Target Tracking in Mobile Robot under Uncertain Environment using Fuzzy Logic Controller

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***Abstract*— This paper discusses a design of fuzzy logic algorithm in a robot. This algorithm is useful for the robot in seeking and reaching the target. The robot is also accomplished with an ability to avoid obstacles. Although the fuzzy rule that is embedded to the robot is very simple, it gives a good result in target seeking and obstacles avoiding task. The originality of this research is an approach to the rules that can simplify the task by creating faster track for the robot in uncertain environment.**

***Keywords*— fuzzy-logic controller; navigation; target tracking.**

I. Introduction

Robots application in detecting dangers is commonly available nowadays. They are more robust and safer than human or animal. By equipping them with some specific sensors, they can be good mobile detectors. They can detect many targets, such as thermal [1], gas [2], survival victim in disaster areas [3,4], and so on. Their ability in detecting the variety of targets depends on the sensors mounted on them. The assembling of vision and perception sensors can help the robots to track to the final target [5], [6]. Even so, in order to minimize the cost of the robot assembling in this research, the capability of the robots in tracking does not rely on the visions or perception. The competence of the mobile robots in this research depends only on the effectiveness of algorithm and distance sensors. By doing this, a low cost mobile robot tracker can be built.

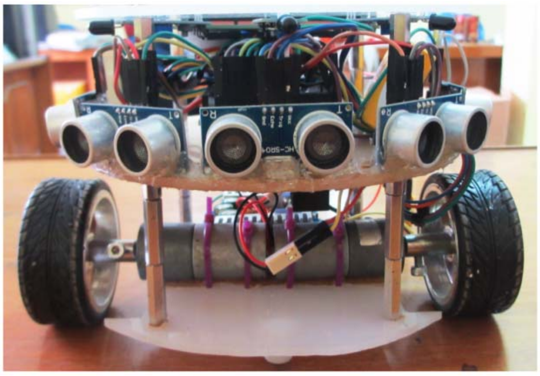
Artificial Intelligent (AI) as one of the computer science branches can improve the performance of mobile robots. It can handle optimization (PSO), data mining (GA), classification (SVM, NN), decision (fuzzy, expert system), and so on. In this research, it utilizes a fuzzy system in order to handle the navigation of mobile robots in an unknown environment. The trajectory of them is based on the received information from attached sensors [6]. There are a lot works use fuzzy logic as the intelligent system [7-9]. It's due to fuzzy logic does not require exact mathematical modelling but rather works on the idea of range between 'zero' and 'one' value. A fuzzy logic controller is a control design where decisions are made by applying a fuzzy interference system based on rule or knowledge containing strings of fuzzy if-then rules [10]. This heuristic knowledge will develop perception-action for the robots to accomplish their task. The fuzzy logic controller is very good to be implemented in the uncertain environment [11-15].

The main features of robot navigation are obstacle avoidance and target tracking. Many researchers had studied about these topics [16,17]. Target tracking is also one of the mostly explored topics in mobile robotics, since this type of robot can be easily deployed to search anything, ranging from dangerous objects to saving human-life. Target tracking using artificial intelligence is also already discussed in several studies; however researchers tended to divide the modules for target tracking and for other tasks of the robot [18-20] or combine fuzzy-logic controller with other type controller to get a better result [21-23]. The module division and/or combination with other type controller will add the complexity to fuzzy-logic controller, while applying it supposes to make the algorithm easier.

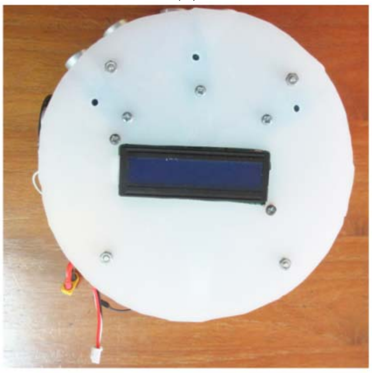
In this study, a mobile robot to track a target where the environmental setting is not predefined was designed; therefore the robot has to find its own way to the target. We design fuzzy logic algorithm to reach the target and avoid obstacles as the artificial intelligence of the robot. We set the rules to be very simple and yet still get a good result. The original of our approach is that we simplify the rules to create faster tracking of the robot in the present of uncertain environment. We also design a low cost robot that can be easily cloned to be swarm robots. Therefore, we also set up originality in the sense of a low cost mobile robot with a simple artificial intelligence algorithm that can be easily upgraded into a more complicated application or swarm robots.

II. Fuzzy Control Based Design Mobile Robot Navigation

This study considers a well applied two-wheeled mobile robot equipped with 3 proximity sensors for obstacle avoidance and 1 heat sensor to track the flame resulted from a burning candle, as shown in Fig. 1. The flame sensor in this paper can be changed into any kind of sensors based on the objective of the robot detector application.



(a)



(b)

Fig. 1. Two-wheeled mobile robot

The main idea of applying artificial intelligence design is to create a simple algorithm over a complex system. We set the fuzzy logic controller based on the designed behavior in tracking and reaching the target. The behaviors usually needed for mobile robot navigation are wall following and obstacle avoidance. However, if we can design a good controller for obstacle avoidance, it will be easy to adjust for wall following algorithm because basically it is almost the same design.

Therefore, in this study a fuzzy logic controllers are designed to navigate the robot from starting position to final position where the target is. As the robot seeks for the target, it will avoid all the obstacles found. In this scheme, three proximity sensors are utilized to avoid obstacles. Target reaching is the priority; the robot will go to target position as soon as the obstacle is avoided. The block diagram of fuzzy controllers design is shown in Fig. 2.

A. **Obstacle Avoidance Control Design**

Obstacle avoidance behaviors design are based on the data acquired by three proximity sensors installed on the robot, the LEFT, FRONT, and RIGHT sensor. Fig. 3 shows the design for obstacle avoidance behavior. As the robot is deployed to reach the target, it is designed to avoid all the obstacles found on the way to reach the target. All the proximity sensors are utilized for the avoidance. The fuzzy logic rules for obstacle avoidance based on robot's behavior design is given in Table. 1. As shown in Table. 1, the input from sensors will affect the motors of the robot and finally, it will direct the movement of the robot. However, the target interception is the main priority of the robot behavior, as the robot senses the target; it will leave any other designed behavior and reach the target.

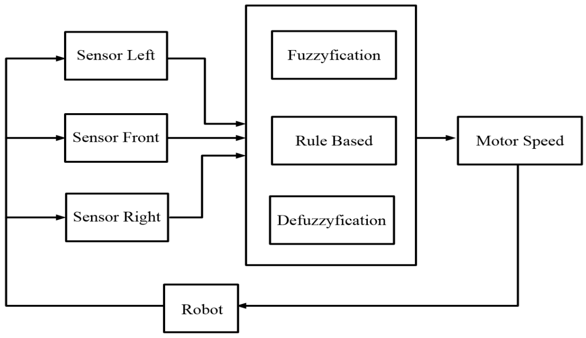


Figure 2. Fuzzy block diagram.

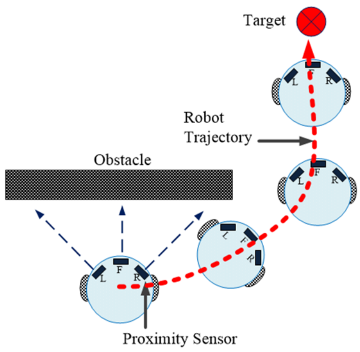


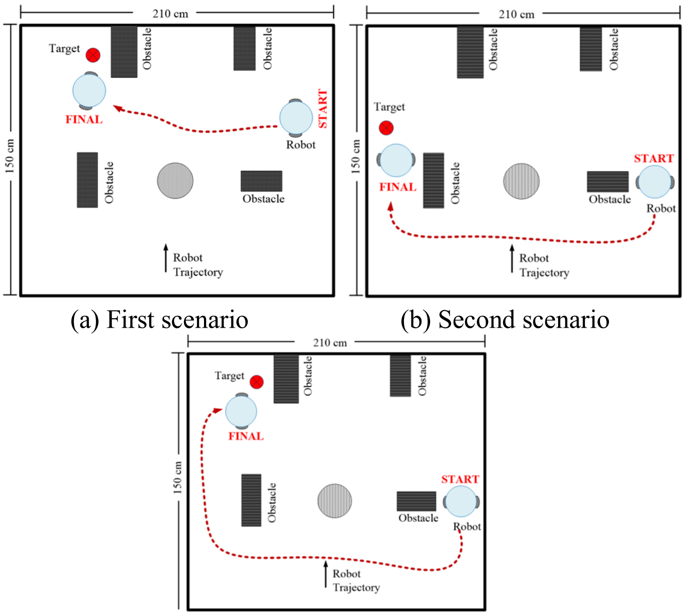
Fig. 3. Obstacle avoidance control design.

Table 1. Fuzzy logic rules for obstacle avoidance

Sensor Left	Sensor Front	Sensor Right	Motor Left	Motor Right	Robot Motion
Far	Far	Far	Full speed	Full Speed	Straight
Far	Far	Near	Reduced speed	Full speed	Turn left slightly
Far	Near	Far	Full speed	Reduced speed	Turn right
Far	Near	Near	Reduced speed	Full speed	Turn left
Near	Far	Far	Full speed	Reduced speed	Turn right slightly
Near	Far	Near	Reduced speed	Reduced speed	Straight slow
Near	Near	Far	Full speed	Reduced speed	Turn right slightly
Near	Near	Near	Stop	Stop	Stop

III. Experimental Setup

We apply the proposed method to a low cost mobile robot, equipped by 3 ultrasonic sensors as the proximity sensors with the ability to detect obstacles/wall from 2-450cm, 5 volt output sensor, 2 mA current and 5 volt input, and 1 flame sensor for tracking a fire (burning candle) as the target. To prove the effectiveness of our proposed method, various scenarios were set-up within test bed area.



(a) First scenario (b) Second scenario

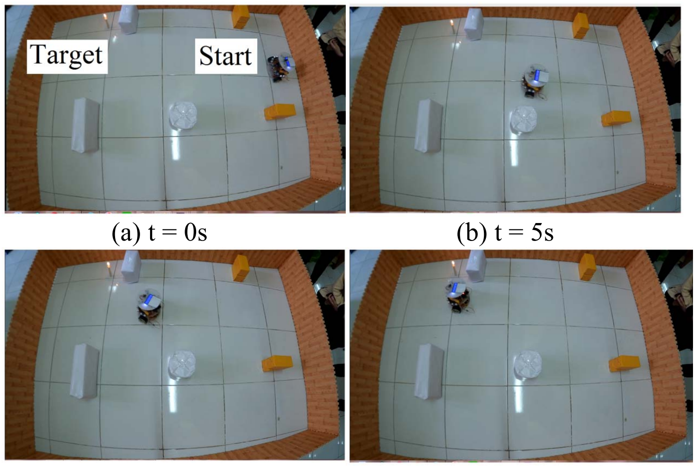
(c) Third Scenario

Fig. 4. Scenarios for obstacle avoidance design

In obstacle avoidance design, we utilized all of the 3 proximity sensors for avoiding obstacles. We set 3 different scenarios shown in Fig. 4 for proving the effectiveness of the proposed method. We also do not apply cost function in this design; therefore the robot would choose its trajectory based on heat detection from the flame sensor. Different starting points and target positions were set to show the ability of robot in reaching target under environment uncertainty. The settings were not pre-map and the robot relied of its sensors for navigation and target tracking.

Figs. 5-7 show the video captures of three scenarios in Fig. 4. Fig. 4a is setting where the robot did not encounter any obstacles. We can elaborate the analysis of video captures as follow :

1. Fig. 5a is the position of robot at t = 0s, the robot is deployed from starting position to reach the target. There is no obstacles found therefore it just followed *Rule 1*, and went straight.
   where:
   Rule 1: IF SL is Far, SF is Far, and SR is Far, THEN ML is FS, and MR is FS.
2. Fig. 5b is the position of robot at t = 5s, the robot did not encounter any obstacles therefore it just followed *Rule 1*, and went straight.



(a) t = 0s (b) t = 5s

(c) t = 6s (d) t = 7s

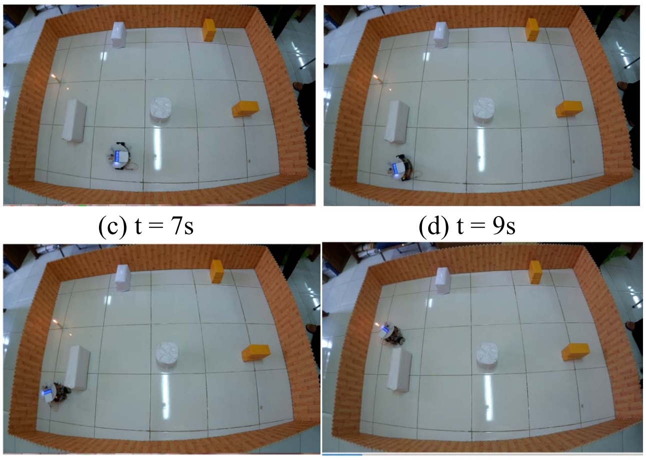
Fig. 5. Video captures of wall following for the first scenario

3. Fig. 5c is the position of robot at t = 6s, the robot did not encounter any obstacles therefore it just followed *Rule 1*, and went straight. As the flame sensor detected the target, the robot started to approach the target.
4. Fig. 5d is the position of robot at t = 7s, the robot reached the target and stopped.

Fig. 4b shows the setting where the robot had to avoid obstacles to reach the target. The video captures of Fig. 4b scenario are given in Fig. 6. The analysis of those video captures is a follow

1. Fig. 6a gives the position of robot at t = 0s, the robot was in starting position where the condition applied according to *Rule 6*, and the robot went straight slowly.
   where
   Rule 6: IF SL is Near, SF is Far, and SR is Near, THEN ML is RS, and MR is RS.
2. Fig. 6b gives the position of robot at t = 1s, where the robot encountered the condition of *Rule 5*. Therefore the robot turned right slightly.
   where
   Rule 5: IF SL is Near, SF is Far, and SR is Far, THEN ML is FS, and MR is RS.

(a) t = 0 s (b) t =1 s



(c) t = 7s (d) t = 9s (e) t = 16s (f) t = 19s

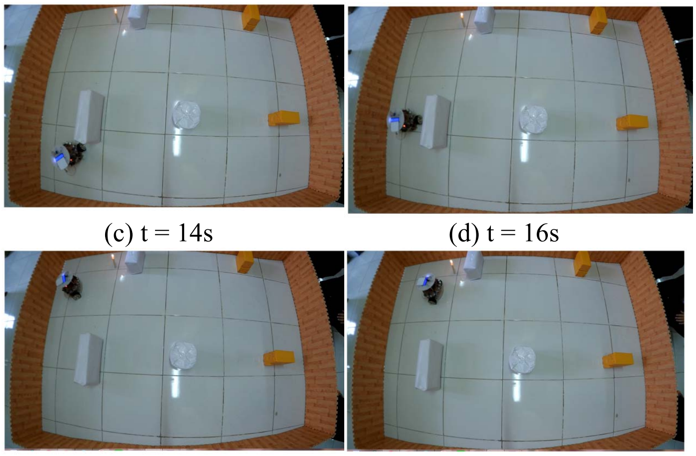
Fig. 6. Video captures of obstacles avoidance for the second scenario

3. Fig. 6c gives the position of robot at t = 7s, the robot found no obstacles and just went straight as stated in *Rule 1*.
4. Fig. 6d gives the position of robot at t = 9s, the robot also found no obstacles and just went straight as stated in *Rule 1*.
5. Fig. 6e gives the position of robot at t = 16s, the robot found an obstacle where *Rule 2* was supposed to be applied, however since the robot sense the target, it turned right slowly.
   where
   Rule 2: IF SL is Far, SF is Far, and SR is Near, THEN ML is RS, and MR is FS.
6. Fig. 6f gives the position of robot at t = 19s, the robot went to the target with the condition of *Rule 6*, therefore the robot moved slowly and as it reached the target, it stopped.

Fig. 4c is the extended setting of Fig. 4b. Fig. 7 shows the video captures of Fig. 4c scen,ario and we can analyze as follow

1. Fig. 7a shows the position of robot at t = 0s, the robot was in starting position where the condition applied according to *Rule 6*, and the robot went straight slowly.
2. Fig. 7b gives the position of robot at t = 10s, the robot found no obstacles and just went straight as stated in *Rule 1*.

(a) t = 0s (b) t = 10s



(c) t = 14s (d) t = 16s (e) t = 20s (f) t = 22s

Fig. 7. Video captures of obstacle avoidance for the third scenario

3. Fig. 7c gives the position of robot at t = 14s, the robot found an obstacle where *Rule 2* was supposed to be applied, however since the robot sense the target, it turned right slowly.
4. Fig. 7d gives the position of robot at t = 16s, the robot found an obstacle where *Rule 2* was supposed to be applied, however since the robot sense the target, it went forward slowly.
5. Fig. 7e gives the position of robot at t = 20s, the robot went to the target with the condition of *Rule 6*, therefore the robot moved slowly and went to target.
6. Fig. 7f gives the position of robot at t = 22s, the robot reached the target and stopped.

From the experimental results of obstacle avoidance setting, we can see that the robot reached the target and avoided obstacles in all the settings within proper speed.

IV. CONCLUSION

We have designed a low cost mobile robot to track and reach a target in an uncertain environmental setting; therefore the robot had to find its own trajectory to reach the target. We applied fuzzy logic controller to reach the target. We simplified the rules but the results are effective as expected. To show the effectiveness of our proposed method, we applied the robot in three settings. From the experimental results, we can see that the robot reached the target and avoided obstacles in all the settings within proper speed. Therefore, we set up originality in the sense of a low cost mobile robot with a simple artificial intelligence algorithm that can be easily upgraded into a more complicated application or swarm robots.

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