

PATH PLANNING OF ROBOT IN STATIC ENVIRONMENT USING GENETIC ALGORITHM (GA) TECHNIQUE

Waghoo Parvez¹, Sonal Dhar²

¹Department of Mechanical Engg, Mumbai University, MHSSCOE, Mumbai, India

²Department of Production Engg, Mumbai University, DJSCOE, Mumbai, India

ABSTRACT

This paper presents the application of genetic algorithm in path planning for a static warehouse environment with multiple objectives. It quantitatively evaluates the performance of genetic algorithm which is used for a variety of applications. In a warehouse equipped with robot for material handling and transportation, the path taken by the robot plays an important role as it defines the time required for transportation. Nowadays transportation cost should also be minimized to minimize the cost of the product, which can be minimized by optimizing the path for transportation. GA is applied for optimizing the path of a robot in warehouses for material handling with a predetermined location as a starting point to reach a pre determined goal. The program has been developed in C++ language. The technique is able to generate feasible, stable and optimal sequence.

KEYWORDS: Chromosome, Genetic Algorithm (GA), Mutation, Optimization, Path Planning.

I. INTRODUCTION

Path planning is a term used in robotics for the process of detailing a task into discrete motions. It is a process to compute a collision-free path between the initial and final configuration for a rigid or articulated object (the "robot") among obstacles. It is aimed at enabling robots with capabilities of automatically deciding and executing a sequence motion in order to achieve a task without collision with other objects in a given environment.

Typically the obstacles and the mobile objects are modeled. Given a source position & orientation for mobile object and goal position & orientation, a search is made for a path from source to goal that is collision free and perhaps satisfied additional criteria such as a short path, a path which can be found quickly or a path which does not wander too close to any one of the obstacles. The general path planning problem requires a search in six dimensional spaces since the mobile object can have three translational and three rotational degrees of freedom. But still there are three dimensional search problems which have two translational and one rotational degrees of freedom. [14]

The Genetic algorithm is an adaptive heuristic search method based on population genetics. Genetic algorithm were introduced by John Holland in the early 1970s [1]. Genetic algorithm is a probabilistic search algorithm based on the mechanics of natural selection and natural genetics. Genetic algorithm is started with a set of solutions called population. A solution is represented by a chromosome. The population size is preserved throughout each generation. At each generation, fitness of each chromosome is evaluated, and then chromosomes for the next generation are probabilistically selected according to their fitness values [4]. Some of the selected chromosomes randomly mate and produce offspring. When producing offspring, crossover and mutation randomly occurs. Because chromosomes with high fitness values have high probability of being selected, chromosomes of the new generation may have higher average fitness value than those of the old generation. The process of evolution is repeated until the end condition is satisfied. The solutions in genetic algorithms are called chromosomes or strings [2].

A genetic algorithm is a search technique used in computing to find exact or approximate solutions to optimization and search problems. Genetic algorithms are categorized as global search heuristics. Genetic algorithms are a particular class of evolutionary algorithms (EA) that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover [11]. Genetic

algorithms have been used to find optimal solutions to complex problems in various domains such as biology, engineering, computer science, and social science.

Genetic algorithms fall under the heading of evolutionary algorithm. Evolutionary algorithms are used to solve problems that do not already have a well defined efficient solution [12]. Genetic algorithm have been used to solve optimization problems (scheduling, shortest path, etc), and in modeling systems where randomness is involved (e.g., the stock market).

The overall organization of the paper is as follows. In section 2 we have represented the related work done by other authors. In section 3 & 4 we introduce the path planning of the warehouse/ environment and the problem representation. In section 5 experimented results for the different environments is provided. Section 6 summarizes about the results obtained and a brief discussion on the results. Section 7 gives the conclusion and the future scope of the paper.

II. RELATED WORK

Recent research into optimum path planning in warehouse or any other environment like construction site layout, site planning, has resulted into the development of such algorithms. Traditional methods of determining an optimal path that traverses from one point to another have been based on graph exploration techniques [2]. David Sislak et al [6] studied the comparison of grid based path planning using Accelerated A* trajectory planning for solving a UAV collision avoidance problem. Ansari Muqueet Husain et al [5] studied the path planning of material handling robot using Ant Colony Optimization technique for warehouse environment to optimize the path. Y Volkan Pehlivanoglu [7] developed a multi frequency vibrational genetic algorithm to solve the path planning problem of autonomous unmanned aerial vehicles. The algorithm emphasizes a new mutation application strategy. Aybars [8] studied the application of travelling salesman problem on a face of cuboid by developing an effective hybrid method based on genetic algorithm. Mohammed Alhanjouri et al [9] compared the performance of Ant colony algorithm with Genetic algorithm for travelling salesman problem and concluded the effectiveness of GA over Ant Colony Algorithm. Rahul Kala et al [10] studied the Robotic path planning in static environments using hierarchical multi neuron heuristic search and probability based fitness where the algorithm is implemented in hierarchical manner on the environment.

III. PATH PLANNING

3.1 Representation of Environment

Many path planning methods use a grid-based model to represent the environment space as shown in Fig. 1. It has been determined that calculation of distance and representation of obstacle is easier with grid-based representation. The grid-based environment space is represented in two ways, by the way of an orderly numbered grid or by the way of (x, y) coordinates plane. It has been found that the orderly numbered grid representation is widely used; therefore this representation method is used in the present study. [3]

| | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 |
| 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 |
| 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 |
| 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 |
| 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 |
| 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 |
| 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 |

Fig. 1 Representation of the environment

3.2 Chromosome Representation

The GA chromosome is selected to be a string that encodes the grid numbers of the optimised path to be taken by the robot in the environment. Grid numbers correspond to intermediate points between the start and the goal defining a segment sequence that forms the path.

3.3 Initialization of Population

The initial population is generated randomly. Some of the generated chromosomes include infeasible paths which intersect an obstacle. An optimal or near optimal solution can be found by genetic operators, even though the initial population includes infeasible paths. [3]

3.4 Objective / Fitness Function

The objective function plays a key role in the reproduction process in terms of obtaining feasible and high fitness solution. Generally in the path planning problems the objective function is considered as the shortest path (1). Optimal path may be the shortest and may lead to least time. Objective value is the sum of distances between each grid.

$$F = \sum_{j=1}^{n-1} d(g_i, g_{i+1}) \quad (1)$$

$$d(g_i, g_{i+1}) = \sqrt{[(x_1 - x_2)^2 + (y_1 - y_2)^2]} \quad (2)$$

3.5 Selection Method

In selection process the best chromosomes among the population will be selected and will be transferred to the mating pool.

3.6 Crossover Operator

Crossover combines the features of two parents in order to create new children from the chromosomes. A single point crossover technique is used in the present study.

3.7 Mutation Operator

Mutation prevents the algorithm to be trapped in a local minimum. Mutation plays the role of recovering the lost genetic materials as well as for randomly disturbing genetic information. It is an insurance policy against the irreversible loss of genetic material [13]. Random mutation technique is used.

IV. Problem REPRESENTATION

Here we define the assumptions made and the values of the operators.

4.1 Problem Assumption

1. The environment is modelled in 2-D space. [5]
2. The environment and obstacles are of polygon shape. [5]
3. The boundary of every obstacle is expanded by an amount that is equal to half of the greater size in the length & width of the robot. [5]
4. The environment is of 10 X 10 units.
5. It should always travel the centre of the grid.
6. It always starts from 0 and terminates at 99.

4.2 Operator values

The program was executed on Sony Vaio Laptop with 2 GHz processor and 2G RAM.

Operators of GA:

Population size = 150
 Crossover Operator = 0.5
 Mutation Operator = 0.05
 No. of generation = 100

V. EXPERIMENTS & PERFORMANCE EVALUATION OF ENVIRONMENTS

In order to validate the program it is run on a number of environments. Results of three different environments are hereby compared to understand the working and results of the environment and algorithm.

| | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 |
| 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 |
| 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 |
| 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 |
| 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 |
| 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 |
| 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 |

Fig.2 Environment no.2 under study

| | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 |
| 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 |
| 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 |
| 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 |
| 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 |
| 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 |
| 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 |

Fig.3 Environment no.3 under study

| | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 |
| 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 |
| 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 |
| 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 |
| 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 |
| 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 |
| 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 |

Fig.4 Environment no.4 under study
 33 - defines obstacle (in yellow colour)

Table 1: Results for different environments for 100 generations each.

| Environment No | Fig No | No. of optimal Solutions | No. of near optimal Solutions | Fitness Value | Generation Number |
|----------------|--------|--------------------------|-------------------------------|---------------|-------------------|
| 1 | 1 | 91 | 9 | 12.72 | 8 |
| 2 | 2 | 94 | 6 | 13.8995 | 1 |
| 3 | 3 | 97 | 3 | 14.4853 | 3 |
| 4 | 4 | 95 | 5 | 17.4142 | 2 |

Table 2. - Table showing the optimum path for various environments.

| Environment No. | Path (grid numbers) | Value |
|-----------------|---|---------|
| 1 | 0 ,11 ,22 ,33 ,44 ,55 ,66 ,77 ,88 ,99 | 12.72 |
| 2 | 0 ,10 ,20 ,31 ,42 ,53 ,64 ,65 ,66 ,77 ,88 ,99 | 13.8995 |
| | 0 ,11 ,21 ,31 ,42 ,53 ,64 ,65 ,66 ,77 ,88 ,99 | |
| 3 | 0 ,11 ,22 ,32 ,42 ,52 ,63 ,64 ,65 ,66 ,77 ,88 ,99 | 14.4853 |
| | 0 ,11 ,22 ,32 ,42 ,52 ,63 ,74 ,75 ,76 ,77 ,88 ,99 | |
| 4 | 0 ,1 ,2 ,3 ,4 ,5 ,6 ,7 ,8 ,19 ,29 ,39 ,49 ,59 ,69 ,79 ,89 ,99 | 17.4142 |

VI. RESULTS & DISCUSSIONS

The results of implementing the Genetic Algorithm on various environments are shown in Table 2. The results from the test indicates that GA can easily find the optimum path successfully using selected parameters. The optimal path found by GA successively increases as the obstacles in the environment increases. For no obstacle in the environment it gives a path value of 12.72 and 17.4142 for an environment full of obstacles. Further around 90% of the solution gives the optimal path and the optimum path is found in merely 2 – 8 generations.

VII. CONCLUSION

Within the environment with a set of already known obstacles the Genetic Algorithm has proved to find the optimal path effectively. The optimal path found by the algorithm satisfies the optimisation criteria which are to reduce the path cost, shorter computation time and smaller no. of generations.

Finally it can be concluded that to find the path of robots is one of the intensive research area which has a significant role in robotics. The program made can be in future applied to a dynamic changing environment to prove its effectiveness with change in the codes of the program.

REFERENCES

- [1] Manoj Kumar, Mohammad Husian, Naveen Upreti, & Deepti Gupta (2010) “Genetic Algorithm: Review & Application” International Journal of Information Technology and Knowledge Management July-December 2010, Volume 2, No. 2, pp. 451-454.
- [2] A. R Soltani, H Tawfik, et al (2002)” Path planning in construction sites: performance evaluation of the Dijkstra, A* and GA search Algorithm”, Advanced Engineering Informatics pg 291-303.
- [3] Adem Tuncer, Mehmet Yildirim (2012)”Dynamic path planning of mobile robots with improved genetic algorithm” Computers & Electrical Engineering submitted for publication.
- [4] Buniyamin N et al (2011) “Robot global path planning overview and a variation of ant colony system algorithm” International Journal of Mathematics and computers in simulation Issue 1 Volume 5 2011 9-16.
- [5] Ansari Muqueet Husain et al (2012) “ Path Planning of material handling robot using Ant Colony Optimization technique” International Journal of Engineering Research & Applications Volume 2 Issue 5 2012 1698 – 1701.
- [6] Šišlák, D., Volf, P., & Pechoucek, M. (2009). Accelerated A* trajectory planning: Grid-based path planning comparison. In Proceedings of the 19th International Conference on Automated Planning & Scheduling (ICAPS) (pp. 74-81).
- [7] Pehlivanoglu, Y. V. (2012). A new vibrational genetic algorithm enhanced with a Voronoi diagram for path planning of autonomous UAV. Aerospace Science and Technology, 16(1), 47-55.
- [8] UĞUR, A. (2008). Path planning on a cuboid using genetic algorithms. Information Sciences, 178(16), 3275-3287.
- [9] Alhanjouri, M., & Alfarra, B. Ant Colony versus Genetic Algorithm based on Travelling Salesman Problem. International Journal, Computer Technology Application Vol 2 (3) 570 – 578.
- [10] Kala, R., Shukla, A., & Tiwari, R. (2011). Robotic path planning in static environment using hierarchical multi-neuron heuristic search and probability based fitness. Neurocomputing, 74(14), 2314-2335.
- [11] David E. Goldberg, Genetic Algorithms in search, optimization & Machine Learning“(Pearson Education Twelfth Impression 2013).
- [12] Melanie Mitchell, an Introduction to Genetic Algorithms (Prentice Hall of India Edition 2005).
- [13] S.N.Sivanandam S.N.Deepa Introduction to Genetic Algorithms (Springer Edition 2008)
- [14] http://en.wikipedia.org/wiki/Motion_

AUTHORS BIOGRAPHY

Waghoo Parvez graduated from University of Mumbai India with a Bachelor Degree in Production Engineering. He is currently pursuing his Masters in Mechanical Engineering with specialisation in manufacturing systems engineering from University of Mumbai. His research interest is in path planning, CAD, Algorithms, Manufacturing.



Sonal Dhar graduated from Sardar Patel University India with a Bachelor Degree in Mechanical Engineering. She then pursued her Masters in Mechanical Engineering with specialization in CAD/CAM & Robotics from Mumbai University. Her research interest is CAD/CAM, Automation, path planning, FMS.

