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Optimization of Time of Mobile Robot using Genetics Algorithm in Exploration of Area

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EDITORIAL BOARD EXCERPT Initially at the Time of Submission (ToS) paper had a 10% plagiarism, which is an accepted percentage for publication. The editorial board is of an observation that paper had a successive close watch by the blind reviewer's which at the later stages had been rectified and amended by the authors (Rajnesh & Neelu) in various phases as and when required to do so. The reviewers had in a preliminary stage remark with minor revisions which at a short span were restructured by the author. The comments related to this manuscript are tremendously noticeable related to **Optimization of Time of Mobile Robot Using Genetics Algorithm** both subject-wise and research wise. The authors have crafted the paper in a structured manner. As the sensor based mobile robot coverage path planning is exigent for robotics management. It mostly increases with the increase in a distance travelled by robot. The paper made an attempt to find such an optimal path for robot by which robot have to travel least distance. All the comments had been shared at a variety of dates by the author in due course of time and same had been integrated by the author in calculation. By and large all the editorial and reviewer's comments had been incorporated in paper at the end and further the manuscript had been earmarked and decided under **"Empirical Research Paper"** as in this work a new algorithm is designed which reduces the power consumption in the robots.

ABSTRACT

Purpose: Sensor based mobile robot coverage path planning is exigent for robotics management. In general, time is mostly increased with increase a distance traveled by robot. Proposed algorithm we will find the optimal path of robot by which robot will have to travel least distance with the least number of turn during traverse. During the exploration of area if the number of turn taken by robot will be decrease than exploration time will be decrease. Combine effect of minimizing distance and number of turn lead to minimize area exploration time.

Design/ Methodology/ Approach: In the proposed method the entire area is graduated into tiny circles with radius same as the radius of the sensing range of the robot. Various prioritization patterns (PP) are deployed to determine the movement of the robot.

Findings: In this work, a new algorithm using GA is designed which reduces the power consumption in the robot, by the reduction in the turns required in the path.

KEYWORDS GA | Path Optimization | Prioritization pattern | STC

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Introduction

The path designing for the environment exploration of a mobile robot based on Sensors finds application in a lot of application such as floor cleanup, lawn moving, street swapping and paint applications. In some critical situation (rescue operations), time is vary important in compare to other factor. There are different way of exploration for the complete coverage of the path planning problem. Some of them are distance transformation[1], spanning tree algorithm[3], cellular decomposition algorithm[2], template based algorithm, and artificial neural networks (ANN). Distance transform model flow of the robot between obstacles like tree based environments. In [4], the researcher proposed a1 boustrophedon cellular decomposition algorithm based on the principle of breaking down of the workspace and to allow the robots to explores each individual cell like an ox. A new neural network[4] algorithm approach is proposed for complete coverage of the path planning robots with an obstruction avoidance of cleaning robots in no stationary environments. Spanning tree, novel technique that attempts to reduce the search space by first constructing a minimal reach ability graph between modules that are within communication range of each other, in the form of a minimum spanning tree (MST).Generally, the following two methods are used for the problem of area coverage: random coverage and exhaustive coverage.

The best applications for the Exhaustive coverage are where the area to be covered by the robot is limited or indoors due to the restrictions of the time and power. The exhaustive coverage isn't suited for exploring larger spaces entirely. On the other hand, random coverage doesn't guaranty absolute coverage and it also doesn't necessitate expensive localisation of sensors or increase in computational power. Although numerous smart coverage schemes are already been designed, however almost all of them makes the same premise of them having sufficient time period for covering the total target area which may not be always available.

Generally, the coverage algorithms are categorized as offline and online algorithms. Offline coverage algorithms use fixed information and environment is known in advance. Complete coverage planned by genetic algorithms, neural networks, cellular decomposition, spanning trees, spiral filling paths and ant colony method falls in this category [5]

In CCPP, two standard basic motions are followed to perform coverage, 1) the square spiral motions, and 2) the boustrophedon (back-and-forth) motion (see Fig. 1). The main advantage of these basic motions is that they can cover region of any shape and can be used as a base for more complex movements particularly in an environment full of obstacles

Fig. 1 (a)
Spiral Motion

Fig. 1 (b)
Boustrophedon Motion (Right)

In literature, while performing CCPP three criterion are given importance, 1) the environment

Decomposition technique, 2) the sweep direction (for reducing total number of turns), and 3) the optimal backtracking mechanism.A common approach used to solve CCPP problem is to mimic the classic "Travelling Salesman Problem(TSP)"[6] to cover the sub-regions within a decomposed environment. A common invariant of TSP approach found in literature is to formulate the coverage of environment as the Hamiltonian cycle problem. A greedy algorithm builds up a solution to the problem gradually by always choosing the next choice that offers the most obvious and immediate benefit[7]. A greedy algorithm makes a locally optimal choice that will lead to globally optimal solution through a sequence of choices made at every intermediate step. Greedy algorithms are generally fast. However, they could fail to find the global optimal solution because they do not operate exhaustively on all the data. A mobile robot comes with the constraints such as bound on its curvature, velocity and acceleration. These constraints restrict the movement of the mobile robot at sharp turns while following the linear piecewise trajectory generated by a CCPP algorithm. While following a trajectory, sharp turns in the generated path cause jerks resulting in discontinuity along the trajectory. Thus, the trajectory cannot be driven at a constant speed. A smooth path enables the robot to follow the trajectory without stopping, slowing down and reorienting on sharper turns.

One more paper [8] paper presented comparison between STC algorithm and CCD[9] algorithm. Author are discuss that STC algorithm is capable to planning complete coverage path 70.27 percentage coverage and without overlapping. While CCD algorithm cover 98.79 percentage. But in same time redundant movement is very high in CCD algorithm. But in both algorithm other dose not care about smoothness of motion of robot.

In order to make these paths applicable for real time applications in such robots, smoothness must be incorporated in robotic path. Smoothness of the path within the planned coverage can be achieved by first reducing the total number of turns and then smoothing sharp corners while keeping the length of path shortest possible [10].

Research Methodology

Focusing on the concept of combining patterns of exploration, referred as chromosomes, in Genetic algorithm for searching better improved method of exploring was the basis of the genetic evolution's principle given by Darwinian & Mendelian. Whilst coverage algorithms assisted in jagged motions, for this a robot pragmatically needs to reduce its speed before accelerating. Thus it can be judiciously commented that the distance covered by robot, with such sharp jagged turns are the driving factors for assessing the true travel time. The study presented levies stress by introducing the process of reducing the jagged turns. Back Tracking Spiral Algorithm (BSA) has been put to use in the study and it has been proposed to use the rectilinear moves symbolized by eight neighbor disk prioritization patterns. The algorithm steps have been presented hereunder:

- Generation of starting population
- Estimation and selection
- Crossover operator
- Mutation operator

The area under study in this piece of work is divided into various small circles with diameter of sensing range of robot. In the proposed method the entire area is graduated into tiny circles with radius same as the radius of the sensing range of the robot. Various prioritization patterns (PP) are deployed to determine the movement of the robot. Few the patterns used in the study are shown in fig.2.

			13			
		24	5	14		
	23	12	1	6	15	
22	11	4	P1	2	7	16
	21	10	3	8	17	
		20	9	18		
			19			

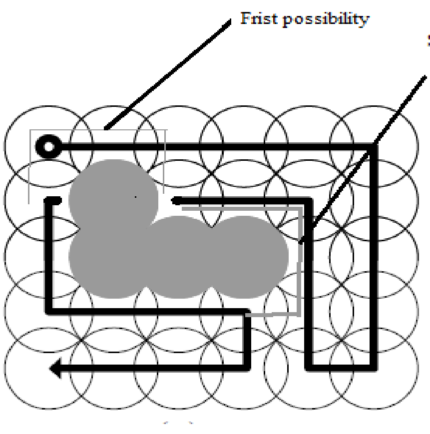
			19			
		20	9	18		
	21	10	3	8	17	
22	11	4	P2	2	7	16
	23	12	1	6	15	
		24	5	14		
			13			

			13			
		14	5	24		
	15	6	1	12	23	
16	7	2	P3	4	11	22
	17	8	3	10	21	
		18	9	20		
			19			

			19			
		18	9	20		
	17	8	3	10	21	
16	7	2	P4	4	11	22
	15	6	1	12	23	
		14	5	24		
			13			

Fig.2 The prioritization patterns used in study

These priorities shown in figure 2 are used to assign movements of the robots as shown in fig 3, whose genetic representation is illustrated in table 1:



(a)

1	2	3	4	5	6
17	xx	16	15	14	7
18	xx	xx	xx	13	8
19	20	21	22	12	9
26	25	24	23	11	10
A jump from 16 to 17 occurs with three double-visited disks					

(b)

Fig.3 (a) The environment (b) chromosome obtained after decoding

Chromosome.1																									
Gens	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
Neighbor	2	2	2	2	2	3	3	3	3	4	1	1	1	4	4	11	3	3	2	2	2	3	4	4	4

Table 1 Genetic representation

As stated, before commencing with the traversing using PP (P1), the entire area is sectioned using circles. The shortest distance calculated by the robot, based on the algorithm, is used to explore the unexplored circles, specifically when a hurdle comes in its way. Figure 2 represents the two possible combinations of the same. First possibility being that the robot happens to traverse the same shortest path that it has already covered. Subsequently all eight PPs are deployed to explore the total path in order to assess the shortest path varying in every pattern. This leads to formation of one chromosome that is obtained after complete transverse movement of robot. Lastly two chromosomes are intermixed after crossover as per the adaptability.

Simulation Results

Path Configuration

The simulation model that has been used is given in this section. The model was put to use to assess the performance of the sighted GA path planning algorithm in an entirely different grid ambience. Coding for the grid simulation and path planning implementation using Neighborhood disk prioritization pattern were used to implement the stated approach. A 2D ambience is modeled as a 2D matrix obstruction position as shown in Fig 2. Testing of the proposed approach was carried out on four different obstructions placement with different area matrix sizes. The data set used composed of 4 different ambiences as illustrated in Table 2. The grid maps sizes are (6*5) cells. The obstruction is placed at place and the backtracking Spiral algorithm based priority pattern is used to develop the path planning where, the robot will move through the disks through the shortest path sweeping the room till the end is reached.

Environments	No of Rows	No of Columns	Obstacle Placements
Environment 1	6	5	8,14,15,16
Environment 2	6	5	11,12,16,17
Environment 3	6	5	8,14,15,20
Environment 4	6	5	5,6,11,12

Table 2. 2D experimental environments

Now, in the next step Genetic Algorithm was utilized for the all possible PP (the 8 paths). This has been put to use to discover the smallest path among them which is different in for each pattern. One full transversal motion of the robot corresponds to the one single chromosome & every cell corresponds to a gene. In the following steps the chromosomes are passed through the crossover process, in which one chromosome is transmuted in relation to the other chromosome and both of these chromosomes are inter - mixed as depicted in fig.3.

Genes	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
Chrom. 1	2	2	2	2	2	3	3	3	3	4	1	1	1	4	4	11	3	3	2	2	2	3	4	4	4
Chrom 2	1	1	1	1	2	2	2	2	2	3	3	3	3	4	1	1	1	4	4	4	19	2	1	2	3
Conv. Chrom 2	3	3	3	3	2	1	2	3	2	2	2	3	2	1	1	4	1	4	4	1	4	7	2	2	3
Mask	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1
Child.1	2	2	2	2	2	3	3	3	3	4	2	2	2	4	4	1	3	3	2	2	2	3	1	1	1
Chrom 3	3	3	3	3	4	1	4	3	4	1	4	1	1	1	2	2	2	10	4	11	1	9	3	3	2
Conv. Chrom 3	3	3	3	3	2	1	2	3	2	1	2	1	1	1	4	4	4	8	2	7	1	9	3	3	4
Mask	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1
Child.2	2	2	2	2	2	3	3	3	3	4	2	1	1	1	4	4	4	8	2	7	2	3	4	4	4
Chrom. 4	1	1	1	1	4	3	4	1	4	3	4	1	4	3	3	2	3	2	2	3	2	11	4	4	1
Conv. Chrom 4	3	3	3	3	2	1	2	3	2	1	2	3	2	1	1	4	1	4	4	1	4	7	2	2	3
Mask	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1
Child.4	2	2	2	2	2	3	3	3	3	4	2;4	3;4	2;4	1	1;2	4;2	1;2	4;1	4;1	1;4	4	11	2;3	2;3	3

Fig.3 Masking probability and changed parametric crossover for 2 chromosomes

Experimental Result

For testing the operation of the proposed scheme, we used various GA methods utilized for solving the PP problem in several environment to examine the performance of our method as represented in Table 4. For the robot obtaining an optimum path, which is time saving and energy efficient, the primary valuation points in the numbers of turns required in the optimum path.

In the first proposed scenario, the Algorithm is evaluated according to the approach in Ref.[11] and our algorithm. A number of readings are taken for each one. Table 3 displays the average number of turns required in the optimum path, and the average crossovers required. It is clear seen by the results that GA with the proposed methods obtains the optimum path in fewer iterations and requires lesser numbers of turns.

Approaches	No of turns in the best path	No of Crossovers
Child Chromosome 1	11	1
Child Chromosome 2	14	2
Child Chromosome 3	16	1

Table 3. Experimental results in the proposed environments.

Approaches	Method	Number of turns in the best path	Number of crossovers
Proposed method	GA based PP algorithm	11	1
Ref.[11]	Dynamic path planning	Random turns (best attempt 78)	0

Table 4. Comparison of different methods for Robot Path Planning.

Conclusion

In this work, a new algorithm using GA is designed which reduces the power consumption in the robot, by the reduction in the turns required in the path. A Better Adjacency Crossover algorithm is designed for the GA method for solving the PP problem. For validation of our proposed algorithm, tests were suggested against various environments with different obstacles and comparison with other existing algorithm. These result provides the optimal path for the proposed GA method. More optimal solution in terms of average turn value and iteration numbers is suggested in the study as compared to other models.

References

- A. Zelinsky, R. A. Jarvis, J. C. Byrne, and S. Yuta, "Planning Paths of Complete Coverage of an Unstructured Environment by a Mobile Robot," in *In Proceedings of the International Conference on Advanced Robotics*.
- H. Choset and P. Pignon, "Coverage Path Planning: The Boustrophedon Cellular Decomposition," in *In Proceedings of the International Conference on Field and Service Robotics, Canberra, Australia,* 2011, pp. 203–209.
- A. Dutta, P. Dasgupta, and C. Nelson, "Spanning Tree Partitioning Approach for Configuration Generation in Modular Robots Dynamic Configuration Generation in MSRs," in *Proceedings of the Twenty-Eighth International Florida Artificial Intelligence Research Society Conference*, 1998, pp. 360–365.
- Y. Guo and M. Balakrishnan, "Complete coverage control for nonholonomic mobile robots in dynamic environments," *Proc. - IEEE Int. Conf. Robot. Autom.*, vol. 2006, no. May, pp. 1704–1709, 2006.
- A. Khan, I. Noreen, and Z. Habib, "On complete coverage path planning algorithms for non-holonomic mobile robots: Survey and challenges," *J. Inf. Sci. Eng.*, vol. 33, no. 1, pp. 101–121, 2017.
- T. M. Driscoll, "Complete coverage path planning in an agricultural environment." p. 71, 2011.
- C. H. P. and U. V. V. S. Dasgupta, *Algorithms*, 1 ed. McGraw-Hill Education, 2006.
- A. Šelek, M. Seder, and I. Petrović, "Mobile robot navigation for complete coverage of an environment," *IFAC-PapersOnLine*, vol. 51, no. 22, pp. 512–517, 2018.
- M. Dakulović, S. Horvatić, and I. Petrović, "Complete coverage D*; Algorithm for path planning of a floor-cleaning mobile robot," *IFAC Proc. Vol.*, vol. 44, no. 1 PART 1, pp. 5950–5955, 2011.
- Y. H. C. and S. Y. O. T. K. Lee, S. H. Baek, "Smooth coverage path planning and control of mobile robots based on high resolution grid map representation," *Rob. Auton. Syst.*, vol. 59, pp. 801–812, 2011.
- Imen Hassani, Imen Maalej, and Chokri Rekik, "Robot Path Planning with Avoiding Obstacles in Known Environment Using Free Segments and Turning Points Algorithm," Mathematical Problems in Engineering, vol. 2018, Article ID 2163278, 13 pages, 2018. https://doi.org/10.1155/2018/2163278.
- M. Alajlan, A. Koubaa, I. Chaari, H. Bennaceur, and A. Ammar, "Global path planning for mobile robots in large-scale grid environments using genetic algorithms," in Individual and Collective Behaviors in Robotics (ICBR), 2013 International Conference on. IEEE, 2013, pp. 1–8.
- Z. Qiongbing and D. Lixin, "A new crossover mechanism for genetic algorithms with variable-length chromosomes for path optimization problems," Expert Systems With Applications, vol. 60, pp. 183–189, 2016.

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The Editorial Board had used the turnitin plagiarism [http://www.turnitin.com] tool to check the originality and further affixed the similarity index which is 10% in this case (See Annexure-I). Thus the reviewers and editors are of view to find it suitable to publish in this Volume-11, Issue-2, Apr-June, 2019

Annexure 1

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Reviewers Comments

Reviewer's comment 1:
It is a well-structured, clear and understandable paper. The introduction portion is really strong but the references lack synonymity.

Reviewer's comment 2:
The title of the paper clearly defines the content. It is very well written manuscript. The author has designed a new algorithm which reduces the power consumption in the robots. This is remarkable and praiseworthy.

Reviewer's comment 3:
The quality of research work produced in this work is very good. The paper contains many interesting facts. To select an optimum and efficient path, number of turns must be minimum which has been achieved perfectly by the newly developed algorithm. Also all possible best cases has also been analysed by the researcher and the explanation of the test cases is good.

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