Optimal Path Determination for Mobile Robots Using Motion Heuristics Search Techniques

Rehna. V. J [a,*], Kehkeshan Jalall [b,1] , Dr. T. C. Manjunath [c,1]

Abstract - **One of the most important problem in robotics is the task planning problem. A task is a job or an application or an operation that has to be done by the robot, whether it is a stationary robot or a mobile robot. The word planning means deciding on a course of action before acting. Before a robot does a particular task, how the task has to be done or performed in its workspace has to be planned. This is what is called as Robot Task Planning. A plan is a representation of a course of action for achieving the goal. How the problem has to be solved has to be planned properly. Robot task planning is also called a problem solving techniques and is one of the important topics of Artificial Intelligence. For example, when a problem is given to a human being to be solved; first, he or she thinks about how to solve the problem, then devises a strategy or a plan how to tackle the problem. Then only he or she starts solving the problem. Hence, robot task planning is also called as robot problem solving techniques. Many of the items in the task planning are currently under active research in the fields of Artificial Intelligence, Image Processing and Robotics. Lot of research is going on in the robot problem solving techniques. In this paper, an optimal path planning algorithm using motion heuristics search problem is designed for a robot in a workspace full of obstacles which are polyhedral and consisting of only triangular objects, the simulation is using C language.**

Index Terms – **Images, Obstacles, Heuristiscs, Shortest path, Freeways**.

I. INTRODUCTION

A typical robot problem solving consists of doing a household work ; say, opening a door and passing through various doors to a room to get a object. Here, it should take into consideration, the various types of obstacles that come in its way, also the front image of the scene has to be considered the most. Hence, robot vision plays an important role. In a typical formulation of a robot problem, we have a robot that is equipped with an array of various types of sensors and a set of primitive actions that it can perform in some easy way to understand the world [37].

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Rehna. V. J, Department of Electronics and Communication Engineering, HKBK College of Engineering, Bangalore, India, MobileNo.: 09632047320., (e-mail: rehna_vj@yahoo.co.in).

Kehkeshan Jalall S, Department of Electronics and Communication Engineering, HKBK College of Engineering, Bangalore, India, Mobile No.: 09480609900, (e-mail: kehkeshaneng@yahoo.co.in).

Dr. T. C. Manjunath, Principal, , Department of Electronics and Communication Engineering, HKBK College of Engineering, Bangalore, India, Mobile No.: 09449820361, (e-mail: tcmanjunath@gmail.com).

Robot actions change one state or configuration of one world into another. For example, there are several labeled blocks lying on a table and are scattered [40]. A robot arm along with a camera system is also there [38]. The task is to pick up these blocks and place them in order [39]. In a majority of the other problems, a mobile robot with a vision system can be used to perform various tasks in a robot environment containing other objects such as to move objects from one place to another; i.e., doing assembly operations avoiding all the collisions with the obstacles [1].

The paper is organized as follows. A brief introduction about the work was presented in the previous paragraphs. Section 2 gives the interpretation of the design of the obstacle collision free path. The mathematical interpretation is developed in the section 3 with its graphical design. Motion heuristics is dealt with in section 4. The section 5 shows the simulation results. The conclusions are presented in section 6 followed by the references.

II. INTERPRETATION OF THE DESIGN OF THE OBSTACLE COLLISION FREE PATH

One of the most important method of solving the gross motion planning problem is to go on searching all the available free paths in the work space of the robot [35]. The space in between the obstacles is referred to as the freeways along which the robot or the object can move. Translations are performed along the freeways and rotations are performed at the intersection / junctions of freeways [36]. This is an efficient method of obtaining an obstacle collision free path in the work space of the robot from source to the goal and is defined as the locus of all the points which are equidistant from two or more than two obstacle boundaries as shown in the Fig. 1 [37]. Once, the obstacle collision free paths are obtained from then source to the goal, then, the shortest path is found using graph theory techniques, search techniques and the motion heuristics [2].

A. Certain advantages and disadvantages of the method of gross motion planning.

- Recommended font sizes are shown in Table 1. It generates paths for the mobile part that stays well away from the obstacles ; since, the path is equidistant or midway between the obstacles and avoids collision with the obstacles [3].
- This method of planning the path using gross motion technique is, it is quite effective especially when the workspace of the robot is sparsely populated with obstacles [34].
- The path obtained is the shortest path [33].

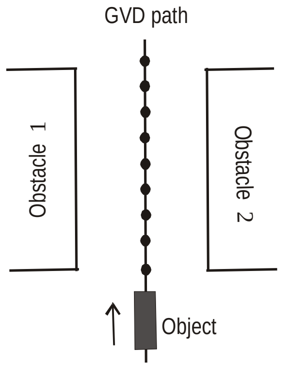

Figure 1. Obstacle collision free path

The method also works successfully when the workspace is cluttered with closely spaced obstacles, as a result of which the designed graph becomes more complex [4].

III. MATHEMATICAL DEVELOPMENT & GRAPHICAL DESIGN OF PATH

Here, we develop the mathematical interpretation of the obstacle collision free path. The robot work space consists of a number of obstacles. The parameters of any obstacles are the edges and the vertices [29]. So, while constructing the obstacle collision free path from the **S** to the **G**, many types of interactions occur [28]. Because, when we move from the source to the goal, we come across edges and vertices of many obstacles [5]. Here, we have considered only the interaction between a pair of edges of two obstacles as shown in the Fig. 2 [27], [1].

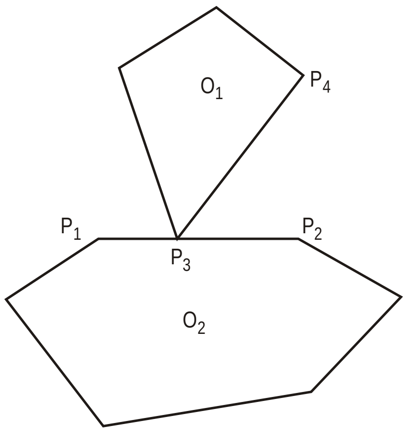

Figure 2. Interaction between a pair of edges of 2 obstacles O_1 & O_2

In this type of interaction between a pair of edges (interaction between an edge of one obstacle with an edge of another obstacle) as shown in the Fig. 2 [26]. How to construct the obstacle collision free path from S to the G when the obstacles are like this? Consider two edges P_1P_2 and P_3P_4 of two obstacles O_1 and O_2 as shown in the Fig. 2. Here, P_3P_4 is an edge interacting with P_1P_2 at the point P3 [6], [25], [1].

P_1P_2 ; P_3P_4 - Two edges of obstacles O_1 and O_2 meeting at the point P_3.

R - Radius of the GVD cone.

λ - Be the distance parameter measured along the edge P_1P_2 measured from P_1.

l_0 - Distance from P1 to P3 along P1P2. l_1 - Distance from P_1 to P_5 along P_1P_2.

l_2 - Length of P3P4.

d - Perpendicular distance from P_4 to P_1P_2.

The radius of the obstacle collision free path along P_1P_2 can be expressed by a piece-wise linear function of λ and is given by Eq. (1), where **sgn** denotes the signum function or the sign of the particular parameter l_2 and d, l_0, l_1 and l_2 are as shown in the Fig. 3 [7], [24], [1].

$$R(\lambda) = \frac{(\lambda - l_0)\,\{l_0 - l_1 + \mathbf{sgn}(\lambda - l_0)\, l_2\}}{d}. \qquad (1)$$

From this equation (1), we can come to a conclusion that [8]

- If $(\lambda - l_0) > 0$; i.e., the point P is lying to the right of P_3; then, l_2 is positive, sgn ( ) is +1.

If $(\lambda - l_0) < 0$; i.e., the point P is lying to the left of P_3; then, l_2 is negative, sgn ( ) is -1.

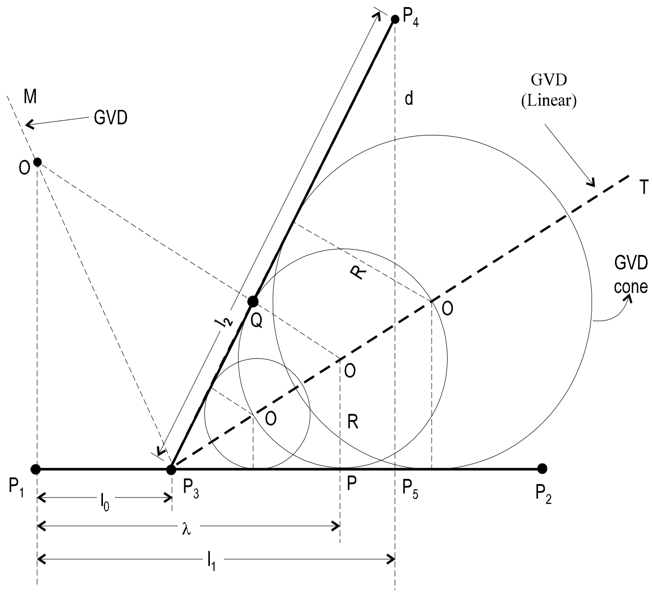

Figure 3. Interaction between a pair of edges

A. First Method of Obtaining the Obstacle Free Collision

Consider a point P any where on the line P_1P_2 and which is at a radial distance of λ from P_1. Draw a $\perp^r$ line (dotted) from P [9], [1]. Find the length of this line $\perp^r$ line (dotted) by using the Eq. (1) and mark the length (PO), where PO is the radius of the obstacle collision free path circle with O as the center. With O as center, draw a circle to pass through the points Q, P. Like this, go on taking different points (P's) on the line P_1P_2 and which is at a radial distance of different λ's from P_1. Go on drawing $\perp^r$ lines from P. Go on finding the length of these $\perp^r$ lines (radii) using the formula, with their centers, go on drawing circles to touch the two edges [1]. Go on joining all the centers of the obstacle collision free path circles. Thus, we get the obstacle collision free path from the source to the goal when the obstacles edges are straight lines [1].

B. Special Method for Obtaining Obstacle Free Collisions

Bisect the angles $P_4 P_3 P_2$ and $P_4 P_3 P_1$ to get different point (O's). With these points as centers, draw the circles with the radii as the perpendicular distances [11]. Join the centers of all the circles, we get the obstacle collision free path, which is nothing but the angle bisector P_3T [12]. Similarly, we get another angle bisector P_3M along which the robot or the object would move, the path being perpendicular to the previous path [10], [1].

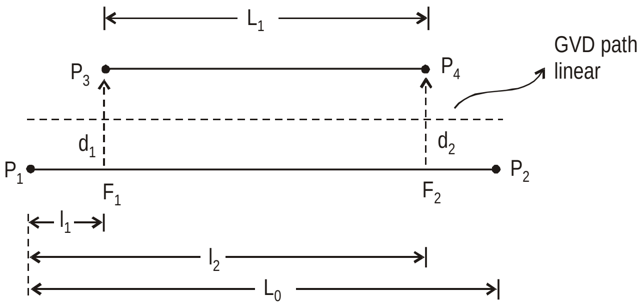

Figure 4. When two edges P_1P_2 and P_3P_4 are parallel

C. Special Case of Interaction Between the Ttwo Edges

When two edges P_1P_2 and P_3P_4 are parallel as shown in the Fig. 4, the obstacle collision free path is the mid-way path between the two edges of the obstacles [24]. Hence, to conclude, the interaction between a pair of edges is linear or a straight line [13]. If the robot or the object held by the tool / gripper moves along the obstacle collision free path, then definitely, there would be no collision of the object or the robot itself with the obstacles.

IV. MOTION HEURISTICS

Motion heuristics is the method of searching an obstacle collision free path in the free work space of the robot from the source to the destination by making use of search techniques such as the graph theory (AND / OR graphs), chain coding techniques and the state space search techniques (best first search, breadth first search) used in Artificial Intelligence [23]. The search techniques used in AI to find the path from the source S to the goal G are called as motion heuristics or the robot problem solving techniques [15]. The word 'heuristic' means to search, an obstacle collision free path [16], [1].

V. PROBLEM SIMULATION

We consider a workspace cluttered with obstacles, especially triangular obstacles. These triangular obstacles are placed either on the table or on the floor, which is simulated on the computer as a 2D rectangular workspace [22]. Using the mouse or using a rectangular coordinates, we specify the source coordinates (x_1 , y_1) [17]. Similarly, using the mouse or using rectangular coordinates, we specify the destination coordinates (x_2 , y_2) [18]. A computer algorithm is written using the user-friendly language C++ to find the shortest path using the formula given in Eq. (1). The results of the simulation are shown in the Figs. 5 and 6 respectively [19]. The motion heuristics used in Artificial Intelligence is used to find the shortest path from the source to the goal [21]. Using this motion heuristics, a number of paths are available from the source to the goal, but it selects a shortest path which is the path shown in yellow color in the Fig. 6 [20].

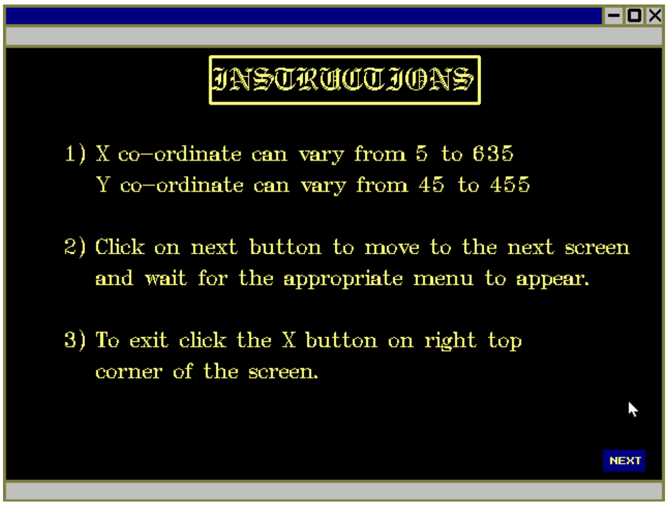

Figure 5. Instructions for entering rectangular coordinates

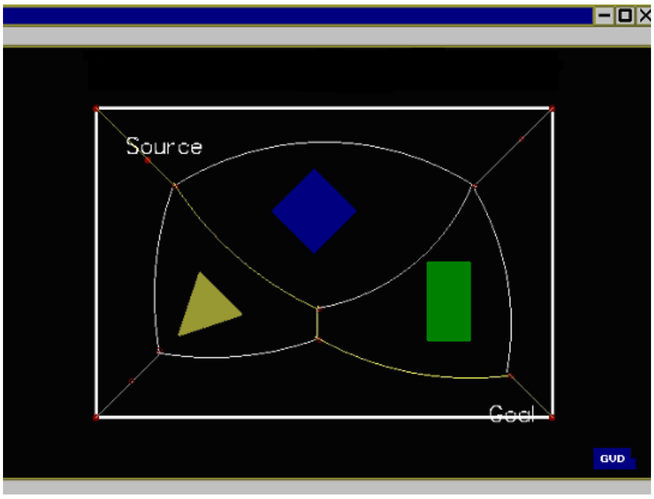

Figure 6. Graphs showing all the available free paths from S to G

VI. CONCLUSION

A new method of finding an obstacle collision free path from the source to the goal when the workspace is cluttered with obstacles is developed using motion heuristics using an user friendly GUI developed in C++. This method is similar to the method of finding / searching a path by the humans. The method was also implemented on a real time system, say a robot and was successful. Thus, the Artificial Intelligence which uses motion heuristics (search methods) is used to find the obstacle collision free path.

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BIOGRAPHY

Rehna. V. J was born in Trivandrum, Kerala State, India in 1980. She studied Electronics and Communication Engineering at the PET Engineering college, Vallioor, Tirunelveli District, Tamilnadu State, India fom 1999 to 2003. She received Bachelor's degree from Manonmanium Sundarnar University, Tirunelveli in 2003. She did post graduation in Microwave and TV Engineering at the College of Engineering, Trivandrum and received the Master's degree from Kerala University, Kerala, India in 2005. Presently, she is a research scholar at the Department of Electronics and Communication Enginering, Noorul Islam Center for Higher Education, Noorul Islam University, Kumarakoil, Tamilnadu, India; working in the area of image processing under the supervision of Dr. M. K. Jeya Kumar.

She is currently working as Assistant Professor at the Department of Electronics and Communication Engineering, H K B K College of Engineering, Bangalore, India. She has served as faculty in various reputed Engineering colleges in South India over the past seven years. She has presented and published a number of papers in national/international journals/conferences. She is a member of the International Association of Computer Science & Information Technology (IACSIT) since 2009. Her research interests include numerical computation, soft computing, enhancement, coding and their applications in image processing.

Kehkeshan Jalall S received her MTech degree in VLSI Design and Embedded Systems from Visweswarayya Technological University, Belgaum, India, in 2009. She is working as a senior faculty at the Department of Electronics & Communication Engineering, H K B K College of Engineering, Bangalore, India. Her research interests include VLSI design Embedded systems , image processing, robotics, and antennas. She has presented numbers of papers in national and international conferences.

Dr. T. C. Manjunath was born in Bangalore, Karnataka, India on Feb. 6, 1967 & received the B.E. Degree (Bachelor of Engg.) from R.V. College of Engg. (Bangalore University), M.Tech. degree with specialization in Automation, Control & Robotics from the Govt.'s L. D. College of Engg. (Gujarat University) and Ph.D. from the prestigious Indian Institute of Technology, Bombay (IIT Bombay) respectively. He has got a teaching experience of nearly 22 long years in various engineering colleges all over the country (Karnataka, Gujarat, Maharashtra) and is currently working as Principal in HKBK College of Engg. (HKBKCE), Bangalore, Karnataka, India. He has published more than 250 publications in the various National, International journals and Conferences and published 3 textbooks on Robotics. He has also published a research monograph cum patent in the International level from the Springer-Verlag publishers based on his Ph.D. thesis topic titled, "Modeling, Control and implementation of Smart Structures", Vol. 350, LNCIS, costing 79.95 Euros. He is a member of IEEE for the past 10 years, SPIE student member and IOP student member for 4 years, life member of ISSS (India), life member of the ISTE (India), life member of ISOI (India), life member of SSI (India) and life member of the CSI (India) and life member cum fellow of the IETE (India).