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An Effective Path Planning of Mobile Robot Using Genetic Algorithm

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***Abstract*- This paper provides a different kind of approach to the dynamic motion planning problems of mobile robots in uncertain dynamic environments based on the behavior dynamics from a control point of view. The conceptual behavior of a mobile robot in motion planning is regarded as a dynamic process of the interaction between the robot and its local environment, and it is modeled and controlled for the purpose of motion planning. Based on behavior dynamics, the dynamic motion planning problem of mobile robots is transformed into a control problem of the integrated planning and control system and the dynamic motion planning problem can be transformed into an optimization problem in the robot's acceleration space. Mobile robot path planning is one of the critical issues in the design of robotic work cells. This paper deals with the design of a battery operated mobile robot and its path planning. Analysis of various robots is conducted and it is found that the robot used in our paper is the best one with high accuracy and had fastest response.**

Keywords— mobile robot; path planning; Genetic Algorithm

I. INTRODUCTION

Now-a-days mobile robots are used in many organizations for the purposes such as path finding, detecting obstacles, image capturing, control the traffic system etc. In the selection of an appropriate mobile robot to meet the requirements, the end user faces with many options while evaluating. Therefore taking the decision in robot selection is more complex because there are many technical and economic factors affecting the performance of the mobile robots and a multi-criterion evaluation approach is required. A better learning and analysis about a system reduces its complexity and increases our understanding. On a reduced complexity, the accuracy that affords computational methods becomes more useful in modeling the system. Genetic algorithm are useful for such systems that are a little more complex but for considerable data exists model free methods. Basically humans are unsuccessful in making quantitative predictions, at the same time they are comparatively efficient in qualitative forecasting the happenings. Also, humans are more disposed to interference from biasing tendencies if they are forced to provide numerical estimations since the elicitation of numerical estimates forces an individual to operate in a mode which requires more mental effort than that required for less precise verbal statements. Mobile robots are predictable to bear various tasks in all kinds of application fields ranging from manufacturing plants, warehouses, transportation, nurse service, tour guide to resource or underwater exploration, national defense etc. In all these applications, a good motion planning method is very important to accomplish tasks efficiently. Hence, motion planning of mobile robots has been extensively researched for many years. The autonomously guided robot knows at least some information about its position and how to reach various goals and or waypoints along the way. The localization or feedback of its current location is calculated by various ways, using sensors, such motor encoders, lasers and global positioning systems.

II. LITERATURE REVIEW

McFetridge et. al [1] proposed about the agoraphilic algorithm as an expectant approach to the path planning for mobile robot. This technique uses virtual, attractive forces derived from the surrounding free space. Motlagh et al. [2] presented a control technique that describes for reactive navigation of mobile robots. They have tried to resolve the problems of large number of rules and inefficient definition of contributing factors. Casual inference mechanism of the fuzzy cognitive map (FCM) is used for deriving the required control values from the FCM's motion concepts and their casual interactions. Fu et al. [3] tried to link small robot with an uncertain environment, in which the robot can sense some basic geometrical features and can take the decision. For the above purpose, a low cost active 3D triangulation laser scanner for indoor navigation of miniature mobile robots is presented. Albagul et al. [4] discussed about the importance of dynamic modeling of mobile robots and is important as because they are designed to travel at higher speed and perform heavy duty work. DeSouza et al. [5] presented a new approach to develop a dynamic model of mobile robot. The control strategy for wheeled mobile robot which they have modeled as rigid body that rolls on two wheels and a castor. There are two levels of motion control strategy, the first level deals with the dynamics of the system and denoted as low level controller and the second level is developed to take care of path planning and trajectory generation and is called higher level controller. Tchon et al. [6] derived the extended Jacobian inverse kinematics algorithm for non holonomic mobile robots. The original kinematics and the augmenting kinematics constitute the extended kinematics. The extended jacobian inverse kinematics algorithm is defined by the inverse jacobian of the extended kinematics defines. Stilman et al. [7] explored global randomized joint space path planning for articulated robots that are subjected to task space constraints. In this paper they describe a representation of constrained motion for joint space planners and develop two simple and efficient methods for constrained sampling of joint configurations. Iocchi et al. [8] felt that knowing the position and orientation of a mobile robot placed in a work environment is a critical element for effective accomplishment of complex tasks requiring autonomous

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navigation. In this paper, they present a self-localization method that is based on the hough transform for matching a geometric reference map with a representation of range information acquired by the robot's sensors. Lee et al. [9] ealized odometry provides fundamental pose estimation for wheeled vehicles. Systematic and nonsystematic errors of odometry should be reduced for accurate and reliable pose estimation. In this paper, they have focused on systematic error sources of a car like mobile robot (CLMR) and suggested a novel method of calibration. Jayaweera et al. [10] described the measurement assisted assembly of aero engine fabricated components and evaluates its capability. The system described in this paper uses in-process measurement sensors to determine the component's exact location prior to the assembly operation. The core of the system is a set of algorithms capable of best fitting measurement data to find optimal assembly of components. Goh et al. [11] presented an advanced weighted model that comprises the values allocated by a group of experts on multiple factors in selecting robots. As per the authors, the model reduces the impact of any decision maker, and a vastly different opinion, on the overall decision. By using their model, boyh of the highest and lowest expert's values on the weights and the subjective factors are removed in this comprehensive method for robot selection. Also the model is illustrated by a numerical example and to show a rank reversal when compared to a model that does not eliminate extreme values.

III. PATH PLANNING OF MOBILE ROBOTS

Whenever artificial intelligence is taken into account, genetic algorithm may be treated as an optimization technique based on natural evolution that is the change over a long period of time. It (GA) has been used as a search technique of many NP problems. Literally Genetic algorithms have been successfully applied to many different kinds of problems, but several factors limit the success of a GA on a specific function. If a comparison is brought between the problems and the ideal solution, the optimal solutions are found not that ideal for genetic algorithms. The fashion in which the points are represented on the search space is an important consideration. A phenomenon measure of performance or fitness value must be available. It must also be feasible to test many potential solutions. As biology says, in nature the fittest individual is most likely to survive and mutate, therefore the next generation should be fitter and healthier because they were bred from healthy parents. Accordingly the same concept can be applied on the robotics for solving path planning problem by first finding the different solutions and then combine those, which are the fittest solutions among them, in order to create a new and healthy solution and should be optimal or near optimal according to the problem.

In robotics path planning is a very common problem for finding the optimal path which can be solved by various methods. There are many algorithms developed for robotic path planning but here we realized the concept of genetic algorithm as more suitable.

A. *VALUE OF THE ASSIGNMENT*

Consider the weighted matrix of the given problem and salve it by using assignment algorithm and called the optimal total cost as a value of the assignment problem. The GA parameters are mentioned in Table 1.

TABLE I. STARTING PARAMETER VALUES

Parameter	Initial value
Population size	10,000
Group size	5
Mutation	3%
Nearby tasks	5
Nearby tasks odds	90%

In this paper a new approach to the dynamic motion planning problems of mobile robots in uncertain dynamic environments based on the behavior dynamics. The fundamental behavior of a mobile robot in motion planning is regarded as a dynamic process of the interaction between the robot and its local environment, and for the motion planning purpose, it is modeled and controlled. No local minima are encountered in most cases. To address the problem of planning the motion of a team of cooperating mobile robots subject to constraints on relative configuration imposed by the nature of the task they are executing. In the said model, constraints between robots graph where each edge is associated with the interaction between two or more robots and describes a constraint on relative configurations. A decentralized motion control system that leads each robot to their individual goals while maintaining the constraints specified on the graph. The main purpose of this work is to propose a new representation method of chromosomes using binary matrix and new fittest criteria to be used as method for finding the optimal solution for robotic path planning problem.

The fittest criterion is: $f(t) = \dfrac{value\ \ of\ \ the\ \ assignment\quad s\ of\ \ the\ \ given\ \ \ problem}{value\ \ of\ \ the\ \ string}$

The concept of the proposed method is drawn from genetic algorithm of artificial intelligence as a basic ingredient which has been used as search algorithm to find the near optimal solutions. We are here introducing the new fittest criteria for crossover, and the algorithm is applied on symmetric as well as asymmetric problem, also presenting asymmetric problem in a new and different way. This work develops a new crossover operator, sequential constructive crossover, for a genetic algorithm that generates high quality solutions to the robotic path planning. The sequential and constructive crossover operator constructs an offspring from a pair of parents using better edges on the basis of their values that may be presented in the parent's structure maintaining the sequence of nodes in the parent chromosomes. The efficiency is compared as against some existing crossover operators; namely edge recombination crossover and generalized N-point crossover for some benchmark instances.

For practical robots optimal path finding or path planning are bound by its available resources. The Genetic Algorithm (GA) search optimization provides the power and versatility or various search algorithms that can be used to provide optimal solutions at the cheapest cost. In this research Evolutionary search algorithm was developed based on the GA to find an optimal path on a dynamic grid. This algorithm directs the resources to be specified through various parameters such that, instead of an absolute optimal solution, it allows for the resources to be predefined resulting in best answer possible with given constraints. It uses cost optimization to find the best quality solution while using minimal resources. The effects of varying different parameters have also been studied to show how optimality is affected. A simulation modeling is developed to understand the various performance statistics for the algorithm with single and multiple Robots. A collaborative flocking scheme allowed for multiple Robots to use GA as a path planning and path finding tool. The implementation shows how such at algorithm can be applied in real world application. A combination of laptop computers with Bluetooth technology are used to control the robots. The agents used GA algorithm to follow a leader robot on a grid.

IV. RESULTS AND DISCUSSIONS

A simulation result is developed to understand the various performance statistics for the algorithm with single and multiple Robots. A collaborative flocking scheme allowed for multiple Robots to use GA as a path planning and path finding tool. The implementation shows how such algorithm can be applied in real world application. The Robotic system is examined for various parameter deviations, such as mutation, crossover, and mating pool. Variable setups of number of tasks and distances combinations are considered as an example. Here 15 independent tasks were considered to accomplish with single and multiple number of robots where each Robot is assigned to a unique set of tasks separately and completes the route by returning to the task started from the same point. Here some simulation experimentation with 15 tasks and four different cases are developed are as follows:

- Single Robot with 15 tasks (Case-I)
- Four Robots with 15 independent tasks (Case-II)
- Four Robots with 15 tasks with constrained (Case-III)
- Four Robots with 15 tasks with initial and final destination (Case-IV)

A. Single Robot with 15 Tasks

Let us define problems that will be solved using GA. This problem is defined in terms of space but can be adapted to many other problems by expanding the dimension or using more complicated heuristics. Eventually this property can be modified such that costs from a node to the adjacent node may vary from node to node. One more complexity that can be added to this general path finding problem is to add moving obstacles allowing for the algorithm to be recomputed when it comes across and unexpected obstacle. This complexity was not pursued in this research but can be a possible expansion for this study. For the purpose of this research a simple robot was built using a light sensor to read the grid and utilized servo motors to follow lines. The robot has some open loop control to turn and move. It had a 'bang bang' controller to follow grey lines on the grid and stop when it reached a black node. When the robot is constructed (above right), it had a light sensor and four wheels, two of which were actuated. Initially 15 tasks are randomly generated in the grid with only one robot. A single Robot moves to each of the tasks and completes the shortest path by returning to the task, started from. Each task is completed by the Robot exactly once shown in Figure 1. The coordinates of 15 tasks (A-O) are presented in Table 2.

TABLE II. COORDINATES OF 15 TASKS FOR CASE I

Sl no.	Name of task	X co-ordinate	Y co-ordinate
1	A	4.8	8.6
2	B	5.1	7.8
3	C	5.1	5.1
4	D	4.9	4.9
5	E	5.1	4.2
6	F	6.2	3.9
7	G	5.0	3.8
8	H	3.8	3.0
9	I	3.0	1.0
10	J	2.0	1.0
11	K	1.4	0.1
12	L	0.8	4.1
13	M	0.8	4.2
14	N	4.1	6.1
15	O	4.8	8.6

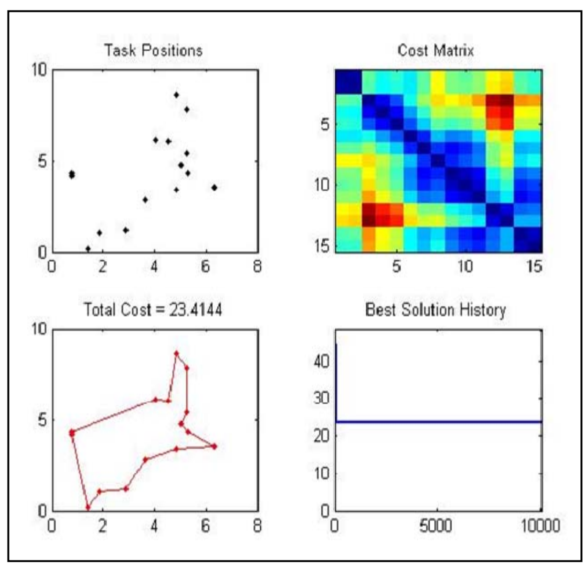

Fig. 1. Optimization of results of case-I

B. Four Robots with 15 Independent Tasks

Each Robot assigns to a unique set of tasks separately and completes the route by returning to the task started from. Each task is assigned by exactly one Robot. The coordinates of 15 tasks are presented in Table 3. All four Robots moves to the tasks independently according to their shortest path and returned to the task, from where they have started, presented in Figure 2. Each task is completed by the Robot exactly once shown in Figure 1.

TABLE III. COORDINATES OF 15 TASKS FOR CASE II

Sl no.	Name of task	X coordinate	Y coordinate
1	A	2.1	1.7
2	B	5.0	1.7
3	C	3.8	1.0
4	D	1.1	5.6
5	E	6.0	6.8
6	F	2.1	6.8
7	G	8.9	7.6
8	H	9.0	9.0
9	I	9.5	10
10	J	7.9	0.8
11	K	9.2	3.0
12	L	9.0	4.9
13	M	8.5	5.0
14	N	6.	3.0
15	O	7.9	2.6

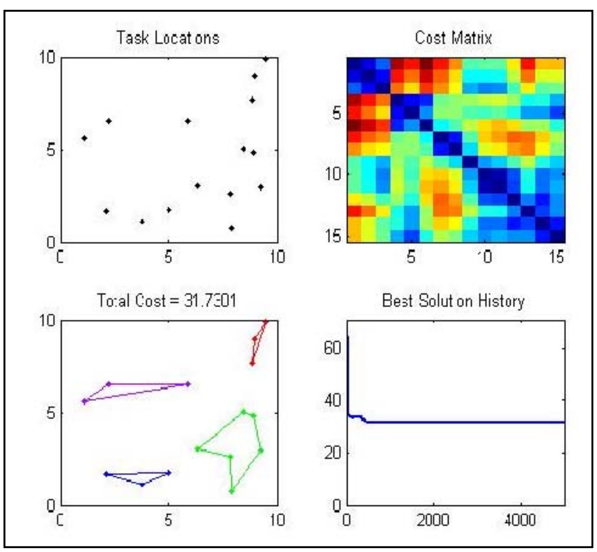

Fig. 2. Optimization of results of case-II

C. Four Robots With 15 Tasks with Constrained

Four Robots with 15 tasks with constrained are to be fixed on the working space. The constrained is to the Robots starting their tasks from any arbitrary point and completes at that point applicable to all robots. All Robots moves to first task and completes the shortest path by returning to the task, started from. Each task is completed by the Robot exactly once excluding starting task shown in Figure 3. The coordinates of 15 tasks are presented in Table 4.

TABLE IV. COORDINATES OF 15 TASKS FOR CASE III

Sl no.	Name of task	X coordinate	Y coordinate
1	A	6.6	0.9
2	B	4.5	0.3
3	C	7.1	2.6
4	D	9.5	1.0
5	E	8.9	2.1
6	F	6.9	5.6
7	G	7.0	7.3
8	H	8.3	9.9
9	I	7.2	7.2
10	J	1.0	3.6
11	K	0.1	3.5
12	L	2.4	5.7
13	M	4.0	5.1
14	N	4.1	4.9
15	O	5.0	5.8

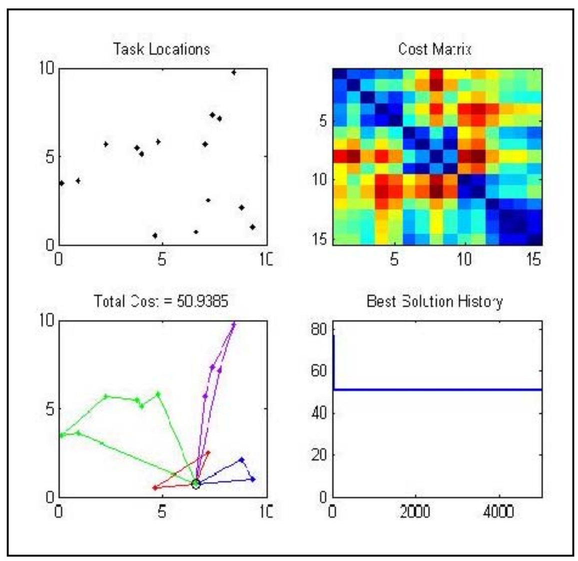

Fig. 3. Optimization of results of case-III

D. Four Robots with 15 Tasks with Initial And Final Destination

Robot assigns to a unique set of tasks and completes the task at another point. Each task is assigned by exactly one Robot. The coordinates of 15 tasks are presented in Table 5. A four Robots moves to the tasks independently according to their shortest path and returned to the task presented in Figure 4. The simulation results of case-IV shown in Figure 4.

TABLE V. COORDINATES OF 15 TASKS FOR CASE IV

Sl no.	Name of task	X coordinate	Y coordinate
1	A	3	4
2	B	4.3	4.2
3	C	3.8	4.5
4	D	4	3
5	E	5.6	1.0
6	F	6.8	2.0
7	G	7.8	5.0
8	H	6.4	6.0
9	I	6.0	7.5
10	J	6.8	8.0
11	K	4.8	8.8
12	L	2.0	9.5
13	M	1.7	7.2
14	N	1.6	4.0
15	O	4.0	3.0

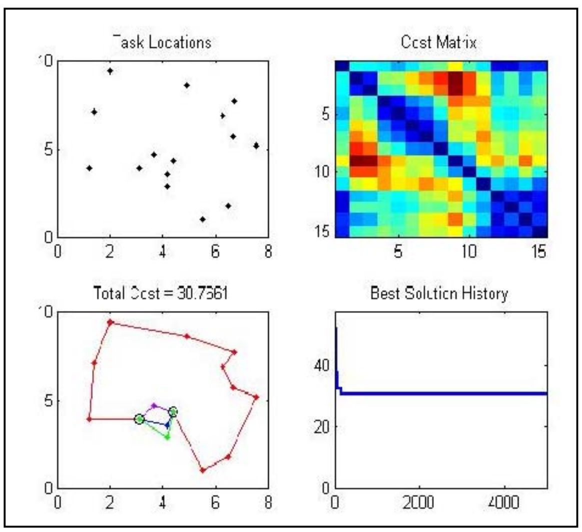

Fig. 4. Optimization of results of case-IV

By comparing all the cases, finally the total cost achieved by the Robot in case-I is less i.e 23.4144 to do all the tasks by a single Robot presented in Figure 5. So it is an effective technique to optimize the task in a better way. The robotic system is developed to assist the user to obtain optimal path to visit n tasks. It is proposed the use of advanced operators of genetic algorithms in order to enhance the rate of divergence, and achieved paths with reasonable time. It is used an interactive user interface enabling users to handle most system features. The developed selection algorithm used helps to select a suitable strategy for selecting a pair of parents for crossover operation. Besides, newly developed fitness function is adopted and has produced reasonable results.

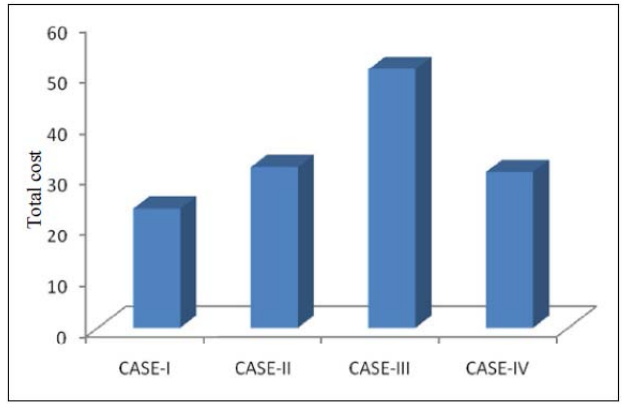

Fig. 5. Comparison of all cases

REFERENCES

[1] L. McFetridge, M.Y. Ibrahim, A new methodology of mobile robot navigation: The agoraphilic algorithm, Elsevier, Robotics and computer integrated manufacturing, 25 (2009) 545– 551.

[2] O. Motlagh, S.H Tang, N. Ismail, A.R Ramli, An expert fuzzy cognitive map for reactive navigation of mobile robots, Elsevier, Fuzzy sets and systems 201 (2012) 105–121.

[3] Guoqiang Fu, Arianna Menciassi, Paolo Dario, Development of a low cost active 3D triangulation laser scanner for indoor navigation of miniature mobile robots, Elsevier, (2012) 0921-8890.

[4] A. Albagul & Wahyudi, Dynamic Modeling and Adaptive Traction Control for mobile robots, International Journal of Advanced Robotic Systems, Volume 1, November 3 (2004), ISSN 1729-8806,pp. 149 – 154.

[5] Guilherme N. DeSouza and Avinash C Kak, Vision for Mobile Robot Navigation: A Survey, IEEE, 2002, pp-237-267.

[6] Krzysztof Tchon And Janusz Janusz Jakubiak, Extended Jacobian inverse kinematics algorithm for nonholonomic mobile robots, International Journal of Control Vol. 79, No. 8, August 2006, 895–909.

[7] Mike Stilman, Global Manipulation planning in robot joint space with task constraints, IEEE, IEEE, June 2010, pp 576-584.

[8] Luca Iocchi, Daniele Nardi, Hough Localization for mobile robots in polygonal environments, Elsevier, Robotics and Autonomous Systems 40 (2002) 43–58

[9] Kooktae Lee, Woojin Chung, Kwanghyun Yoo, Kinematic parameter calibration of a carlike mobile robot to improve odometry accuracy, Elsevier, (2010) 582–595.

[10] Nirosh Jayaweera, Phil Webb, Craig Johnson, Measurement assisted robotic assembly of fabricated aero-engine components, Emerald Group Publishing Limited, (2010) 56– 65.

[11] Chon-Huat Goh, Yung-Chin Alex Tung, Chun-Hung Cheng, A Revised Weighted Sum Decision Model for Robot Selection, Computers Ind. Engng Vol. 30, No. 2,193-199, 1996.