Genetic Algorithm Based Path Planning and Dynamic Obstacle Avoidance of Mobile Robots

Woong-Gie Han, Seung-Min Baek and Tae-Yong Kuc
Intelligent Control and Dynamic Simulation Lab.
School of Electrical and Computer Eng.
Sung Kyun Kwan University
Chunchun-dong 300, Changan-gu, Suwon, Kyungki-do 440-746, KOREA
email : tykuc@yurim.skku.ac.kr

ABSTRACT

A simple path planning scheme is proposed for navigation of mobile robots while avoiding obstacles. In generating the goal directed dynamic path, the path panning scheme uses a genetic search algorithm whose coding technique speeds up the execution of genetic search for fast path generation. The fitness value of the generated paths is evaluated in terms of the safety from the obstructing dynamic objects and the distance to the goal position by the genetic algorithm. The execution time of genetic search is further accelerated by projecting the two dimensional data to one dimensional ones to reduce the size of search space.

Keywords : Genetic Algorithm, Dynamic Obstacle Avoidance, Mobile Robot

1. INTRODUCTION

The main difficulties with finding an optimum path for mobile robot navigation arise from the fact that the analytical methods are too complex to be used in real-time and enumerative search methods are overwhelmed by the size of the search space [8]. On the other hand, GAs have been shown to be very efficient at finding an optimum path in very large workspaces. A number of results exist in the literature which show the application of GAs to robot path planning [10]. Among the results, Khoogar and Parker [7] considers the path planning problem in a plane using a planar robot. Ram et. al. [9] applied GAs to a mobile robot navigation problem in a 2-D space with stationary obstacles. Toogood et. al. [10] developed a path finding method for stationary obstacle avoidance by applying GAs to a 3-DOF robot manipulator.

In this paper, an optimal path planning strategy using the genetic algorithms is proposed for the navigation of autonomous mobile robots with real-time dynamic obstacle avoidance. The majority of path planning schemes with GAs that includes obstacle avoidance have been global off-line path planning methods under static environments. However, under a highly time-varying dynamic environment like as the micro robot soccer playground[2], a dynamic path planner should cope with the changing operating condition by modifying the configuration of global path to the goal. In the proposed path planning method, a genetic searching algorithm is used in generating via-points after finding the objects by the vision system. For the real-time path planning with moving obstacle avoidance, the global optimization process becomes very difficult in general. Therefore, we use in this paper a simple cost function which consists of distance and safety measure for short and safe path generation to the goal. The proposed path planning scheme makes it possible to direct the robot motion at each instant of the trajectory and shorten the computation time for real-time obstacle avoidance.

2. PROBLEM STATEMENT

Consider a mobile robot moving on a planar ground and avoiding dynamic obstacles. The mobile robot is guided by a supervisor which consists of a vision system and path planner. The supervisor which can be external to or located onboard the mobile robot needs to direct the mobile robot to reach a goal position while avoiding the moving or attacking obstacles by providing a safe and short path to the goal. Therefore, the planar ground constitutes a dynamic environment for the mobile robot to work with. An interesting example of such a dynamic environment is the soccer playground for micro robots[2]. In such dynamic environments for a mobile robot, two important issues which should be solved for successful steering of mobile robot to the goal position are real-time identification of the moving objects and fast generation of reasonably short and safe dynamic path to the goal. Assuming the former issue resolved by the higher level visual processing system, we provide in this paper a simple dynamic path planning scheme based on a genetic search algorithm for fast generation of via points the mobile robot can track for successful steering to the goal position. In designing the genetic search algorithm for path planner, we pay our attention to the reduction of search space for real-time generation of safe and short path.

3. THE GENETIC SEARCH ALGORITHM

After finding objects and goal position, a genetic searching algorithm is activated in the path planner to generate via-points for a short and safe path to the goal. Genetic algorithms(GAs) are searching and optimization algorithms based on the mechanics of natural selection and natural genetics in biological systems. The GAs implements a "survival of fitness" strategy within a population of competing potential solutions. Each solution is represented by a set of parameters coded in some form, usually as a binary string. This coded string is called chromosome and represents a single point in the multidimensional domain of the search space. A simple and general algorithm incorporating three basic operations is used to cause an evolutionary exchange in the population of solution. These three operations, selection, crossover, and mutation, allow an efficient balance between exploitation of knowledge of better solution, selection based on "survival of the fittest", and exploration of previously unvisited parts of the search domain, crossover and mutation. The generation by generation evolution of the population of potential solutions results in a convergence towards the "best" possible solution [5].

3.1. Parameter Coding Scheme

Assume that the position of robot on a two-dimensional workspace is represented in the fixed X-Y coordinate system. In robot path planning problem by using the GAs, the via-points of a path constitutes the parameter sets coded into binary strings. In genetic searching algorithm, the coding technique is important in that the length of binary strings as well as the size of search space determines the on-line computation time for a given fitness function. Therefore, we devise a simple coding technique to reduce the length of string and thereby accelerate the speed of on-line searching algorithm. Assuming that the initial positions of the robot and goal are known, the length of binary string can be shorten by projecting the two-dimensional data to one-dimensional ones as shown in Fig. 1. In Fig. 1, the set of node points G's is located at equal distance along the straight line from the start to the goal position. Therefore, G's becomes the search space for each via-point of robot path and the via-point candidates are specified by the one-dimensional data.

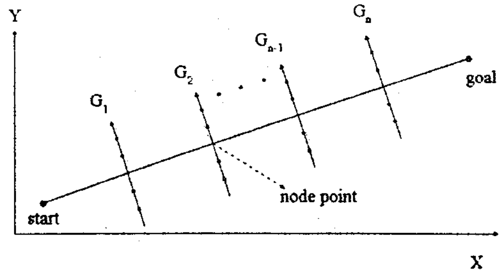

Figure 1. Projection of search space

To further reduce the size of data in each search space and thereby accelerate the speed of genetic searching algorithm, the dynamic allocation of starting points at each via-point is also used, which reduces the search space dramatically as shown in Fig. 2. In Fig. 2, the origin of the ith perpendicular search line is the knot point in the i-1th search line.

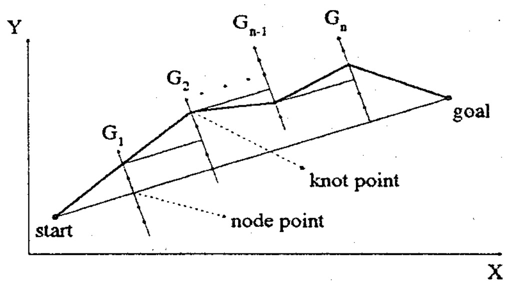

Figure 2. The coding structure

3.2. Fitness Function

The fitness value of strings should be increased if the position of robot is close to the goal position(short path) and far from the moving obstacles(safe path). In view of this fact, the fitness function is implemented using the distance parameters of robot to the goal position and moving obstacles. The distance parameters of robot are defined in Fig. 3.

Using the parameters, the fitness function is constructed as follows:

$$fitness = \alpha \sum_{i=1}^{n} \frac{L_i}{l_i} + \beta \sum_{i=1}^{n} d_{min_i}, \tag{1}$$

where

l_i : distance between the knot point and goal
L_i : distance between the node point and goal
d_{min_i} : the minimum distance between the knot point and obstacles
α, β : the weighting factors.

The fitness function consists of two components: the

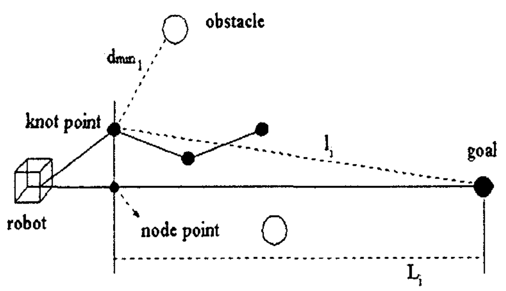

Figure 3. Distance parameters

first one is the rate of distance of node position to that of knot position both from the goal position for short path consideration. This is equivalent to minimizing the deviation of the robot path from the global minimum path of straight line from the start to goal position. The second is the minimum distance of robot to the obstacles for safe path consideration. In addition, the weighting factors α and β can be adjusted to obtain the optimal via-points for short and safe path to the goal while avoiding the moving obstacles.

3.3. Dynamic Modification of Local Path

The low-level navigation algorithm generates dynamic local paths between via-points, which enables the mobile robots move along the paths while avoiding obstacles. That is, in case when the obstacles move fast around the robots, a reactive or instantaneous modification of local path may be necessary in the low-level navigation algorithm by using some local sensors such as IR range scanner [11]. In addition, a smoothing algorithm at corners of dynamic local paths can be implemented as shown in Fig. 4.

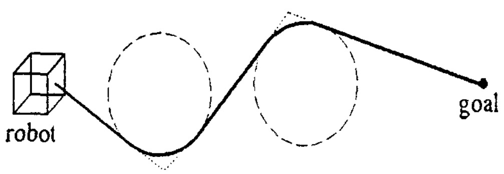

Figure 4. A smoothing algorithm for dynamic path

4. SIMULATION AND EXPERIMENTAL RESULTS

In this section, simulation and experimental results are given by applying the proposed path planning method to navigation of a mobile robot. Fig. 5 - Fig. 7 demonstrates robot navigations under a static environment. The genetic algorithm is shown to be implemented successfully in the global path generator in-real time, where the maximum speed of mobile robot is 1.2 m/s. Fig. 8 shows the convergence of fitness value while finding a via-point for a global path within a sampling interval. Fig. 9 and Fig. 10 demonstrate that the weighting factors α and β in (1) can be used to shape the path profile for mobile robots. Fig. 11 and Fig. 12 show the dynamic path generation and moving obstacle avoidance has been accomplished under dynamic environments. Fig. 12 shows that a local navigation algorithm modifies the dynamic path to reach the goal. In addition the experimental results which demonstrates successful usage of the proposed path planning scheme are also shown by a video tape recording accompanied by this paper.

5. CONCLUDING REMARKS

In this paper, a simple path planning scheme using the genetic search approach is proposed for mobile robot navigation on a dynamic planar ground. The proposed scheme is simple enough to be executed in real-time and effective under dynamic environments as well as static environments. Computer simulation and experimental results are given to show the feasibility of the proposed scheme.

REFERENCES

[1] N. Ayache and O. D. Faugeras, "*Maintaining representations of the environment of a mobile robot*," Autonomous Robot Vehicles. Berlin: Springer-Verlag, 1990.

[2] Seung-Min Baek, Woong-Gie Han and Tae-Yong Kuc, "Cell-Based Motion Control of Mobile Robots for Soccer Game," *Proceeding of Micro-Robot World Cup Soccer Tournament (MIROSOT'97)*, KAIST, Daejon, Korea, 1997.

[3] Y. Bar-Shalom and T. E. Fortmann, "*Tracking and Data Association*," Mew York: Academic Press, 1988.

[4] H. Van Brussel, J. Vandorpe, and G, J huang, "An integrated control system for enhanced autonomous navigation of mobile robots," *Proc. Sec. Int. Conf. Mechatronics and Robotics*, Duisburg, Germany, Sept. 27-29, pp. 297-318, 1993.

[5] David E. Goldberg, "*Genetic Algorithms in Search, Optimization, and Machine Learning*," pp28-145, 1989.

[6] Y. Kanayama and S.Yuta, "Vehicle path specification by a sequence of straight lines," *IEEE Trans. Robotics Automat.*, vol.4 ,no.3, pp265-276, June 1988.

[7] A. R. Khoogar and J. K. Parker, "Obstacle Avoidance of Redundant Manipulators Using Genetic Algorithms," *Proc. IEEE International Conference on Robotics and Automation*, 1991.
[8] J.C.Latombe, "*Robot Motion Planning*," Kluwer Academic Publishers, Massuchusettes, 1991.
[9] A. Ram, R. Arkin, G. Boone and M. Pearce, "Using Genetic Algorithms to Learn Reactive Control Parameters for Autonomous Robotic Navigation," *Adaptive Behavior*, vol.2, No.3, 1994.
[10] H. Toogood, H. Hao, C. Wong, "Robot Path Planning Using Genetic Algorithms," *Inter. Conf. on SMC*, vol. 1, pp. 489-494, 1995.
[11] J. Vandorpe, H. Van Brussel, and H. xu, "LiAS: A reflexive Navigation Architecture for an Intelligent Mobile Robot System," *Trans. on Industrial Electronics*. vol. 43, no. 3, pp. 432-440, June 1996.

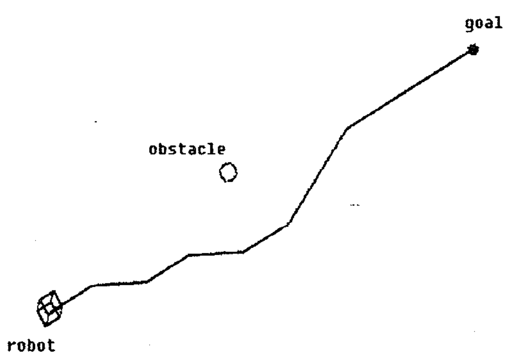

Figure 5. Path generation while avoiding one static obstacle

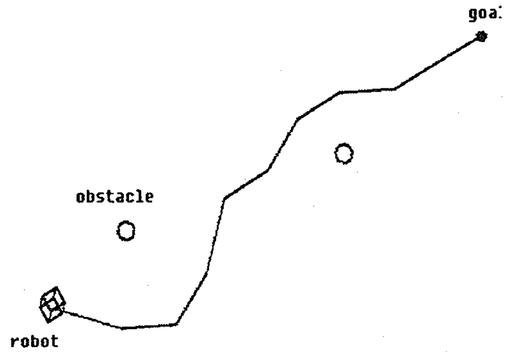

Figure 6. Path generation while avoiding two static obstacles

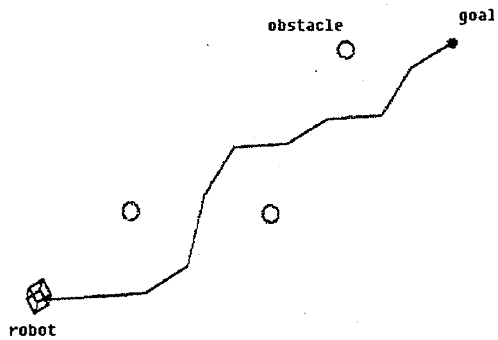

Figure 7. Path generation while avoiding three static obstacles

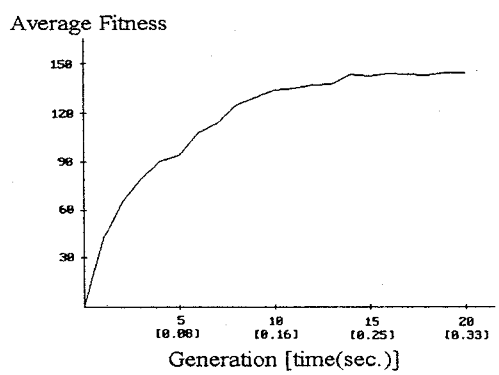

Figure 8. Evolution of average fitness function in a sampling interval

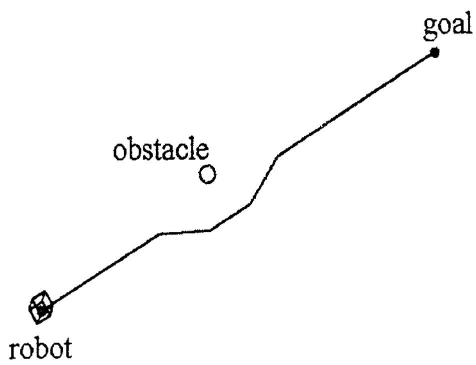

Figure 9. Effect of weighting factors on the shape of generated path (α = 300 β=0.01)

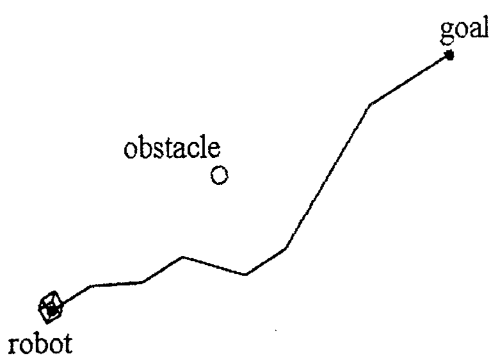

Figure 10. Effect of weighting factors on the shape of generated path (α = 100 β=0.3)

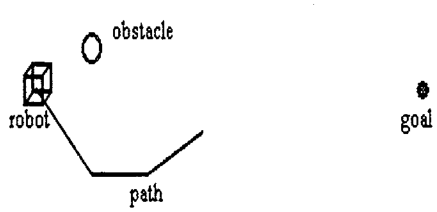

Figure 11. Path generation under the initial static environment

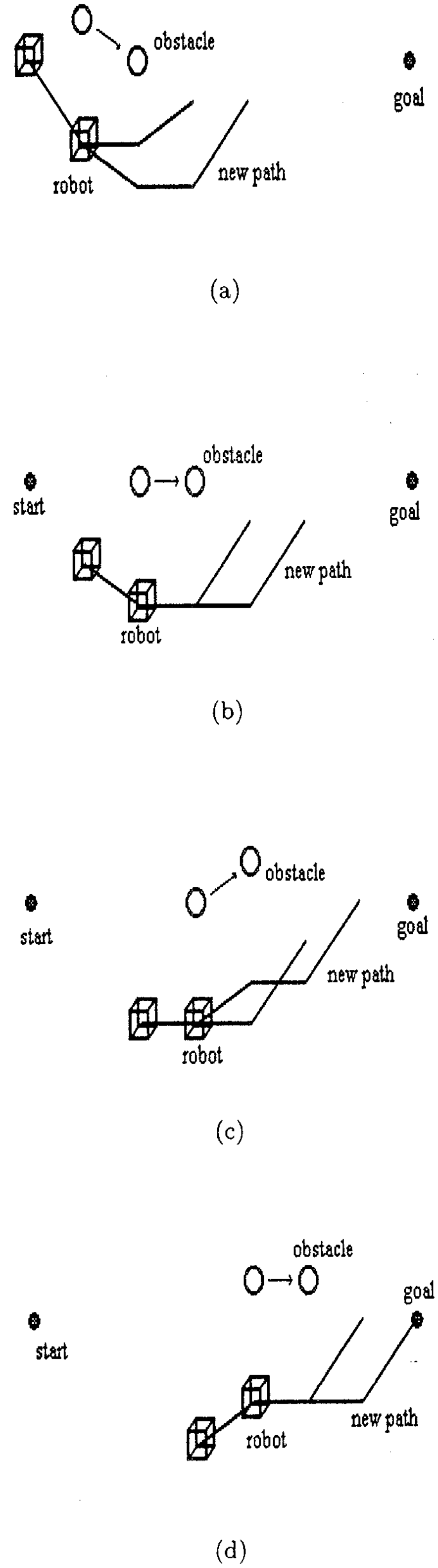

Figure 12. Path modification under the dynamic environment