and a path can be represented by their respective X and Y coordinates. Each path has two chromosomes to be represented, one for X coordinates and the second for Y coordinate, for example.

Path(x,y) = {(1,1), (1,3), (2,5), (3,6), (4,8), (4,9), (10,10)}

Chromosome x= {1, 1, 2, 3, 4, 4, 10}

Chromosome y= {1, 3, 5, 6, 8, 9, 10}

Randomly select one node within the obstacle area, say randomly A.

To find the distance, *d*, between start node (node x) and node A using the following equation:

$$d = \sqrt{(x_2 - x_1) + (y_2 - y_1)} \qquad \text{... (1)}$$

where coordinates of node x and node A are (x_1,y_1) and (x_2, y_2) respectively

Almost all of the individuals of the initial population in the genetic algorithms are assumed to be generated randomly. This is simple and fast but will lead to 3large quantities of infeasible paths and so required long time to achieved population size.

The proposed method does not use fixed population size and it starts with small population size. During iteration, the population size increased and balanced to avoid the start up or initial time. The Delete algorithm is designed to delete the infeasible path. Figure (3) shows the flowchart of the Modified Genetic Algorithm (MGA).

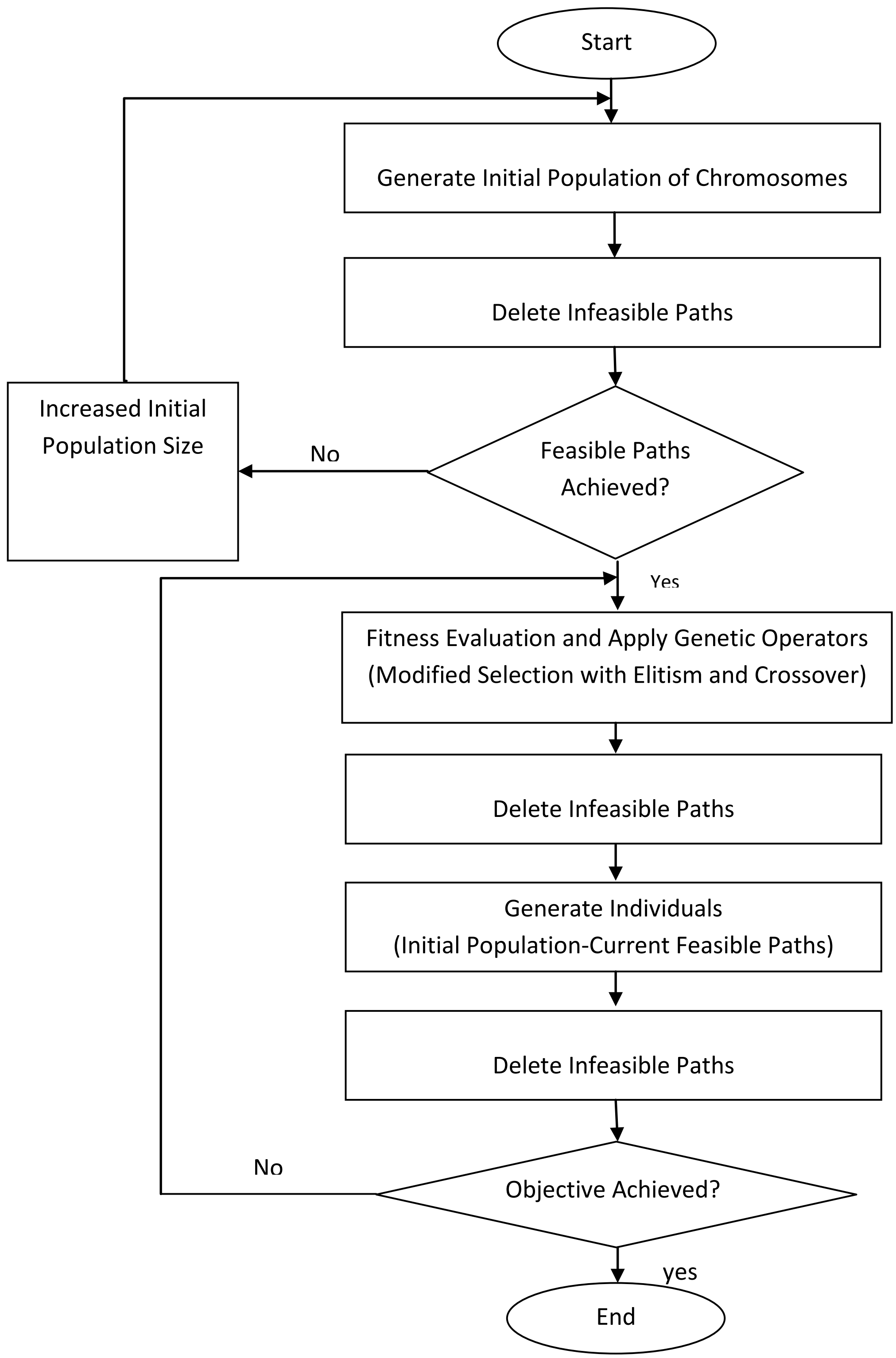

Start
Generate Initial Population of Chromosomes
Delete Infeasible Paths
Feasible Paths Achieved?
No
Increased Initial Population Size
Yes
Fitness Evaluation and Apply Genetic Operators (Modified Selection with Elitism and Crossover)
Delete Infeasible Paths
Generate Individuals (Initial Population-Current Feasible Paths)
Delete Infeasible Paths
Objective Achieved?
No
yes
End

Figure (3) Flowchart of the proposed MGA.

The goal of the modified genetic algorithm is to minimize the total distance from the starting position to the desired goal without colliding with any of the obstacles in the environment. The fitness function is the inverse of the total distance. The fitness function is defined as

$$F(x_i) = \frac{1}{\sum_{i=1}^{l} d(x_i)} \quad \text{... (2)}$$

Where *i=1, 2, 3,…,n*,

(x_i) represents the ith chromosome, (n) is the population size and (d (x_i)) is the distance of the ith path in the environment, and ***l***, is the number of link that consist path. It is obvious that the best individual will have maximum fitness value.

The selection operator starts with selected group of parent randomly and then sorted the population according to the fitness values. The fitness assigned to each individual depends only on its position in the individuals rank and not on the actual fitness value. This method is used to combine the Rank-based fitness assignment and Tournament selection**.** It is most popular selection method due to its simplicity and it is very fast.

Crossover operation: One point random crossover operators are used in the proposed algorithm; it consists of the following four main steps:

Step1: Select the best fitness chromosome (parent 1) and worst fitness chromosome (parent 2), then Select the second best fitness chromosome (parent 1) and second worst fitness chromosome (parent 2), Similar process is repeated until all chromosome “that selected by selection operator” is selected.

Step2: Use a random number to select one node as crossover point.

Step3: Swap the contents before or after the crossover point of two parents’ individuals.

Step4: Use delete algorithm to check the two newly generated off springs

It is clear that there is no mutation operator used in the proposed approach. Generation algorithm is used to increase the diversity of the population and help to prevent the population from stagnating at any local optima. During iteration, Generation algorithm continues generate path instead of infeasible path created by crossover operator.

The outline procedure for carrying out the modified genetic algorithms path planning is described by the following steps :-

Step 1 Initialize the population of chromosomes randomly according to population size.

Step 2 Delete infeasible paths created by initial generation algorithm.

Step 3 if no feasible paths is achieved, increased initial population size and go back to step 1.

Step 4 Perform the following steps until the predefined condition is achieved:

- Evaluate the fitness function values for each chromosome.
- Apply elitism selection.
- Select a new generation (using the modified selection approach).
- Apply genetic operator (only one point crossover).
- Delete infeasible paths created after apply crossover operator.
- Generate new chromosomes instead of infeasible path created by crossover operator to increase the diversity of the population. It helps also to prevent the population from stagnating at any local optima. The number of chromosome generation equal to Initial population size minus current feasible paths.
- Delete infeasible paths created by generation algorithm.

Step 5 Go back to step 4 if the optimization requirement is not attained, else **go to** step 6

Step 6 Terminate Algorithm.

3 Path Planning Simulation Results

The proposed approach is implemented in five environments and simulations are obtained using MATLAB R2010b (m-file). Four of these environments are the same environment uses in [8, 10, and 11]. The fifth environment has very large size and a few approaches can deal with such size due to the complexity and difficultly to support this size and the ability to find optimal or near optimal path with satisfied time.

3.1 First Environment

The effectiveness of the proposed algorithm is demonstrated by simulation. Five experiments perform on the environment as shown in Figure (4), this environment is the same environment that is used in [8] the starting location is grid (0) and the desired goal is grid (99). The blank grids represent obstacle free areas where mobile robots can move freely. The black areas represent obstacle areas, whose boundaries are formed by their actual boundaries plus a safety distance that is defined with consideration of the size of the mobile robot in order to enable the mobile robot to be treated as a point in the environment. The following are the typical parameters for the proposed genetic algorithm:

Initialization population = 3000, Crossover rate = 0.5, No of iteration = 200 iteration

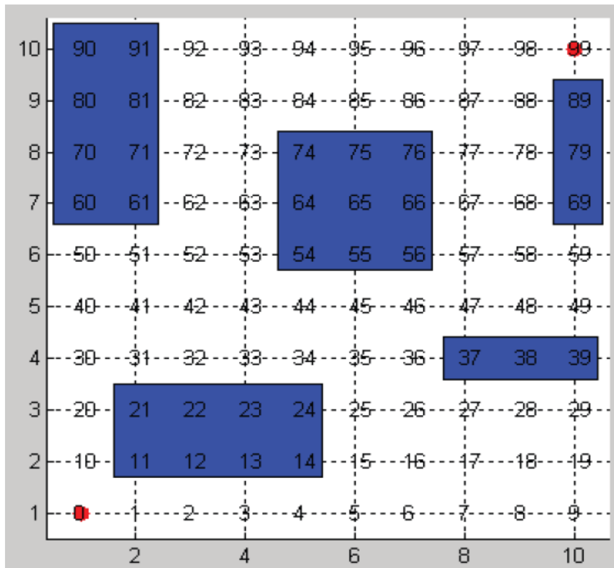


Figure (4) Diagram of Environment (10 by 10) [8].

While Figures (5 and 6) show the best path.

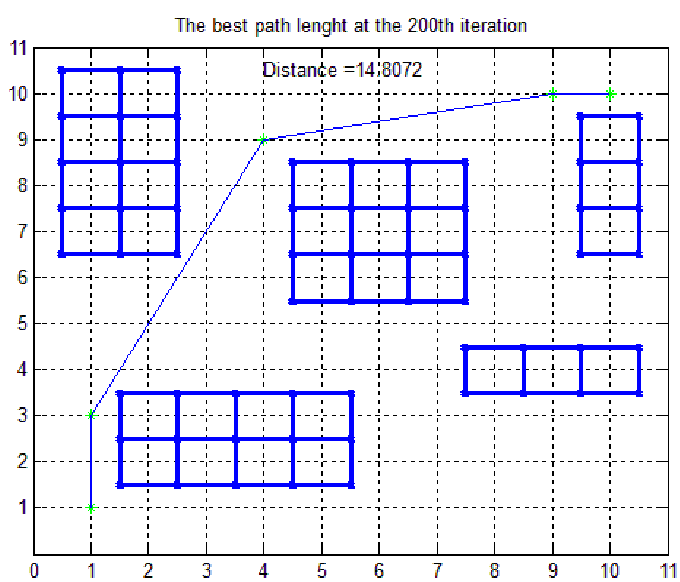


Figure (5) Best Path generated by first, third, fourth and fifth Experiments using the proposed algorithm.

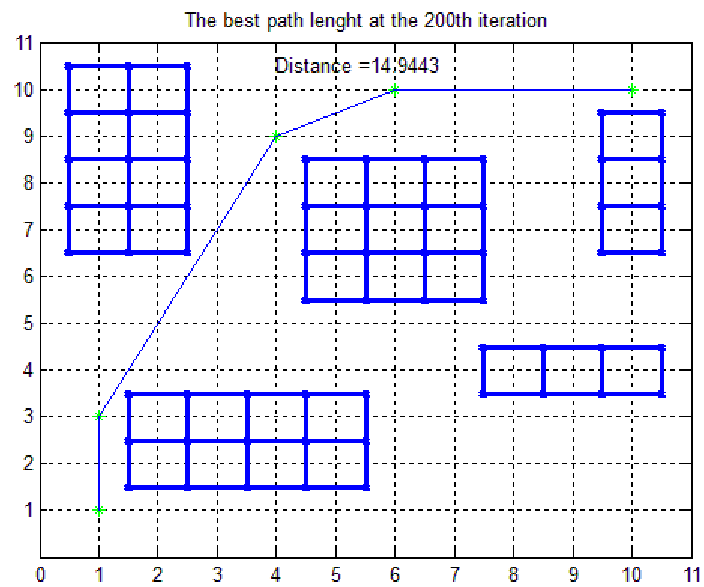


Figure (6) Best Path generated by second experiment.

To proof the efficiency of the proposed method over the method that is introduced in [8] in the general global path planning problems, the comparative study is introduced in the performance through the computer simulation. The simulation of the proposed approach shows that the elapsed time of each experiment is less than 100 seconds. Figure (5) shows the best solution generated by most experiments. Figure (6) shows the worst solution generated by only one experiment. Table 1 shows the compared with the results of the ''Improved Genetic Algorithm" [8], the optimal path obtained by proposed algorithm is shorter so the mobile robot required less time and energy to reach to the target. From the above, one can see that, the global optimal path obtained by proposed approach is shorter and more stable.

Table 1 The results of the two algorithms

Algorithm / Performance	The results of the proposed algorithm	The results of the "Improved Genetic Algorithm" [8]
The best length path	14.8072	15.0860

The worst length path	14.9443	15.5712
Execution time(s)	100 Second	---------

Second Environment

Five experiments performed on two environments to compare the performance of proposed method with method that is introduced in [11]. The Working environment is shown in Figuer (7).

The following are the typical parameters for the proposed method:

Initialization population = 1000
Crossover rate = 0.5
No of iteration = 200 iteration

The experiments show that if the algorithm does not converge which means there is no path between the start point and the target, an error is returned. This is shown in Figure (7).

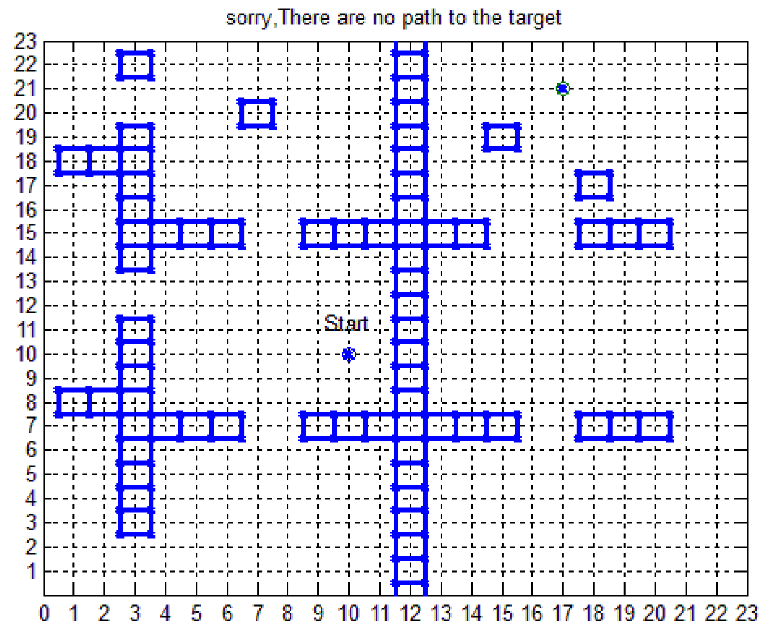


Figure (7) Closed environment.

Another environment is used which is the same that is used in [11]. It is shown in Figure (8).

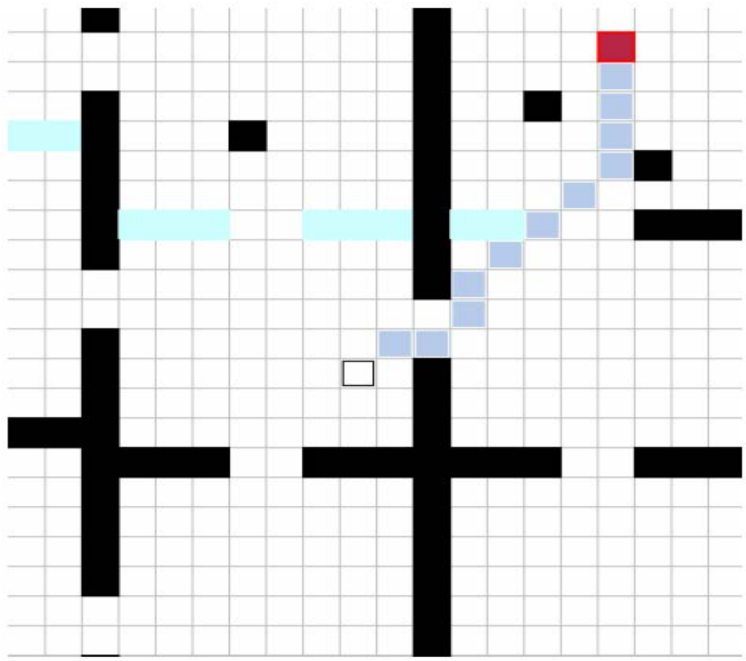


Figure (8) the best solution generated by the method in [11].

From simulation of the proposed method one can show that the elapsed time of each experiment is less than 46 seconds. Figure (8) shows the best solution generated by the method in [11]. Figure (9) shows the best solution generated by most experiments is 13.5357. Figure (10) shows the worst solution generated by only one experiment.

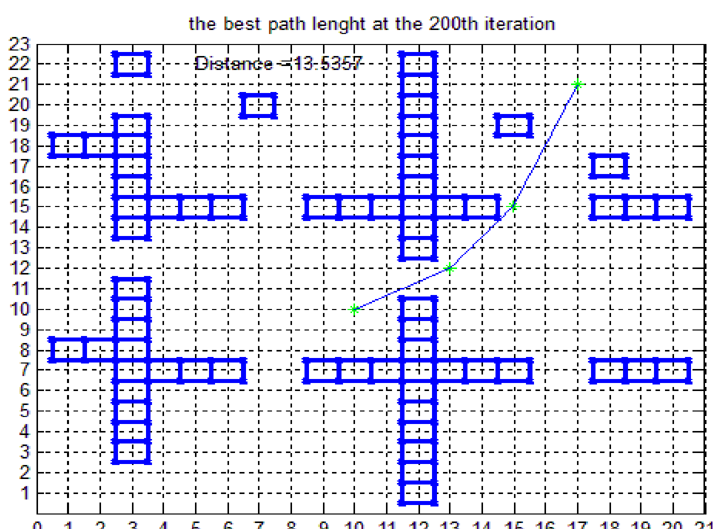


Figure (9) best Path generated by first and third experiments Using the proposed algorithm

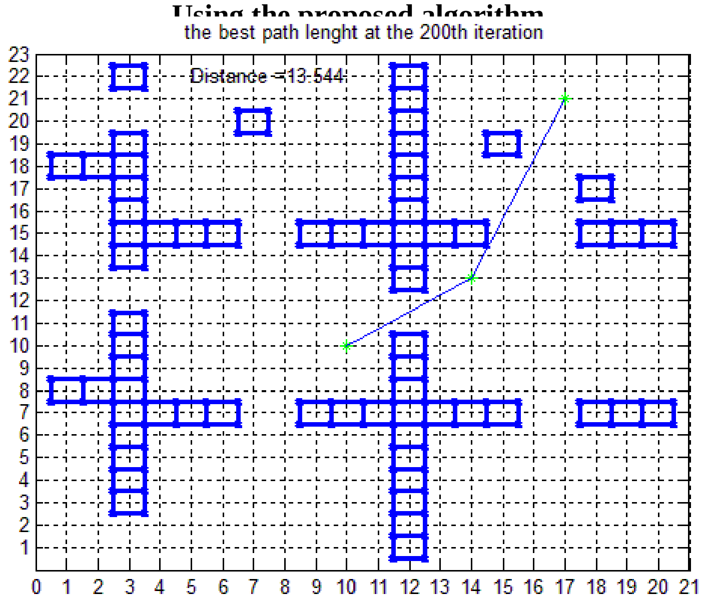


Figure (10) Best Path generated by second and forth experiments using the proposed algorithm.

In Table (2), one can see that, compared with the results of the [11], the optimal path obtained by Proposed algorithm is shorter so the mobile robot required less time and energy to reach to the target.

Table (2) The results of the two algorithms.

Algorithm / Performance	The results of the proposed algorithm	The results of the "Neural Network Method" [11]
The best length path	13.5357	14.4853
The worst length path	13.544	-------
Execution time(s)	46 Second	---------

From the above, one can see that, the global optimal path obtained by the proposed method is shorter than the method that is used in [11].

Third Environment

Five experiments perform on one environment to compare the performance of the proposed method with method that is introduced in [10]. The following are the typical parameters for the proposed modified genetic algorithm:

Initialization population = 1000

Crossover rate = 0.5

No of iteration = 200 iteration

Figure (12) shows the best solution generated by all five experiments is 20.6917. Figure (13) shows the best solution generated by the [10] is 22.7279.

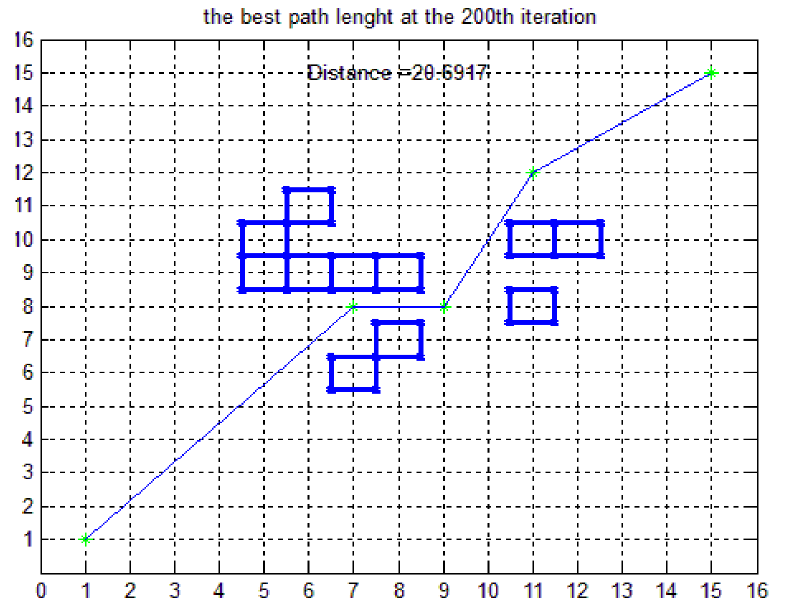
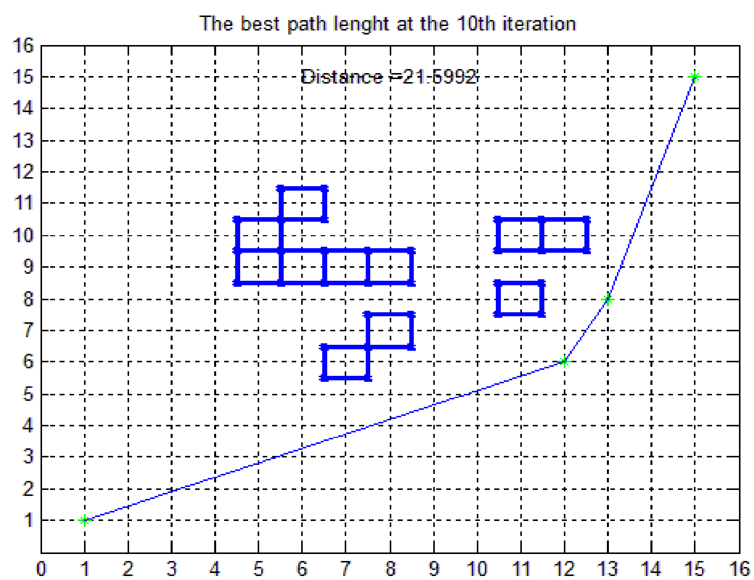


Figure (12) Best Path generated by the five experiments using the proposed algorithm.



1000

Figure (13) Best Path with safety generated by the five experiments Using the proposed algorithm.

Table (3) shows the results of the two algorithms. From the above, we can see that, the global optimal path obtained by the proposed method is shorter because in all experiments the distance is less than 22.7279.

Table (3) The results of the two algorithms.

Algorithm / Performance	The results of the proposed algorithm	The results of the "Genetic Algorithm" [10]
The best length path	20.6917	22.7279
The worst length path	20.6917	22.7279
Execution time(s)	23 Second	3.142 s

Another five experiments perform on the above environment but the safety distance is increase to ensure the robot avoid the obstacles in very small area environments. The following are the typical parameters for the proposed modified genetic algorithm: Initialization population = 100, Crossover rate = 0.5, No .of iteration = 10 iterations.
The simulation of the proposed method shows that the elapsed time of each experiment is less than 3 seconds but in [10] is 3.142 seconds. The best solution generated by all five experiments is 21.5992. But the best solution generated by the [10] is 22.7279.This is shown in Figure (14).

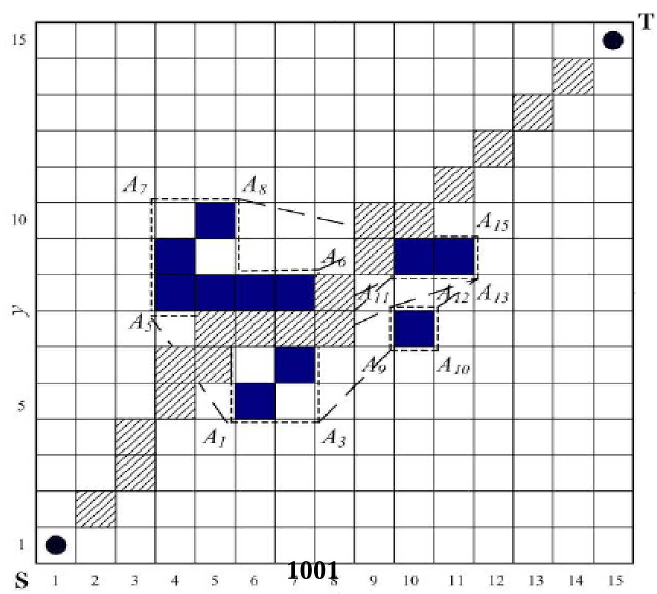


Figure (14) Working environment [10].

In Table (4), one can see that, compared with the results of the ‘‘Genetic Algorithm” [10], the optimal path obtained by proposed algorithm is shorter so the mobile robot required less time and energy to reach to the target. The execution time of the proposed algorithm is also less than three second so the optimal path creates more quickly.

Table (4) The results of the two algorithms.

Algorithm / Performance	The results of the proposed algorithm	The results of the “Genetic Algorithm” [10]
The best length path	21.5992	22.7279
The worst length path	21.5992	22.7279
Execution time(s)	3 Second	3.142 sec.

From the above, one can see that, the global optimal path obtained by the proposed method is shorter because in all experiments. It is also faster. The proposed modified genetic algorithm has better stability.

Forth Environment

Some traditional methods generate the optimal solutions but these algorithms, however, may not work in large environments. The time required by these methods would be very high in some conditions.

The performance of the proposed modified genetic algorithms is tested by very large environments (250 X 250) grids map. The following are the typical parameters for the proposed modified genetic algorithm:

Initialization population = 1000

Crossover rate = 0.5

No of iteration = 20 iteration

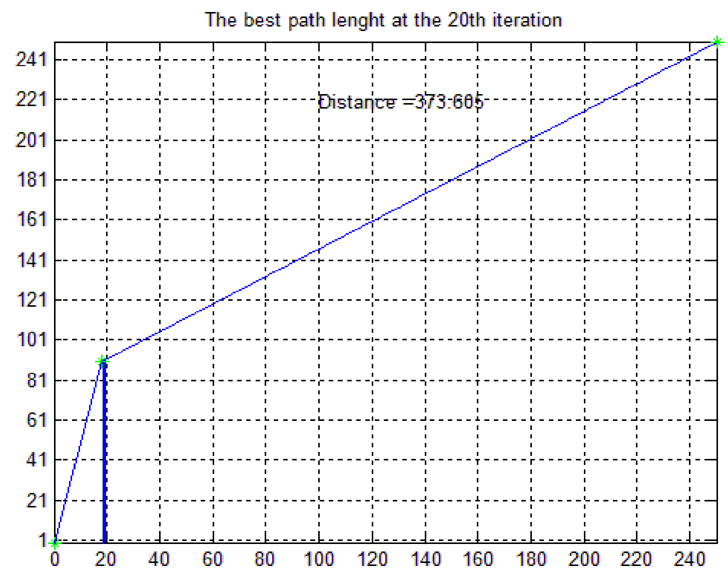


Figure (15) Path generated by five experiments using the proposed algorithm.

Figure (15) shows the same path distance generated by the five experiments and it is the shortest path can be generated so it is optimal path. In Table 5, the optimal path obtained by Modified Genetic Algorithm (MGA) algorithm is the shortest path that can be generated so it is optimal path. The mobile robot required less time and energy to reach to the target.

Table (5) The simulation results of the MGA algorithm.

Algorithm / Performance	The results of the proposed algorithm
The best length path	373.605
The worst length path	373.605
Execution time(s)	85 Second

Fifth Environment

Very large square environment is tested successfully by modified genetic algorithm. But the most practical large environment is rectangle with very long length and medium

width. The performance of the proposed modified genetic algorithms is tested by very large (1000 X 50) grids map. The following are the typical parameters for the proposed modified genetic algorithm:
Initialization population = 1000
Crossover rate = 0.5
No of iteration = 20 iteration
Fig. 16 shows the same path distance generated by the five experiments on the rectangle environment and it is the shortest path can be generated so it is optimal path. . In Table 6, the optimal path obtained by MGA algorithm is the shortest path that can be generated so it is optimal path. The mobile robot required less time and energy to reach to the target.

Table (6) The simulation results of the MGA algorithm.

Algorithm / Performance	The results of the proposed algorithm
The best length path	1004.4479
The worst length path	1004.4479
Execution time(s)	135 Sec

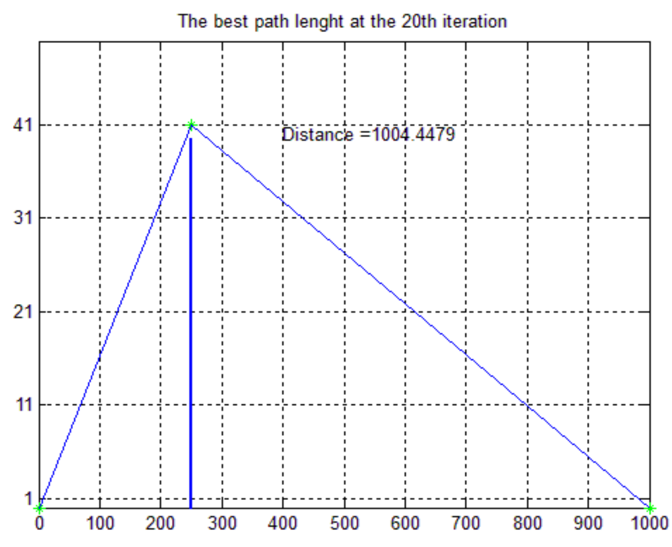


Figure (16) Path generated by the five experiments using the proposed algorithm.

From the above, one can see that, the global optimal path obtained by the proposed method is optimal because there is no path between these two points shorter than this path. It is also very stable method.

CONCLUSIONS

From the simulation results one can notice the following

1. The Proposed algorithm has better results in the path planning of mobile robot in comparison with soft computing path planning algorithms in terms of minimizing distance of the path which is led to decrease the time and energy to reach to the target position. Modified selection operator and modified procedure for carrying out a genetic algorithm are used to achieve this goal.
2. The modified selection operator ensures that the search process is global and does not simply converge to the nearest local optimum. It involves randomly choosing members of the population which increase the reliability and diversity. The modified procedure for carrying out a genetic algorithm can solve the infeasible path problems. All tests that are performed on different environments showed that it has better path distance than the results of the other algorithms of soft computing.
3. Adaptive population size and no mutation operator are used in the proposed algorithm which is led to improve the execution time. Adaptive population size grows depending on the size, structure and the number of obstacles in the environment which is led to decrease the execution time. No mutation operator is also decreased the execution time.
4. The proposed algorithm can balance between the execution time and distance of the solution path. A test of the path planning that is performed on third environment showed that the execution time decreased to three seconds when the iteration number is decreased.
5. The Modified Genetic Algorithm can work successfully in very large environment and generate optimal solution; this is clearly shown in Five Environment.
6. The Proposed algorithm has the capability to find path planning of the closed environments which is no path between the start point and the target. The Proposed algorithm can analyze the whole environment before the mobile robot start movement to decide if the mobile robot moves toward the target or not. A second environment test of the path planning showed that the proposed algorithm discovered there is no path to the target after five seconds execution time only, and then it can prevent the mobile robot to start move toward the target.

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