Modified Genetic Algorithms for Optimum Path Planning for Mobile Robot

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***Abstract*—In this study, modified genetic algorithm is proposed to be used to find optimal path between a starting and goal point in grid environment for a mobile robot. Distinguishing Algorithm (DA) was employed to incorporate only feasible paths as initial populations and thus improve the path planning efficiency. Proposed genetic algorithm feature simple representation of the path.**

***Keywords*— Genetic Algorithm (GA), Distinguishing Algorithm (DA), optimum path planning, mobile robot.**

I. Introduction

Path planning is an important issue in mobile robotics. In an environment with obstacles, path planning is to find a suitable collision-free path for a mobile robot to move from a start location to a target location. The main behaviors of the mobile robots are Goal Seeking, Obstacle Avoidance and Wall Following. Generally, some optimization criteria with respect to time, distance, or energy must be satisfied. Other constraints with respect to velocity, acceleration and turning radius of mobile robots should also be taken into consideration. Distance is a commonly adopted criterion [1].

In the past two decades, different conventional methods have been developed to solve the path planning problem, such as global C-space methods, potential field methods and neural networks approaches. Each method has its own strength over others in certain aspects, but also shows lack of adaptation and a non-robust behavior. To overcome the weakness of these approaches researchers explored variety of solutions, Genetic Algorithm (GA) was proposed which used to control a mobile robot moving in an environment which has static obstacles and/or dynamic obstacle [2]. GA have been widely used owing to its strong optimization ability.

Although GA is a powerful optimization algorithm, there exist a few problems. First, infeasible paths in initial population can greatly affect the performance of the genetic algorithm. Secondly, after performing crossover and mutation, the offspring may contain paths that are not feasible [1].

In order to generate initial population with feasible paths, modified genetic algorithm is proposed. In this study, Distinguishing Algorithm (DA) is proposed for generating initial population so that all individuals in first generations have feasible paths.

II. System overview

Initial populations are generated randomly. It is then passed through the Distinguishing Algorithm to eliminate the infeasible paths and thus keep generating required number individuals until all the individuals in the initial population are feasible. Then the fitness of all the individuals is calculated. Then, two parents are selected from the initial populations two create two off springs. Crossover and mutation are performed on the off springs. These off springs are then passed through DA to check their feasibility. The procedure is repeated for certain specified number of iterations. The flowchart of proposed genetic algorithm is shown in Figure 1.

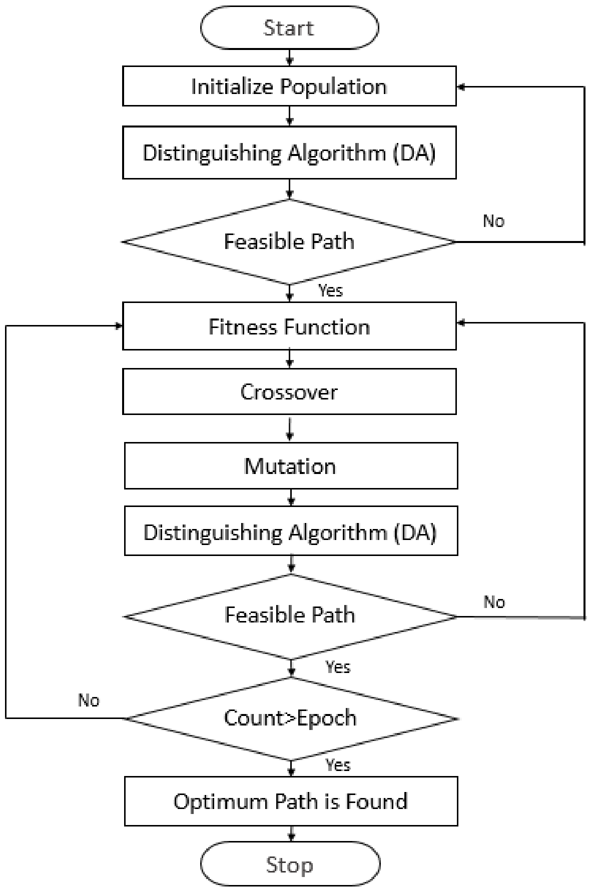

Fig. 1. Flowchart for Proposed Genetic Algorithm

The proposed modified genetic algorithm works as follows:

A. Initial Population

1. Environment Representation and Encoding Scheme

The environment representation and encoding scheme are the key issues of genetic algorithms. In this paper, mobile robot environment is represented by a number of grids, as shown in Figure 2.

In Figure 2(a), the starting location is co-ordinate (1.5, 1.5) and the desired goal is (10.5, 10.5). The blank grids represent obstacle free areas where mobile robots can move freely. The black areas represent obstacle areas. The mobile robot is to be treated as a point.

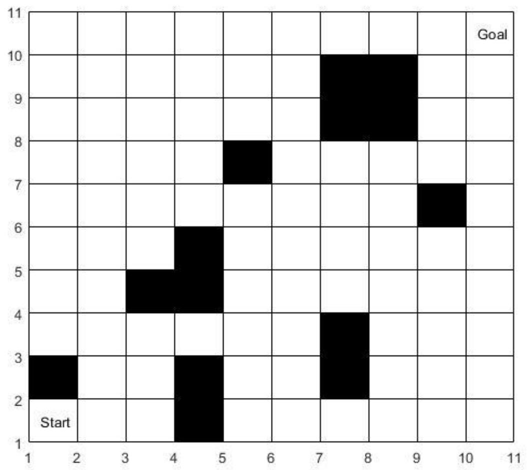

Fig. 2. (a) Plot of the environment 10 x 10

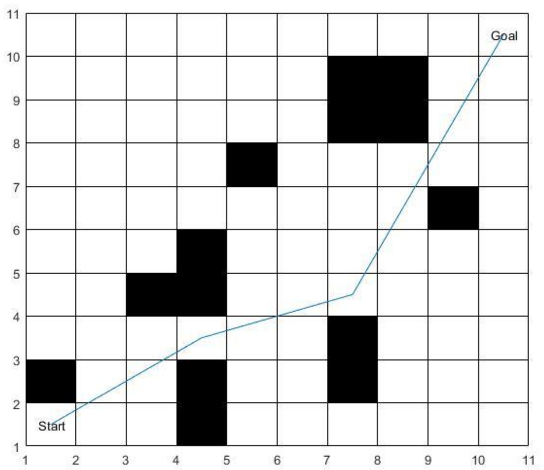

Fig. 2. (b) Environment with feasible path

Each gene in a chromosome is an x-y co-ordinate and a segment is formed by joining two gene co-ordinates. Therefore, a path is formed by joining such segments with (1.5, 1.5) as start point and (10.5, 10.5) as end point of the path.

Figure 2(b), shows an example of a feasible paths formed by combining path segments. This feasible path can be encoded as

Feasible (x, y) = {(1.5, 1.5), (4.5, 3.5), (7.5, 4.5), (8.5, 6.5), (7.5, 8.5), (10.5, 10.5)}

2. Distinguishing Algorithm (DA)

A DA is specifically employed to detect whether a path is feasible of not.

The basic idea is to check if the segment connecting two co-ordinates passes through the obstacle region. If it does, the path becomes infeasible.

The algorithm of DA is as follows:

Step 1: Generate the equation of line of $m(x_1,y_1)$ and $n(x_2,y_2)$ by:

$$\frac{x}{x_2-x_1}-\frac{y}{y_2-y_1}=\frac{x_1}{x_2-x_1}-\frac{y_1}{y_2-y_1}$$

Step 2: Calculate the point of intersection of this line with the equation of lines forming obstacle and check if the intersection point lies within the obstacle and the region of the segment.

Step 3: In case where the intersection point lies within the obstacle area, DA is terminated, and the path is categorized as infeasible path.

Step 4: If the intersection point does not lie within the obstacle region, Step 1 to Step 3 are repeated until all nodes in the particular path are explored.

Step 5: This explored path is categorized as feasible path.

B. Fitness Function

Our aim is to minimize the total distance travelled by the mobile robot. Thus, we choose the fitness function as

$$F\ (x_i)=\frac{1}{\mathrm{dist}(x_i)}$$

where i=1,2,3,…,n, x_i represents the i^{th} chromosome, n is the population size and $\mathrm{dist}(x_i)$ is the distance of the i^{th} path in the environment. It is obvious that the best individual will have maximum fitness value [1].

C. Crossover operators

One point random crossover operator was performed between consecutive pairs after randomly shuffling the population to generate off springs. A crossover probability variable was created to govern the probability of crossover occurring on the chromosome pairs.

Crossover operation consists of following main steps:

Step 1: Select consecutive pairs from initial population for performing crossover.

Step 2: Use a random number to select one node as crossover point.

Step 3: Swap the coordinates of the selected node.

D. Mutation operator

Swap mutation was performed to generate randomness and increase diversity of the population. A mutation probability variable was created to govern the probability of mutation occurring in the chromosome. However, after performing crossover and mutation operators the path generated may be infeasible and so DA is used to classify the path as feasible or infeasible.

Mutation operation consists of following main steps:

Step 1: Generate two random node numbers for swaping ensuring that the first and last nodes are not swapped.

Step 2: Swap the nodes at the generated index numbers.

Step 3: Use DA to classify the paths.

E. Selection process

Population with best fitness are chosen as initial population for the following generation. This tournament selection process leads to selection of best fitness populations only as a mating population for next generation which may lead to loss of diversity. It was observed that this caused convergence in the first generation itself and to avoid this, slight modification was proposed in the selection process. According to this, for first few generations, only the population with minimum fitness were selected for mating. After which tournament selection was employed. Better results were observed with this modification.

III. RESULTS AND DISSCUSSION

The effectiveness of the algorithm is demonstrated by simulation. The following are the parameters for the proposed modified genetic algorithm.

Initial Population size = 20

Chromosome length = 6

Probability of crossover = 1.0

Probability of mutation = 0.9

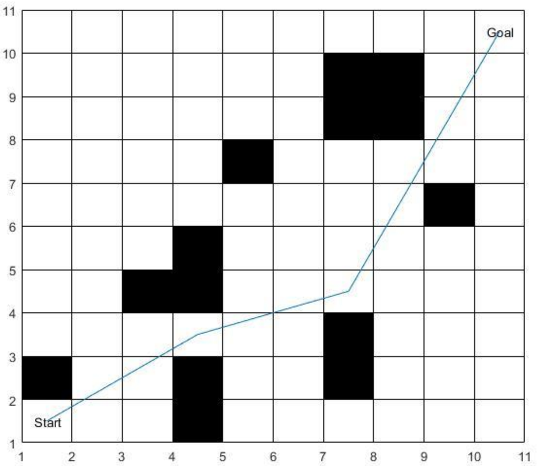

Fig. 3. (a) Best Fitness Path

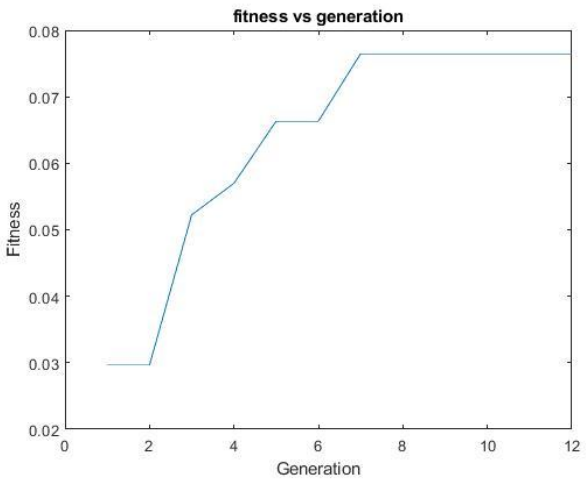

Fig. 3. (b) Best fitness value vs Generations

The fitness of the path generated has been observed to improve each generation until it converges to a fixed value of fitness. From Figure 3 (b) we can observe that the fitness value rises from 0.03 to 0.076 from first generation to 7^{th} generation respectively. The fitness value converges at 7^{th} generation in this trial.

IV. CONCLUSION

This study proposes use of modified genetic algorithm for path planning of a mobile robot in environment with static, known obstacles. The DA used for generating feasible paths is observed to work properly but there is a scope for improvement in terms of the computational efficiency of the algorithm. Using proposed modifications in the selection process improved the results. Increasing the number of individuals in the initial population also improved the fitness of the best path obtained at the expense of increase in computational time.

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