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# A Predictive Collision-Free Fuzzy Algorithm for Mobile Robots to Avoid Obstacles Moving at Variable Speeds

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**Abstract**: In this paper, a new algorithm for mobile robot navigation is presented. Some previous works have been proposed to solve this problem which only assumes the obstacles moving at constant speeds. However, differently from the unrealistic assumption, the obstacles can move at variable speed in the real world. The goal of the proposed algorithm is assisting mobile robots smoothly avoid moving obstacles which continuously change their speed by predicting collision. The mechanism is based on fuzzy logic system of two inputs which are the angle of obstacle relative to the direction of robot and the distance between obstacle and robot. The output will be adjustment angle of the heading of robot to avoid possible collisions with obstacles.

**Keywords:** Robot navigation, moving obstacle, fuzzy logic.

## 1. INTRODUCTION

There is a growing interest in service robots due to the fact that robots should find their way out of sealed working stations in factories to our homes and to populated places such as museum halls, office buildings, railway stations, department stores and hospitals. The gained benefit comes along with the necessity to design the robot in a way that it is able to operate in a list of complex situations.

This includes at least the ability to navigate autonomously, avoiding mobile or static obstacles especially in crowded and unpredictably changing environment. A successful way of structuring the navigation task in order to deal with the problem is within behavior based navigation. Behavior based navigation systems have been developed as an alternative to the more traditional strategy of constructing representation of the world and then reasoning prior to acting. The basic idea in behavior based navigation is to subdivide the navigation task into small easy to manage, program and debug behaviors (simpler well defined actions) that focus on execution of specific subtasks.

Considering the moving obstacle in obstacle avoidance is always important in robot navigation. From studying previous works [1], [2] and many experiments, it can be realized that if speed of mobile robot and moving obstacles are two fast, it might lead to the result of collisions.

This paper presents a new algorithm for obstacle avoidance mechanism based on Fuzzy Approach [3] in case of considering the change in speed of mobile robots and moving obstacles. By defining 2 inputs which are the angle of obstacle relative to the direction of robot and the distance between obstacle and robot, then input information is fuzzfied into fuzzy set memberships. The output will be adjustment angle of the heading of robot to avoid possible collisions with obstacles. Input distances can be classified as members (or partial members) of the fuzzy sets {‘near’, ‘far’, or ‘very far’}, and input angles as {‘small’, ‘medium’, or ‘large’}. The Fuzzy sets of output are {‘Very Sharp’, ‘Sharp Turn’, ‘Med Turn’, ‘Mild Turn’, ‘Zero Turn’}. The defuzzified values are then given to a separate module that will interpolate the speed and rotation component into actuator or rotor control instructions, specific to the type of vehicle being controlled.

In order to improve the existing system based on fuzzy logic, a modified method of obstacle avoidance for mobile robots is proposed. By implementation the predictive collision-free fuzzy algorithm with change in the speed of robots and the speed of moving obstacles, it proves that number of crashes between obstacles and mobile robots are smaller than the existing method [1].

## 2. PREDICTIVE COLLISION-FREE FUZZY ALGORITHM FOR MOBILE ROBOT NAVIGATION.

The mechanism of obstacle avoidance used in the Hybrid Fuzzy A* method (HFA) [1] does not satisfy with the situation of considering various environments, such as the change in the speed of moving obstacles or mobile robots. Robots should adapt to the dynamic environments. Hence, the above disadvantage is a problem that can be deeply researched in order to reduce the number of collisions between mobile robots and obstacles.

A new algorithm which is named as predictive collision-free algorithm is proposed to solve this problem in this paper. Using the new algorithm, robots can predict whether collision will appear or not. Firstly, mobile robots update their position and the position of moving obstacles in every short period of time $\Delta t(s)$. Based on this parameter, the velocity of robots $(\overrightarrow{V_R})$ and the velocity of moving obstacle $(\overrightarrow{V_{obs}})$, robots calculate the moving distance $(\overrightarrow{D_R})$ between their previous position and current position. Assume that mobile robots can detect and measure the velocity of moving obstacles in allowable limit distance. Thus robots also find out the moving distance of moving obstacles $(\overrightarrow{D_{obs}})$ in $\Delta t(s)$. By checking whether $\overrightarrow{D_R}$ intersect $\overrightarrow{D_{obs}}$ or not, robots can predict collisions. In case of appearance of collisions, robots then react by pausing in $\delta(s)$, and the adjustment angle is re-calculated to avoid obstacle.

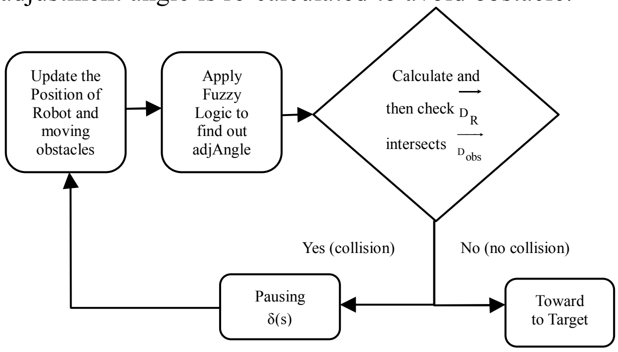



**Fig 1. Flow chart of the predictive collision-free algorithm**

**2.1 Assuming**:

+ Consider moving obstacle and speed vector of Robot $\overrightarrow{V_R}$ and speed vector of obstacle $\overrightarrow{V_{obs}}$

+ Mobile robots can detect and measure speed of moving obstacles in allowable limit distance.

+ $\Delta t$: period of time to re-calculate adjustment angle (adjAngle)

+ $(X_{R1}, Y_{R1}); (X_{R2}, Y_{R2})$: The positions of robot at time t and $t + \Delta t$

+ $(X_{Obs1}, Y_{Obs1}); (X_{Obs2}, Y_{Obs2})$: The positions of obstacle at time t and $t + \Delta t$

**2.2 Predictive collision-free algorithm (PCFA)**:

1. *Update the Position of Robot and moving Obstacles*
2. *Apply Fuzzy Logic to find out adjAngle.*
3. *Calculate* $\overrightarrow{D_{obs}} = \overrightarrow{V_{obs}} * \Delta t$ *and* $\overrightarrow{D_R} = \overrightarrow{V_R} * \Delta t$

*if (*$D_R \otimes D_{obs}$ *(Point M)= True)*

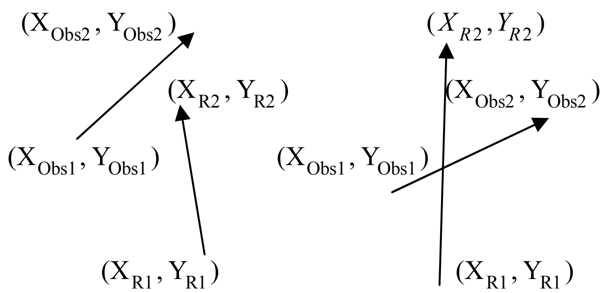
*then (Robot_Pause,* $\delta$*);*

*return 2;*

*else if (Robot_toward to Destination);*

where $D_R \otimes D_{obs}$ = True if $(X_M \in [X_{R1}, X_{R2}])$ and $(X_M \in [X_{obs1}, X_{obs2}])$

Flow chart in figure 1 shows the steps of PCFA. Why the algorithm is named predictive collision? Because by applying this algorithm, mobile robots can predict crash between them and moving obstacles, then robot can react in order to avoid collision. First step is mobile robots will update their positions and moving obstacle as well. Next step is applying Fuzzy Logic which is the same work as HFA [1]. The third step is very essential in this algorithm. The idea is the definition of a short period of time $\Delta t$ (s) for mobile robot to re-calculate adjustment angle. Based on $\Delta t$ and the $\overrightarrow{V_R}$ and $\overrightarrow{V_{obs}}$, it is easily to find out $\overrightarrow{D_R}$ and $\overrightarrow{D_{obs}}$ respectively. Now, two situations can be appeared in the figure 2:




a) $|\overrightarrow{D_R}|$ does not intersect $|\overrightarrow{D_{obs}}|$ b) $|\overrightarrow{D_R}|$ intersect $|\overrightarrow{D_{obs}}|$

**Fig 2. Checking collision**

In case of the first situation, mobile robot will not collide to moving obstacle. If the second situation happens, it means there is a collision. In order to check this situation, it only has to examine whether $X_M$ satisfied concurrently 2 condition $X_M \in [X_{R1}, X_{R2}]$ and $X_M \in [X_{obs1}, X_{obs2}]$ or not. If 2 above conditions are matched, then robot can predict that there will be collision. The solution here is pausing robot in a very short time $\delta$ (s). After stop in $\delta$ (s), robot returns to step 2 to find out a new adjustment angle. Then mobile robot goes toward to target. It needs to be mentioned that $\delta$ and $\Delta t$ are two experimental parameters which can be chosen after experiments are conducted repeatedly.

## 3. EXPERIMENT RESULTS

### 3.1 Implementation

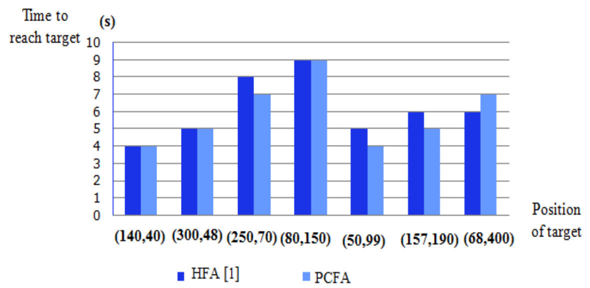
The simulation is implemented by using Microsoft Visual C++ 2010. After performing many experiments, we decide to choose the values of 2 parameters $\Delta t$ and $\delta$ are 1s and 0,01s respectively. It can guarantee that if the value of speed of robot is 30 (pixel/s) and the speed of 2 moving obstacles is 25 (pixel/s), there will be no collision when mobile robot moves in the map. The experiment is implemented in the map which has 2 moving obstacles, 3 un-moving obstacles and 1 robot. The experiment uses the map which has size of 800x420. There are three types of components in the map:

unmoving obstacles, moving obstacles, targets and mobile robot. All of obstacles have shape of rectangles. The sizes of three unmoving obstacles are (20x20), (50x20), (20x50) with the positions are (304, 95), (400, 210), (278, 248) respectively. Two moving obstacles have the size of (20x20), (40x30) and the initial positions are (552,155), (101,133). In addition, these two obstacles move in 2 directions, horizontal and vertical. The initial speeds of two moving obstacles are same at 25 (pixel/s). Target is also represented by a rectangle of (15x15) with the initial position of (50, 37). It can be updated in every event BUTTON_DOWN. Lastly it is information of robot. Robot is represented by a rectangle of 30x20. Its initial position is (50, 50) and initial speed is fixed at 30 (pixel/s).The reason of choosing all components represented by rectangles is make it easier to determine the center of components. It effects to the accuracy of collision evaluation.

### 3.2 The proposed method in case of remaining all speeds.

In this test, the speed of mobile robot is fixed at 30 pixel/s) and the speed of moving obstacles is also remained 25 (pixel/s). The result shows there is no collision by applying the proposed method PCFA and the HFA [1] also. However, to be more objective, one aspect is time of reaching target are compared between 2 methods. Some target positions are picked up randomly. Then the test is implemented by 2 methods.

**Table 1. Performance comparison of 2 methods (remaining all speeds)**




Following the table 1, it shows that there is slightly difference of time of reaching target between HFA [1] and PCFA. In general, PCFA has better result to reach target than HFA [1].

### 3.3 Performance evaluation of PCFA.

This test is implemented with positions which is picked up randomly as same as 3.2. The graph in figure 3 represents the result of HFA [1] and proposed method PCFA in case of changing the speed of mobile robots while remaining the speed of moving obstacles is 25 (pixel/s). The range of changing speed of mobile robot is [30, 60]. The graph shows that from [30, 35] no collision happens. When the speed of robot increase in [35, 60], robot starts colliding to obstacles. However, the graph shows that applying the proposed method PCFA reduces one collision in comparison with the HFA [1]. It proves that performance of PCFA has nearly 50% better than HFA [1]. It has to be reminded that collisions which are considered here appear only between mobile robot and moving obstacles.

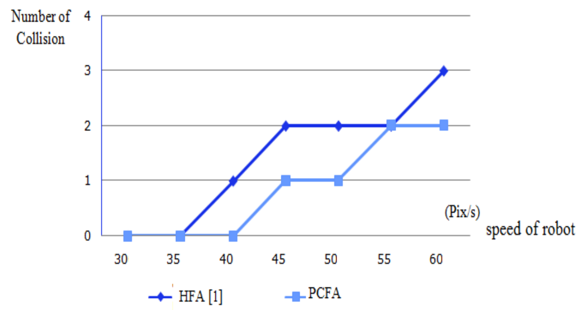



**Fig 3. Performance comparison of two methods (changing speed of robot)**

In the graph 4, the speed of two moving obstacles is changed from [25, 50] while the speed of mobile robot is remained at 30 (pixel/s). Observing two methods represented by 2 types of lines, it is obvious to realize that the proposed method PCFA always shows the better performance than the HFA [1]. This test is implemented in same positions which are picked up randomly in 3.2.

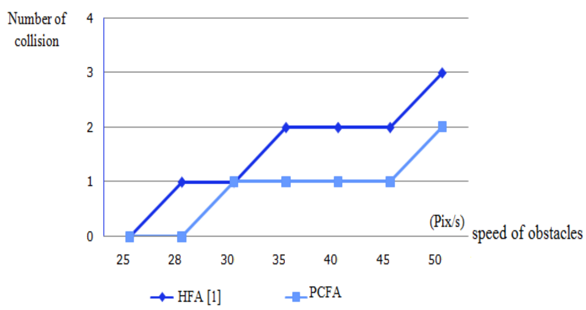



**Fig 4. Performance comparison of two methods (changing speed of moving obstacles)**

## 4. CONCLUSION

Moving obstacles in the obstacle avoidance are a difficult problem challenging. Some methods have been proposed to solve this problem which only focuses on the moving obstacles at a constant speed. However, differently from the unrealistic assumption, the obstacles can move at variable speed in the real world. Conventional, robots cannot turn to avoid obstacle on time, if the speed of robots and moving obstacles are too fast. In this paper, a new algorithm which is named as predictive collision-free algorithm (PCFA) is proposed to solve this problem. Mobile robot updates its position and the position of moving obstacles in every short period of time $\Delta t(s)$. Using the new algorithm, robot can predict whether collision will appear or not. Mobile robot then reacts by pausing in $\delta(s)$, and the adjustment angle is re-calculated to avoid obstacle. With the initial condition of environments, there is no collision in many experiments. Nevertheless, by testing with changing in the speed of mobile robot in [30, 60] and the speed of moving obstacles in [25, 50] proves that PCFA has nearly 50% collisions reducing in comparison with HFA [1].

PCFA, however, is not perfect in every situation. This paper is only tested with a fixed environment. The future work should face up to the un-know environment. Otherwise, the new mechanism needs to be analyzed in more circumstances, for instance taking account to relationships between $\Delta t(s)$, $\delta(s)$ with the speed of robot and moving obstacle to choose the best value of two parameters in order to get higher performance.

## ACKNOWLEDGEMENT

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