Mobile Robot Obstacle Avoidance By Using Fuzzy Logic Technique

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Abstract—**This paper present an obstacle avoidance approach for e-puck module by using Fuzzy Logic controller. The input from eight (8) IR sensors and the output of the motor speed will be used to construct the Fuzzy Logic rules. Test environment, e-puck robot and Fuzzy algorithm was model and programmed by as a Webots Pro Simulation software. The Fuzzy system for e-puck robot was validated in a few environments. The result shows the e-puck module can avoid that static obstacles successfully until it reach a goal point. The robot performance in term of distance and time was recorded when the robot works in simple, average and complex obstacle environments.**

Keywords- *Path Planning, Fuzzy Logic Controller, Obstacle Avoidance*

I. INTRODUCTION

Mobile robot navigation is one of system that able to navigate, consists of movement activities like avoiding obstacles and safe path planning. Hence, robot navigation includes different interrelated activities such as perception, mapping , exploration and path planning. Path planning is an effective way that to determination of obstacle avoidance and finding the goal of collision free path planning.

There are several problems encountered regarding to mobile robot with obstacle avoidance approach. The way of detection of avoidance must be the right method to avoid the collision. Sensors must be able to detect and adapt with the environment because sometimes there are confusion between the sensors. Therefore, there are many obstacle avoidance approaches that could be applied to encounter the problems.

The robot has to make safe path to detect obstacles before reaching to the goal without any collision. To solve this problem, an apparent researcher is using several methods such as Fuzzy Logic, Neural Network, Genetic Algorithm, Artificial Potential Field Approach and also other methods. Then, Fuzzy Logic approach is used is to avoid collisions, detect obstacle and stop the robot in order to avoid breach of the detour obstacles. Fuzzy Logic approach is not only for detection of an obstacle. It also has been used to find the goal.

Najah Yousfi, Chokri Rekik, Mohamed Jalluli and Nabil Derbel are purposed Gradient Method to optimize consequences of a Sugero Fuzzy Logic Controller [1]. This paper are implemented on a Kheperra II mobile robot. The input based on the distance and the angle that to control the right speed and the left speed. The method of avoiding an obstacles consists of three (3) sensor on mobile robot. This method are proven successful to real motion simulation by giving a good performances. The other Fuzzy Logic controller was applied by Mohsen Shayestegan that implemented on the e-puck robot in Webots software [2]. This research depending on the sensor as the input, then the speed is their output. The method of detection based on the obstacle avoidance approaches and wall following approaches.

In order to realize the collision avoidance of the mobile robot, it is also proven by using Ant Colony Optimization (ACO) [3]. This approach present that ACO shows the optimization motion for mobile robot from the start position (nest) to the target position (food) in free collision environment. Furthermore, Qiau Liu, Yong Gang Lu and Cun-xi Xie have proposed the study on development of Genetic Algorithm under multi obstacle environment [4]. The input controller of this research are the angle between the obstacle and the goal, and also the distance between the obstacle. Genetic Algorithm that used to optimize based on the moving speed and turning angles of mobile robot that are combined by two methods which is path planning and Genetic Fuzzy Algorithm.

Furthermore, Hani Safadi [5] has solved some problems regarding to the uses of potential field technique. This technique uses artificial attractive and repulsive force that has been set to the goal point and obstacles in the field. Based on their results, the methods are proven works whereby the robot can reach the goal point while avoid the obstacle. However, there are still continuous research by using Fuzzy Logic method to avoid the obstacle. This is because the different Fuzzy Logic rules was used based on the robot applications. Different application has a different usage of robot with a different input from sensor and output from actuator. Therefore, this research was proposed to create a Fuzzy Logic controller that can help the e-puck robot path planning system. The IR sensors was used as the input for Fuzzy Logic controller where else the camera will be used e-puck to go to the goal point. The robot performance will be validate and tested in different complexity of environments.

II. Scope Of Work

Path planning mobile robot is required to find the safest path from starting point to the goal point while avoiding the obstacles in the environments. The complexity of the field are determined by the researcher. Webots simulation software consist of Graphical User Interface (GUI) to create environment, obstacle and robot module. The environment is created by the presence of scattered obstacles consists of simple, average and complex environments. Therefore, it concentrates more on mobile robot in static environment. For a simple environment, three solid square shape obstacles were used. Then, the average and complex environments has more than four solid obstacles.

The robot used in Webots is the e-puck module which consist of eight(8) infrared (IR) sensors and camera. IR sensor are proposed to detect any obstacle and avoid the collision. Thus, the camera is used as a vision sensor that mounted to the E-puck module as a supervisor to seeking the color of goal.
The input and output parameters are designed by using Fuzzy Toolbox in MATLAB. Fuzzy Logic controller is implemented as a instructor to e-puck module to observe the distance sensor either detect or not and move forward to goal point by using camera.

This paper is proposed to collect data based on e-puck safe path planning while avoiding the obstacles. The e-puck performances are validated based on the movements, time and distance taken from the starting point to the goal point.

III. Methodology

The methodology of this research are declared as below:

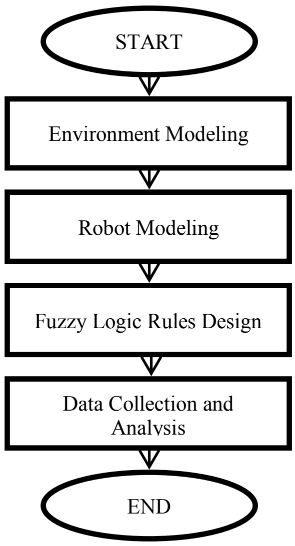

Figure 1: The overall methodology

A. Environment Modelling

Webots PRO is used in this research to create a simulation world for robot to navigate in a three environments. These environments will be modeled by setting the scene tree to adjust the size of environment, time step, real time, lighting and other settings needed for the mobile robot.

The basic setting of the environment should has four (4) walls with the area of 1 meter times 1 meter (1m x 1m) and several square shapes obstacles based on researcher's environment. The walls and obstacles are created based on add a 'Solid' node and 'shape' node at the scene tree. Appearance and Geometry nodes will appear and add corresponding nodes to create the wall's shape depending on the size and color. Then, add the 'boundingObject' node with 'Box' and add 'Physics'.

B. Robot Modelling

E-puck module is chosen implemented in this research because it is provide extensions such as differential wheels, IR sensor, camera module to performing collective self assembly. Figure 2 below shows the E-Puck module of Webots simulation. The Red lines represent the directions of the eight (8) IR sensor from PS0 to PS7. The green arrow indicated the front of E-Puck module. This E-Puck module that equipped with C programming compiler. In order to fulfill the task, the testing and calibration should be done by taking mobile robot turning angle and moving speed.

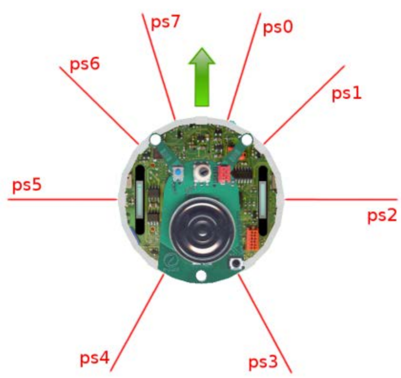

Figure 2 : The IR sensors orientations of E-Puck Module

C. Fuzzy Logic Design

MATLAB is used to get the Fuzzy Logic rules. The inputs are eight IR sensors and the output is the modification of speed by obstacle basic rules. E-Puck needs to read the values of the IR sensors. It is scaling the value of amount of light that is between 0 to 2000. If the threshold sensor value reach and more than 1000, it means that the obstacle is detected. If the sensors value is 0, there is no obstacle detected.

The output are consist of five movements which are turn to the left (neg90), slightly left (neg45), straight (val0), slightly right (pos45) and turn to right (pos45). The E-Puck robot used differential wheels while the movement based on the speed of rotation and its direction. If both the wheels are driven same direction and speed, E-Puck will move forward. If both wheels are turned with equal speed in opposite directions, so E-Puck will turning left or right. The speed of movement to complete rotation of the wheels is 100 ticks per second. The Fuzzy Logic values to driven either straight forward or reverse without stopping for distance needed with sets speed for differential wheels is 500, it is due to increase speed and reduce the time. Turning degree speed is used when obstacle are detected with speed for differential wheels is set to 100. Then for every step mobile robot moves, it should evaluate its sensors and camera to search any possible actions and generating the output based on algorithm:

For move forward and reverse
Left_speed = +SPEED;
Right_speed = +SPEED;
For turning rate
Turning left:
Left_speed = -SPEED;
Right_speed =+SPEED;
Turning right:
Left_speed = +SPEED;
Right_speed = -SPEED;

Figure 3 represent Mamdani Systems Using Fuzzy Logic Toolbox with 8 input, 9 rules and 5 output data to perform Fuzzy Inference System(FIS). FIS interface with membership function to display a diagram of each input of IR sensors and each output movements. Figure 4 shows the membership function of the input named ps0. Obviously, the range is between 0 to 2000 and trapezium shape is used as it describes faster reaction of the IR sensors detection. Figure 5 shows membership function for the E-Puck output movements. It shows which movements that the E-Puck needs to execute at certain values. Figure 6 shows the list of rules that defines the behavior of the movements. Fuzzy Logic approach is used to prove the rules of movement is related with the output at the Webots software.

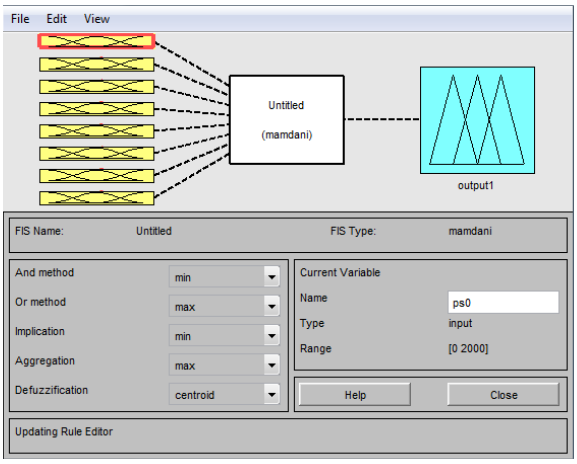

Figure 3 : Fuzzy Logic design

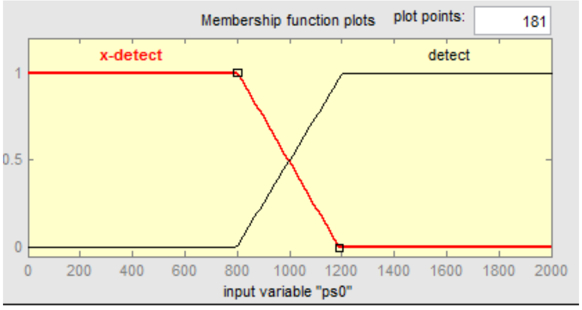

Figure 4: Example of input membership function for group 1

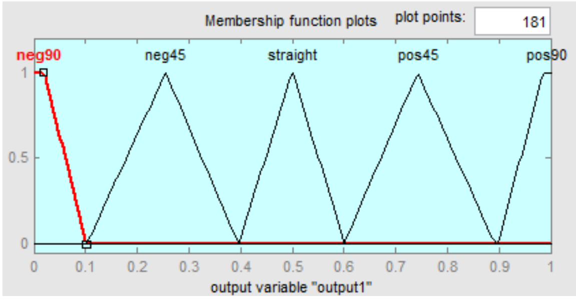

Figure 5 : Example of output membership function

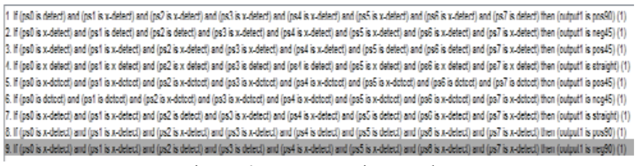

Figure 6 : Fuzzy Logic set rules

D. Data Collection and Analysis

From the experiment, there are data that will be collected and analyzed. The first analysis would be on the e-puck module. Turning angle and speed of the mobile robot will be the input. Then, the e-puck performances are validated from the distance and time taken from starting point to the goal point. The e-puck successions to reach the goal point is also accounted. Furthermore, the e-puck turning angle determination and movement speed are also being analyzed. Another analysis are FIS for Fuzzy Logic Controller and Webots GUI's that display the e-puck movements from starting point to the goal point.

IV. RESULTS

A. Fuzzy Logic Output

The overall outputs for Fuzzy system are based on turning angle determination and movement speed of the e-puck module. Angle and speed are manually tested by the researcher. Table 1 below shows the result of the time step needed to make the robot turn to a certain angle. The e-puck turning speed is set to 100 radius per second. The time step was adjusted to gain bigger angles so that the e-puck could turn based on the user's favor. Each data shows 45 degree per increment.

Table 1: E-Puck turning angle determination

TIME STEP	LEFT SPEED	RIGHT SPEED	RADIAN	DEGREE
889	100	100	0.79161	45.36
1778	100	100	1.57462	90.22
2667	100	100	2.3584	135.13
3556	100	100	3.14146	179.99
4445	100	100	2.3584	224.88
5334	100	100	1.57462	269.75
6223	100	100	0.79161	314.66
7112	100	100	0.00839	359.52

Table 2 shows the e-puck movement speed specifications. A positive value of speed should move the wheel forward, and a negative is backwards. A motor speed are set to the value of 500 for one rotation per second. Then, the speed of the right motor and left motor will influence the robot movements. Therefore, the technique for turning the wheels either left turn or right turn should be set by opposing the speed and insert the delay for time step of the e-puck.

Table 2: Data analysis of movement speed

	LEFT SPEED	RIGHT SPEED	ROBOT STEP	DEGREE
FORWARD	500	500	0	0
REVERSE	-500	-500	0	0
TURN LEFT	-100	+100	1778	90
TURN RIGHT	+100	-100	1778	90

B. Fuzzy Logic Rules in MATLAB

Based on Figure 9, FIS is the rule viewer to test the fuzzy logic controller outputs. The rule viewer shows the result of the system with all rules have been inserted into the rule editor. FIS shows all parameters of input and output values which is eight (8) input sensors and nine (9) rules Mamdani FIS inputs.

The sensors which have detected the presence of an obstacle are based on the position of the sensor. The distance for the sensors to detect obstacle is declared to be more than 1000. Any values lower than 1000 are considered lies in no detection range.

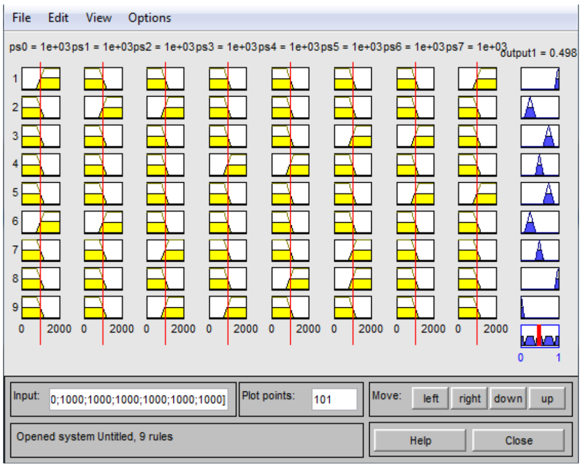

Figure 9 : Fuzzy Inference System

Figure 10 below is an example of rules in Matlab Editor where the values of sensor (ps3) and sensor (ps4) are set to the value of 1000. When these sensor values were set to 1000, the output shows the exact movements that the mobile robot will execute in the GUI. In this example, the output value is 0.499 indicating that the e-puck will move straight forward.

Figure 10 : Example of PS3 and PS4 are detected

C. E-Puck performances in avoiding the obstacles

The e-puck performance for average environment shows by figure below. Based on figure 11, e-puck start moving from the starting point and perform no actions until simulation runs. After the simulation run, e-puck moved towards the goal point while avoiding obstacles. It took 21.200 seconds for the e-puck to move 0.97 meter in the middle point of the simulation. Figure 13 shows the e-puck successfully reached at the goal point by moving for 1.326 meter and took 40.128 seconds.

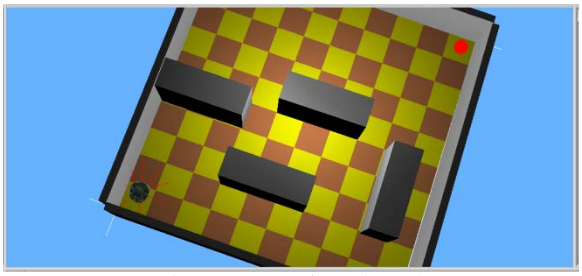

Figure 11 : E-puck starting point

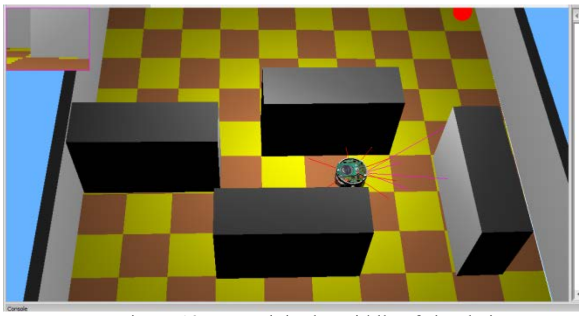

Figure 12 : E-puck in the middle of simulation

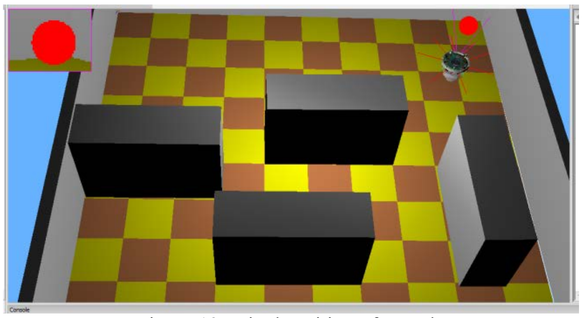

Figure 13 : Final position of e-puck

Table 3 represent the performances of e-puck in three environments which are simple, average and complex. The e-puck performance for simple environment shows that distance and time taken for e-puck to reach the goal point was 1.317 meter in 30.112 seconds. Next is the e-puck performance in average environment. The result shows that e-puck took 40.128s to travel to the goal point. The distance it took to reach the goal point was 1.326m. Finally, e-puck took 1.15.216 minutes and 1.584m to reach the goal point in the complex environment. The overall performances show that by implementing fuzzy logic system in a complex environment, the time taken to reach the goal point will be much longer.

Table 3: E-Puck performances in three environments

PERFORMANCE	SIMPLE	AVERAGE	COMPLEX
DISTANCE	1.317m	1.326m	1.584m
TIME	30.112s	40.128s	1.15.216 min
REACH GOAL	Success	Success	Success

V. CONCLUSION

This paper is presenting a mobile robot path planning and obstacle avoidance by using fuzzy logic approach for an E-Puck module. The result shows that fuzzy logic approach was successfully applied to the e-puck mobile robot for its to find safest path to the goal point. The e-puck mobile robot was able to find the goal point successfully with the guidance from the vision sensor. The results proved that this approach are suitable to be adapted within simple, average and complex environment. However, e-puck need more time to complete its tasks within complex environment compared to simple environment.

Moreover, this research can be improvised by using compass, emitter and receiver or other devices. These are the devices that can be applied to improve mobile robot goal seeking in the environments. Furthermore, by implementing another controller combined with present fuzzy logic controller will also enhance the overall system of the E-Puck. It is to ensure better performances can be obtained.

VI. REFERENCES

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