Mobile Robot Navigation by Using Fuzzy Information of Moving Two-Wheeled Motion Features

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***Abstract* – The purpose of indoor and outdoor mobile robot navigation is to move the mobile robot toward target with stable target navigation. In this study, motion information from the movements of the two-wheeled mobile robot is used as an input to the Fuzzy membership function (MF), which is designed in the preliminary experiments. The probability value outputted from the MF is used to move the forward velocity of the mobile robot called AHMAD-R toward target. The experimental results show that the proposed fuzzy approach has the stable target navigation and could be used to navigate the mobile robot in the indoor environment.**

***Index Term*— Mobile robot, Stable target, Navigation, Fuzzy information**

I. INTRODUCTION

The navigation system plays an important role and task in the research of the mobile robot navigation. Navigation of mobile the robot includes a variety of theories and technologies such as an odometry technique, an ultrasonic mapping and a vision system [1-3]. Moreover, the mobile robot navigation technique could be divided to three parts, which are self-localization, path planning and map-interpretation. The most famous navigation technique is the map-interpretation by using the vision based system. A camera is used as a sensor to capture image information in the environment.

The obligations of a real-time performance, computational power and accuracy of estimation contribute to some of the major problems that must be taken into account when designing the system of navigating an autonomous mobile robot. This mobile robot should interact autonomously with the changes in the information received from the environment [4]. This is the reason an artificial intelligence with the combination with statistical and probability approaches are needed to train the mobile robots learn the working environment and do a decision by themselves. A real-time performance must be enhanced in order to allow the robot to assess its situation and respond accordingly to its surroundings with or without obstacle in the route [5-8]. And, Obstacle avoidance is a feature that permits the robot to dynamically detects the presence of an obtrusive object or obstacle that would prevent its planned action and change it navigational plan [9-11].

In this project, the fuzzy probability approach is proposed to navigate the two-wheeled mobile robot toward target with stable navigation. Based on the preliminary experiments, the fuzzy MF is designed, which describes the movement model of the mobile robot. On the other hand, the probability value outputted from the MF decides the movement and orientation of the mobile robot at time *t+1*. At the end of the study, the experimental results show that the proposed algorithms could be used to move the mobile robot toward target with the stable target navigation.

This research paper organized as subsequent: Section II encompasses literature review of the related researches. Section III presents the methodologies of the proposed algorithm. Section IV divided into 2 sections, 1st section describes the experiment setup where the 2nd section demonstrates the experimental results. Section V expresses the conclusion over the current research.

II. LITERATURE REVIEWS

Planning and navigation of an autonomous mobile robot involves purposeful decision-making and execution that a system utilizes to achieve its highest-order goals. Two skills

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needed in navigating the mobile robot, which are path planning and obstacle avoidance [10-11]. The mobile robot needs to be trained about various conditions in the working environments. Training means development intelligence of the mobile robot [12-13]. The mobile robot must be knowledgeable about the environment [14]. Various sensors need to be installed to the mobile robot. Sensor's outputs are sent to the main processor or the robot brain for the purpose of the decision making. On the other hand, the sensor's outputs are shared among sensors installed to the mobile robot. A sensor fusion technique is needed to fuse information between sensors and the main processor of the system [15].

In the preliminary experiments, data acquired from the various sensors are analyzed to characterize the various aspects related to the mobile robot such as motion information, the existing of obstacle in the environment and the capability of the mobile robot to reach the target with a minimum time [16, 17]. Preliminary experimental data are used to train the mobile robot by using various machine learning approaches such as mereology-mereotopology, fuzzy reasoning, neural network and etc [2,3,18].

Mobility and autonomous control promise various advancements in robotics technologies. An unmanned Arial Vehicle (UAV) is commonly be used in Europe by a policeman for monitoring human activities to prevent crimes. Autonomous UAV technology is needed for the UAV to fly between the buildings in the town. In the manufacturing industries, autonomous mobile robot is used in the production line to do the complicated tasks like to produce products related to the aerospace industry. In medical, an intelligent mobile robot works with a medical doctor in the surgery room. In this application, a knowledge based engineering technique is needed to design the mobile robot.

III. METHODOLOGIES

A. *Overview of the proposed works*

Fig. 1 provides the overview of the proposed system. In the preliminary experiments, the membership functions (MFs) are designed, which describe motion information for both the right and left wheels represented by V_R and V_L, respectively. MFs are installed in the system and are used as the references to the current velocities of the $V_R(t)$ and $V_L(t)$. The mobile robot is in the stable target navigation if the resulting $V_R - V_L$ at time t is equally to zero.

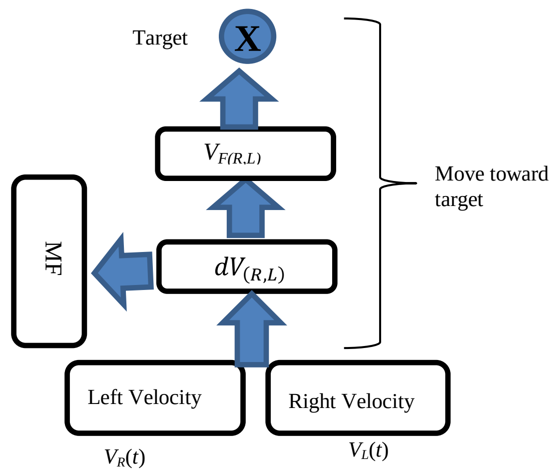

Fig. 1. Overview of the proposed works

B. *The mobile robot model*

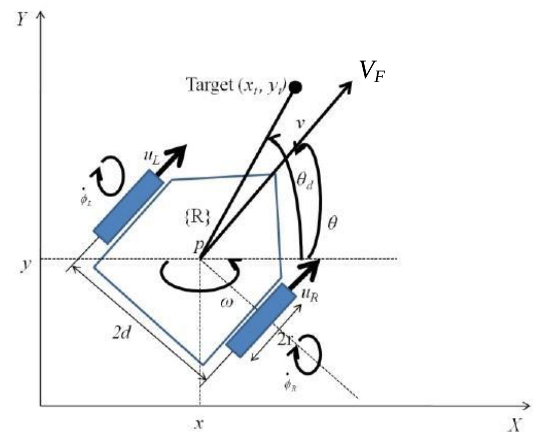

Fig. 2. A differential steering system of the mobile robot

(x, y) : Local coordinate
(X, Y) : Global coordinate
R : Position of robot in 2D space (x, y)
θ : Orientation of robot in 2D space (x, y)
r : Radius of the wheel
$2d$: Distance between left and right wheels
V_F : Forward velocity of the robot
ω : angular speed of the robot
V_L&V_R : Velocity of the left and right wheels.
$\dot{\O}_R$&$\dot{\O}_L$: angular speed of right and left wheels

The posture of the mobile robot provides information about its movements with respect to the floor [1,16]. The kinematic model of the differential drive mobile robot is shown in Fig. 2. The speed relative to the ground of the right and the left wheels can be expressed by the following equations (1) and (2).

$$\mathrm{V}_R = \phi_R = \frac{\Delta\phi_R}{\Delta t} \tag{1}$$

$$\mathrm{V}_L = \phi_L = \frac{\Delta\phi_L}{\Delta t} \tag{2}$$

The forward speed $V_{F(R,L)}$ and the angular speed $\omega_{(R,L)}$ of a mobile robot are related to the wheel speeds, and it can be expressed as shown in equations (3) and (4). *F*, *R* and *L* denote the forward, right and left, respectively.

$$V_{F(R,L)} = \frac{(V_R+V_L)}{2} = \frac{r}{2\Delta t}(\Delta\emptyset_R + \Delta\emptyset_L) \quad (3)$$

$$\omega = \frac{1}{2d} = (V_R + V_L) = r/2d\Delta t(\Delta\emptyset_R + \Delta\emptyset_R) \quad (4)$$

The angular speed of the left and right wheel of mobile robot can be expressed as follows:

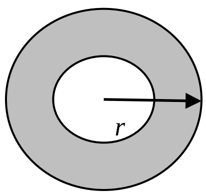

Fig. 3. The right and left wheels of the mobile Robot

$$D = 2\pi r \quad (5)$$

$$Ro = \frac{Dis}{D} \quad (6)$$

The time taken *t*, in 1 rotation is defined as:

$$t = \frac{t_{total}}{Ro} \quad (7)$$

The ratio of angular speed for the right and left wheels $\acute{\emptyset}_{(R,L)}$ is given in equation (8).

$$\emptyset_{(R,L)} = \frac{\emptyset_R}{\emptyset_L} = \frac{2\pi}{t} \quad (8)$$

Dis, *D*, *Ro*, *t* and t_{total} denote the moving distance, the perimeter of the wheel, the total rotation of the wheel, the time taken in 1 rotation, and the total time taken of a certain distance, respectively.

C. Designing of fuzzy membership function (MF)

Fuzzification is a process of changing a real scalar value into a fuzzy value [0,1]. In the preliminary experiments several parameters are chosen as the variables of the stable target navigation. In this project, the difference between the right and left velocity $dV_{(R,L)}$ are chosen as a variable of stable target navigation to design MF as shown in equation (9).

$$dV_{(R,L)} = V_L - V_R \quad (9)$$

A triangle fuzzifier is chosen in the experiment as shown in Fig. 4. The forward speed of left and right wheel is controlled by the output value of MFs by comparing the left and right wheels velocity. Input to the MFs is the difference speed between the left and right wheel velocity as shown in equations (9). The action taken by system is based on designed Rule Base as stated in Table 1. The output membership function for mobile robot to reduce the error speed between left and right velocities were designed as Fig. 5, by either increase, decrease or keep the current left or the right wheels velocity.

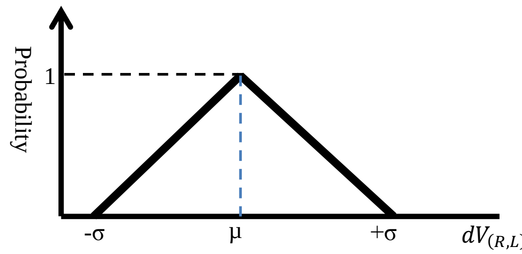

Figure 4: Triangular fuzzifier used in the experiments

Table 1: Fuzzy rules based for stable target navigation

$dV_{(R,L)}$	V_L	V_R
PB	Decrease	Increase
PS	Decrease	Keep
ZE	Keep	Keep
NS	Keep	Decrease
NB	Increase	Decrease

Where, *PB*, *PS*, *ZE*, *NS* and *NB* denote Positive Big, Positive Small, Zero, Negative Small and Negative Big, respectively.

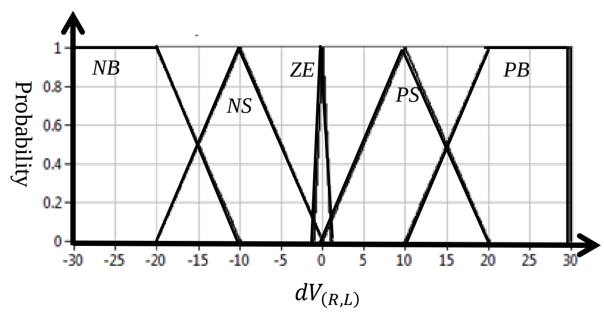

Fig. 5. Fuzzy MFs of the navigation system

IV. EXPERIMENTS

A. Experimental setup

In the experiment the mobile robot called AMAD-R was used to acquire data as shown in Fig. 6. The mobile robot was equipped with two units of Sayama DC Geared motor model RB-35GM to drive it toward the target. A DC motor driver named MD30B was used to control the installed motors. A LabVIEW 2012 was used as the software to design the algorithms. Figure 7 shows the system configuration of the mobile robot. Table 2 describes the experimental parameters used in the experiments.

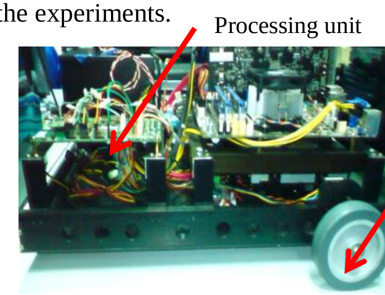

Fig. 6. AMAD-R

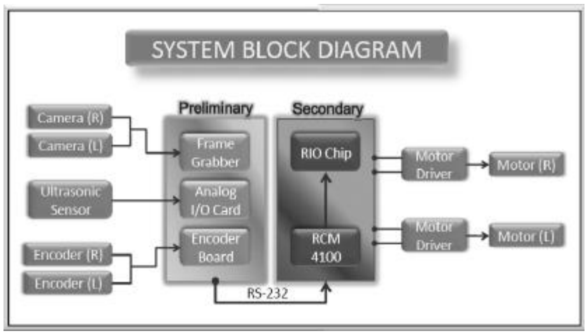

Fig. 7. System configuration of AMAD-R

Table II
The experimental parameters

Parameters	Characteristic
Target distance	3 meter
Trial	10 times
Variable	$V_{F(R,L)}$

B. *Experimental results*

The experiments were conducted to analyze the forward velocity $V_{F(R,L)}$ before and after applying fuzzy approach. Table 3 shows the experimental results of 10 trials for left wheel velocity V_L, the right wheel velocity V_R, and the forward velocity $V_{F(R,L)}$ before applying fuzzy approach. The graph in Fig. 8 represents the forward velocity $V_{F(R,L)}$ after 10 trials. The average and standard deviation of the forward velocity to reach the target were 10.2 cm/s and 0.33 cm/s, respectively. Table 4 shows the experimental results of 10 trials for left wheel velocity V_L, right wheel velocity V_R, and the forward velocity $V_{F(R,L)}$ after applying fuzzy approach. The graph in Fig. 9 represents the forward velocity $V_{F(R,L)}$ after 10 trials. The average and standard deviation of the forward velocity to reach the target were 8.5 cm/s and 0.15 cm/s, respectively. The value of standard deviation data was smaller while applying fuzzy approach, which shows the mobile robot move toward the target with stable target navigation. The smaller average value shows that the fuzzy technique as a controller took a longer time to do a decision of navigating the mobile robot.

Table III
Navigation data before applying fuzzy algorithmic approach

Trial	V_L (cm/s)	V_R (cm/s)	$V_{F(R,L)}$ (cm/s)
#1	14.8	12.9	10.54
#2	14.3	12.5	10.23
#3	14.5	12.5	10.24
#4	13.8	12.0	9.89
#5	13.8	12.0	9.85
#6	13.9	11.9	9.77
#7	13.9	12.1	9.89
#8	15.1	12.9	10.70
#9	14.8	12.7	10.45
#10	14.7	12.7	10.39

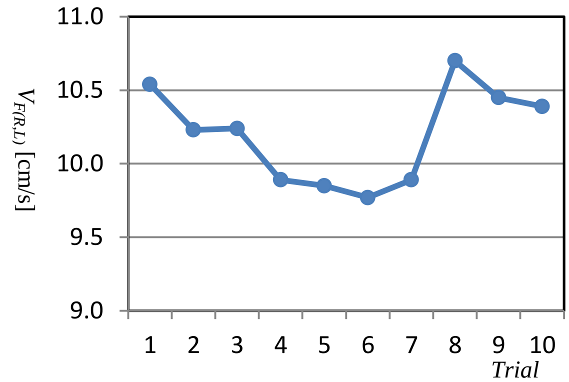

Fig. 8. $V_{F(R,L)}$ before applying fuzzy approach

Table IV
Navigation data after applying fuzzy algorithmic approach

Trial	V_L (cm/s)	V_R (cm/s)	$V_{F(R,L)}$ (cm/s)
#1	11.1	10.9	8.4
#2	11.2	10.9	8.5
#3	10.7	10.6	8.2
#4	10.9	10.9	8.4
#5	11.2	11.1	8.6
#6	11.2	11.1	8.6
#7	10.9	10.9	8.3
#8	10.9	11.0	8.5
#9	11.4	11.1	8.7
#10	11.2	11.2	8.6

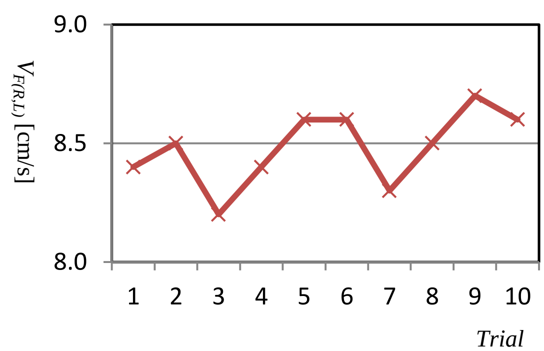

Fig. 9. $V_{F(R,L)}$ after applying fuzzy approach

V. CONCLUSIONS

The research works propose the use of fuzzy technique to navigate the mobile robot with the stable target navigation. In the preliminary experiments, several navigation experiments are conducted to acquire random data for the purpose of designing the fuzzy MFs. While navigating the mobile robot, the main controller does the decision based on the probability value outputted from the MFs. On the other hand, the main system does the decision based on the previous experiences of navigating mobile robot. The experimental studies are conducted to compare the forward velocity before and after applying fuzzy approach. The result shows that by applying fuzzy approach the mobile robot moves toward the target with the stable target navigation. In the future, other parameters derived from the mobile robot kinematic model could be employed as the variable to design the MFs.

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