ONLINE GEOMETRIC PATH PLANNING ALGORITHM OF AUTONOMOUS MOBILE ROBOT IN PARTIALLY-KNOWN ENVIRONMENT

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Abstract: The two- dimensional path planning with obstacle avoidance for autonomous mobile robot in indoor environment moving with constant speed is presented. The objective is to find the near optimal collision free path form partially known environment by giving a desired start and goal position and orientation with data from range sensor. When possible, the optimize path is first created offline from known information such as data from robot navigation or given map by using optimization search method. Following the optimal path, if the sensor attached to mobile robot receives the obstacles signal in range from1-5 meter in 180 degree around it in driving direction, we recalculate the new path using the piecewise Hermite spline to control orientation of the robot in each sub path and overcome the tangential discontinuity problem. From this algorithm, we get the satisfactory path with smooth curve along the entire route in order to take gradually rate of change of steering angle for future path control algorithm in considerations. This method also guarantee that the robot is able to safety moves towards the goal using its knowledge and sensor information or prove that the robot can not move anyway in case of not possible to reach it.

Keywords: Path Planning, Mobile Robot, Obstacle Avoidance, Piecewise Hermite Spline, Smooth Path Control.

1. Introduction

Robotics research areas are concerning designing, manufacturing, application, etc. One important research area is autonomous mobile robot that becomes nowadays more challenge. It is being developed that operate under a wide variety of condition, especially without human. Typical applications include robots performing delivery task in any area such as underwater, construction site or even in the office and buildings in both indoor and outdoor environment. Much research effort is now expended on the development of autonomous robot that robot can investigate an unexplored place with sensor data reading such as odometry, sonar, laser scanner and camera. It can also possess a model of its environment and be able to determine its position in such environment. Additionally the path planning aims at providing an optimal path from an initial to goal position, preventing collision or so called obstacle avoidance and tracking of moving object.

Path planning and navigation are the process of getting a feasible and safe trajectory from the start or so call current position of robot to the goal. In most problem, it is firstly planned offline for the robot which lead the robot to its destination assuming that the environment is perfectly know and stationary. In this research, it aims at solving the mobile robot problem running in indoor environment. The solution to this problem gives the optimal path that the robot can move. The next problem, the locations of the obstacles are not known in advance but know by the sensor when these are within a sensor range. The robot changes its path when it senses the danger areas. It is referred to as the dynamic path planning.

Two-dimensional data provided by a radial laser range scanner is concerned with two-dimensional information. That means, from that data, we have got the information approximating the shape of the environment, and the update process will involve a correspondence problem between segments from the current map and segment from the local map obtained at each position. Precise position estimation is required in order to refer both representations to a cartesian coordinate system with parametric equation.

Figure 1 compares the path planning process with the human perception and determination. If one will go in any unknown area, he needs his eye to see all environments and make the decision where he can go with out colliding anything between the path. How good is he planning, due to his experience and thinking method. There can be many possibilities for one problem and if we not know, what will be happen next in the future, we can not find the exactly optimal path. Like human, robot has to have one of difference kind of sensor and then the algorithm program as the robot brain in order to make a decision, where it goes.

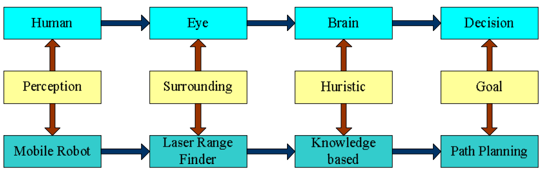


Figure 1: Comparison of function between human and mobile robot equipped with sensor [1]

2. Path Planning

In this framework, we take the 2D path planning in to account to get the safety and smooth trajectory. Figure 2 shows the process of the procedure. Firstly the robot is planned to go follow the path that calculate from the surrounding that we know from e.g. the localization process.

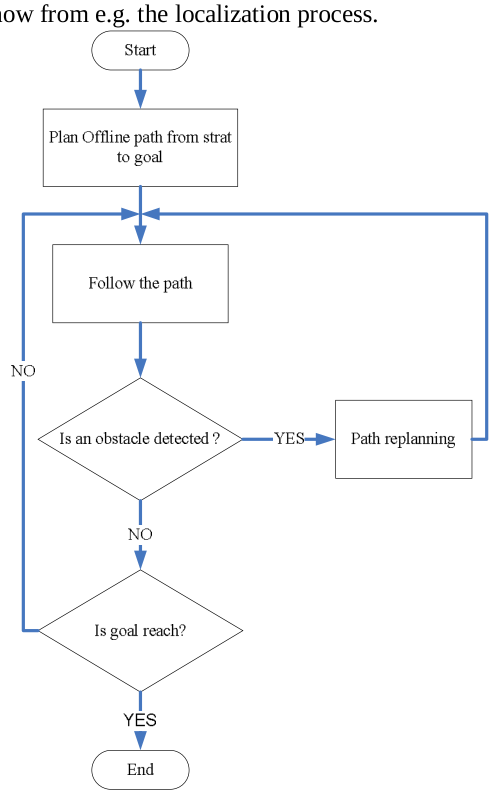


Figure 2: Diagram of path planning method

This process we deal with the know point and search the path like optimization search, spline interpolation with the shortest arc length. Afterthat we let the robot run in this route following the calculating one until it get the new information about obstacle by the sensor equipped with it. Next the new trajectory must be replanning by the information about the robot position and orientation at this point and the next decision point. We calculate the new path by the spline that is match this criteria with at least tangential continuity to the last path that it can walk smoothly by concerning the streeing angle and the number of change of curvature.

3. Spline curves

The problem of generating a smooth curve through an ordered set of two-dimensional points is one that often arises in computer graphics. The curves generated can represent handwriting, sketching, contour lines or other graphical objects. The requirements for a suitable curve generator include simplicity of specification, smoothness, ease of calculation and locality. Simplicity of specification is achieved by requiring that the curve must interpolate (pass through) the given data points. This requirement allows the method to be used to reconstruct time or space sub-sampled curves such as handwriting. The smoothness criterion requires that the generated curves be visually pleasing when displayed on the output device. The locality requirement means that only a few neighbouring points are needed to calculate a curve segment. Ease of calculation requires that the algorithm be simple and fast enough to be implemented on a microprocessor. Spline curves is the mathematic representation that allow the user draw and control the shape of complex curve by using the control points but instead of interpolating curves, spline do not pass exactly to control points.

To match our criteria about control point in both position and orientation, we consider the easiest type of spline. The cubic Hermite spline, name after Charles Hermite is introduced as piecewise third degree spline. Each polynomial consists of two control points and two control tangents. Using the explicit relation between x and y in Rectangular coordinate is sometimes has some pitfall e.g if the path is plan linearly parallel or nearly to y direction, that give us large amount of sensitivity, ill condition and divide by zero problem. For this reason parametric curve with parameter t lies between 0 and 1 is taken into account

Given an sub interval from start to goal [S, G] and a function $f:[S,G]\to\Re$, find the cubic polynomial, the piecewise hermite spline in the interval $[a,b]$ can be written in $f_i : [a,b] \rightarrow \Re$ with derivative $f_i' : [a,b] \rightarrow \Re$ where $[a,b]$ is the end point of each interval.

From the set of partition points $x = (x_0, x_1, \ldots, x_n)$ and $y = (y_0, y_1, \ldots, y_n)$ we can find a set of cubic polynomial by introducing the parametric t. where $0 \le t \le 1$ as shown in figure 3. It is shown how each end of the segment can join together with the smoothness. By nature of hermite interpolation we can gain only the tangential continuity but if we need to maintain the constant speed, the curvature continuity is required. If we see in figure 3, the tangent is the same direction but different magnitude. To overcome this problem we use w_1, w_2 to weight the slope vector to be equal. As shown in figure 4, if the slope magnitude is changed, the various results of the path is received.

$$f_i(t_i) = a_{i1} + a_{i2}t_i + a_{i3}t_i^2 + a_{i4}t_i^3 \tag{1}$$

For C^1 continuity we differentiate with respect to x using the chain rule

$$Df_i = \begin{bmatrix} \Delta x \dfrac{dt_i}{dx} \\ \Delta y \dfrac{dt_i}{dy} \end{bmatrix} \tag{2}$$

$$Df_{i+1} = \begin{bmatrix} \Delta x \dfrac{dt_{i+1}}{dx} \\ \Delta y \dfrac{dt_{i+1}}{dy} \end{bmatrix} \tag{3}$$

We force f_i and f_{i+1} to match the slopes

$$w_1 D_x f_i(1) = w_2 D_x f_{i+1}(0) \tag{4}$$

$$p(t) = \begin{bmatrix} t^3 & t^2 & t & 1 \end{bmatrix} \begin{bmatrix} 1 & -2 & 1 & 1 \\ 3 & 3 & -2 & 1 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \begin{Bmatrix} p_S \\ p_G \\ w_1 v_S \\ w_1 v_G \end{Bmatrix} \tag{5}$$

Where p_S, p_G, v_S, v_G are the position at start and goal and the tangential vector at start and goal repectively w_1, w_2 are weighting function

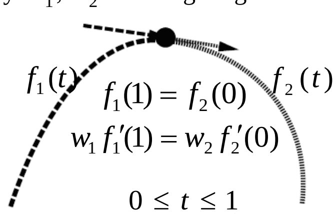


Figure 3: Piecewise cubic hermit spline of segment i and $i+1$

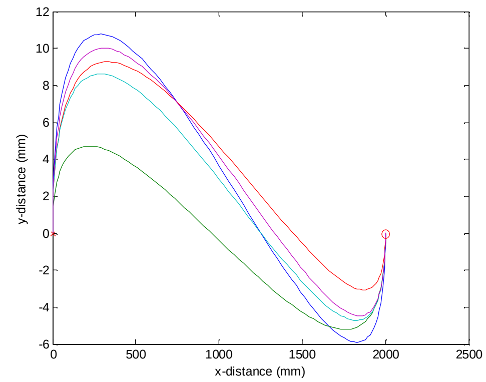


Figure 4: Hermite spline with difference weighting function in segment i

4. Path Criteria

The first criteria is the shortest arc length at the instant but we can not tell about that is the minimize length because we do not know what will be found in the next. The arc s at each section can defined with the parameter t as

$$s = \int_a^b \sqrt{\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2}\, dt \tag{6}$$

Steering angle is use as constratint of optimal the calculate path because we need that robot can run as smooth as possible. With this topic, the lateral dynamic of vehicle is model because we are interested in the cornering action or the curvature path that we will proposed later in motion planning

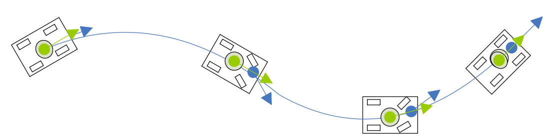


Figure. 5: Path planning using spline concerning steering angle Green-velocity vector, blue-steering direction

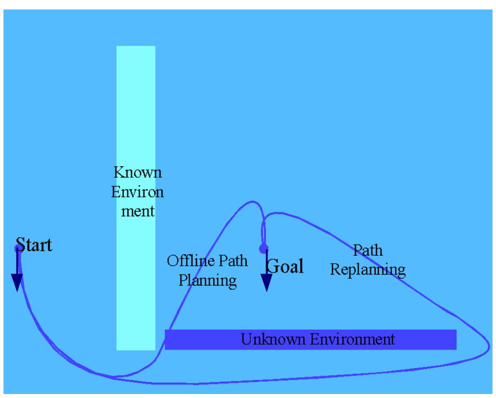
5. Simulation Results

As mention above in this example scene 2mx2m with the known obstacle size 1.5mx0.3m and the unknow ofstacle that the sensor can detect later with the size 1.5mx0.15m in plane. Fist with only the known object we calculate the offline path as shown in figure 6-a,-b,-c in the difference enviroment. In

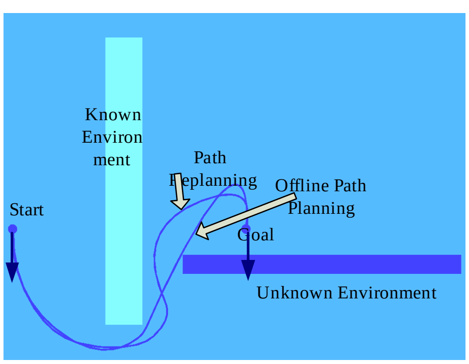
6-a the we calculate the offline path with 4 control points at start and goal with orientation and two between at the bottom of the known object by using B-spline interpolation [2], [3]. We get the are length as 3.4274 m. Next following the path untill the unkown object is sensed then we calculate the new control points. In this situation have 4 controls point in between and the completer arc length is 5.24375 m.

In figure 6-b, the known object lies on the same way as in figure 6-a. but the unknow object stay further, so that there is the gap from two object. This problem, the robot might go the same way of the pre planning trajectory but with difference algoritim and one more control point give the path small various compare to figure 6-a. The total are length is 3.62575 m.

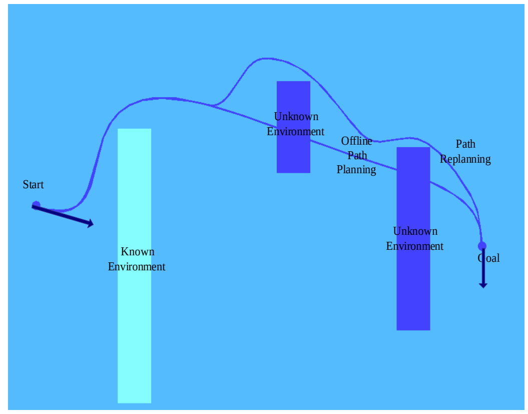
The last example situation shown in figure 6-c is more complicate with the same fashion offline path calcution with arc length 4.56524 m. The robot will see the second object between and make a decision how to go from the point that the robot determine the obstacle to goal and walk follow it. Unfortunately the robot saw the next unknow object and calculate the next time with the attemp that it go as smooth as possible with the arc lenngth 6.42532 m.



(a)



(b)



(c)

Fig.6 Example of path planning and replanning in different environment

6. Conclusion

In this work we present the path planning algorithm by using cubic hermite spline interpolation in two dimensional partially unknown environment. The algorithm guarantee that the path can reach the goal or otherwise if it is not possible, the robot has to stop and return the message. First we let the robot go the the offline pre planning trajectory and if the sensor sense the obstacle, it must be replanning with the criteria of shortest arc length at the instant and smooth path. The latter have further effect on motion planning with considering the steering angle

7. Bibliography

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