Navigation System for Olfactory Mobile Robot by Using Machine Vision System

Gamma Aditya Rahardi
Department of Electrical Engineering
University of Jember
Jember, Indonesia
gamma.rahardi@unej.ac.id

Khairul Anam
Department of Electrical Engineering
University of Jember
Jember, Indonesia
khairul@unej.ac.id

Ali Rizal Chaidir
Department of Electrical Engineering
University of Jember
Jember, Indonesia
ali.rizal@unej.ac.id

Devita Ayu Larasati
Department of Electrical Engineering
University of Jember
Jember, Indonesia
devita.ayularasati@unej.ac.id

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***Abstract*— Combustion of fuels to produce heat or other forms of power has been the cornerstone of industrial processes. Liquefied Petroleum Gas (LPG) is an alternative fuel, which is used primarily as a fuel in most spark-ignited internal combustion engines. Therefore, the incidence of leakage in gas cylinders needs to be considered, in order to avoid fire, poisoning, and even death to those around it. Olfactory mobile robot can be used to detect gas content. Thus, the source of the gas leak in the industry and in the storage area for LPG gas cylinders can be identified. This paper emphasizes on robot navigation by using Machine Vision System (MVS) to speed up the process of finding the exact location of the gas leak source. Several tests were carried out on several aspects. The test results on the motor drivers show that the robot can move well. While the MVS testing shows that the programming algorithm for image processing is able to recognize track borders. Then, the results on gas sensors testing show that the robot can find the source of the gas leak and can adjust it to the required robot speed. The last test, which is on the whole system, shows that the duration needed to find the source of the gas leak is in accordance with the distance from the source of the gas leak.**

Keywords*— *olfactory mobile robot; navigation system; machine vision system

I. Introduction

Robotics is a science in the field of technology which can help and replace the work of humans in completing their tasks. Nowadays, everything needs to be done effectively and efficiently. Therefore, robotics is needed to fulfill this condition. Robotics technology can be applied to many field, such as industry, medical, agricultural, and even entertainment field.

There are several robotics technologies that have been used in industry [1-3]. In this paper, an olfactory mobile robot has been designed that is able to navigate in an industrial environment that implements a combustion system with LPG. It is undeniable that the use of LPG can have a leakage accident. Olfactory mobile robot is a robot that can move freely and can detect gas content around it. Therefore, it can used to find out the source of gas leaks in industrial locations and LPG cylinders storage which can cause fire, poisoning, and even death in the surrounding environment [4].

Three things of concern in this technology are the navigation system, monitoring system, and decision makers. Navigation can be done autonomously or by following operator orders. Both of these navigation properties can be done by using MVS method. The use of MVS on a mobile robot can walk autonomously by following the path to be passed [5], and can walk by looking at the operator's gesture to determine the robot's movement [6] [7]. The advantage of MVS is can minimize the sensor system which placed on the robot to navigate.

II. Olfactory Mobile Robot Design

A. Hardware Design

Olfactory Mobile Robot is a wheeled robot that has a gas sensor. The robot is designed by placing the gas sensor on the front, consisting of 2 gas sensors and 4 hot-wires. This olfactory robot consists of 2 TGS gas sensors, 3 proximity sensors and 4 Hot-wire Anemometer sensors. The robot drive use 2 DC motors on the back and has wheels in the shape of a tank wheel as shows on Fig. 1. The motor driver circuit uses the Btn 7960 which can produce large currents with a maximum of 6A.

B. Software Design

The software is designed to recognize the terrain that will be traversed by the olfactory mobile robot. The camera takes picture of the area in front of the olfactory mobile robot. Then the image is converted into a binary image, by separating the back image from the front image. The function of the binary image is to control the olfactory mobile robot based on the detected lines.

The step to perform the background separation process is to convert the obtained image into Ycbcr image using equation (1), Ycbcr is considered to be better in character recognition than RGB images [8].

In every image is possible that there will be noise in the form of spots, to reduce the noise, the next step is to perform a median filter using equation (2). The median filter is useful for removing spots in an image [8], whereas nbor is sub image RGB and Iorig is RGB image.

The next step is segmentation. It used to separate the background from the image is to perform the thresholding process using equation (3), the threshold value is set to separate the background image from the foreground, the foreground image is represented by the pixel value in each Ycbcr parameter with a value of 255 (in white), while the pixel color of the background image is black.

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.2568 & 0.5041 & 0.0979 \\ -0.1482 & -0.291 & 0.4392 \\ 0.4392 & -0.3678 & -0.0714 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} \quad (1)$$

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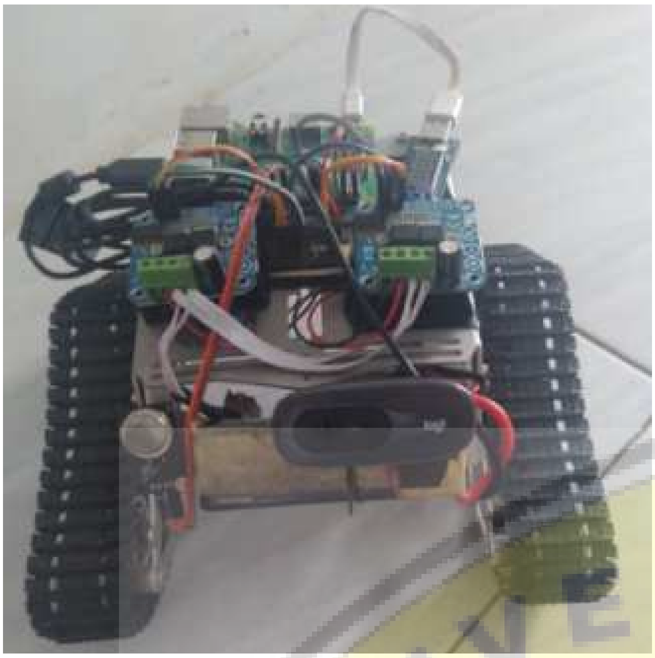


Fig. 1. Olfactory mobile robot design.

$$Y[x,y] = median(I_{orig}[i,j], i,j \in n_{bor}[x,y]) \quad (2)$$

$$G(x,y) = \begin{cases} 1 \ if \ T_y \max \ \geq Y(x,y) \geq T_y \min \ \cap \\ \quad T_{cr} \max \ \geq Y(x,y) \geq T_{cr} \min \ \cap \\ \quad T_{cb} \max \ \geq Y(x,y) \geq T_{cb} \min \\ 0 \ if \ T_y \max \ < Y(x,y) < T_y \min \ \cap \\ \quad T_{cr} \max \ < Y(x,y) < T_{cr} \min \ \cap \\ \quad T_{cb} \max \ < Y(x,y) < T_{cb} \min \end{cases} \quad (3)$$

Where G (x, y) is the binary image, Y (x, y) is the Ycrcb image, Ty max and Ty min state the maximum and minimum threshold values for the components Y, Tcr max and Tcr min state the maximum and minimum threshold values for the components cr, Tcb max and Tcb min represent the values threshold maximum and minimum cb component.

C. Fuzzification System

The integration of the fuzzy system used in the olfactory mobile robot can be seen in Fig. 2 which has 2 fuzzy inputs, namely gas sensor 1 and gas sensor 2, for the output is the movement of motor 1 and motor 2. A fuzzy input value that comes from fuzzification process is then entered into a rule that has been created to be used as a fuzzy output. The rule base can be seen in Table I.

III. Test Result

Some tests have been carried out on this work include motor drivers testing, MVS testing as robot navigation, gas sensors testing and testing of the whole system.

A. Motor Driver Testing

The test is carried out to determine the movement of the robot to the input value in the form of analog and digital values from the microcontroller. The movement of the robot is forward, backward, slide right and left, turn right and left, and stay still. Table II shows the results of the test. The table shows that the robot can perform basic movements based on the state of the digital values on Port A and PWM 1, PWM 2 Pins. When the robot rotates to the right and left, PWM 1 and PWM 2 are the same, but the values at port A are different, this is because port A is used to change the direction of rotation of the motor.

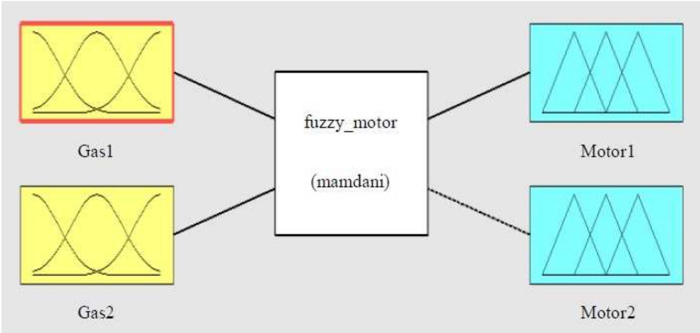


Fig. 2. Fuzzy system block diagram.

B. MVS Testing

The test is carried out using a web camera type camera or called a web cam. This camera is used to take image information of the robot's navigation path, the image used for robot navigation. This test uses a white paper that has two black lines. The results of the test can be seen in Table III.

Table III shows that the algorithm that has been made is able to recognize the robot's navigation line. This is marked with a yellow area. The yellow area is an area that will be used by the robot to determine the robot's movement. The movement of the robot is determined based on the values of Pka and Pki, in the table it can be seen that when the image appears to have the same area of yellow on the right and left sides of the center column (light blue line) then Pka and Pki have a value of 50. If one area is yellow looks less than others, for example in the second image in Table II has a value of Pka = 125 and Pki = 9. This shows the algorithm that has been made allows it to be used as an identifier for the robot navigation line and the Pka and Pki values can be used as parameters to determine the speed of the robot's drive. The Pka value is used to determine the speed of the robot's left wheel, while the Pki value is used to determine the speed of the robot's right wheel.

TABLE I. Fuzzy System Rule Base

Gas 1	Gas 2	M_{ka}	M_{ki}
Low	Low	Slow	Slow
Low	Medium	Medium	Slow
Low	High	Medium	Slow
Medium	Low	Slow	Medium
Medium	Medium	Medium	Medium
Medium	High	Medium	Slow
High	Low	Slow	Medium
High	Medium	Slow	Medium
High	High	Fast	Fast

TABLE II. ROBOT MOVEMENT TESTING

Port A (Hex)	PWM		Robot Movement
	PWM1	*PWM2*	
0x0C	200	200	Forward
0x03	200	200	Reverse
0x86	50	50	Turn right
0x29	80	80	Turn left
0x26	80	80	Spin right
0x89	80	80	Spin left
0x00	0	0	Stuck/ brake

C. Gas Sensor Testing

The next test of the olfactory mobile robot is to add a fuzzy method to the system to regulate the motor speed. The motor speed is set based on the concentration level of the gas sensor obtained. In the olfactory mobile robot the use of a fuzzy system to facilitate the movement of the robot in detecting the source of gas leaks. The fuzzy method used has 2 gas sensor inputs and 2 PWM outputs in the room using an LPG gas source.

The results of the previously designed fuzzy will be calculated and displayed on the monitor. In Table IV, it can be seen the results of the fuzzy calculations used. The closer the gas source is, the gas sensor will detect low and the motor speed will also be slow, otherwise if the gas sensor detects high then the motor speed will be fast. So that the fuzzy design made is in accordance with the program algorithm.

D. Whole System Testing

The next test is to combine a web camera on an olfactory mobile robot. The use of web cameras is intended to assist navigation in finding sources of gas leaks based on paths that have been demarcated.

This test is carried out indoors by providing a source of carbon monoxide gas. The test is carried out with different gas source distances. The test also combines the location of the gas source where the wind source is located at an angle of 0º from the robot and the location of the gas source is at an angle of -60º from the robot. The test results are presented in Table V. When the robot is given a distance of 3, 6, 0 and 15 meters from each gas source, the duration needed to reach it is 27, 36, 45, and 65 seconds, respectively. This shows that the distance from the gas source affects the duration to reach the gas source.

IV. CONCLUSION

Olfactory Mobile Robot using MVS navigation has been able to detect the path boundaries that are traversed. The motor driver used for the movement of the olfactory mobile robot works well. The programming algorithm for image processing is able to recognize track borders. Testing the gas sensor on the motor rotation according to the algorithm that has been made. Olfactory mobile robot has been able to find the source of the gas leak with a duration that is adjusted to the distance. If the distance from the gas source is getting further away, the duration needed is also getting longer.

TABLE III. LINE DETECTION ALGORITHM TESTING FOR ROBOT NAVIGATION

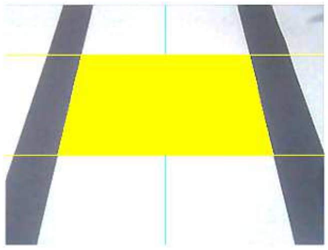
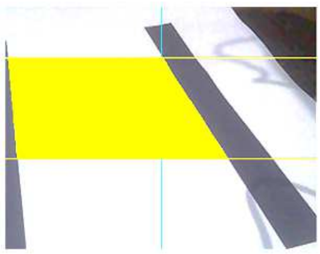
Image	P_{ka}	P_{ki}
	50	50
	125	9
	34	87
	71	74
	137	2
	2	135

TABLE IV. FUZZY CALCULATION RESULTS ON ARDUINO

Gas1	Gas2	Motor1 (PWM)	Motor2 (PWM)
25	15	200	200
25	112	225	200
151	112	217	235
13	10	200	200
107	175	218	218
100	100	225	209
95	73	207	209
177	27	200	225
177	182	218	218

TABLE V. WHOLE SYSTEM TESTING RESULTS

Gas source distance (m)	Duration (s)
3	27
6	36
10	45
15	65

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