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Finger Cue for Mobile Robot Motion Control

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ABSTRACT

The current technology enables automation using a robot to help or substitute humans in industry and domestic applications. This robot invasion to human life emerges a new requirement to set a method of communication between a human and a robot. One of the oldest languages is a finger gesture that can be easily implemented as an interface to communicate with the robot. This interface is made possible by implementing image detection that connected to the actuators of the robot to respond to human orders. This paper presents a method to navigate robots based on human fingers cue, including "Forward," "Backward," "Turn right," "Turn left," and "Stop" to generate the forward, backward, turn right, turn left, and stop motion. The finger detection is facilitated by a camera module (NFR2401L) with the image plane of 640 ×480 and 30 fps speed. If the fingers are detected in coordinates x<43 and y<100, the robot moves forward, in x<29 and y<100-coordinates, the robot turns left, and in x<19 and y<100-coordinates, the robot turns right. The experiment was conducted to show the effectiveness of the proposed method, and to some extent, the robot can follow human cues to navigate its assigned location.

Keywords: Finger Cues, Human-robot Communication, HSV, Image Processing, Thresholding.

1. INTRODUCTION

The current technology has enabled humans to live side by side with robots; therefore, it is crucial humans communicate with the robot directly, creating a new society where robot becomes the integrated part of human life [1]-[5]. The first application of robots is in industry, and it has substitute humans in some manufacture lines, such as robots equipped with arm substitute humans in picking and placing objects. The other crucial application of robots in industry and domestic is as a transport robot. The transport robot can be an autonomous robot where a system substitutes the driver [6].

An autonomous transport robot can be more effective if it can find a way to communicate to a human directly to accomplish its task without crashing into any objects. The simple hand gesture is enough to create a cue for robot motion [7]-[17]. Mobile robot navigation is a process of planning and controlling a robot from one place to another, and the right cue might ease this navigation process [15]-[17].

The visual cue is made possible by the increase of camera technology, which is not only getting cheaper but also getting smaller that more accessible to installing anywhere. The application of fisheyes and an omnidirectional camera can make a more comprehensive view for detecting any necessary object or target. However, camera application comes with a challenge, and it requires a particular computational time that needs a certain graphic board specification [18]. The currently available microcontroller in the market cannot provide this technical specification.

The researcher has to find a way to zip the image processing into the limited memory capacity of a microcontroller. One of the ways to address this problem is by designing a simple image processing just enough to detect the necessary features of an object [19]. Even though stereo vision is more reliable in detecting an object and deciding the distance it, it is still cannot be accommodated.

This paper presents a finger cue to navigate a mobile robot acting as a transport robot in the industry. The image processing in this paper is made simple but effective enough to recognize visual cue indicated by hand signals. The finger cue in this study is generated by a bare hand without using any gloves, sensors, and other devices such as in [20][21]. The robot is expected to communicate with the human through these simple cues, including "thumbs up," "clench fist," "no," "right," and "left." The effectiveness of the proposed method is proven by moving the robot using the signals. The objective of this study is to initiate an automatic transport system project by giving the robot a visual cue for its navigation.

2. THE PROPOSED METHOD

This study proposed a method of controlling mobile robot motion and navigation using human hand/finger cues. This method can be applied for automatic transport or parking system, where human gives cue and robot follow the cue accordingly. The proposed method is shown in the block diagram in Figure 1, and the electrical schematic diagram is given in Figure 2 to show the electrical connection of components presented in Figure 1.

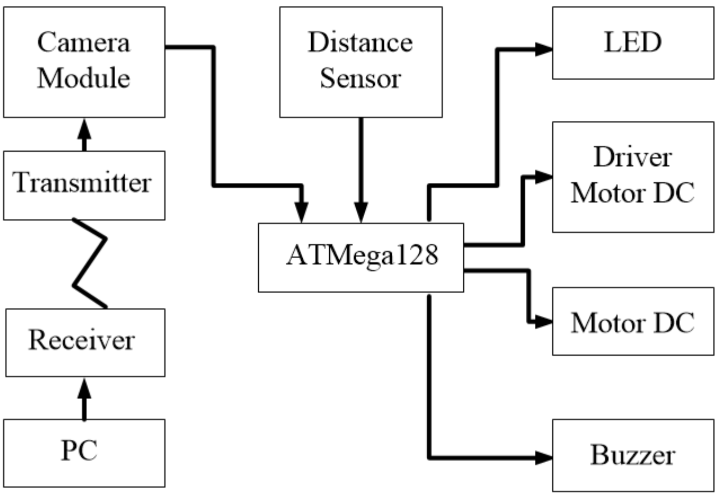

FIGURE 1. Block diagram of the proposed method.

The mobile robot considered in this study is the HBE-RoboCAR-Vision, which is the experimental mobile robot used in the Robotics Laboratory of Electronics Study Program. HBE-RoboCAR-Vision is shown in Figure 3 equipped with a built-in camera connected to the image processing module installed in a PC, as shown in Figure 1. The advantage of using this robot is that it is ready to use with editable

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software. The user can focus on robot vision without the requirement to pay attention to hardware.

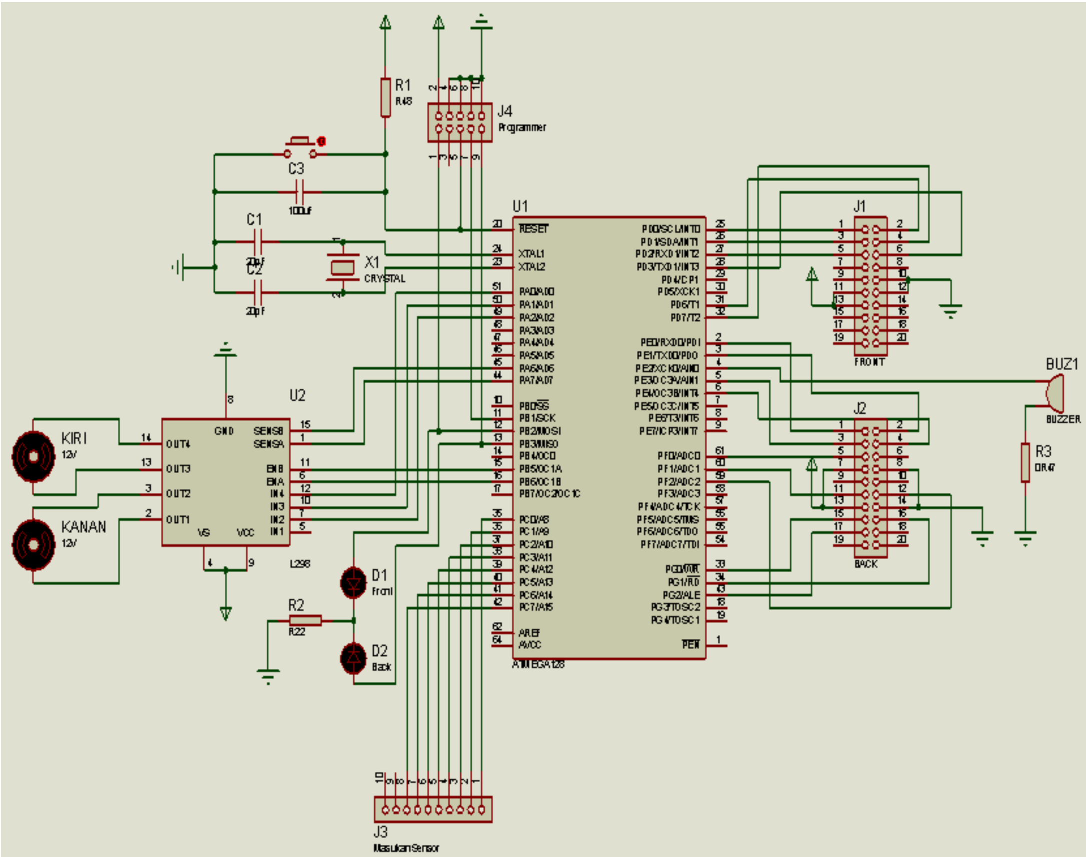
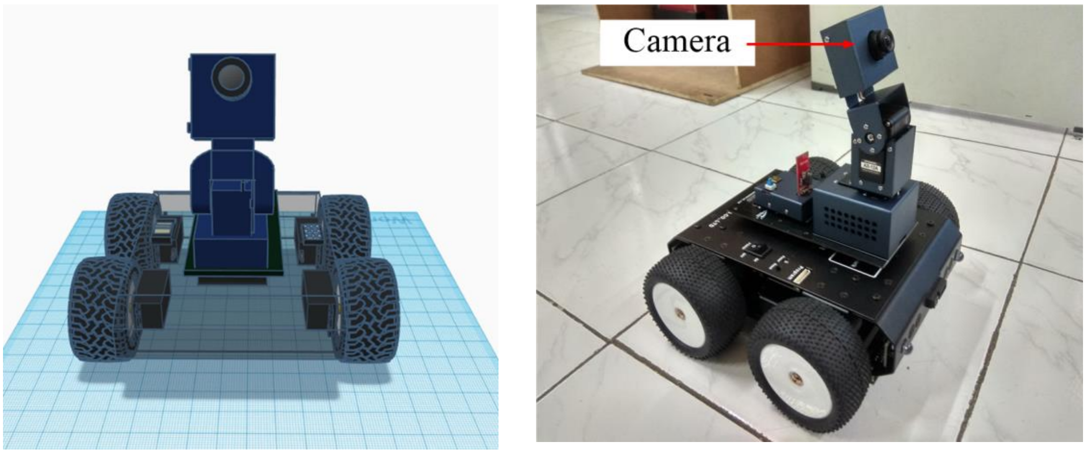


FIGURE 2. Electrical schematic diagram.



(a) Front view (b) Side view

FIGURE 3. Robot HBE-RoboCAR-Vision considered in this study.

The inputs for the system are finger shape images captured by camera online and processed to differentiate the finger shape and compared with the reference inputs given to the robot database. The captured image is processed in the PC, and the communication between the camera module and PC is conducted using the transmitter attached to the PC and receiver installed on the robot. The distance sensors are to ensure the robot knows the obstacles found during its assigned task. Microcontroller ATMega128L processes the inputs to controlled robot motion by directing the robot to be left or right. The direction is conducted by monitoring the PWMs of DC Motor.

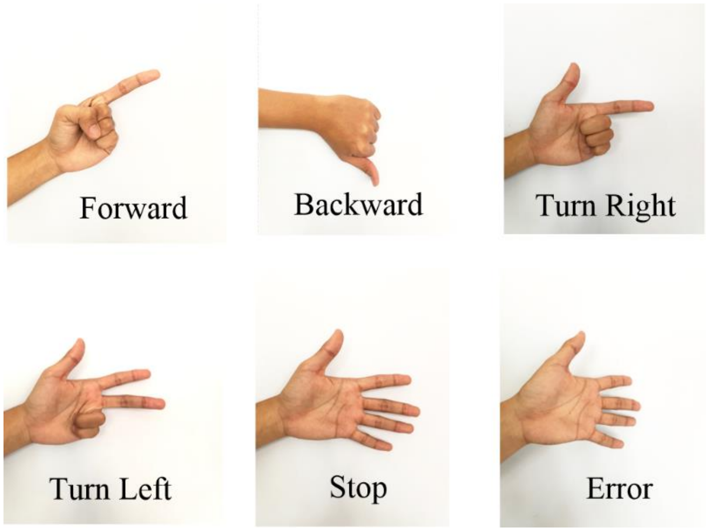


FIGURE 4. The finger cues for controlling the robot.

The image processing conducted in this study is to recognize the hand cues from a human operator, as shown in figure 4. The robot needs to know the shape of a human finger that drives the robot motion. The first step of image processing is by converting the raw image to grayscale to flatten the image and to prepare it for further processing. The next step is HSV (Hue, Saturation, Value) to detect an object based on light intensity on a particular color in the matrix of the digital image. The test was performed using six kinds of colors, i.e., brown, yellow, green, blue, black, and white. The hue, saturated, and value is achieved by:

$$H = \tan\frac{3(G-B)}{(R-G)+(R-B)} \quad (1)$$

$$S = 1 - \frac{\min(R,G,B)}{V} \quad (2)$$

$$V = \frac{R+G+B}{3} \quad (3)$$

The next step after HSV processing is the thresholding methods that replace each pixel in an image with a black pixel if the image intensity is $I_{i,j} \leq T$ where T is the fixed constant. All the image intensity with $I_{i,j} > T$ is replaced with white. Therefore, the hand is considered black, and the background is white. The result of

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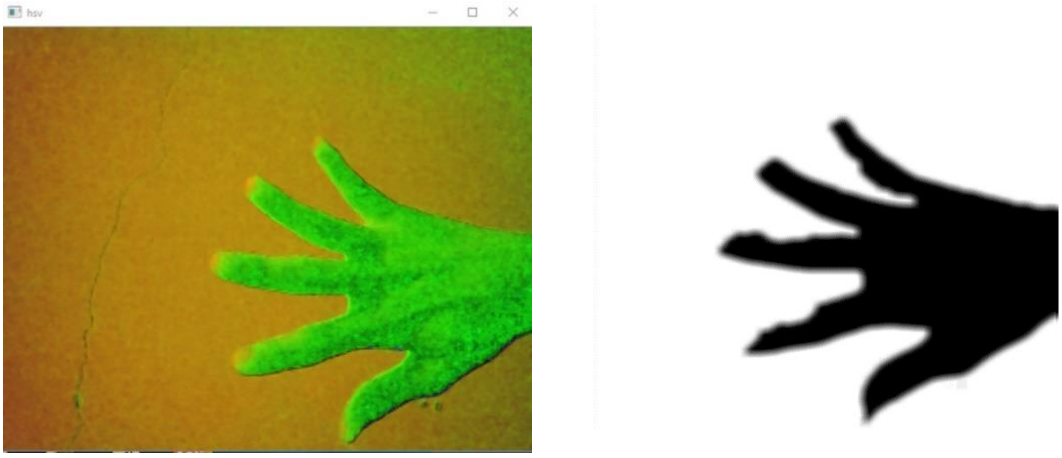
image processing is shown in Figure 5, where the HSV process is in Figure 5(a), and the thresholding process is in Figure 5(b).

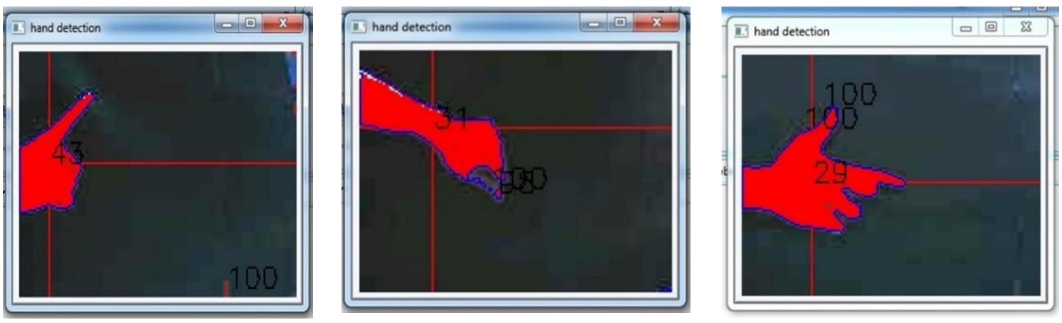


(a) HSV processed image. (b) Thresholding processed image.

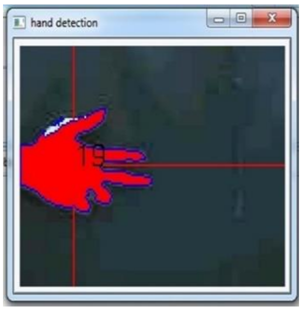
FIGURE 5. Image processing for finger detection.

3. RESULTS AND DISCUSSION

The experimental environment is set to move the robot by taking cues from the human finger. The image processing is conducted, and the results are shown in Figure 6. The cues are including "Forward", "Backward", "Turn right", "Turn left", and "Stop". The "Forward" cue is shown in Figure 6 (a) to generate the forward motion. The "Backward" cue is shown in Figure 6 (b), where the robot goes on the backward motion. The "Turn right" cue is shown in Figure 6 (c) to make the robot turn right. The "Turn left" cue is shown in Figure 6 (d) that makes the robot turns left. The stop motion is achieved by the "Stop" cue in Figure 6 (e). If the hand angle is not right, the program returns the "error" message shown in Figure 6 (f).

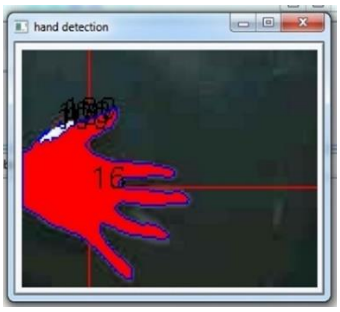


(a) Forward cue (b) Backward cue (c) Turn right cue



(d) Turn left cue

(c) Stop cue



(f) Error cue

FIGURE 6. Finger cues to drive robot motion.

The microcontroller applied in this study is ATMega 128L that communicates with a camera module (NFR2401L) to detect the shape and color of the finger cues. The considered image plane is 640×480 with 30 fps speed. The image plane size is chosen by considering the speed of image processing. The detection is classified as:

- If the figure cues are detected in coordinates $x < 43$ and $y < 100$, then the right motor is 1 (High) while the left motor is 1 (High),
- If the figure cues are detected in coordinates $x < 29$ and $y < 100$, then the right motor is 1 (High) while the left motor is 0 (Low),
- If the figure cues are detected in coordinates $x < 19$ and $y < 100$, then the right motor is 0 (Low) while the left motor is 1 (High).

The summary of the finger's x and y-coordinates axis is shown in Table 1.

(a) Forward motion

(b) Turn Left

(c) Turn right

(d) Stop

FIGURE 7. Finger cues and robot motion during experiment.

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TABLE 1.
Hand cues coordinates detection and the resulted robot motion.

Coordinates	Robot Motion	Left Motor	Right Motor
$x < 43$ and $y < 100$	Forward	1 (HIGH)	1 (HIGH)
$x < 29$ and $y < 100$	Turn right	1 (HIGH)	0 (LOW)
$x < 19$ and $y < 100$	Turn left	0 (LOW)	1 (HIGH)

Five experimental was conducted in three conditions, the first condition is only forward track, the second one includes turning right, and the third one includes turn right and turn left. The time taken to complete the tasks is shown in Table 2. The more complex track requires more time to accomplish; however, at some point, the robot can follow the cues.

TABLE 2.
Experimental duration accomplishment.

Track Condition	Time required (s)				
	1	2	3	4	5
Only forward	12.02	12.10	11.90	13.34	12.30
Including Turning Right	11.15	12.33	16.58	16.91	16.53
Including Turning right and left	25.14	23.80	14.80	18.22	16.11

The image processing to recognize finger cues are conducted online in a PC and sends in real-time to the robot; therefore, continuous communication between the robot and PC is a must. The experiment was conducted to know the maximum distance between the robot and the PC. Table 3 shows that the maximum distance is 7 meters.

TABLE 3.
Distance test between camera module on robot and PC.

Exp to	Distance (m)	Status
1	3	Connected
2	4	Connected
3	5	Connected
4	6	Connected
5	7	Connected
6	8	Not Connected
7	9	Not Connected
8	10	Not Connected

Table 4 shows the voltage and current output on the robot's motors when finger cues are applied to the robot. Four DC motors are installed on the robot, 2 motors on the left wheels, and the other two on the right. The motors are working based on the output of microcontroller ATMega 128L. Table 4 shows the voltage and current during robot motion of "forward", "turn right", "turn left", and "stop". The microcontroller rules the motion by the controller power input (voltage $\times$ current), such as when both motors are "1", then the motion is forward.

TABLE 4.
The voltage and current on the robot, measured during robot motion.

No	Left Motor		Right Motor	
	Voltage (V)	Current (mA)	Voltage (V)	Current (mA)
Forward	4.8	5.7	4.8	5.7
Turn right	0	0	5.2	6.7
Turn left	5.2	6.7	0	0
Stop	0	0	0	0

Image processing is a method that is prone to illumination. Robot sometimes fails to follow the cue when the illumination and fingers position is not in the right lighting and angle. The component value "V" in HSV is the one affected. The darker condition, the value of "V," is getting smaller, and getting bigger in brighter conditions. Figure 7 shows that, to some extent, this robot is following finger cue from the user or human. This cue is intended as an interface for a human to communicate with the robot.

4. CONCLUSION

This paper proposed a method to navigate robots based on human fingers cue, and also considered as a way to set communication between the human and a robot. The finger cues are including "Forward," "Backward," "Turn right," "Turn left," and "Stop" to generate the forward, backward, turn right, turn left, and stop motion. The finger detection is facilitated by a camera module (NFR2401L) with the image plane of 640×480 and 30 fps speed. If the figure cues is detected in coordinates $x < 43$ and $y < 100$, robot moves forward, if the figure cues is detected in coordinates $x < 29$ and $y < 100$, robot turns left, and if the figure cues is detected in coordinates $x < 19$ and $y < 100$, robot turns right. The experiment was conducted to show the effectiveness of the proposed method, and to some extent, a robot can follow human cues to navigate in its assigned location.

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