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Multi-objective Optimization of Mobile Robot Path Planning Using Genetic Algorithm

Balaji A[1], Padmanabhan Panchu K [2]
[1]*PG scholar, Department of Industrial Engineering*
Anna University, Chennai, Tamil Nadu, India.
[2]*Asst.Professor, Department of Industrial Engineering*
Anna University, Chennai, Tamil Nadu, India.

ABSTRACT: *This paper proposes an idea for finding a multi-objective optimal path for a mobile robot in a given known environment from a user defined initial point to final point. The objectives considered here for optimization are, length of the path and smoothness of the path. The length of the path is defined as distance covered by the robot while it moves from one point to another and the optimal length of path is shortest path that reaches the final point after avoiding obstacles. Smoothness is defined as the number of turns taken by robots to reach the final point. Since the robot changes its pose by turning, the velocity of robot reduces which results in more consumption and as well as the time to reach the destination. First objective here ensures the distance travelled by the robot to destination point is to be minimum and the second objective ensures that the turns are minimum and thus robots need not reduce its velocity while turning. Ultimately, with the optimization of these two objectives, the robot can reach the location as soon as possible and without reduction of any velocity. The proposed idea can allow the robot, to find the optimal solution, which has shortest path and smoothest path.*

Key words: *genetic algorithm, length of the path, robots, smoothness.*

I. INTRODUCTION

In the past two decades, robotics has achieved its greatest success in the field of industrial as well as manufacturing sector. Yet, for its success, it suffers from the fundamental issue of mobility. When we talk about mobility, there are some critical elements to be focused and addressed. The critical elements of the robots are kinematics of locomotion, sensors for determining the robot's environment and techniques for localizing with respect to its map. Apart from that there has been a lot of interest on robot's cognitive level. Cognition, talks about the robots decision making and it's all strategies to reach the goal, when it moves from one point to another point. The cognition ability is directly linked with the path planning, why because, for a given environment robot has to plan a path between two specified locations which is a collision-free and should satisfy certain optimization criteria. So far a lot of approaches have been proposed for path planning. Most of these were based on single objective and inflexible in rapid responding to changes in the robot's goal and in the environments. To overcome the weakness of the problems some authors have explored variety of solutions [1] [2]. Even after also some have identified and made some improvements in that solution [3]. Yet, it is not suitable for some applications. Because there may be some applications robot has to satisfy more than one objective and many approaches have been proposed by authors so far [4][5][6].The past thirty years have seen a rapid growth in the popularity and use of evolutionary algorithms. [7]Evolutionary algorithms for robot path planning include Probabilistic Roadmaps Method (PRM) Simulated Annealing (SA), Genetic Algorithms (GA),

Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO) and Tabu Search (TS). The major differences between one method and another lies within the scheme used to represent the solution and semantics of the operators and measures used to evaluate their fitness. Since Genetic Algorithms (GA) are powerful procedures for searching large, complex problems, it is widely used to search solution spaces in near-optimal ways. In this study, we propose our initial idea to select the optimal solution in such a way that it satisfies both the objectives and which will be able to handle static environment.

II. PROBLEM DEFINITION

The mobile robot path planning is usually defined as follows: given a robot and knowledge about an environment, plan a path between two specified locations, which is obstacle-free and should satisfy the optimization criteria. The optimization criteria's concentrated in this study are path length and smoothness i.e., number of turns taken by robot to reach the end point. Different authors use different techniques to solve the path planning problems according to two factors. One is the type of environment i.e., static or dynamic [2] and another one is the type of path planning algorithms i.e., global or local. The static environment is defined as the environment which doesn't contain any active entities (moving objects) other than a navigating robot; while the dynamics is the environment which has active entities (i.e., human beings, moving machines and moving robots). The global path planning algorithms uses a complete knowledge about the search environment and that all area must be static. On the other hand local path planning can be able to respond if any changes in environment.

III. ASSUMPTIONS

To use GA for solving the path planning, we have made some assumptions about environment and presence of obstacles.

- Convert the search environment into a grid (cell) type of environment (Figure.1)
- Specify the starting point and the destination point, where the path to be established.
- Defining the presence of the obstacles in the grid environment.
- According to problem definition, the path is defined by a set of points P_1, P_2, P_3, P_4, P_5….. P_n and coded in a suitable way.

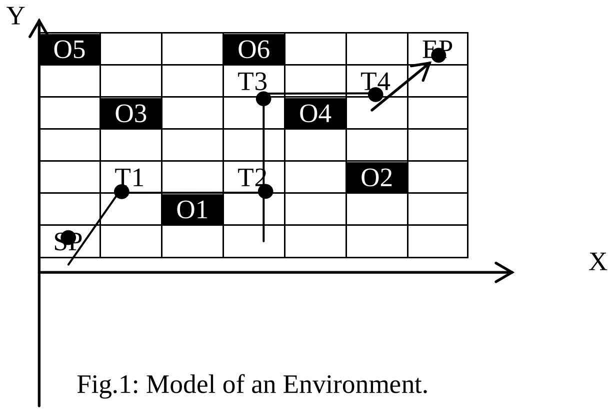

Fig.1: Model of an Environment.

Fig.1 depicts the model of an environment, where the environment is split into cell type of environment. Starting point and the ending point are defined from the user. Obstacles (O1, O2, O3, O4, O5, and O6) are located at the appropriate places. T1, T2, T3, T4 are the turns taken by the robot to reach the end point.

IV. CHROMOSOME DESIGN

In this section we discuss the design of chromosome and the steps involved in the path planning process.

4.1 Initialization: Create an initial population with a predefined population size. The population contains number of individuals (i.e., chromosomes).Each chromosome consists of set of points (i.e., genes) represents intermediate points. Each individual in the population represents a solution for the given problem. In this study path is defined as a set of points connecting the starting point and the end point.

SP	P_1	P_2	P_3	...	…	…	…	P_n	EP

Fig.2: Representation of chromosome.

$P_{1,}$ $P_{2,}$ P_3 ----- Intermediate points connecting the starting and the end point.

V. MULTI OBJECTIVE FITNESS FUNCTION

Most of the approaches use a single criterion like shortest path. But it practice it's not so. It has to satisfy more than one condition to obtain a feasible solution. A Path which is having a shortest path may or may not satisfy all other criteria. For example a shortest path need not be a safety one.

A common approach for calculating multiple objectives is the simple additive weighting (SAW) method, in which a weighted sum of multiple objectives is expressed as a conventional single-objective function in the form of,

Fitness function = $w_1z_1 + w_2z_2 + w_3z_3 + \ldots\ldots$ (1)

Where Z_1, Z_2 are the multiple objectives and W_1, W_2 are the weightages given to the objectives based on applications.

In this study the path length is defined as distance between the points connecting the starting point and ending point. Criterion for smoothness is defined as the number of turns taken by the robot to reach the endpoint.

The first objective function path length is defined as,

$$F_{path\ length\ (x,\ y)} = \sqrt{} (X_{i+1} - X_i)^2 + (Y_{i+1} - Y_i)^2 \quad (2)$$

The second objective function is defined as,

$$F_{smoothness\ (x,\ y)} = \text{No of turns} \quad (3)$$

The overall function is obtained by weighted sum of these two shortest and smoothest objectives:

$$\text{Fitness} = (W_1 * F_{pathlength(x,\ y)}) + (W_2 * F_{smoothness\ (x,\ y)}) \quad (4)$$

We can able to minimize the overall fitness function by assigning weightages to each criterion. So that a shortest path with the least number of turns is obtained. The weights of the shortest and smoothest fitness functions, W_1 and W_2 are 1 and 0.25. The weightages for the objective function may vary from one application and another.

Some of the individuals available in the population are selected, based on the objective function i.e., minimize or maximize the objective function. Crossover is performed on the selected individuals. The last individuals are deleted, so that population size is maintained in a constant manner.

VI. PARAMETERS OF GA

6.1 Probability of Cross over (P_C): The Probability of crossover for standard algorithm is between 0.6 to 1.0. In this study we have taken this value as 1.0, which means that the Cross-Over rate is performed every time.

6.2 Probability of Mutation (P_m): The Probability of mutation is less than 0.1 at the standard algorithm. Here, we have assumed this value as 0.01.

6.3 Number of Cross Over Points: In this study we have used two points cross over.

6.4 Maximum Iteration Number (N): Maximum genetic algorithm number is a parameter which means how many generations the algorithm will be executed. Here, the value of N=30.

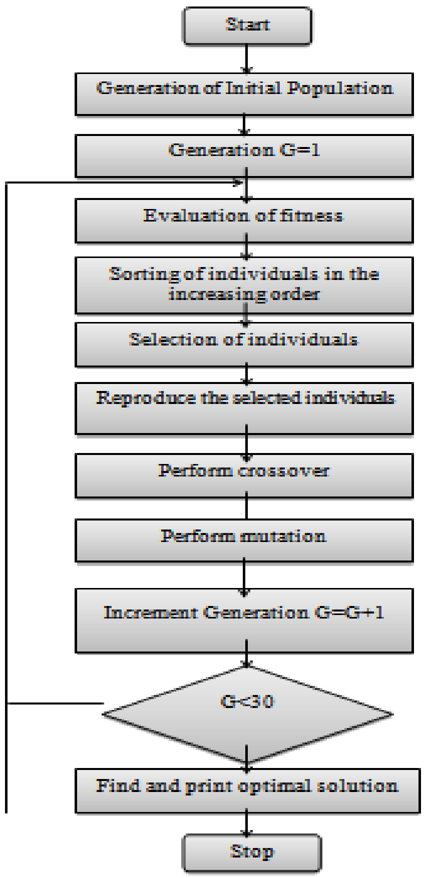

Fig.3. Flow diagram of path planning.

VII. EXPERIMENTS

In this study we perform the experiments using GA in two different sizes of grid (cell) environment with different population size. The goal is to investigate the behavior of GA in that case and effect cross over in each experiment. These two experiments are implemented with the help of 'MS Visual C++' language.

7.1 Experiment 1: It is performed in a 10 X 10 gird environment with a population size of 10.

7.2 Experiment 2: It is performed in a 20 X 20 environment with a population size of 10 and 20.

In all the experiments best fitness values are calculated and identified. Obstacles are located at appropriate places in the environment.

Table 1: A 10 X 10 grid environment

EXP #	POPULATION SIZE	BEST FITNESS VALUE	NO OF GENERATION
1	10	16.143	30

Table 2: A 20 X 20 grid environment

EXP #	POPULATION SIZE	BEST FITNESS VALUE	NO OF GENERATION
1	10	32.9987	30
2	20	31.9564	30

VIII. CONCLUSION

In this study we proposed our idea of using genetic algorithm approach to solve the multi-objective path planning and proposed a fitness that utilizes the path length as well as number of turns. We explored the performance of GA with different gird size environment and different population size.

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