Development of Potential Function Based Path Planning Algorithm for Mobile Robot

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Abstract: A potential field method for solving the problem of path planning based on global and local information for a mobile robot moving among a set of stationary obstacles is described. The concept of various method used path planning is used design a planning strategy. A real human living area is constructed by many moving and imminence obstacles. Home service mobile robot must avoid many obstacles instantly. A path that safe and attraction towards the goal is chosen. The potential function depends on distance from the goal and heuristic function relies on surrounding environments. Three additional combined methods are proposed to apply to human living area, calibration robots position by measured surrounding environment and adapted home service robots. In this work, we proposed the application of various path planning theory to real area, human living. First, we consider potential field method. Potential field method is attractive method, but that method has great problem called local minimum. So we proposed intermediate point in real area. Intermediate point was set in doorframe and between walls there is connect other room or other area. Intermediate point is very efficiency in computing path. That point is able to smaller area, area divided by intermediate point line. The important idea is intermediate point is permanent point until destruction house or apartment house. Second step is move robot with sensing on front of mobile robot. With sensing, mobile robot recognize obstacle and judge moving obstacle. If mobile robot is reach the intermediate point, robot sensing the surround of point. Mobile robot has data about intermediate point, so mobile robot is able to calibration robots position and direction. Third, we gave uncertainty to robot and obstacles. Because, mobile robot was motion and sensing ability is not enough to control. Robot and obstacle have uncertainty. So, mobile robot planed safe path planning to collision free. Finally, escape local minimum, that has possibility occur robot do not work. Local minimum problem solved by virtual obstacle method. Next is some supposition in real living area

Keywords: potential field, path planning, heuristic method, intermediate point, and mobile robot

1. INTRODUCTION

Path planning is required for any mobile robot, to accomplish a selected mission, and may be realized either through a fully autonomous process or a partially interactive one. While navigating towards the target, a reactive mobile robot plans autonomously its global path in preprocessing map about global region, and local path in real time based on the immediate surrounding information sensed.

The potential field method provides simple and effective motion planners for practical purpose [1]. However, there is a major problem in the local path planning using the potential field approaches, which is local minimum can trap a robot before reaching its goal. The heuristic method provides effective path in local path planning [2]. However, path was planed by heuristic method, which is made wrong path to target.

The algorithm discussed in this work is a potential method based on global information and heuristic method based on local information. We introduce a concept of contain many methods for real human living area. Consider the problem of many rooms in the home. An mobile robot selects many path to the goal. However, it has any data about wall, furniture, pat, human and etc. May be mobile robot is collision by pat or any things. So a mobile robot moves with global and local path planning in each case. Our propose is safe path planning for moving and imminence obstacle.

The Section 2 briefly describes work in the area of path planning. Section 3 introduces the basic methods. Global path planning and obstacle avoidance are described in Section 4. Some experimental results are given in Section 5.

2. PAPER SIZE AND FORMAT

In the past, several authors [5], [6], [8] have worked on the path planning problem in a virtual environment. In [5], Subbarao Kambhampati and Larry S. Davis proposed an approach based on the idea of quad-tree method. All above references used global methods, which can generally be viewed as a search process for a path in a graph. Several fundamental questions related to the complexity of various formulations of the path planning problem in a static and known answered in [4], [7], [9]. But in reality, information about the environment is generally not completely known, with the exception of some simple obstacle and small area.

In [7], Ashraf Elnagar and Anup Basu proposed an approach based on the idea of using safe path by heuristic method and control of speed and acceleration of robot. Consequently, he and other researchers have studied the problem of find shortly and efficiency path in unknown environment.

R. H. T. Chan, P. K. S. Tam and D.N.K. Leung studied the problem of reaching a given goal position in an unknown static environment [9]. They propose heuristic and quad-tree methods to solve this problem.

Potential field method has problem that is local minimum problem. W.L. Xu, S.K. Tso and Z.K. Lu [10] are studied virtual obstacle method. Virtual obstacle method is useful to solve local minimum problem.

3. Introduction of Basic Methods

In this section, we introduce two basic methods that used in this work. One is the potential field method that is used to planning global path. That is useful method for planning global path. The other is the heuristic method that is used to planning local path. That is used to avoid imminence and moving obstacle.

3.1 Potential fieild method

To introduce the problem formally some basic definitions are needed. Potential field method is give high potential to obstacle and low potential to goal position. This Theory is based on Force Inducing an Artificial Repulsion from the Surface (FIRAS, from the French). The first artificial potential field function used (Khatib and Le Maitre 1978) was based on the values of the function $f(x)$. Using the shortest distance to an obstacle O, we have proposed (Khatib 1980) the following artificial potential field;

$$U_0(x) = \begin{cases} \frac{1}{2}\eta\left(\frac{1}{\rho} - \frac{1}{\rho_0}\right)^2 & if \quad \rho \le \rho_0 \\ 0 & if \quad \rho \succ \rho_0 \end{cases}$$

where ρ_0 represents the limit distance of the potential field influence and ρ the shortest distance to the obstacle O.

Any point of the robot can be subjected to the artificial potential field. The control of Point Subjected to the Potential (PSP) with respect to an obstacle O is achieved using the FIRAS function,

$$F^*_{(O,psp)} = \begin{cases} \eta\left(\frac{1}{\rho} - \frac{1}{\rho_0}\right)\frac{1}{\rho^2}\frac{\partial \rho}{\partial x} & if \quad \rho \le \rho_0 \\ 0 & if \quad \rho \succ \rho_0 \end{cases}$$

Where $\partial\rho/\partial x$ denotes the partial derivative vector of the distance from the PSP to the obstacle,

$$\frac{\partial \rho}{\partial x} = \left[\frac{\partial \rho}{\partial x}\frac{\partial \rho}{\partial y}\frac{\partial \rho}{\partial z}\right]^T$$

3.2 heuristic method

The local path, computed as described in the algorithm, defines a solution unless the mobile robot gets stuck in front of an obstacle

For instance, of there is an obstacle that blocks the local search window of the mobile robot to go around the obstruction. This can be achieved by selecting a new position and a new orientation for the mobile robot. The new position should be at minimum distance from the current position of the mobile robot, and have a maximum possible angle (Φ) from its current orientation so that the mobile robot avoid the obstruction as much as possible. It is clear that we have two sets of positions satisfying the above requirement. One set is to the left of the mobile robot and the other is to its right. The choice between these sets is determined randomly at a detect end point, and the chosen direction is followed until the current obstacle is avoided. If the mobile robot encounters another detect end point with a different obstacle, it will apply the heuristic again. Randomization is much better than choosing a specific direction (left or right) along the path. It guarantees that the mobile robot does not keep on moving in a loop. After selecting a set of points, the mobile robot starts testing for the point that has the maximum possible orientation angle from its current orientation (Φ). If the point is reachable then the mobile robot will move to it and start planning again from that point, otherwise it will look for the point with the next maximum orientation, and repeat the process until it finds a suitable position.

One advantage of the above heuristic is that it increase the capability of the mobile robot to avoid to detect end situations. Another benefit is that it prunes the search space. However, it does not take into account partial obstructions, the removal of which constitutes a key factor in improving the efficiency of the algorithm (see Fig. 1(b)-(d)).

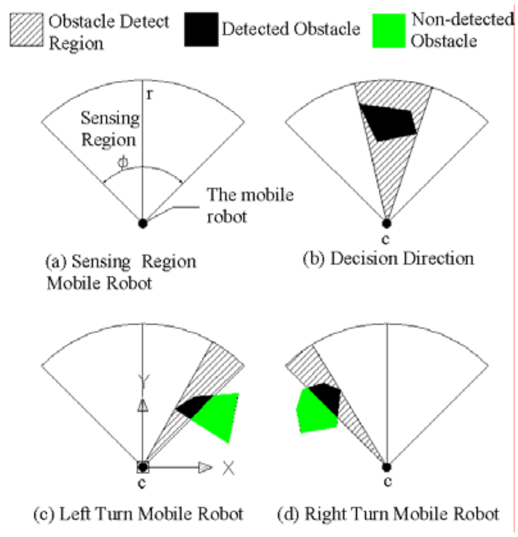


Fig. 1. Heuristic method

3.3 Sub-goal method

When the robot detects multiple obstacles, it needs to avoid the obstacles passing the space between them. We propose a path planning algorithm using the distance profile histogram in order to make the best arrangement. A typical shape of the distance profile histogram is displayed in the polar coordinate system attached to the robot's local frame. Between obstacles, there are occupied regions and empty region is too narrow for the robot to pass through, it is discarded. Next, select the target region among the empty regions. The target region is a set of empty sectors and the global goal direction must be close to the region than other empty regions. Now, find the right-most angle and the left-most angle in order to exploit the geometrical feature. These angle are measured in the local polar coordinate system. Actually the angles can be obtained from the sector numbers. And then the middle point of the space between two occupied regions is computed using the distance profile histogram values as below. This middle point is just a temporary goal point.

4. Research and Simulation

Potential field method is imperfection method. As the place where construct by many rooms, kitchen, restroom and etc. Mobile robot is must avoid many obstacle as furniture, human, some of imminence obstacle and unexpected moving obstacle as pat. So we present of intermediate point that is able to calibration mobile robot's position and recognition obstacle error.

Intermediation point is seemed sub goal. But that point is important to mobile robot in unknown environment. Intermediation point was positioned in doorframe and between walls as between two adjoined room. The point has great advantage that is remove local minimum and calibration position and recognition error.

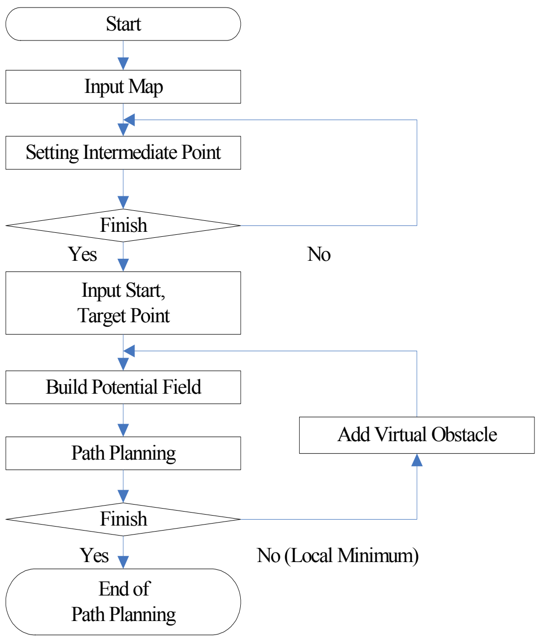


Fig. 2. Global path planning

4.1 Global Path Planning

Global path planning is constructed by potential field method. Potential field method has local minimum problem. To solve problem so we use virtual obstacle method. Potential field method algorithm needs some data as map, start and target point. If occur local minimum problem during path planning virtual obstacle algorithm use to solve that. And we need intermediation point to remove local minimum problem (see Fig. 2.). Obstacles, wall and starting point has high potential. Target point has very row potential. Initial potential field construct start and target point, wall and permanent obstacles. In real area, obstacles create many imminence obstacles and moving obstacles. So final potential field is constructed by all obstacles, start and target point. In fig. 6 map is construct wall, start point, target point and imminence obstacle. In fig. 7 is final value of potential field that contain all imminence obstacles.

4.2 Local Path Planning

Local path is changed by heuristic method. The mobile robot is detecting the obstacle and decide own direction. Local path planning is made during moving. We need mobile robot's move algorithm with heuristic method (see Fig. 3.). Mobile robot is detecting obstacle, new path planning and calibration position and recognition error (see Fig. 4.). We require robot has uncertainty but uncertainty occur collision to obstacle, wall, and imminence obstacle. So we suggest intermediate point. Intermediate point are gave very efficiency result. In mobile robot moving, mobile robot is always memory about all region, but intermediate point is mobile robot memory and calculate small area as room, kitchen and living room. This step robot is always moving so mobile robot need fast and efficiency calculation and sensing technology.

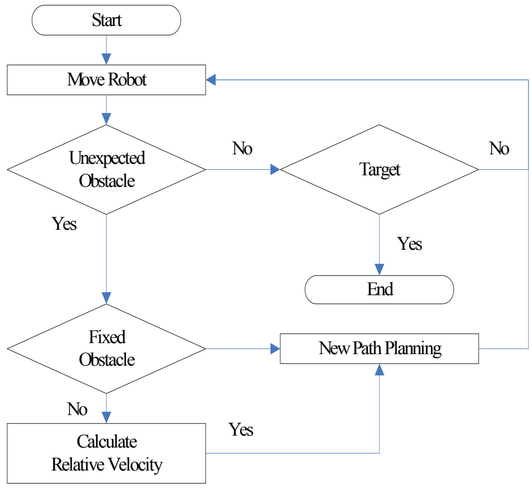
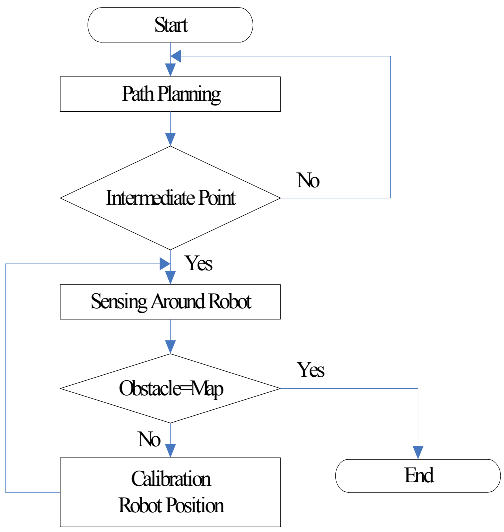


Fig. 3. Local path planning

Fig. 4. Calibration error with intermediate point



4.3 Simulator

Global and local path planning is tested by simulator. Simulator is constructed by visual program with start, target point, wall, fix obstacle, imminence obstacle (see Fig. 5.). Simulator control all items to desire design in any area.

Simulator starts setting region area that is square rectangular but in real living area is not square, so we give wall for not square rectangle. Next setting of start and target point, setting points are appear in screen with brown and green colors.

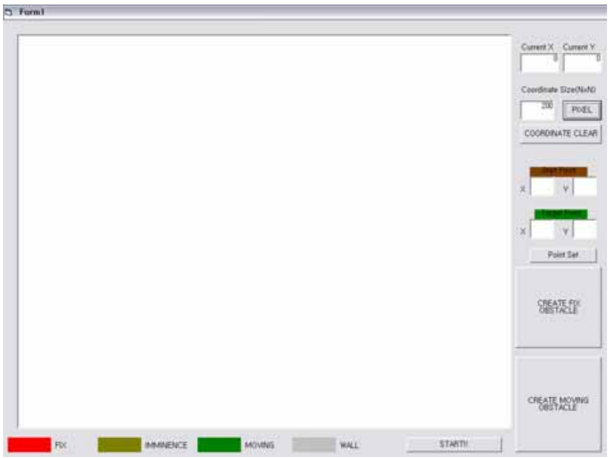


Fig. 5. Simulator

5. Simulation Result

We test path planning in area there exist wall and imminence obstacle. The size of area is composed to 200 X 200 cells. Let start point is (25,60), target point is (170,170). Some imminence obstacles are exists in the area. Fig. 6 show the robot paths simulated in complex environments. Considering the environment, the robot, moves directly towards the target along a straight line, then turns to the left and right towards the target. And figure shows that local minimum problem is not existed that is important evidence. Fig. 7 show the robot potential simulated in environment. We confirm the intermediate point in door and high potential in obstacle position. Do not consider about potential in rooms there is not contain start and target point.

Fig. 6. Test environment

Path planed surrounding of obstacle. Fig. 8 show the test environment there is three fix obstacles. Simulator planed path and move robot. We obtain distance data that is between robot and obstacle. And we give uncertainty in obstacles and robot. Figs. 9 and 10 shows the distance graph about give uncertainty in obstacles. Each obstacle has uncertainty about 7~9cells. Robot a trend of maintains about 7 cells distance to obstacle. Maintains distance is very safe in mobile robot. But safety path is not efficiency path but collision is harmful in mobile robot.

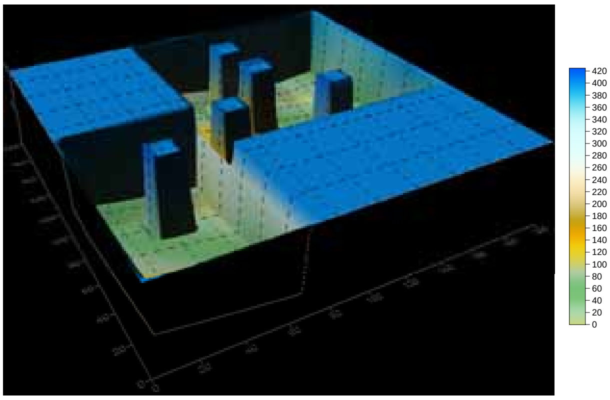


Fig. 7. Potential value in 3-D

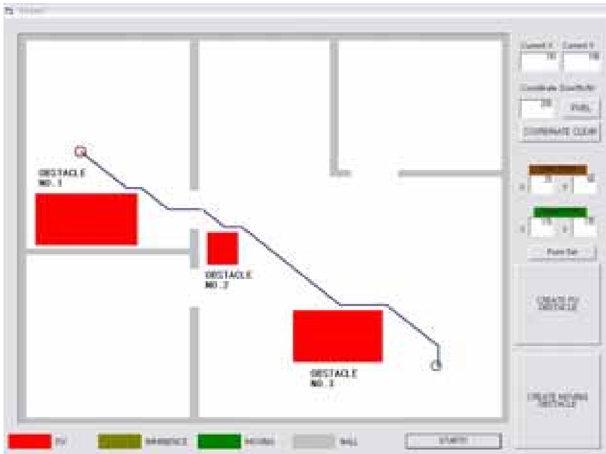


Fig. 8. Environment of uncertainty simulation

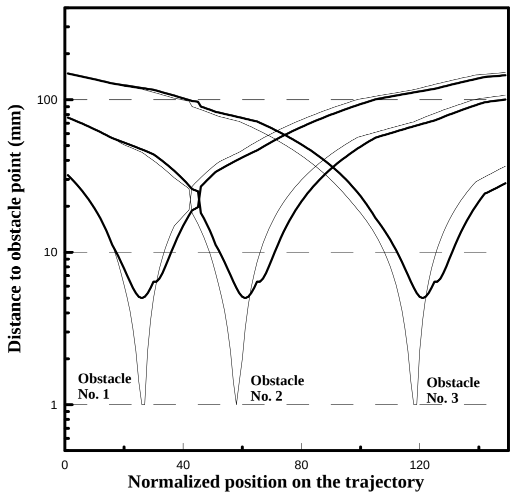


Fig. 9. Simulation result (obstacle's uncertainty)

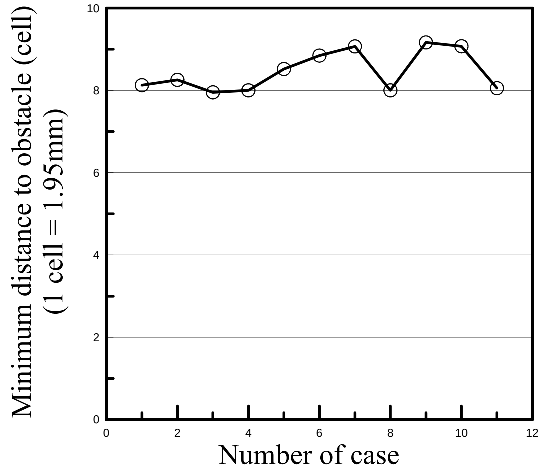


Fig. 10. Minimum distance (obstacle's uncertainty)

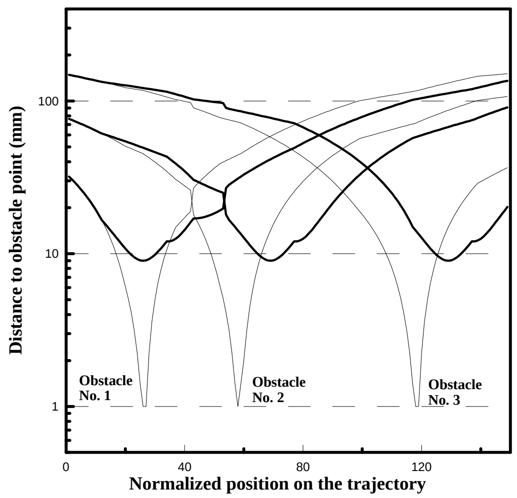


Fig. 11. Simulation result (robot's uncertainty)

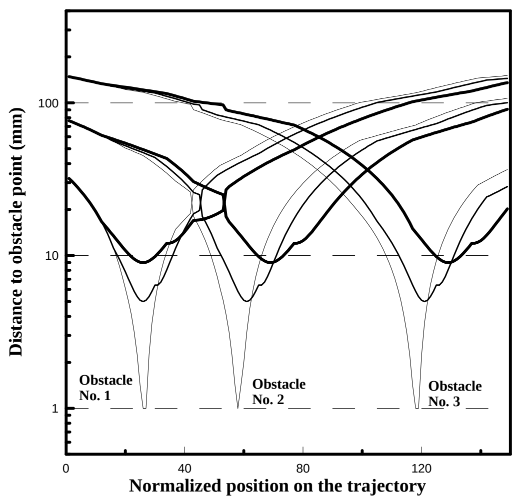


Fig. 12. Simulation result (robot's and obstacle's uncertainty)

Fig. 13. Environment occur local minimum

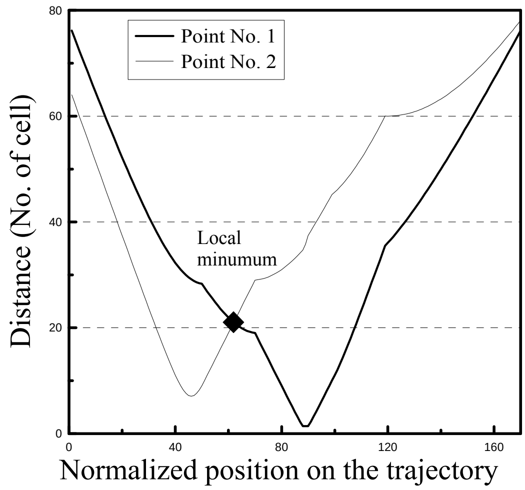


Fig. 14. Local minimum distance of basis points

Fig. 11 show the distance graph about give uncertainty in robot. Robot has about 3~4cell uncertainty. Robot uncertainty is more safety path planning. Mobile robot's size is various. So in this work, mobile robot's size is 1 cell. If change mobile robot's size, this simulate is easy apply. Figs. 12 show the total distance graph about robot and obstacles has uncertainty. We obtain final result in mobile robot that has obstacles and robot uncertainty. If mobile robot detected obstacles to smaller than origin size, our theory is cover about 25~40mm. If someone required path changed uncertainty value to more, our simulator is relate robot's own size.

Fig. 13 show solve local minimum problem. In the path that is connected one room to other room don't consider about local minimum problem. But in the path that is link one to the other point in same room we must consider local minimum problem. Obstacles which have to be avoided are surrounded by an attractive potential field. The attractive potential is generally a below shaped energy well which drives a robot to its center if the environment is unobstructed. In an obstructed environment, a repulsive potential energy hells to repel the robot are added to the obstacles. The robot experiences the force which equals the negative gradient of the potential. This force drives the robot downhill until the robot reaches the position with the minimum energy. So, mobile robot will stop in local minimum point. Local minimum problem solved by virtual obstacle algorithm (see Fig. 2.).

Fig. 14 show the distance of basis point 1 and 2. Two lines intersection point is local minimum point.

6. Conclusions

In this work, we proposed the application of various path planning theory to real area, human living. First, we consider potential field method. Potential field method is attractive method, but that method has great problem called local minimum. So we proposed intermediate point in real area. Intermediate point was set in doorframe and between walls there is connect other room. Intermediate point is very efficiency in computing path. That point is able to smaller area, area divided by intermediate point line. The important idea is intermediate point is permanent point until destruction house or apartment house. Second step is move robot with sensing on front of mobile robot. With sensing, mobile robot recognize obstacle and judge moving obstacle. If mobile robot is reach the intermediate point, robot sensing the surround of point. Mobile robot has data about intermediate point, so mobile robot is able to calibration robot's position and direction. Third, we gave uncertainty to robot and obstacles. Because, mobile robot was motion and sensing ability is not enough to control. Robot has 10~20mm uncertainty and obstacle has 15~20mm uncertainty. So, mobile robot planed safe path planning to collision free. Finally, escape local minimum, that has possibility occur robot do not work. Local minimum problem solved by virtual obstacle method. Next is some supposition in real living area

A method for planning a path for a mobile robot moving among object of similar real space that is human live.

In the problem that is someone call mobile robot and then mobile robot move start but sometimes moving mobile robot meets some pat or baby. Some methods are not applied about this problem but in our method is able to solve problem as follows.

a. Build up potential field
(Creat intermediation point on the global map)

b. Select shortly path
(Find lower potential value)

c. Determined intermediation point by sensing
(Calibration position and recognition error)

d. New path planning by heuristic method
(Avoid move and imminence obstacle)

e. More safety path planning
(Include uncertainty of obstacle and robot's distance, minimum distance to robot and obstacle is about 25~45mm)

f. Safety escapable local minimum
(By virtual obstacle maintain about 30~50mm)

The performance of this method was tested by some areas that similar human living house and apartment house. We confirmed that this method is able to apply to area there human living.

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