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Global Optimal Path Planning of Mobile Robot Using Genetic Algorithm

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Abstract: Global Optimal path planning of mobile robot is a challenging part in robotics. The objective of the path planning is to move from one location to another location without collides with other obstacles and with shortest feasible path. This paper tends to propose how Genetic Algorithm (GA) can be applied for path planning of a mobile robot. GA is an intelligent method that searches for an optimal solution in given set of solution. The propose algorithm is able to find an optimal path for a robot and it overcome many problems encountered by traditional search techniques such as the gradient based methods. The simulation result demonstrates that these methods have a great potential to solve the proposed problem.

Keywords: genetic algorithm; global path planning; mobile robot; optimal path.

1. INTRODUCTION

The field robotics has been developed significantly in the last couple of decades; however the important issue of it is mobility. The most fundamental intelligent task for a mobile robot is the ability to plan a global optimal path from its initial to final location while avoiding all obstacles located on its way [1].

The optimal path planning problem and collision-free path for a mobile robot has been important research field and there are various approaches have been introduced to implement path planning for a mobile robot [2]. The approaches are according to environment, type of sensor, robot capabilities etc, and these approaches are gradually toward better performance in term of time, distance, cost and complexity. The numerous approaches applied for optimal path finding problems. Most of these methods were based on the concept of space configuration [3].These technique show lack of adaptation, a non robust behaviour and global optimal path planning. To overcome the weakness of these approaches researcher explored variety of solutions [4]. Genetic Algorithm (GA) has been recognized as one of the most robust search algorithm for complex optimization problems.

GA is one of the modern heuristic algorithm based on the principal of Charles Darwinian theory of evolution to natural biology [5] and [6].GAs are intrinsically different from more conventional optimization technique. GAs is global search techniques that are inspired by the mechanics of natural evolution to guide their exploration in search space.

The GAs techniques can generate a high quality solution within the shorter calculation time and stable convergence characteristics. They required little knowledge of problem itself and need not required that the search space is differentiable over continuous. Therefore, GAs method is an excellent global optimization method for solving complex engineering problems.

In this paper, the global optimization method GA is used to find shortest and collision –free path in predictable environment which will be able to handle static obstacles. There simulation results demonstrate that the GA has a great potential to find a solution of the closed environment for a mobile robot. This paper is organized as follows. Starting with the introduction in Section I, Section II give basic background theory of GA. Section III describes problem description and section IV explains proposed algorithm for optimal path and obstacles avoidance of mobile robot. Section V explains GA under various constraints and presents simulation and result analysis of mobile robot. Sections VII outline the conclusion.

2. GENETIC ALGORITHM

The GA [7]-[8] is a global optimization and search technique based on the principles of genetics and natural selection. GA differs significantly from most classical optimization techniques in many aspects. First of all, unlike classical methods, GA are not gradient based, i.e. they do not require the objective functions to be continuous, neither do they need information about the derivatives of the objective functions, therefore they can handle problems with discrete solution spaces. Second, the search mechanism is stochastic in nature, which makes them capable of searching the entire solution space with more likelihood of finding the global optima. Third, GA are able to solve problems with nonconvex solution space, where a classical procedure usually fails. All these differences make GA superior over classic methods in some real world applications, particularly for some very complex engineering problems. For eg: complex control system engineering problems [9], complex truss-beam design, component's design, and structure design.

In GA, the individuals (solutions) in a population are represented by chromosomes; each of them is associated to a fitness value. According to the principle of survival of the fittest, the population reproduces, crossovers, mutates and produces a new generation that is fitter than the old generation. Those processes are done again and again until the fittest chromosome is found and the best result of the problem is obtained. Fig.1 shows GA process flowchart having key blocks as initial population, fitness evaluation, and optimization.

Simple GA has three basic operator's selection, crossover and mutation. A GA starts iteration with an initial population. Each member in this population is evaluated and assigned a fitness value. Strings with higher fitness values have more opportunities to be selected for reproduction in next step. Reproduction makes the clones of good chromosomes but does not create new one because of this crossover operator is applied. Crossover operator produces new individuals which have some part of both the parents' genetic material. The crossover probability indicates how often crossover is performed. Using reproduction and crossover on their own will generate a large amount of different strings.

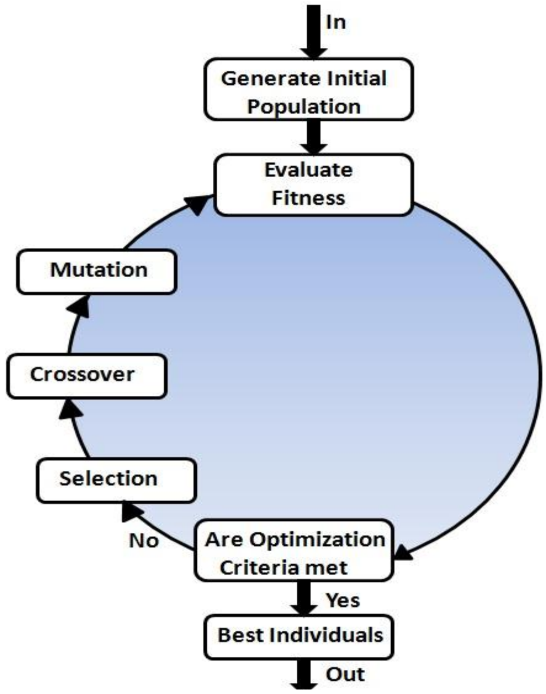

Fig.1.Genetic Algorithm process flowchart.

3. PROBLEM DESCRIPTION

The mobile robot path planning problem is typically formulated as follows: given a mobile robot and a description of an environment, we need to plan a path between two specified locations, a start and end point. The path should be free of collision and satisfies certain optimization criteria (i.e., shortest path) [11]. According to this definition, path planning problem is categorized as an optimization problem.

Researchers distinguish between various methods used to solve the path planning problem according to two factors, (1) the environment type (i.e., static or dynamic) [12], (2) the path planning algorithms (i.e., global or local) [11]. The static environment is defined as the environment which doesn't contain any moving objects other than a navigating robot; while the dynamic is the environment which has dynamic moving objects (i.e., human beings, moving machines and moving robots). The global path planning algorithms requires a complete knowledge about the search environment and that all terrain should be static. On the other hand, local path planning means that path planning is being implemented while the robot is moving; in other words, the algorithm is capable of producing a new path in response to environmental changes [11].

To use GA for solving the path planning problem, we have to make some assumption about the environment and position of obstacles.

1. Convert the search space to grid graph (map), it consists of 20×20 grid.
2. Specify the left bottom corner (X1, Y1) is the starting point while the right top corner (X2, Y2) is the destination point of the path.
3. Defining the static obstacles locations on each node of the grid, the shape of an obstacle is always a circle, but the size of the obstacle is variable from 1 to 5 grid points.
4. The positions of the obstacles are randomly selected and can be located at any grid point in the map except at points close to the starting point region or close to the goal point region.

The goal is to determine a shortest global path from source to destination by avoiding obstacles in the optimal time using genetic algorithm.

4. PROPOSED ALGORITHM

Fig.2 shows the proposed genetic algorithm work flow. The first step consists of the generation of the initial population. The fitness of each chromosome in the population is then evaluated. The fitness function used here considers both collision avoidance and smoothness of the path. Selection is done by the Roulette wheel method. There is a chance that the best solution (chromosome) is lost in the selection process. So a technique called Elitism is used here. Elitism is used to keep track of the fittest chromosome obtained during the process and ensures that the fittest chromosome is present in the forthcoming generations. This is followed by the application of reproductive operators. The proposed GA [13] uses single point crossover and mutation. Thus a new population of chromosomes for the next generation is obtained. The process is repeated for the next generations. This is done iteratively for "n" generations until the algorithm converges to a single solution. This solution depicts an optimal path (that is both short and smooth) the robot can take. The genetic algorithm yields an optimal path in fewer generations than the traditional GA.

Main step in proposed path planning algorithm:

A. Initialization: Create an initial population with a predefined population size. The population contains number of individuals (i.e., chromosomes). Each individual represents a solution for the problem under study.

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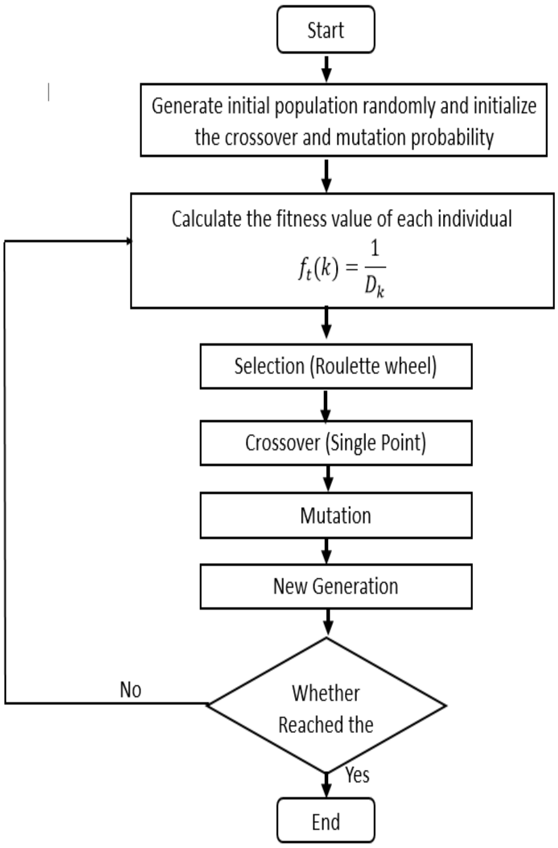

Fig.2.Flow chart of optimal path planning

In our case, each solution is in fact a path between the start and end point in the search space. The initial population with size n can be presented as:

$$\text{Initial Population} = < P_1 , P_{2\,,} P_{3\ldots\ldots\ldots} P_n >$$

B. Crossover: A group of chromosome undergoes crossover at each generation. All the crossover events are controlled by a predetermined Pc (crossover rate). In other words, the algorithm creates a random number in [0 1] for each chromosome. If the generated number is less than Pc, the chromosome is a candidate for the crossover event, otherwise the chromosome proceed without crossover. The left most genes and the right most genes will avoid the crossover event since these two points are the start and target points and cannot be eliminated. For the purpose of diversity, the crossover point bit is randomly selected in each generation.

C. Fitness function: To compute the fitness function for an each individual chromosome, we should have the coordinates of each point in the individual chromosome. Thus, we can compute the distance between any two points in the search space (i.e., environment of the robot). Thus, the better chromosome has the smaller distance.
The length of the feasible path is compute as:

$$D_k = \sqrt{(X_{k+1} - X_k)^2 + (Y_{k+1} - Y_k)^2}$$

The fitness function used in this particular problem is

$$f_t(k) = \frac{1}{D_k}$$

Where D_k is the path length for k^{th} chromosome.
X_k and Y_k are robot's current horizontal and vertical positions, X_{k+1} and Y_{k+1} are robot's next horizontal and vertical positions.

D. Elitism:In order to keep the best chromosome from each generation, the elitism method is employed. The main goal of the elitism rule is to keep the best chromosome from the current generation. Thus, under this rule, the best chromosome from each generation will not undergo any mutation or crossover event and will safely move onto the next generation. Since the best or elite member between generations is never lost, the performance of GA can significantly be improved. The remaining chromosomes are then sorted according to their fitness.

5. GENETIC ALGORITHM UNDER VARIOUS CONSTRAINTS

The source and the destination location are obtained from the user and the corresponding nodes are located in the two dimensional grid environment. In this section, the implementation of GA to solve path planning problem is demonstrated.

A. GA in Obstacle Free Environment
The initial population which is the possible path between the given source and the destination is generated and displayed in the environment. For each chromosome, the fitness function is evaluated and the fitness values are sorted out in ascending order. Then each time two chromosomes from the initial population are selected as parents and crossover is performed to produce two off springs. This process is repeated for all the chromosome in the initial population .Then mutation is performed for each chromosome. The best results obtained after implementing the GA are shown in Table I and the best discovered path using GA is shown in Fig.3.

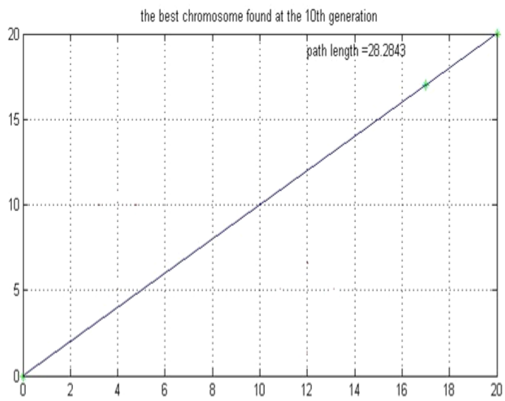

Fig.3.Possible path when there is no obstacles

B. GA with Static Obstacles
The obstacle location is fixed in the grid environment. While generating the initial population (which is the possible paths between the given source and the destination), the presence of the obstacle was detected. For each chromosome, the fitness function is evaluated and the fitness values are sorted out in ascending order. The path

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with the obstacle will have the highest fitness value. Then each time two chromosomes from the initial population are selected as parents and crossover is performed to produce two off springs. This process repeated for all the chromosomes in the initial population. Then mutation is performed for each chromosome.Fig.4, Fig.6 and Fig.8 shows the various possible paths to reach the target from the source in the grid environment and the best discovered path using GA is shown in Fig.5, Fig.7 and Fig.8.The best results obtained after implementing the GA are shown in Table I.

TABLE 1 SIMULATION RESULT FOR THE WORKING ENVIRONMENT USING GA

Specification	No Obstacles	Two Small Obstacles	One Large Obstacles	Many Small Obstacles
Crossover Rate (Pc)	025	0.25	0.25	0.25
Mutation Rate(Pm)	0.2	0.25	0.2	0.4
Path Length	28.2843	28.809	30.4631	31.0657
No of Via Point	2	4	3	3
Elitism usage	Yes	Yes	Yes	Yes

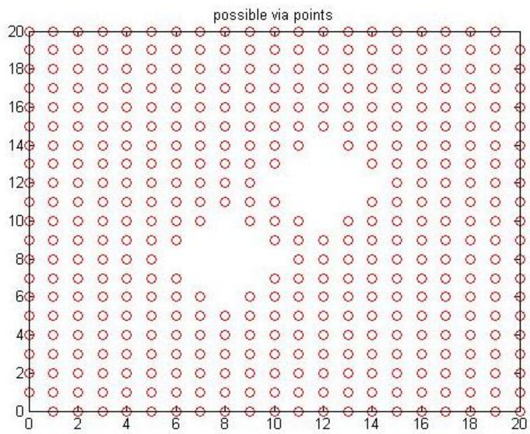

Fig.4.Possible Paths when two obstacles present at (8,8 and 12,12)

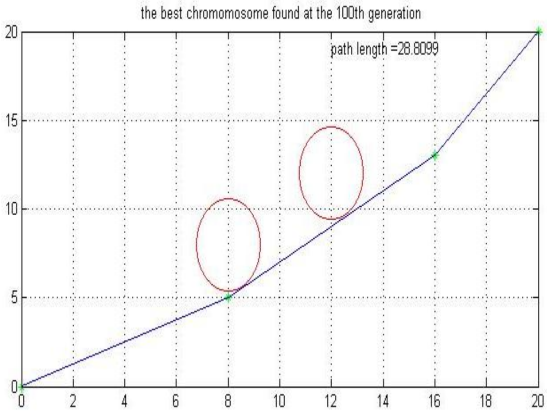

Fig.5.Optimal Paths when two obstacles present at (8,8 and 12,12)

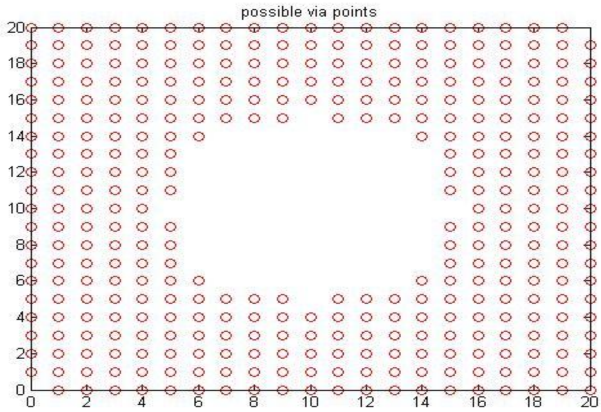

Fig.6.Possibel Paths when one big obstacles present at (10,10)

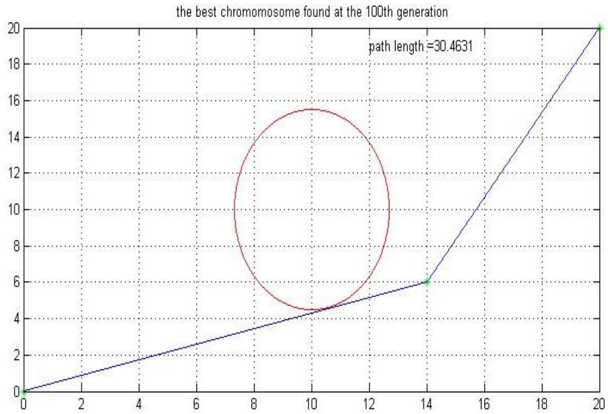

Fig.7.Optimal Paths when when one big obstacles present at (10,10)

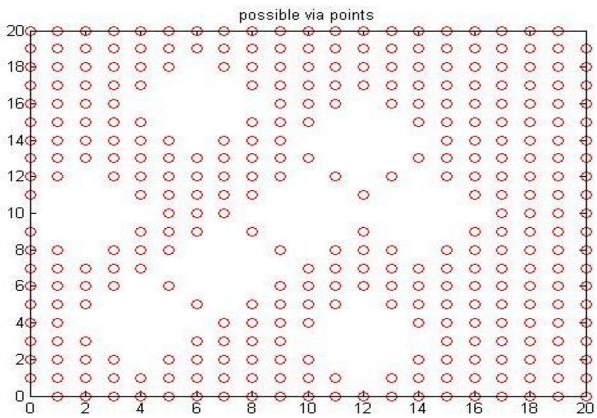

Fig.8.Possible Paths when many obstacles present

6. CONCLUSION

The path planning algorithm has been successfully presented using GA technique. It is proven based on the discussed result, the optimum path produced by the algorithm can move a robot from initial location to final location without collide with any obstacles in complex environment. The GA algorithm has a great potential to find a solution of the closed environment.

Future research can investigate the performance of GA algorithm in dynamic environment and 3D path finding.

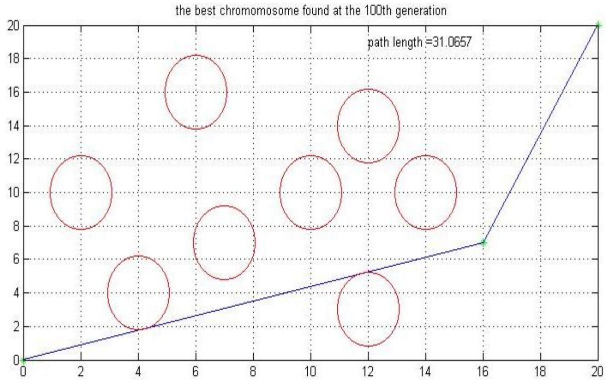

Fig.9.Optimal Paths when many obstacles present

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