Available online at www.sciencedirect.com

ScienceDirect

IFAC-PapersOnLine 49-1 (2016) 178–182

Terrain Based D* Algorithm for Path Planning

C. Saranya[1], Manju Unnikrishnan[2], S. Akbar Ali[3], D. S. Sheela[4] and Dr. V.R. Lalithambika[5]

[1]Scientist/Engineer, SCG, ISRO Satellite Centre, India
[2]Deputy Division Head, CGFSD, Vikram Sarabhai Space Centre, India
[3]Division Head, CGFSD, Vikram Sarabhai Space Centre, India
[4]Group Director, Control and Guidance Design Group, Vikram Sarabhai Space Centre, India
[5]Deputy Director, Control Guidance and Simulation Entity, Vikram Sarabhai Space Centre, India

Abstract - Path planning algorithms provide autonomy in mobile robots to reach targets even in unknown environments. Path planning using grid based techniques such as A and D*, are cost function based, which is primarily a function of the distance to be travelled to reach the target. Robots targeted for outdoor environments should consider the terrain features also during path planning. In this paper, a modified approach of D* path planning algorithm is proposed. In addition to distance to be travelled, terrain slope estimate is also used in cost function computation to plan the path. The algorithm was simulated and tested with different terrain slopes. Results with different test scenarios are also brought out.*

Index Terms — Terrain based Path planning, D* algorithm

I. Introduction

Mobile robots are supplemented with Path Planning algorithms to enable them to reach target autonomously. Several techniques are available in literature for path planning. Steven M.LaValle(2006) gives an overview on various approaches to Path Planning. Grid based techniques such as A* and D* algorithms are classical methods of path planning. These algorithms reach the target in shortest path, provided path is available. Takayuki Goto et al (2003), briefs on the Heuristics of A* algorithm. GopiKrishnan et al (2011) gives a comparison of different path planning techniques. Y. Koren et al (1991) & Jorge Nieto et al (2010) deal with other approaches to Path Planning.

Grid based algorithms plan the path based on cost functions. Cost functions are based on distance to be travelled to reach the target point. For even-terrain environments distance to be travelled will be the deciding factor for path planning. However for outdoor environments especially un-even terrains, nature of terrain will also play a major role. The effort spent by the rover while climbing up or down an un-even region has to be accounted in addition to the linear distance to be travelled.

Also additional terrain features can be included to make the path planning more efficient. Genya Ishigami et al (2011) & Xie Yuan et al (2010) discuss on approaches to terrain based path planning. For instance nature of the terrain can also be used to determine the regions which are traversable by the rover. Rocky regions can be discarded as obstacles. Marshy and slippery terrains are also to be avoided to prevent wheel slippage.

Terrain Ruggedness index (TRI) gives the amount of elevation difference between the adjacent cells. Based on the range of TRI, the level of ruggedness can be determined. Based on the level of ruggedness, level or nearly level regions can be identified for path planning.

In this paper a modified version of D* algorithm is presented where cost function computation also involves terrain based factors. In addition to the distance to be travelled, a factor based on 3D slope of the terrain is included in the cost function computation.

The algorithm was simulated in C and tested for different terrain slopes. Following is the categorization of the Paper: Section II describes the modified D* algorithm for terrain based path planning. Section III describes the Simulation while Section IV discusses the results. And Section V gives the conclusion.

II. Modified D* Algorithm For Terrain Based Path Planning

D* algorithm is a grid based approach. Ref 8 & Ref 9 give the overview of D* algorithm and its applications. The area of exploration is split into n x n grid. Each cell in the grid has a state to denote the presence or absence of obstacles. The basic cost function of D* is based on distance to be travelled. As the region to be explored is split into squares, the cost involved in moving along and across the cell is the same. Moving to the diagonal cell requires additional cost. Let 'p' be the cost of moving horizontally or vertically in the cell. Then cost function is given in equation 1

$$\text{Cost}(x,y)_{hor|ver} = p * \text{units}$$

$$\text{Cost}(x,y)_{diag} = (\sqrt{2} * p) * \text{units} \qquad (1)$$

The above cost function is modified to include a factor based on the terrain slope. The slope of terrain and its azimuth is computed from 3D points.

Consider two points A(x1,y1,z1) and B(x2,y2,z2). The slope between the points A and B is computed as per equation 2. The azimuth (in degrees) or the orientation angle measured clockwise from North is given in equation 3

$$\text{Slope} = (z2-z1) / \sqrt{((x2-x1)^2 + (y2-y1)^2)} \qquad (2)$$

Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2016.03.049

$$\text{Azimuth} = (180 / \prod)\ \tan^{-1}((x2-x1)/(y2-y1)) \quad (3)$$

Cost function of D* algorithm is modified as per equation 4 to accommodate a term based on the terrain slope. The factor in the equation can be tuned based on different terrains.

$$\text{Cost\_Function} = \text{Cost}(x,y) + \text{abs}(\text{slope}) * \text{Fact} \quad (4)$$

Ascending a slope is given a higher factor compared to descending. For moving across a level terrain factor is made zero. The cost of moving vertically or horizontally in a cell of size 40 cms is taken as 10 units. The cost of moving diagonally is assumed to be 14 units. Factor for ascending is assumed to be 20 while for descending it is taken as 10.

If ascending

Fact = 20

Else if descending

Fact = 10

Else

Fact = 0

End If

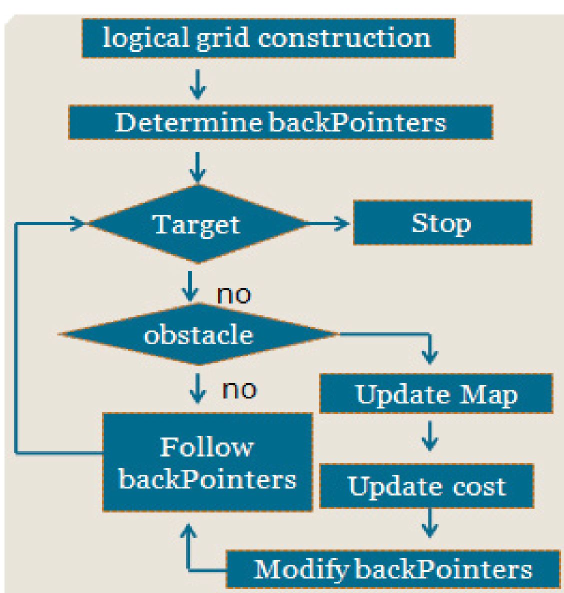

Figure 1: D* algorithm

Based on the above equations, cost functions are computed for all the cells. Rover moves through the cells which have the least cost functions. The flowchart of the algorithm is given in Figure 1.

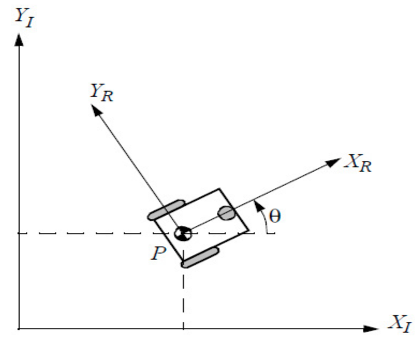

Figure 2: States of Rover

III. SIMULATION

Modified D* algorithm for Terrain based path planning was implemented in C.

An ideal rover was assumed. Cost functions computed based on the terrain information of the adjacent cells is used to identify the cell with the minimum cost function. Rover then moves to the chosen cell.

During experimentation each cell was assumed to be of 40 x 40 cms. The cell size could be decided based on the dimensions of the actual rover. It could be planned in such a way that rover will be confined within a cell at any point of time.

The location of the rover can be described with three states(x, y, θ) at any instant as in Figure 2. The orthogonal rotational matrix to map the rover's motion from global reference frame to its local reference frame is given in equation 5.

$$R(\theta) = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (5)$$

Since rover can move to only one of its adjacent eight cells, it has eight possible orientations as in Figure 3.

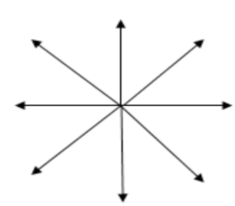

Figure 3: Eight possible orientations of rover as it moves to adjacent cell