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AUTOMATED GUIDED VEHICLE (AGV) NAVIGATION AND LOCALIZATION USING FUZZY SYSTEM AND RFID

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Abstract

Manufactured goods distribution system is a very important part in the production chain. Delivery of goods from one point to another point affects the effectiveness of the production process. At the moment, most companies whose business are in manufacturing require automation, including distribution of goods. One application of automation in the distribution of goods is AGV (Automated Guided Vehicle). Companies need AGV that can move in complex pathways. The movement includes a selection of AGV path traversed and AGV terminal position. This research discusses the design and implementation of an AGV navigation and position information settings. AGV navigation uses fuzzy logic in its algorithm, while position setting of the AGV uses Radio Frequency Identification (RFID) to recognize the position of the robot at each terminal. From the testing result, the system obtained a success rate of 96% in movement of the robot from one terminal to another terminal using the RFID. RFID can be read at both speed of the robot i.e. 6,9 and 7,13 m/min.

Keywords: Automated Guided Vehicle; Fuzzy logic; RFID; Shortest Path

1. Introduction

In the modern era, new technology is developing rapidly in many system applications. One of an example of the system application is in industrial applications. Today, industries tend to use robot technology to help man's job. Today's industries need robot technology based on tools to support goods localization. One of example in this kind is the Automated Guided Vehicle (AGV). AGV is a vehicle that is automatically controlled by a navigation system with pattern movement control to its destination. The use of AGV will ease operators to move goods from one place to another.

There were many research done on localization and navigation. One method to do a localization in a room is to put landmarks on known places and to use sensors which are installed in the robot to sense the surroundings [1], landmarks are used as reference for robot navigation. Many landmark positions were proposed by researchers; they are on the floor, on the wall or horizontal view [2-6], and ceiling or vertical view [7,8]. Many researches chose ceiling as robot's navigation reference because ceiling landmarks have an advantage on dynamic obstacle and restructurization tolerance. Chih-Jen Wu and Wen-Hsiang Tsai uses ceiling landmark [8]. They use a picture of a circle as landmark and omnidirectional camera as recognizer. De Xu uses natural features on the ceiling [9].

Uncertainty and inaccuracy are two problems on control system. Inaccuracy in measurement could cause an error. Several techniques were done to solve the problems. Fuzzy logic have become a medium for collecting human intelligence, human experiences, and deal with control process' uncertainty [10]. Today, fuzzy logic become a popular topic on control engineering and is considered as a most simple solution to special cases by designers. Fuzzy logic's advantage to traditional solutions is that it is now possible to make "reasons" as a human being has, effectively responding to complex input to deal with linguistic language. Furthermore, fuzzy logic is suitable for low cost cheap sensors implementation. System with fuzzy logic could easily improve by adding new set of rules to intensify its performance or to add new features. Membership function and rule are two important points in fuzzy logic. Many techniques were introduced to develop those membership function and rules. J.M. Jou et al. propose Adaptive Fuzzy Logic Control [11]. The system could done an adaptive fuzzy interference process using various interference parameters, just like shape and location of membership function, dynamic, and speed.

In our proposed method, we use an RFID reader which is integrated with photodiode sensors located in the bottom of the Automatic Guided Vehicle (AGV) as landmark sensing sensors and is also integrated with RFID tags as landmarks on AGV's track. By our method, AGV can very quickly recognize the landmark. The obtained results consist of three informations: AGV's terminal name, AGV's branching points, and RFID tag's unique code data. Navigation method used by the AGV is fuzzy logic, fuzzy logic smoothens AGV's movement so that RFID scanning rate becomes higher. Avoiding obstacle is not included in this research; we only focus on track choosing, navigation and AGV localization.

2. Automatic Guided Vehicle (AGV) System

Design and implementation of the vehicle have hardware and software aspects. The system uses line sensor which has LEDs and photodiodes, all 24 sensors are installed in a circular plane.

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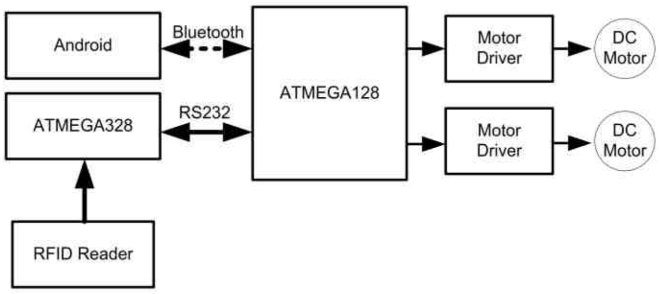

Fig 2.1. Block Diagram of AGV System

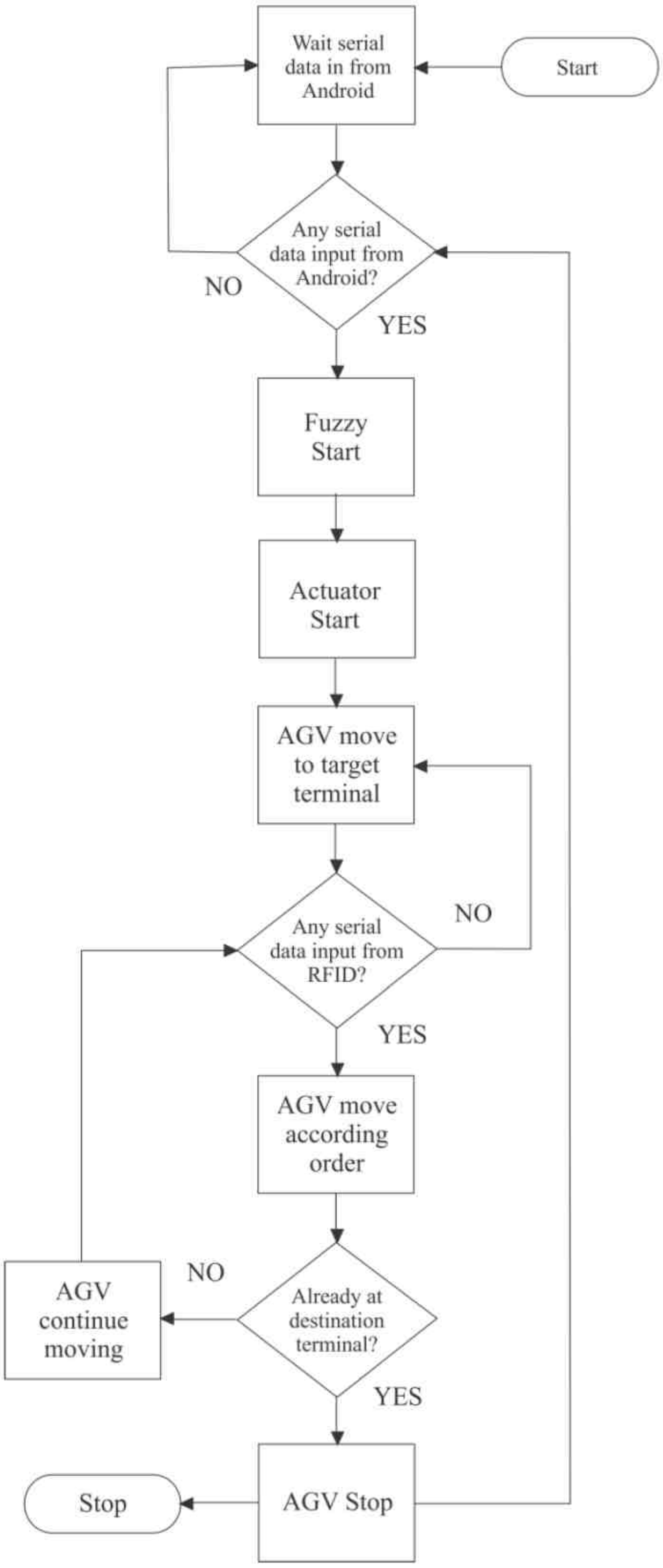

Fig 2.2. Master Minimum System Flowchart

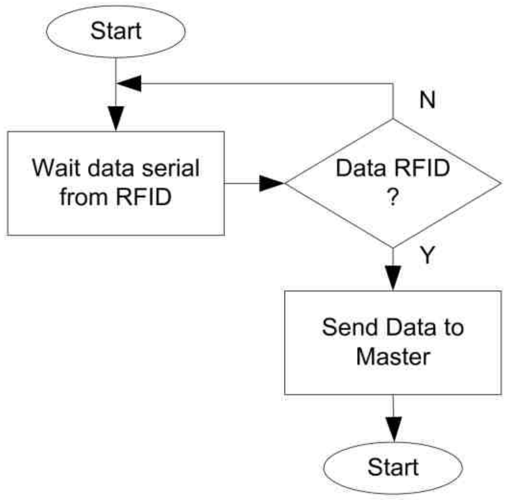

Fig 2.3. Slave Minimum System Flowchart

The robot gets the input from an Android device, and is equipped with two controllers, ATMega 328 as Slave Microcontroller to process RFID tag input and ATMega 128 as Master Microcontroller to process the data from the Slave Microcontroller sent to robot's actuator output. Fuzzy logic and shortest path finder using RFID logic are implemented in the Master Microcontroller. Communication between the microcontrollers takes place by serial communication. The outputs are two DC motor drivers which are connected to DC motor as the robot moves and steers itself. The RFID reader is implemented in the bottom of the AGV to read RFID tags that are already implemented on the track. RFID tags are used by the robot to pick a lane and to give information on robot's whereabouts.

2.1 Radio Frequency Identification

RFID system design starts by installing RFID reader on the bottom of the AGV, integrated with the photodiode sensors. RFID tags are implanted in every terminal and on track's branches. RFID tags used here are passive tags whose dimension is depicted on figure 2.5. Placing of two RFID tags on the robot track can be seen on figure 2.6. The purpose is to prevent failure in RFID tag readings. Fig 2.7 shows the RFID reader reading RFID tags in which the reader scans RFID tag when any antenna is near the center of RFID reader less than 5 cm away.

2.2 Fuzzy Logic As AGV's Movement Control

A fuzzy system, which could give complex output from a simple system, is used in AGV to get output with great accuracy. The designed Fuzzy System have two inputs, AGV's slant angle (θ) and AGV's position error to the line (ρ). The AGV's slant angle information is extracted from AGvV's line sensor. With fuzzy method, from a measured angle, the robot could be moved to a specific angle according to AGV's need. Those conditions are then translated into fuzzy system and are named

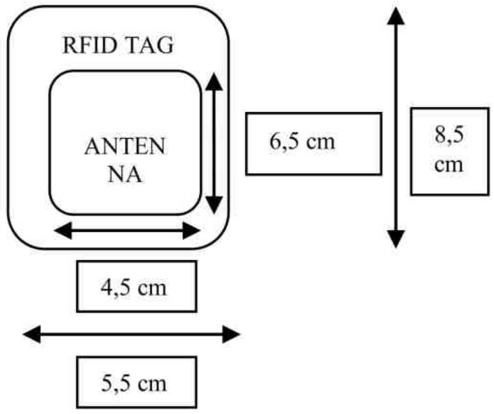

Fig 2.4. RFID tag dimension

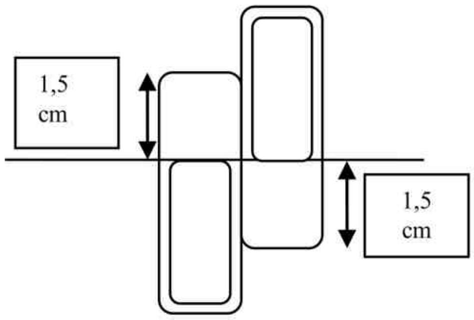

Fig 2.5. RFID tag placing

membership function. Each membership function, inputs and outputs, has different range values and those membership functions are grouped to become rules. Those rules represent every condition and show which solution is most fitted to a condition.

Hence with fuzzy system, left and right wheel speed value can be controlled to achieve a certain position according to the line on where the system is following.

In the line sensor system, there are 24 ADC inputs from line sensors. Each input of the ADC is an output of photodiode in the sensor system. Each photodiode has value from center to the right and left side. From center to right, the values of photodiode are represented by number -1 to -12. From center to left side, the values of photodiode are represented by number 1 to 12. These value are converted into 7 linguistic value, i.e. **MOST MOST LEFT (MML), MOST LEFT (ML), LEFT (L), CENTER (C), RIGHT (R), MOST RIGHT (MR), and MOST MOST RIGHT (MMR)** with trapezoid and triangular membership function. The membership functions are shown on fig 2.7.

There are two system outputs, namely the left and the right DC motor speed. The system output, which is speed, has 7 linguistic values, i.e.: **MOST_SLOW (MS), SLOWER (SR), SLOW (S), NORMAL (N), FAST (F), FASTER (FR), and MOST_FAST (MF)**.

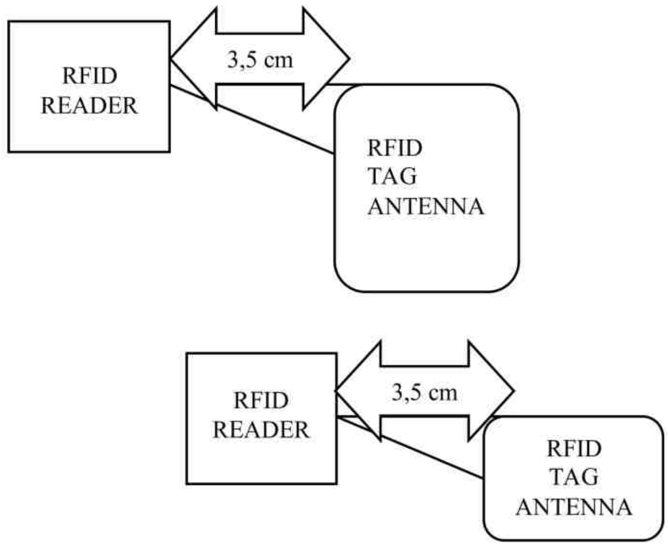

Fig 2.6. RFID reader's scan on RFID tag's antenna

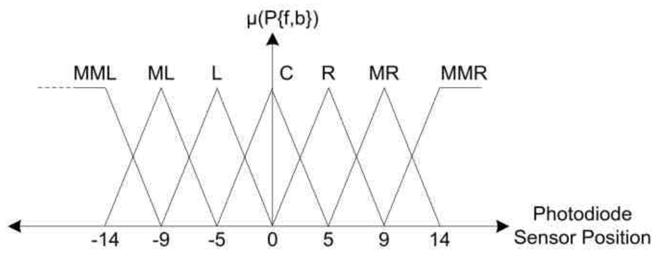

Fig 2.7. Front side and back side of line sensors membership function

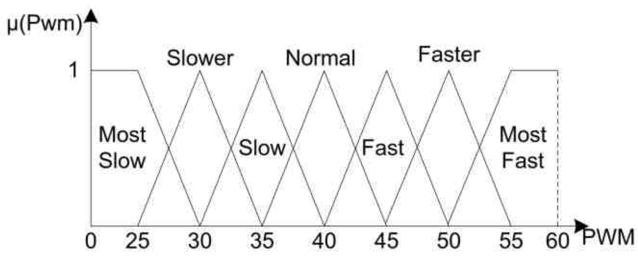

Fig 2.8. DC Motor output membership function

Table 2.1. Fuzzy rule for right motor control

	MML	ML	L	C	R	MR	MMR
MML	MS	MS	MS	MS	SR	S	N
ML	MS	MS	MS	SR	S	N	F
L	MS	MS	SR	S	N	F	FR
C	MS	SR	S	N	F	FR	MF
R	SR	S	N	F	FR	MF	MF
MR	S	N	F	FR	MF	MF	MF
MMR	N	F	FR	MF	MF	MF	MF

Table 2.2. Fuzzy rule for left motor control

	MML	ML	L	C	R	MR	MMR
MML	MF	MF	MF	MF	FR	F	N
ML	MF	MF	MF	FR	F	N	S
L	MF	MF	FR	F	N	S	SR
C	MF	FR	F	N	S	SR	MS
R	FR	F	N	S	SR	MS	MS
MR	F	N	S	SR	MS	MS	MS
MMR	N	S	SR	MS	MS	MS	MS

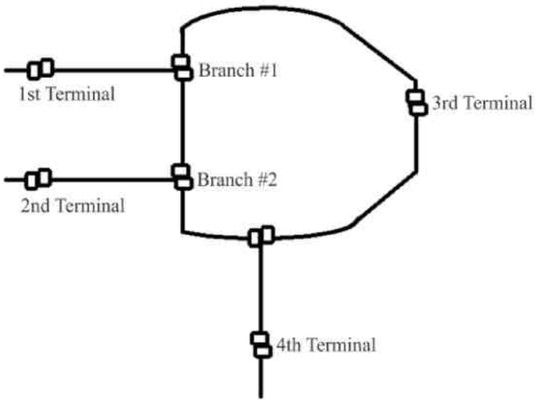

Fig 3.1. Robot track map with terminals and RFID tags locations

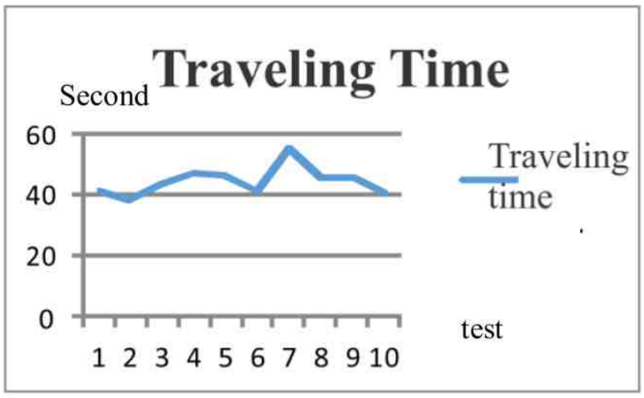

Fig 3.2. First test traveling time

The membership functions are shown in Fig. 2.8. The membership functions are connected by fuzzy rules. The rules of fuzzy system are described on table 2.1 and 2.2.

The intersection of error front sensor and error error back sensor with respective membership functions $\mu(P_f)$ and $\mu(P_b)$ is a fuzzy set $\mu(PWM)$, written as

$$\mu PWM = Min[\mu P_f, \mu P_b], \quad (1)$$

Thus the final fuzzy output in the value of pulse of speed of the right and left wheel are calculated as

$$pwmL, pwmR = \frac{\sum_{i=1}^{n}(zi.\mu i)}{\sum_{i=1}^{n}\mu i}, \quad (2)$$

where μi is the aggregated output memberships function, and zi is the output result in every rules. The pulse width modulation (PWM) output for motor DC left and right are derived from membership function shown on Fig.2.8.

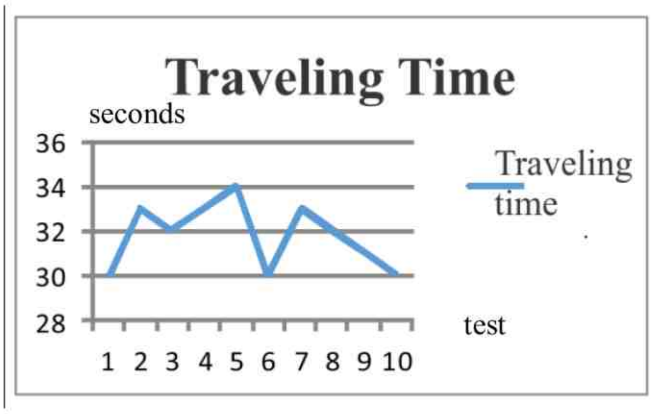

Fig 3.3. Second test travelling time

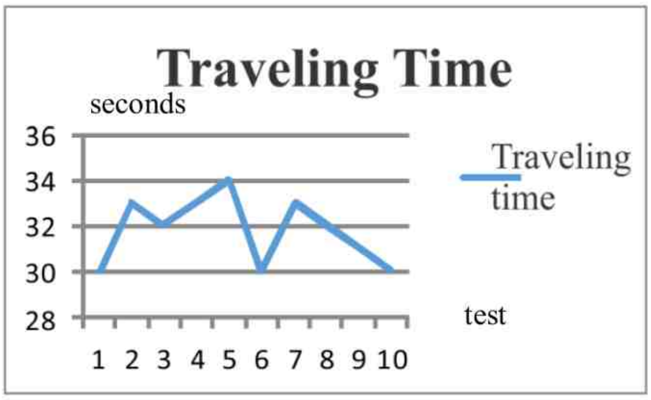

Fig 3.4. Third test travelling time

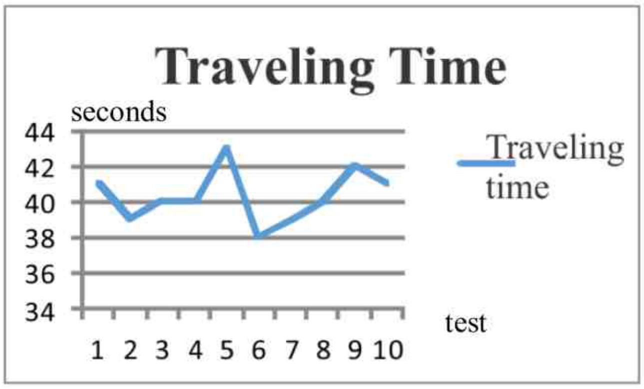

Fig 3.5. Fourth test travelling time

3. System Trial and Result

In the test, the system is a track design which consists of several terminals and branches. Figure 3.1 shows the track design consisting of 4 terminals and

3 branchings. The AGV trials are done by moving AGV from one terminal to another from various starting positions. RFID tags are installed in every terminals and branchings on the track. The test are done several times to get the system success rate. The first test is run from the 4th terminal to the 1st terminal, the second trial is run from the 4th terminal to the 2nd terminal, third test is run from 4th terminal to the 3rd terminal, fourth test is run from 3rd terminal to the 1st terminal, and fifth test is run from 4th terminal to 2nd terminal.

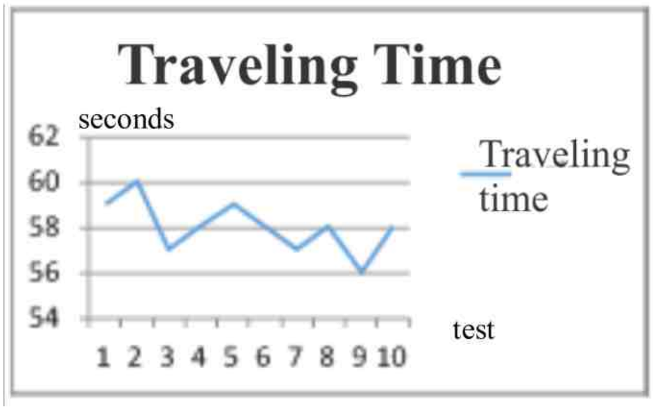

Fig 3.6. Fifth test travelling time

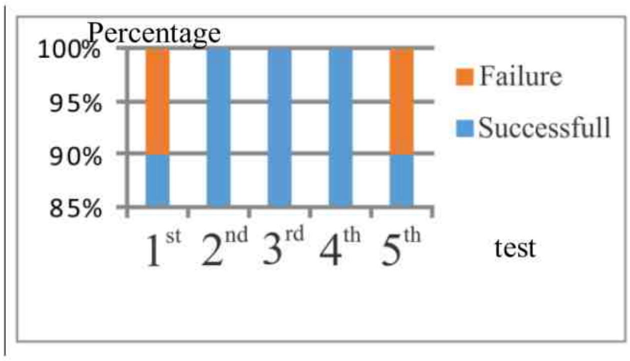

Fig 3.7. Success rate

Test result shown at Fig 3.7 shows a robot success rate of 96%. From the test from 4th terminal to 1st terminal robot's success rate is at 90% with travelling time approximately 42,9 seconds and ranging 509 cm. From the test from 4th terminal to 2nd terminal robot's success rate is at 100% with travelling time approximately 31,8 seconds and ranging 373 cm. From the test from 4th terminal to 3rd terminal robot's success rate is at 100% with time approximately 31,9 seconds and ranging 379 cm. From the test from 3rd terminal to 1st terminal robot's success rate is at 100% with travelling time approximately 40,8 seconds and ranging 475 cm. From the test from 3rd terminal to 2nd terminal robot's success rate is at 90% with travelling time approximately 57,3 seconds and ranging 668 cm.

4. CONCLUSIONS

A 6,945 m/min robot speed is gained as a result of a test from 4th terminal to the 1st terminal, 7,037 m/min from the 4th terminal to the 2nd terminal, 7,128 m/min from the 4th terminal to the 3rd terminal, 6,985 m/min from 3rd terminal to the 1st terminal, and 6,994 m/min from 3rd terminal to 2nd terminal test.

In the experiments, the fuzzy logic navigated AGV has a high accuracy and position information system using 2 RFID tags produces a very low error rate with a ranging 6,9 – 7,13 m/min speed.

Using RFID, the location information can be easily recognized, because of unik Identification number of RFID. The process of landmark recognition is faster than which used image processing [2,3]

Acknowledgments

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References

[1] I. Loevsky, I. Shimshoni, "Reliable and Efficicient Landmark Based Localization For Mobile Robot", *Robotics and Autonomous System*, Vol. 58, No. 5, 2010, pp. 520-528.

[2] Rusdinar. A, Kim. J., Lee. J., Kim. S., "Implementation of real-time positioning system using extended Kalman filter and artificial landmark on ceiling", *Journal of Mechanical Science and Technology*, vol. 26, no. 3, 2012, pp. 949-958.

[3] Wu C-J, Tsai W-H., "Location estimation for indoor autonomous vehicle navigation by omni-directional vision using circular landmark on ceiling", *Robotics and autonomous system* vol. 57, 2009, pp. 546-555.

[4] Rusdinar. A., Kim. S., "Modeling of vision based robot formation control using fuzzy logic controller and extended Kalman filter", *International Journal of Fuzzy Logic and Intelligent Systems*, vol. 12, no. 2, June 2012.

[5] Rusdinar. A., Kim. S., Vision-Based Indoor Localization Using Artificial Landmarks and Natural Features onthe Ceiling with Optical Flow and a Kalman Filter, *International Journal of Fuzzy Logic and Intelligent Systems* Vol. 13, No. 2, June 2013, pp. 133-139.

[6] Gerhard K. K., Enderlw S., "Self localization using sporadic featurs", *Robotics and Autonomous System* vol. 40, 2002, pp. 111-119.

[7] Ho C. T., Chen L. H., "A Fast Ellipse/Circle Detector Using Geometric Symmetry", *Pattern Recognation*, vol. 28, No 1, 1995, pp. 117-124.

[8] S. Panzieri, F. Pascucci, R. Setola, and G. Ulivi. "A low cost vision based localization system for mobile robots". *In proc. 9th Mediterra-nean*

ISSN: 9772477798001

conf. Control Automatic., Dubrovnik, Croatia, 2001.
[9] Xu D., Han L., Li Y. F., "Ceiling based visual position for an indoor mobile robot with monocular vision", *IEEE Transaction on Industrial Electronics*. Vol 56, No. 5, May 2009.
[10] L. A. Zadeh, "Fuzzy sets", *Information and contol*, Vol. 8, 1965, pp.338-353.
[11] D. Simon, "Sum normal optimization of fuzzy membership function", *International Journal of Uncertainty, fuzziness, and knowledge based system*, Vol. 10, No. 4, 2002, pp.363-384.

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