Autonomous Robot Path Planning Using Ant Colony Optimization and Evolutionary Programming

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ABSTRACT

This paper proposed an evolutionary approach for mobile robot path planning. The proposed method combines the Ant Colony Optimization (ACO) algorithm as a local search procedure and the Evolutionary Programming (EP) algorithm to optimize the feasible path found by a set of local procedures. It explores the ACO algorithm to determine the shortest feasible path from any current position to the target position in unknown environment with static obstacles. Criteria used to measure planning effectiveness include the path length and the smoothness of planned paths.

Keywords: ***Mobile Robot, Path Planning, Ant Colony Optimization, Evolutionary Programming***

1. INTRODUCTION

The topic of navigation is one of the focused problems in correlation of autonomous mobile robots. The mobile robot is expected to be used in higher, deeper, and dangerous environment such as military reconnaissance, emergency rescuing, aerospace exploration, and underground detection, where human are difficult or cannot imagine to reach [1]. For this, the path planning area that as one of planning research in robotics grew significant over time after Lozano-Perez and Wesley [2].

Navigation consists of two essential components known as localization and path planning. The first one refers to the ability of determining accurate position at any moment relative to the search space according to the environment perceptions gathered by sensors. Whereas path planning consist in designing a collision path from an initial position (state) to a target position (goal) and optimize it with respect to some criteria such as distance, time, cost, and energy.

The methodologies for path planning problems are categorized into classical and heuristic approaches. The classical methods have dominated this research area in the past. However, since the environment becomes complex and dynamic, research with Meta-heuristic approaches have been attracting considerable research interest in recent years so that to overcome the drawbacks of classical methods [3].

Many studies have used representative heuristic methods in order to efficiently generate a feasible solution for path planning mobile robots in complex environment. Huang and Tsai applied Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) together to generate an initial feasible path [4]. GA is used in the papers where the fitness is evaluated with respect to the path length or sum of angles and where genetic operators are conducted for the evolution [5]. Martínez-Alfaro and Gómez-García accomplished the obstacle avoidance for a mobile robot by applying Fuzzy Control and Simulated Annealing (SA) [6].

Several other studies used Artificial Bee Colony (ABC) and Ant Colony Optimization (ACO). Contreras-Cruz, Ayala-Ramirez, and Hernandez-Belmonte used ABC to find a feasible path after scattering the randomly generated points in a free space, which has been calculated in advance [7]. Furthermore, Garcia et al. introduced a fuzzy function and ACO for the framework of an autonomous mobile robot path planning by dividing a map into grid points [8].

ACO algorithm is heuristic method, that have been successfully used to deal with the complex nature of this NP-Complete problem such as the problem of path planning for mobile robot. This work presents the proposed method that combines ACO as a local search procedure and the Evolutionary Programming (EP) algorithm to optimize the feasible path found by a set of local procedure. It is inspired by the ABC-EP planner [9], but ACO replaces the ABC algorithm to build the visibility graph.

2. Model Environment

The problem should be represented to search a feasible path successfully. The environment is a two-dimensional map where all the objects including robot, obstacles, start and target point are located. It shows in Figure 1. Mobile robot assume as a circle object, which is represented by S(Sx,Sy). The static obstacles can be any shape and size with a representation by O(Ox,Oy). Goal is defined as a triangle object, which is represented by G(Gx,Gy). A sequence T of motion commands let the robot move from a start position S to a target position G between vertices V(Vx,Vy).

For the path planning problem, ACO and EP have been experimented on developing methods as a single evolutionary technique. ACO find path that are feasible but not optimal. EP encounters problems to avoid collisions in the robot path but it is able to improve the path when it starts with a feasible one.

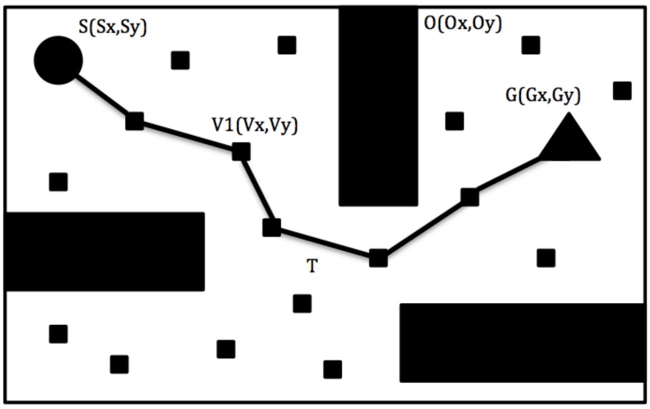

Figure 1 Model of Environment

This paper combines two different techniques. Firstly, ACO generate local search procedures to find a feasible path free of collision by connecting free configuration between the path from the start position S to the goal position G. Secondly, the feasible path is optimized a global way in terms of length and smoothness by using EP.

3. Path Planner Using Ant Colony Optimization

Ant colony optimization (ACO) is one of the most popular swarm intelligence techniques. This method was inspired by the structure of the ant's natural behavior looking for food. Ants leave a pheromone trail when they go to the food source and back to the nest. The pheromone trail works as an indirect means of communication between the ants. It identifies the pathways to the food source. All the ants move with the same speed and spread pheromone the same rate at the time. The pheromone evaporates at a constant rate as well. Meanwhile, ants tend to move along the trail that has a high pheromone density so more ants will choose the shorter path. Hence the shortest pathways will be mostly used and contain accordingly the highest concentration of pheromone [10].

According to the basic principles of ACO and path planning requirements, the method can be described as follows: firstly, set the basic parameters of ACO, including Information inspiration factor α and hope inspiration factor β, pheromone intensity Q and evaporation coefficient ρ, etc. [11]. Then put m ant at the starting point of the map (Number is 0). Each ant takes the starting point as the current node applied probability selection function. Select the follow-up node. If the follow-up node, which is to be selected, includes the end node (number is N), ends this tour, and get a complete path. After each ant end the travel, partially update pheromone, and compare with the current optimal path. If the path obtained is shorter than the optimal path, then replace the optimal path with the current path. When all N ants end the tour, do global pheromones updates. At this point, one iteration completes number of iterations increment. When the number of iterations reaches the maximum, or algorithm stagnation, the algorithm is complete.

The specific process of the basic ACO simulation is as follows [12]:

a) Parameter setting: take the value of all parameters which are selected, refer to empirical values, information inspiration factor α and hope inspiration factor β, pheromone intensity Q and evaporation coefficient ρ.
b) Initialization: Take the value of pheromone τ at time.
c) Pheromone updates strategy: when the process finds the shorter path than the current optimal path, the pheromone can be updated and current optimal path is replaced.
d) Cycles: take the count of ants and maximum number of iterations.

4. GLOBAL PATH PLANNING USING EVOLUTIONARY PROGRAMMING

The EP was proposed by Fogel [13]. It is extension of GA that has flexibility in the solution representation. In this paper, EP based global path planning optimization, works in the phenotype space whilst the GA works in the genotype space. As the ABC-EP planner, In EP there is not crossover operator, evolution process is only performed using mutation operators. The EP procedure are Initialize the population; Repeat: expose the population to the environment, compute the fitness for each member, randomly mutate each parent, evaluate parents and children, select members of new population; Until some condition is met.

a. Individual Representation

The initial population of paths are generated by using the feasible initial path T. A path T is linked list of M vertices. It can be seen in Figure 1. The last vertex is the goal position of the robot. The solution of the planning problem is the optimized of the path generated by local search procedures.

b. Evolution Process

The mutation enables the evolution process. It shows in Figure 2. Each path in the population generates a new path by using some mutation operators. A mutation operator is applied only if it generates a free collision path. The probabilities of the operators were selected by trial and error. In this approach, the operations implied by the mutation operators are as follows:

1. Delete: select at random a vertex in the path, and then delete it.
2. Smooth: select at random a vertex in the path. Compute a random point A(x,y) in the segment of the past vertex with the selected vertex. Compute a random point B(x,y) in the segment of the selected vertex with the next vertex. The new value of the selected vertex is now the point A(x,y). Insert a new vertex in the next position using the point B(x,y).
3. Update: find at random a vertex of the path, generate a new free collision vertex, and update the information.
4. Visibility: select in a random way two vertices, and then the vertices between them are removed.

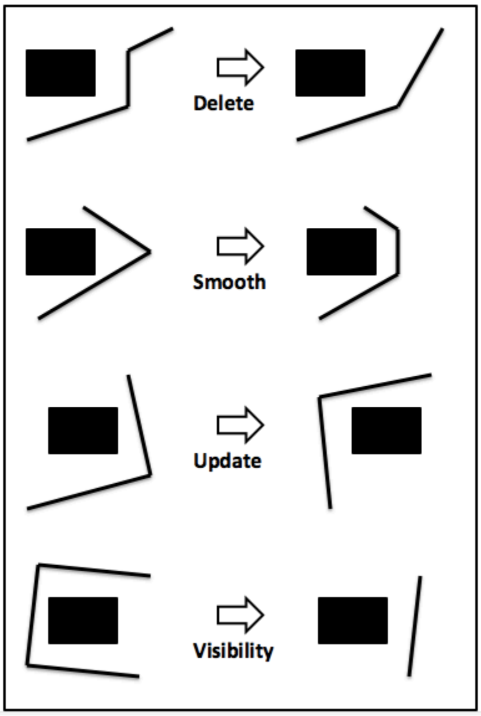

Figure 2. Graphical description of the mutation operators

c. Fitness Evaluation

This proposed method uses an objective function as fitness evaluation. Euclidean distance (dT) is used to compute the path length between M vertices (V). The best path is the shortest length.

$$dT = \sum_{i=1}^{M-1} ||V_i(x,y) - V_{i+1}(x,y)||$$

The population doubles in size after applying the mutation operators. The best half among the parents and the children is retained, and the other half is discarded.

5. Conclusion

The paper presents a new approach of optimization technique for the mobile robot path planning. The methodology is based in a meta-heuristic method. The proposed method includes two sequential approach. Firstly, Ant Colony Optimization generates a feasible path of navigation from initial position (state) to a target position (goal). Secondly, the method uses Evolutionary Programming to refine the feasible path. It improves the path in order to obtain short and smooth the collision-free path.

In future research, the proposed approach used in this paper could be proved by simulation experiments. It could be applied also in an experimental robotic platform to show the performance of the method.

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