Path Planning for Multiple Mobile Robots in Static Environment using Hybrid Algorithm

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***Abstract*— In global path planning, finding the optimal path between the starting point and the destination is one of the fundamental problems. Thanks to the recent developments in robotics, meta-heuristic optimization algorithms can be used in path planning. In this study, a new hybrid algorithm based on Genetic Algorithm (GA) and A* algorithm has been developed to solve the navigation problems of multiple mobile robots in a static environment with intermediate target points. The aim of this hybrid approach is improving the productivity of the GA and the most important performance criteria determined in path planning such as time and cost. A graphical interface based on user friendly MATLAB-GUI (Graphical User Interface) has been developed to show the effectiveness of the developed method. It is hoped that the developed system will have an extensive usage area in autonomous transport systems. (*Abstract*)**

***Keywords*— genetic algorithm, A* algorithm, mobil robot path planning** *(key words)*

I. INTRODUCTION

Energy consumption in mobile robots is important and therefore a shortcut is preferred. This makes the usage of the smart path algorithm essential. Two important points are need to be considered in order to solve path planning problems. One of them is the environment type in path planning and the other one is path planning algorithms. In a static environment, everything is fixed except the mobile robot and the whole solution is absolutely determined before starting the application. However, in dynamic or reusable environments, the robot and everything except the robot can be mobile. Therefore, it is necessary to do more planning updates about the robot and the environment. Path planning algorithms are also classified as general and local path planning. The global path planning algorithm requires a definite knowledge about the search environment, and the search environment must be static. In this approach, the algorithm constructs the entire path from the starting point to the target point before the vehicle starts moving. However, in local path planning, the road finding process is carried out while the robot is moving. In other words, the algorithm has the ability of creating a new path in response to environmental changes. Conventional and intelligent methods are used for finding the optimal path. It is seen that both methods are applied in the literature.

In the literature, many algorithms and methods such as A *[1], D * [2] algorithms are used to find the shortest path in path planning of mobile robots. Since existing algorithms cannot solve all kinds of path planning problems, researchers have concentrated on working on new algorithms that offer solutions to complex optimization problems using intelligent methods. Zeng et al. have developed an optimal path planning approach using the results obtained by the Dijkstra algorithm in GA and A * hybrid algorithms. Researchers have shown that the hybrid approach, developed according to the Dijkstra algorithm, is better at solution quality, computation time and search speed. [3]. Qu et al. have proposed a new approach which makes global path planning for GA-based multiple mobile robots. In the new approach, a new parameter named modification has been added to traditional GA parameters. They also made partial changes in the fitness function, selection, mutation and crossover parameters in the new approach. Thus, they achieved an efficiently planned global path planning very close to optimum avoiding collisions between the start and end points [4]. In their study, Taharwa et al. aimed to find the shortest path reducing the number of steps that the mobile robot between the starting and ending points. For this purpose, the GA using the Manhattan heuristic function was used while the fitness values of the most convenient path were found. They made the mobile robot move in four directions with this Manhattan heuristic function. This ensured to reduce the number of complex areas in path planning [5]. Lu et al. discussed the problem of global path planning based on genetic algorithms in their study. They created path rules based on the genetic algorithm to obtain optimal path solution in their research. These rules are not applied in the developed GA selection parameter but they are applied in the mutation parameter. The simulation results show that the new GA efficiency is increased and the optimum path is obtained [6].

In this study, unlike existing studies in the literature, a hybrid approach based on GA and A * algorithm has been developed to solve the navigation problems of multiple mobile robots in a static environment with intermediate target points. The aim of this hybrid approach is improving the productivity of the GA and the most important performance criteria determined in path planning such as time and cost. GA operators such as crossover and mutation are suitable for solving the problem of multiple mobile robots path planning. By virtue of the A* algorithm's feature of working in local solutions, it will provide effective solutions with the GA that provides a global solution. A graphical interface based on user friendly MATLAB-GUI (Graphical User Interface) has been developed to show the effectiveness of the developed method. It is expected that the

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developed system will have a wide usage area in autonomous transport systems..

II. Global Path Planning Using Genetic Algorithm and A* Algorithm

A* algorithm is generally a search algorithm that has the heuristic function which is used to find the optimal path in the path planning of mobile robots. To increase the productivity of the path that is obtained from A* algorithm, a hybrid algorithm approach is developed by combining it with GA, a meta-heuristic algorithm.

A. Identification of Static Environment

In this study, grid-based map model, which is generally used in path planning in defining the static environment, is used for the static environment navigate (Fig.1).In this method, the working environment is divided into squares of the same dimensions. Multiple mobile robots move using the coordinate plane (x, y) in the environment which is shown in Figure 1.

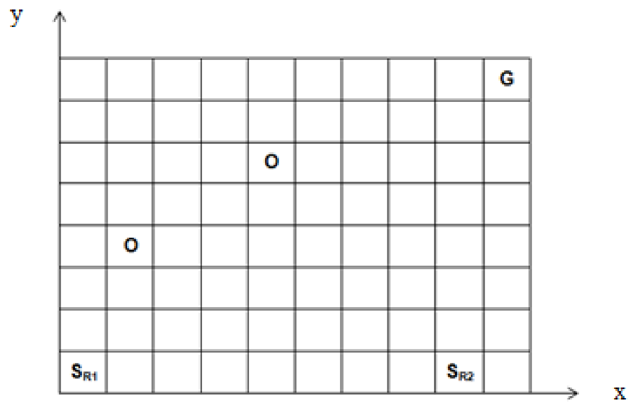


Fig. 1. Identification static environment with grid based map

S: Start position
G: Goal position
O: Position of objects

B. A Algorithm*

The A * algorithm is used to find the shortest and least costly path between the start node and the target node. Eq.(1) is used for the shortest path calculation.

$$f(n) = g(n) + h(n) \quad (1)$$

The distance function g (n) is defined as the length of the passed way between the starting node and the current node. As for the heuristic function h (n), it represents the length of a straight line between the current node and the end node. This is also called bird's-eye distance between the current node and the target node. Algorithm spreads from the starting node to the lowest valued f (n) node.

C. Genetic Algorithms

Genetic algorithms based on natural evolutionary / biological processes and a metaheuristic method were first developed and used in 1975. Genetic algorithms, which are part of the evolutionary computation, are an iterative and probabilistic solution method derives from modeling the process. It uses random search techniques for the solution and is based on parameter coding. Genetic algorithms are used in solving optimization problems of different areas, information systems, machines learning, robot path planning, wing Aerodynamic etc. [7-8]. Genetic algorithms and solution steps can be summarized as in Figure 2.

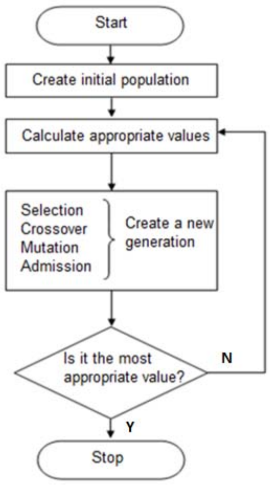


Fig. 2. Flow chart of genetic algorithms

Chromosomes describe the paths between the start and the goal position in path planning problems. Different coding methods can be used depending on the working environment representation used when forming chromosomes. In this study, the coordinates of the cells are integers (x, y) which can be encoded. S: Start position, G: Goal position, O: Position of objects, GA: Chromosome and gene structure in Figure 3.

Chromosome representation of starting conditions used in path planning

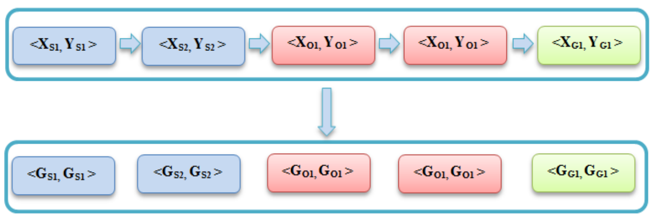


Fig. 3. Chromosomes coding

D. Hybrid Algorithm based Fitness Function

To construct the hybrid algorithm, the evaluation function used for node selection in the A * algorithm and the fitness function that increases the stability feature in the GA will be used. In path planning, it is aimed to find an appropriate or suitable path between starting point and target point considering some criteria such as distance, time and energy. The aim in this study is selecting GA to optimize the path between the beginning and the destination by reducing the cost of the chromosomes to minimum.

To calculate the shortest and least costly way, the heuristic functions that have an important place in the A* algorithm will be used as the objective function used in GA.

These are determined as Manhattan, Euclidean, and Diagonal heuristic functions. The objective functions are optimized by using GA equations in Eq. (2) and Table 1.

$$f_g = \sum_{i=1}^{n-1} d(p_i, p_{i+1}) \tag{2}$$

TABLE 1. HEURISTIC DISTANCE FUNCTION

Heuristic Function	**Equation**
Manhattan	$d(p_i,p_{i+1}) = \lvert x_1 - x_2 \rvert + \lvert y_1 - y_2 \rvert$
Euclidean	$d(p_i,p_{i+1}) = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$
Diagonal	$d(p_i,p_{i+1}) = \lvert x_1 - x_2 \rvert + \lvert y_1 - y_2 \rvert + (\sqrt{2}-2) * \min\{\lvert x_1 - x_2 \rvert, \lvert y_1 - y_2 \rvert\}$

Here, f_g is the fitness function of GA, p_k is the expression of the chromosomes with the gene, and n is the length of the chromosomes. The objective function is given as the sum of the distances between each chromosome on the road.

The Euclidean function, which is one of the heuristic distance functions given in Table 1, is obtained from the sum of the distances between the two chromosomes as shown in Figure 4.

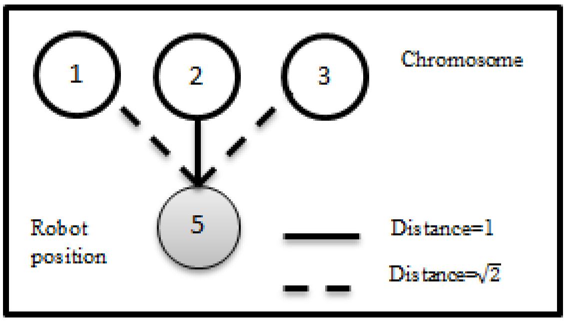


Fig. 4. Euclidean distance between two chromosome positions

The evaluation function obtained by combining A* and GA algorithms is given in Eq. (3).

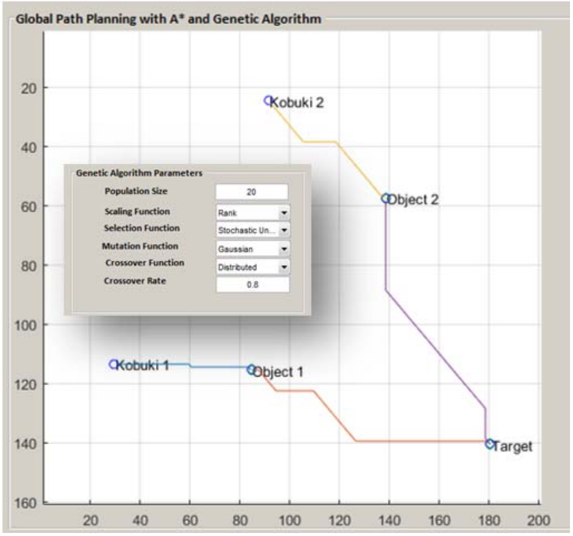
$$f^*(n) = g(n) + h^*(n) \tag{3}$$

Here;

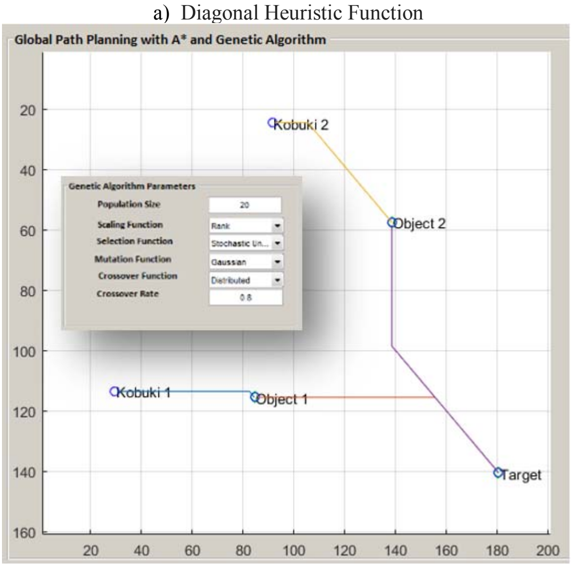
$h^*(n)$ is the optimized cost of the path from node n to the destination. The heuristic functions shown in Table 1 are used for $h^*(n)$.

III. GRAPHICAL USER INTERFACE AND PERFORMANCE EVALUATION FOR GLOBAL PATH PLANNING

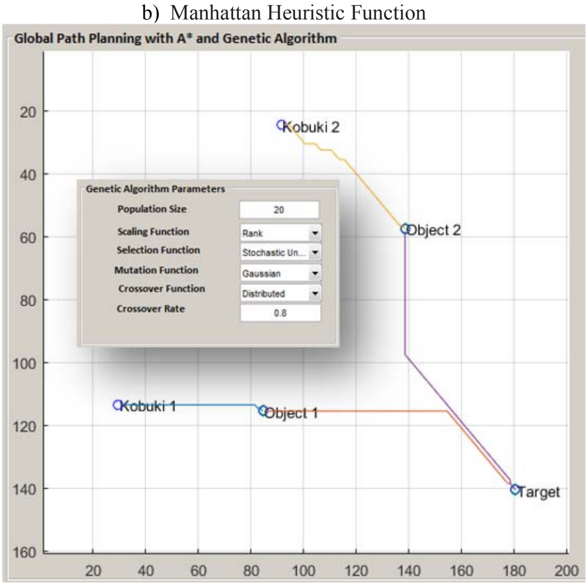
A MATLAB-based graphical interface (GUI) has been designed for using the developed system easily. In the static environment of 200x160 in the Global Path Planning section, the starting points of the Kobuki robots and objects are represented by round shapes. As shown in Figure 5, it is aimed to show the effect of three different heuristic functions in this hybrid approach..



a) Diagonal Heuristic Function



b) Manhattan Heuristic Function



c) Euclidian Heuristic Function

Figure 5. The effects of different heuristic functions in hybrid approach

TABLE 2. COMPARING THE PERFORMANCES OF THE PROPOSED ALGORITHM

GA Parameters	Population Size	20	100	100
	Scaling Function	Rank	Rank	Fractional
	Selection Function	Stochastic	Roulette	Roulette
	Mutation Function	Gaussian	Uniform	Adaptive
	Crossover Function	Distributed	Arithmetic	Heuristic
	Crossover Rate	0.8	0.8	0.8
	Heuristic Function	**Elapsed Time(sec)**		
Kobuki 1	Euclidean	17,68	17,66	17,16
	Manhattan	17,61	16,88	17,47
	Diagonal	15,88	16,09	15,86
Kobuki 2	Euclidean	15,69	15,52	15,55
	Manhattan	17,75	17,98	17,50
	Diagonal	13,60	13,79	13,67

In Table 2, running times are compared when three different GA parameters and different heuristic functions are used for seeing the performance of the proposed algorithm. When the obtained results are examined, it is seen that running times are decreased by changing parameters and heuristic functions.

IV. CONCLUSIONS

In this study, a hybrid algorithm is developed as a new approach to the global path planning problem for multiple mobile robots in a static environment. Hybrid algorithm is obtained by combining GA and A * algorithm. The aim of this hybrid approach is improving the important criteria such as time and cost which affects the productivity and performance of the GA. By using the developed algorithm, the most suitable path or the closest one is obtained in a shorter time by changing GA parameters and heuristic function.

Thus, it is seen that the developed new hybrid algorithm has a better performance than the other algorithms. In the next study, the optimization of the shortest path and the shortest time in a dynamic environment avoiding collisions by using the proposed algorithm will be studied.

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