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Fuzzy Logic Control Design for Leader-Follower Method Using Zigbee Communication Module

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Abstract

Technology nowadays is developed rapidly. One of technology development is mobile robot that can addopt behaviour of the living creature like swarm insect. There are several kinds of form and task can be done by mobile robot, one of them is leader follower. Leader follower is the concept of position changing to tracking formation from leader robot. Position changing movement of two robots are used Xbee series1 communication module that functionalized as a end device (for leader robot and follower robot), router (Xbee map 1 and 3), and coordinator (Arduino Mega). Besides, mobile robot also need control sistem to determine of position changing. Control system being use fuzzy logic control which used two input like distance and angel and output like right and left PWM. The implementaion of control mobile robot is begin with the followers position is fixed straight to the line, turn left, and turn right. The test that has been done shows position error $X_{straight}$ = 1%, Xt_{right} = 2%, and X_{left} = 3%. It because turning the velocity of mobile robot faster than CMPS10 measurement.

Keywords: mobile robot, leader follower, fuzzy logic control, xbee module

1. Introduction

Technology of robotic nowadays is developed rapidly. It is proved by looking for their recent application on adapting human activity. The latest developments of robotic are mobile robot leader-follower. The development of robot simulation by using leader-follower method is expected to be realized in daily life such as unman vehicle, disaster robot, and other application [1].

Leader-follower concept is a new approach to multi robot coordination system that connects of human being like colonies of insect (ants and bees). Leader Follower method that make the robot follower follow the leader robot with distances and angles that relatively constant, so the overall geometric formations unchanged. The advantage of this concept in robotic research is improvement of search capabilities in dynamic range [2-3]. Leader-follower that inspired by swarm robot is implemented in the form of a straight formations behind the leader robot. Varoius type of formation can be implemented on mobile robot depend on the exploration area [4]. Thererfore, in the movement for the formation is not using GPS as device that determining the position, but using wireless communication module Zigbee. Zigbee communication module is the one of transceiver modules are designed with the standard of Zigbee/IEEE 802.15.4 using radio frequency. It cause mobile robot is not operated outdoor but indoor, so mobile robot using Zigbee communication module. Hence from this case, using ultrasonic sensors and compass is one of several choise that can implemented on mobile robot. But, measuring distance between robot using ultrasonic sensor, there is limitation, to measure the distance because the usage of ultrasonic is only up to 5 metres [5-6].

Another research about leader-follower formation is using infrared as a distance sensor. The usage of infrared sensor is limitation to measure distance over 30 cm. Therefore, in this research will be used ultrasonic sensor (HCSR 04) to measure the distance and compass sensor (CMPS10) to measure the different angle between leader and follower robot. Position of leader and follower using trigonometri method can be found after robot get the distance and angle from HCSR04 and CMPS10 [7-8]. Besides, design and implementation of leader-follower concept, mobile robot need an obvious control system. Without obvious direction and modeling system, robot will difficult to control. Hence, it is needed control system that able to resolve the issue. Fuzzy logic control is the intellegent control that can control robot movement. In this paper, fuzzy logic control is not embedded in the robot but located in ground station. Fuzzy logic is used on the implementation of mobile robot system serves as a controller which determines the position of leader and follower and PWM rotation of the DC motor .So, in this case Zigbee is used to transmit and receive data from mobile robot [9].

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2. Experiment

2.1 Mobile Robot System

System that has been implented can avoid the position between leader and follower. Follower which has goal to measure off parameters that related with leader's movement is equipped with compass sensor and HC SR04 sensor. Both leader and follower robot also equipped with wireless communication nodes to communicate with ground station. Schematic diagram of the overall system on leader follower robot shown on Fig. 1.

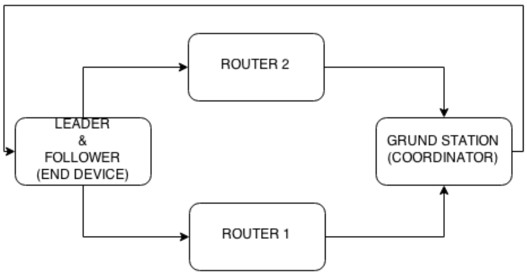

Fig. 1. Schematic diagram of overall system on leader-follower robot

2.2 Design and Realization of Fuzzy Logic Control

Fuzzy logic works based on linguistic rules are made to look like an expert operator in the control process. Fuzzy logic are used in design and implementation of mobile robot system on leader-follower method function as a controller which determines the distance and angle of leader and follower with the direction of rotation PWM from DC motor's. Stages flowchart of design fuzzy logic is shown on Fig. 2.

Fuzzy logic is designed in system uses two inputs, namely distance value and angles detected by HCSR04 sensor and CMPS10 sensor and two outputs, namely right PWm and left PWM. Flowchart of Fig. 2 can be described as follows :

2.2.1 Fuzzification

Fuzzification is a process for converting an input from crips set become a fuzzy set (linguitic variables) normally used in the fuzzy set with a membership function. In this paper, fuzzification designed using two inputs in the form if distance and angle with the output are right PWM and left PWM. Fig. 3, 4, and 5 are membership function of input and output design fuzzy logic system.

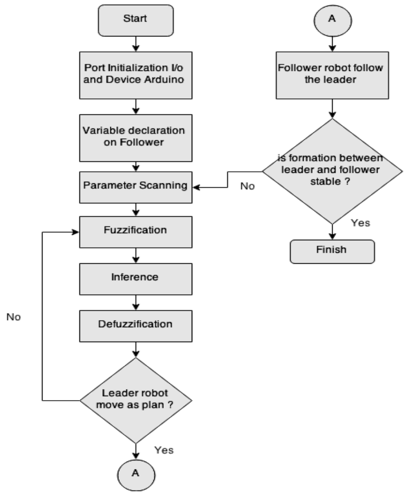

Fig. 2. Design flowchart of fuzzy logic

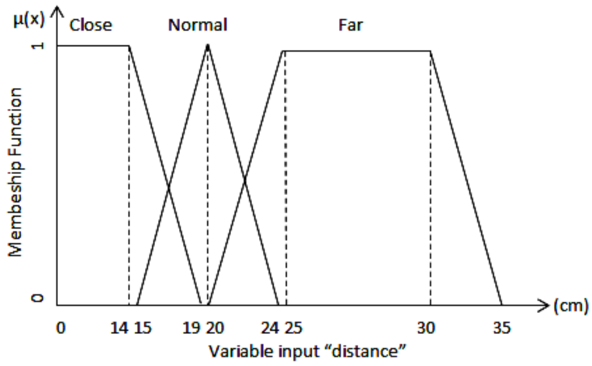

Fig. 3. Membership function of distance

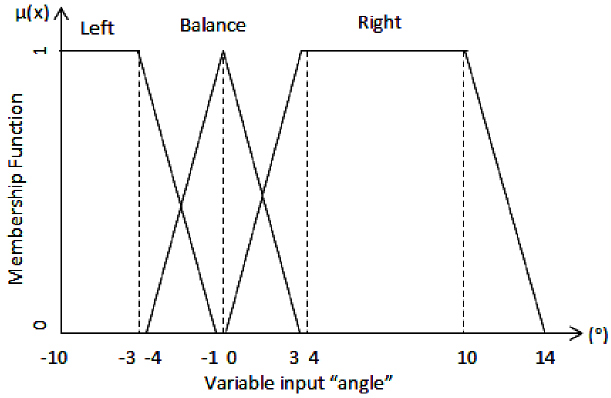

Fig. 4. Membership function of angles

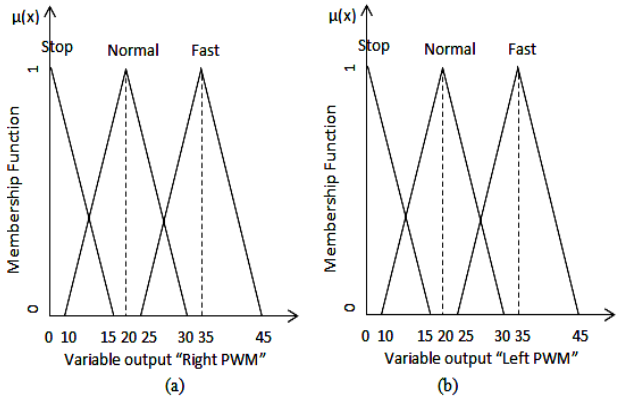

Fig. 5 Membership function of a) right PWM and b) left PWM

2.2.2 Rule Base

Rule base is the membership function mapping input to output membership function. This mapping requires a rule that indicates where the output membership function if value of the input and the other which is located at specific value. Table 1 is design rules of fuzzy logic system.

Table 1
Fuzzy rules

Angles / Distance	Left	Balance	Right
Close	Right : stop Left : stop	Right : stop Left : stop	Right : stop Left : stop
Normal	Right : stop Left: normal	Right: normal Left : normal	Right:normal Left : stop
Far	Right:normal Left : fast	Right : fast Left : fast	Right : fast Left: normal

2.2.3 Decision-making logic

In this section,consider system input value to determine the output value as a forms of decision-making. System consists of some rules, that conclusions are obtain from swarm and correlation of the rules. There are three methods used in performing fuzzy inference system. They are mas, additive, and probabilistic OR.

In max method, solution fuzzy set obtained by taking the maximum value rule, then use it to modify the fuzzy area, and apply it to output by using OR operator (union) [10]. Generally can be writtern as follows :

$$\mu_{a \cup b}(x) = \max \{\mu_a(x,)\ \mu_b(x)\} \quad (1)$$

with : $\mu_{a \cup b}$ = union of membership function
μ_a = membership function A
μ_b = membership function B

Decision of table 1 can be described as follows :

- If angle left and distance close, then right PWM stop and left PWM stop.
- If angle balance and distance close, then right PWM stop and left PWM stop.
- If angle right and distance close, then right PWM stop and left PWM stop.
- If angle left and distance normal, then right PWM stop and left PWM normal.
- If angle balance and distance normal, then right PWM normal and left PWM normal.
- If angle right and distance normal, then right PWM normal and left PWM stop.
- If angle left and distance far, then right PWM normal and left PWM fast.
- If angle balance and distance far, then right PWM fast and left PWM fast.
- If angle right and distance far, then right PWM fast and left PWM normal.

2.2.4 Defuzzification

Defuzzification is the opposite of fuzzification, which is the mapping of fuzzy sets to crips output. Input of defuzzification process is a fuzzy set obtained from composition of fuzzy rules. In this paper, fuzzy logic is designed by using mamdani method with calculation output value using centroid method. The results of defuzzification is the output of fuzzy logic control system.

Defuzzfication described as [10]:

$$y* = \frac{\int y\,\mu(y)\,dy}{\int \mu(y)dy} \rightarrow y* = \frac{\sum y\,\mu(y)}{\sum \mu(y)} \quad (2)$$

With : y = result of fuzzy logic
y* = output fuzzy logic control
μ(y) = membership function

2.4 Design of Communication System

In this paper using 5 Xbee communication module for communication process, which two modules placed on each mobile robot., two other modules are connected directly in the corner which is used data receiver and link to two of mobile robot, and one module as a coordinator.

Communication system is designed in two-way communication, however inter-leader robot and follower robot do not communicate directly but through a station ground (coordinator). Design communication shown on Fig. 6.

3. Results and discussion

3.1 Implementation of fuzzy logic control

By designing fuzzification and rule base in fuzzy logic control system will be obtained defuzzifition output current that will be used to drive the dc motor actuator. The movement of robot is done by straight lines that effect to the difference of distance and angles value between leader robot and follower robot.

Overall testing system of the robot leader and follower leader do as much as three times that at the initial position follower are straight, tilted to the right, and tilted to the left. Fig. 7(a) and (b) shown plotting result of movement leader robot and follower robot at the initial position straight and tilted to the left.

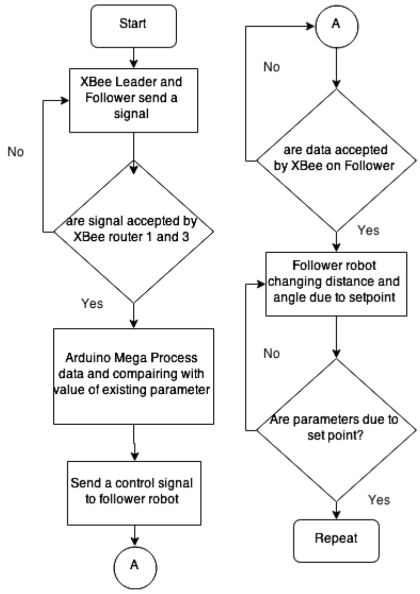

Fig. 6. Communication system of leader-follower

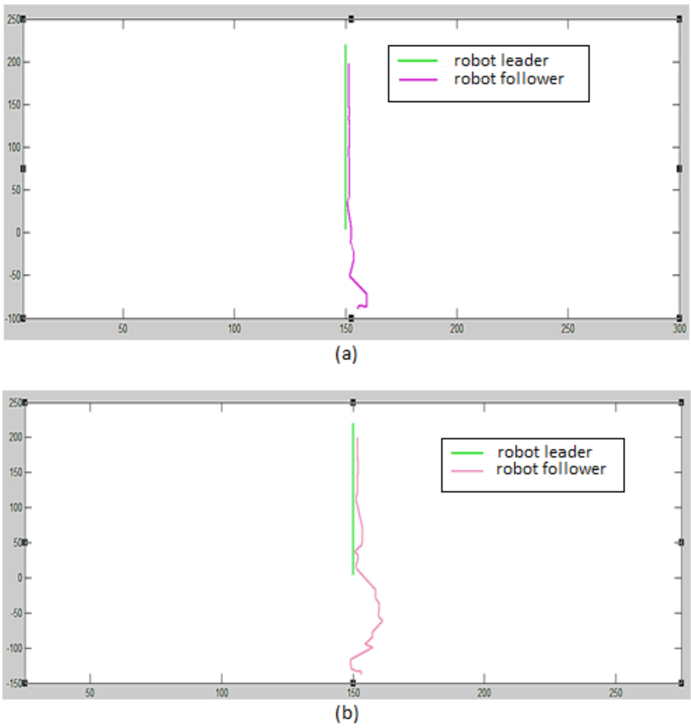

Fig. 7. Plotting position of leader and follower at the initial position (a) straight, (b) tilted to the left

In Fig. 7 (a) it can be seen that follower robot can follow the position of the leader robot. However, follower robot moving a little longer due to fuzzy control which occurs in ground station must be corrected each of rule base. So that when leader robot has to move, the follower robot is still waiting for a response that is appropriate to control the movement of the robot follow the leader. This is caused by changes in robot movement faster than changes the measured by CMPS10 so that value of trigonometric calculations determine the position of the follower also changed, besides program delay between leader robot and follower robot quite a long involve acceptance and delivery follower communication signals sometimes crash.

As well as at the initial position straight, when the position follower robot tilted to the right and left, follower robot can follow the position of the leader robot. When the position follower robot tilted to the left, angles of follower robot will be smaller than the angles of the robot leader resulting follower robot distance measurements would be very large. As well as when the follower at the initial tilted to the right.

3.2 Test Result

The test result of data for three conditions can be seen on Fig. 8. Parameters that is measured include angle error and position (X and Y) error form robot while the resulting output is PWM.

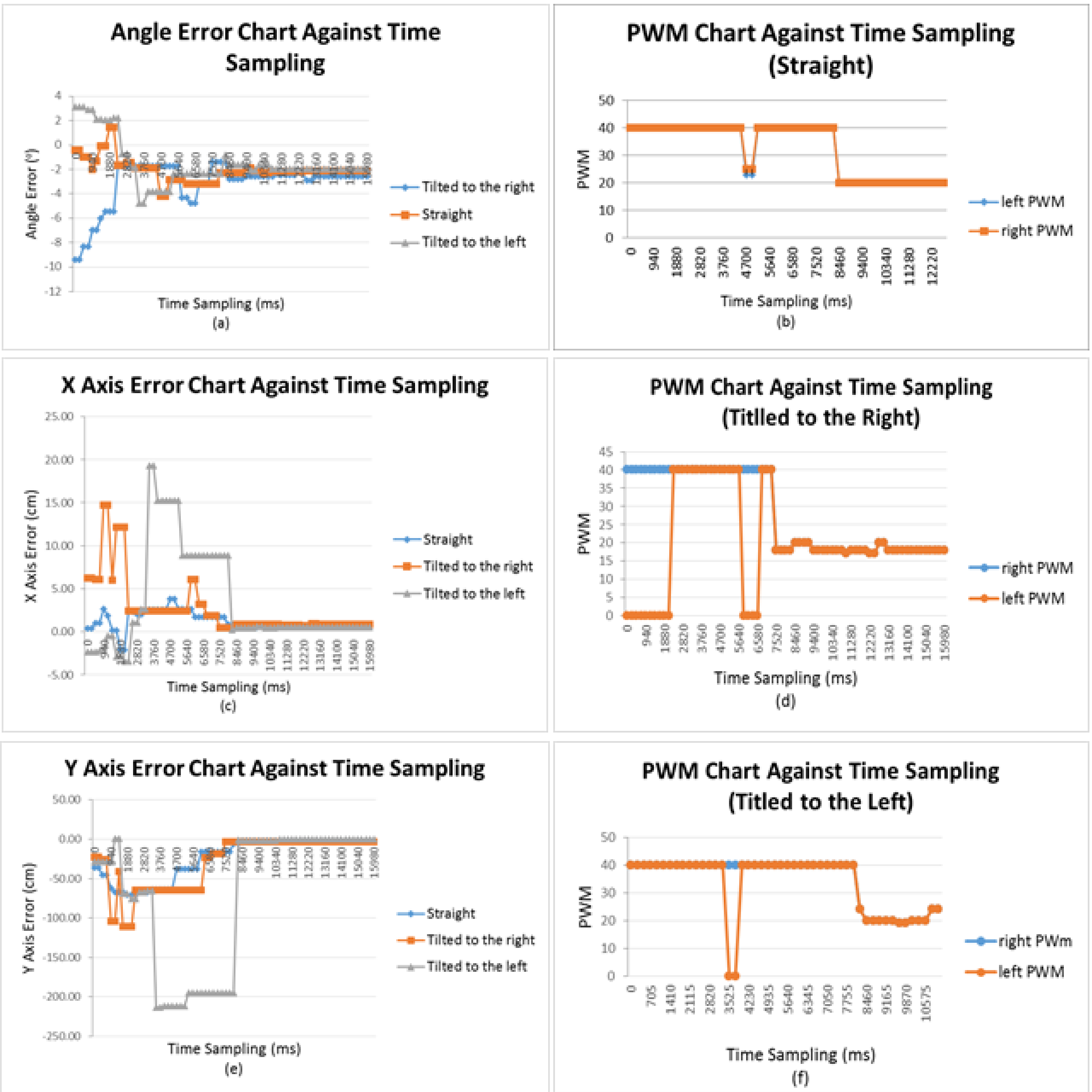

Fig. 8. System Test Result Chart

In Fig. 8 (a) it can be seen that error at the beginning position straight, tilted to the right, and tilted to the left have large error because of the angle different between leader and follower, when robot is movement, error that can be result of follower robot become smaller and be going on 0^o. It cause result of compass sensor that inconsistent at the one point and other because the influence of magnetic field on the area.

In Fig. 8 (c) it can be seen that the X position at the initial straight, tilted to the right, and tilter to the left have fluktuative error at the beginning movement and will be going on 0^o. It because at the beginning robot like whatever, follower robot will keep the formation of the leader robot. In Fig. 8 (c) can be seen that the largest error at the initial position tilted to right and tilted to the left. It because the influence of magnetic field on the area, so measuremen of compass sensor sometimes inconsistent while on the same point.

As for in Fig. 8 (e) can be seen that error of the Y position at tilted to the left has large error. It because response of follower robot has long delay, so the follower robot must checking the response to get the good response.

In Fig. 8 (b) can be seen that right PWM and left PWM are overlap, but at the time of 4700 ms – 4935 ms value of right PWM and left PWM are not same. This is because at the time of sampling the follower robot moves turned to adjust formation of leader robot.

While in Fig. 8 (d) can be seen that value of right PWM and left PWM are overlap, but at the beginning of follower movement there is a difference value right PWM and left PWM. This is because at the beginning position follower tilted at the right. So that at the beginning of follower movement, follower will adjust by moving formations turned right.

Same as at the initial position of follower robot tilted to the right, on Fig. 8 (f) can be seen that moving of robot is overlap. But when time sampling at the time 3525 ms – 3760 ms right PWM and left PWM are not the same because follower move to turned for adjust the position against leader.

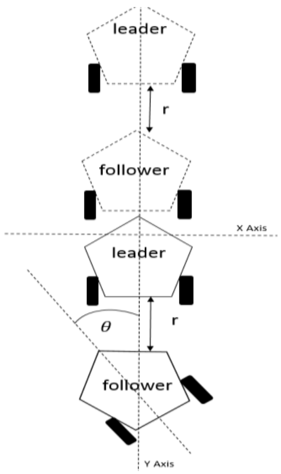

Fig. 9. Illustration movement of the robot

Result of taking data from overall testing that has been done then processed to obtain the error of the position X and Y. But the deviation from two robot can be seen from the error position X follower. The data can be shown on Table 2.

Table 2
X Axis Error

Initial Position	***Error* X**
Straight	1%
Tilted to the right	2%
Tilted to the left	3%

4. Conclusion

Implementation of fuzzy logic to the follower robot as a whole in keeping the formation of leader robot is likely to have a constant final value. At the initial position straight, control responses received well and can keeping the position. But, when the initial position robot tilted to the right and tilted to the left the responses robot received less well. This is due the control is received by the robot follower sometimes late, so sometime causing sizable error in position. Besides, range time of follower changed direction faster than changed the compass sensor measurement.

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