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TRAFFIC CONES DETECTION FOR AUTONOMOUS GROUND VEHICLE

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ABSTRACT

Jelajah V-18 is an autonomous vehicle prototype where can navigate autonomously using Global Positioning System (GPS) for long-distance navigation and can find out the surrounding conditions to navigate short distances using cameras and proximity sensors. The vehicle also has a system that can search and recognize a static object using an image processing system. This research focuses on the detection of an objects in the form of traffic cones using the (Hue, Saturation, Value) HSV method to recognize objects by the color, then with the binary method the image of the object will be converted back to get the edges of the object shape and contour where the system can recognize the shape of the object. Based on the implementation and experiments conducted, the robot can detect traffic cone objects with a success rate of 100 percent at a distance of 1-6 meters and 35.67 percent at a distance of 7 meters.

Keywords**:** Autonomous vehicle, Object Detection, HSV Method, Binary Method, Contour Detection.

INTRODUCTION

Autonomous cars are vehicles that are able to sense the surrounding environment and navigate without human assistance (Hussain, et al, 2018 and Reuschenbach, et al, 2011). Autonomous car consists of several tools and sensors to find out the environment, such as radar, camera, laser beam, GPS, lidar and computer vision (Liu, et al, 2019, Kim, et al, 2018, Yong, et al, 2015 and Lee, et al, 2015). All tools will be connected to a main system to control and process information from sensors to identify the right navigation path, as in one of the studies conducted by (Hartono, et al, 2020) that creates and implements an autonomous vehicle model that can navigate close-distance to avoid the surrounding objects using a proximity and switch sensor to achieve the specified several long-distance coordinates.

There are many major benefits in the implementation of an autonomous vehicle: improving traffic conditions, business opportunities and increasing revenue, ease of use and convenience, consumer-centric experience and an autonomous parking (Hussain, et al, 2018). And the most important benefit is improved safety and reduce traffic accidents especially caused by human error such as research conducted by (Nizar, et al, 2019) develop a close-range navigation system on an autonomous vehicle focused to detect and avoid collision between vehicles and humans using image processing with You only look once (YOLO) deep learning algorithm and for the human avoidance decision-making systems using fuzzy algorithms based on human position data and distance data taken using an ultrasonic sensor, in the development of autonomous cars to solve a problem arises particularly regarding safety while driving.

Objects on the road can be in the form of static objects or moving objects such as pedestrians, bicyclists or other vehicles. The ability to classify objects precisely and accurately is very important to become a source of data in the system in distinguishing types of objects, and then the distance between objects and vehicles is calculated for the decision of safe direction of movement for vehicles. In this particular study, we focused on the detection and classification of static objects in the form of traffic cones using the HSV method to recognize objects by the color, the binary method to get the edges of the object shape and contour where the system can recognize the shape of the object. For future works, we plan to implement the method and combine it with other obstacle sensors for navigating because each sensor type has inherent strengths and weaknesses. Radars are very strong at accurately determining distance and speed even in challenging weather conditions but can not read street signs or see the color of a stoplight. Cameras do very well reading signs or classifying objects, such as pedestrians, bicyclists or other vehicles. However, they can easily be blinded by dirt, sun, rain, snow or darkness. Lidars can accurately detect objects, but they don't have the range or affordability of cameras or radar (Liu, et al, 2019 and Kocic, et al, 2018).

RELATED WORKS

As previously mentioned that Jelajah V-18 is an autonomous vehicle based-prototype where can navigate autonomously using GPS for long-distance navigation according to the coordinates that have been entered and can find out the surrounding conditions to navigate short-distances using proximity sensors as made by (Hartono, et al, 2019) that creates and implements an autonomous vehicle model that can navigate close-distance to avoid the surrounding objects using a proximity and switch sensor to achieve the specified several long-distance coordinates.

With the same robot platform, (Nizar, et al, 2019) develop a close-range navigation system on an autonomous vehicle spesified and focused to detect and avoid collision between vehicles and movement object (humans) using image processing with You only look once (YOLO) deep learning algorithm and for the human avoidance decision-making systems using fuzzy algorithms based on human position data and distance data taken using an ultrasonic sensor, in the development of autonomous cars to solve a problem arises particularly regarding safety while driving.

In the actual implementation, Jelajah-V18 is given the task of finding several traffic-cones that are placed at each coordinate point as the robot's target locations. To meet this need, there are two main system parts of the robot. First is the search system part and the second is the detection system part. The search system here is a drive set system with wheels, sensor modules and components as well as a set of controllers consisting of a main microcontroller unit, a special microcontroller unit handling sensor input readings for navigation and a special microcontroller controlling motor movement. The three microcontrollers communicate with each other via a serial protocol system.

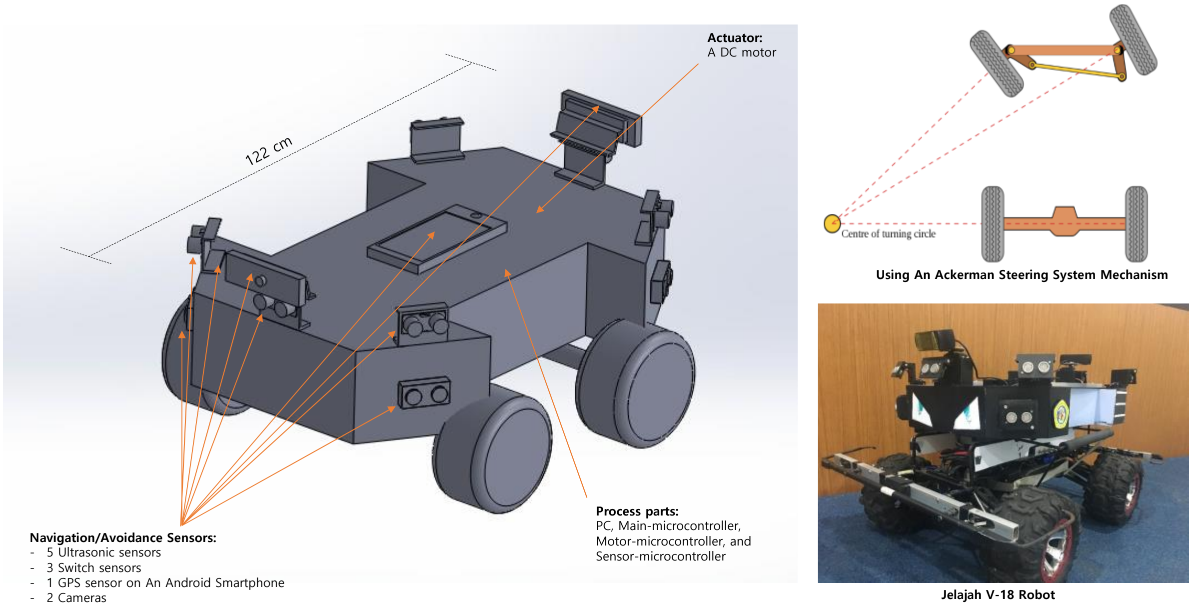

FIGURE 1. Jelajah V-18 Robot: Mobile Robot Model Design, Robot Steering System and Component Layout

The second is the hardware part of the traffic cone detection system which consists of two cameras and two servo motors along with other mechanics to rotate the camera. This study using two cameras. This is done in addition to overcoming the limitations of the camera capture area as well as to speed up and simplify the detection process without having to move the robot. A mini PC is used as a controller to process camera data in detecting traffic cones. After the traffic cone is found, the robot navigates to the traffic cone and touches it.

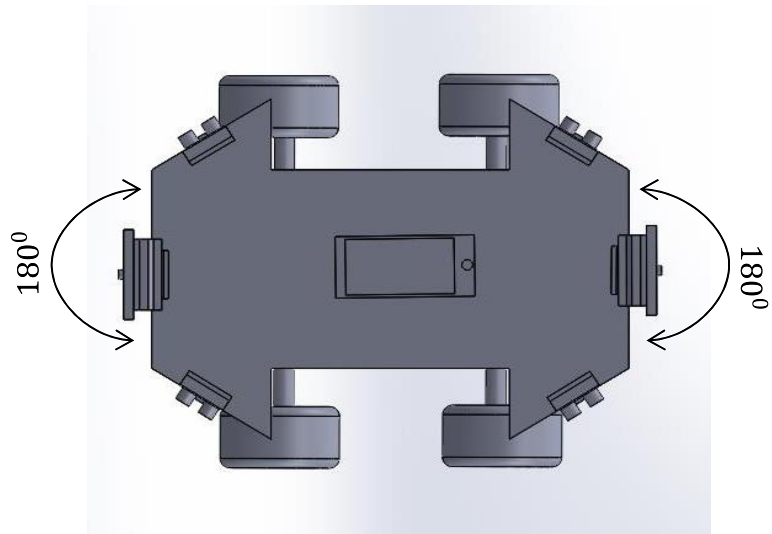

FIGURE 2. Layout Hardware and Componen of Traffic Cone Detection System on Jelajah V-18 Robot

DESIGNING A STATIC OBJECT DETECTION SYSTEM: TRAFFIC CONES

In the design of the traffic cone detection system by Jelajah V-18, there are three main constituent parts of the system, namely the input section, the processing section, and the output section. These three parts determine the system to work as desired. Figure 3 will illustrate the overall system block diagram. Each part of the system is connected and has its respective functions. The input section functions to receive input from the measured parameters, then in the process section, each parameter received will be processed and later will become an indicator for the output section. In general, the way the traffic cone detection system works is that there are two input devices, namely a camera that will take pictures of the surrounding conditions, then the images will be processed by and processed by the computer using predetermined techniques which will later be converted into certain values and sent to the microcontroller to be converted back into a value which will be executed into action by the output device.

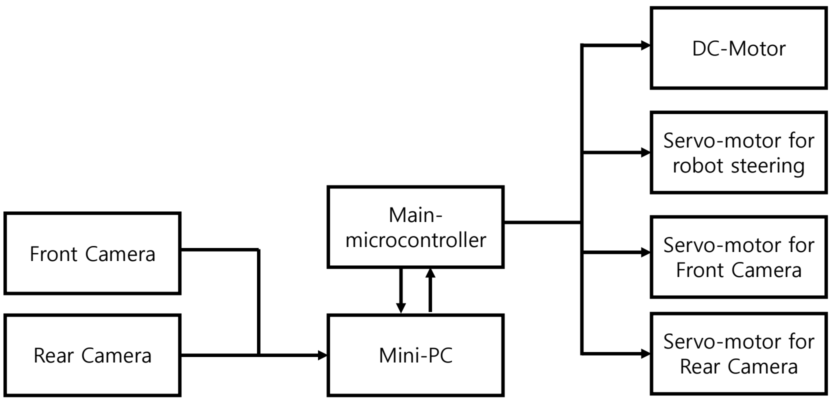

FIGURE 3. Main System Block Diagram for Traffic-cones Detection

SOFTWARE SYSTEM DESIGN

The algorithm design includes a traffic cone search algorithm that is on the microcontroller and a traffic cone detection algorithm on the personal computer. The following in Figure 4 is an algorithm on the microcontroller, this algorithm is used to detect traffic cones. Algorithms start from receiving orders from personal computers, carrying out the search process, and sending search results data to the personal computer.

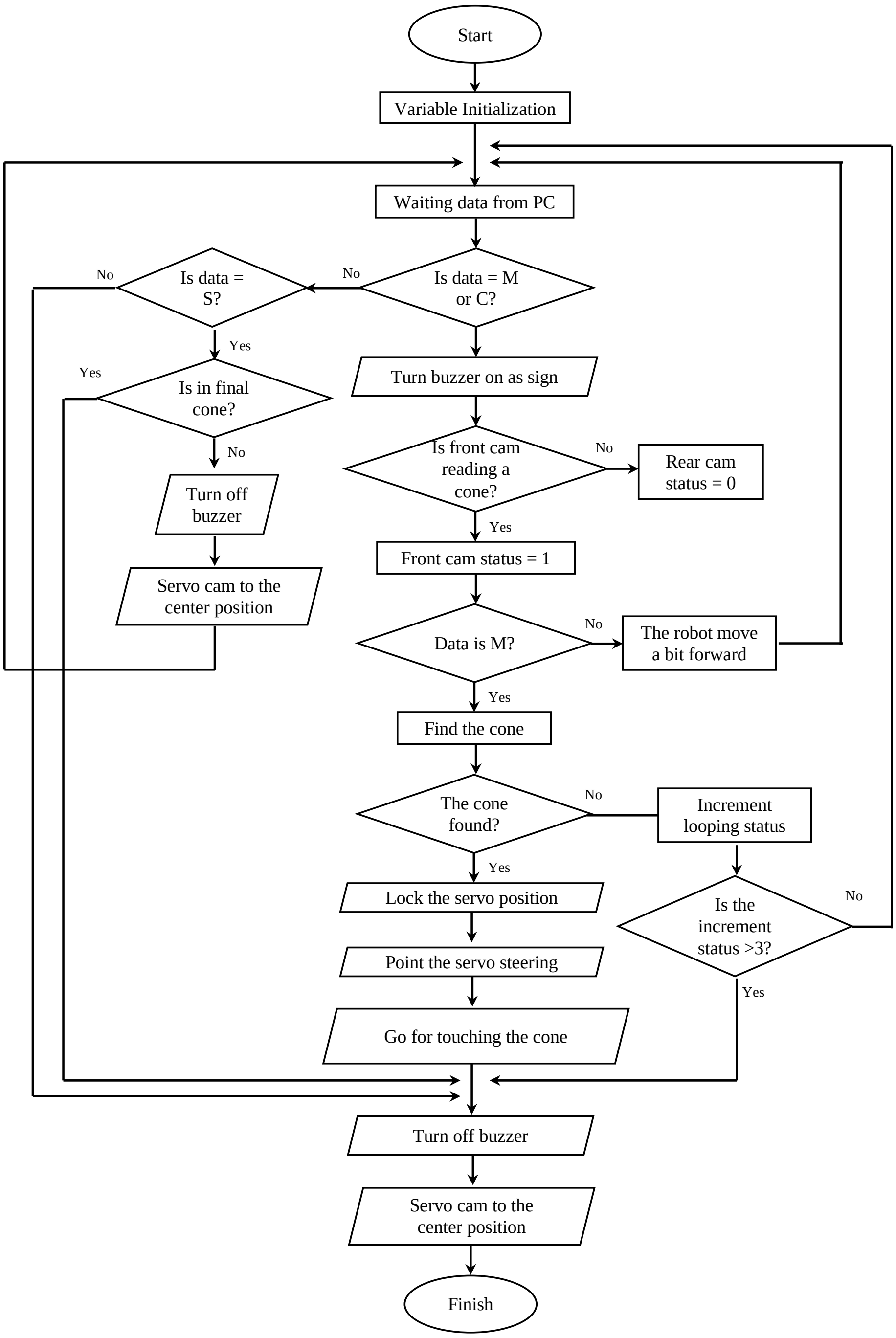

FIGURE 4. Algorithm for Searching Traffic Cone on Microcontroller Side

Then the traffic cone detection algorithm will be installed on the personal computer to detect the presence of traffic cones in the area around the robot, later the personal computer will get image data around the robot from the camera then it will be processed by the algorithm before it becomes data to be sent to the microcontroller. If one camera manages to detect the traffic cone, the computer will focus on the camera which detects the traffic cone only and turns off the other cameras. The following is in Figure 5 the algorithm carried out by the PC in processing the images taken by the camera.

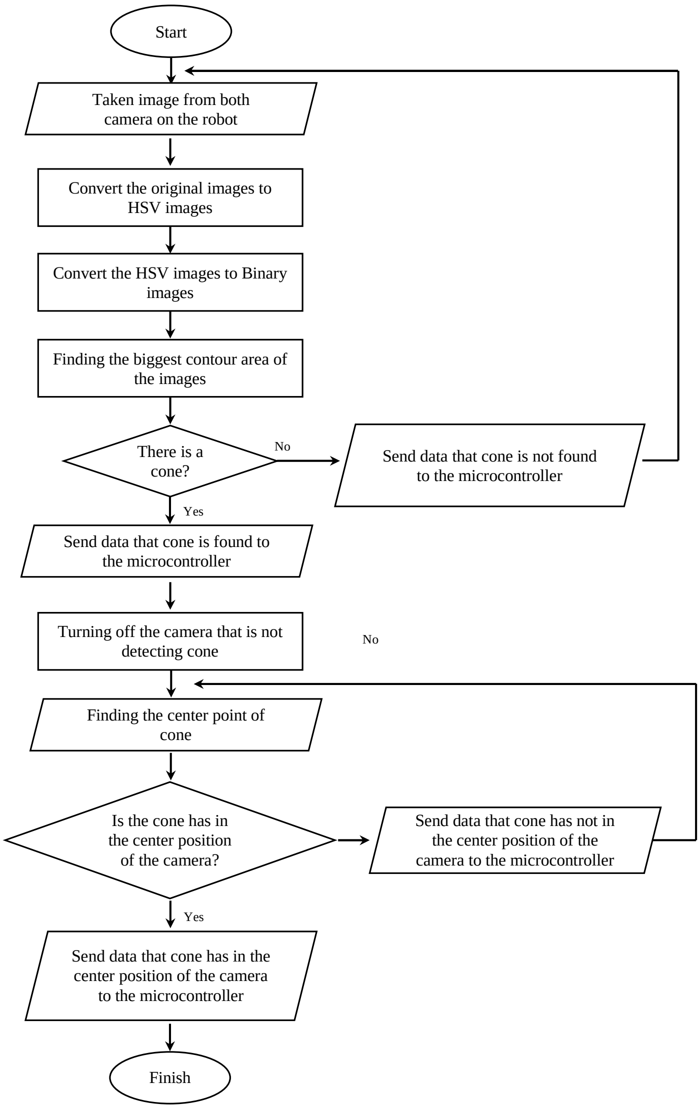

FIGURE 5. Algorithm for Detecting Traffic Cone on the PC Side

CONE DETECTION

When the robot is run and it has got the predetermined coordinate point, it will then carry out the cone detection process. In the algorithm to segment a traffic cones as describes before, can devided into three main steps: color conversion, contour detection and last is object recognition as seen on figure 6.

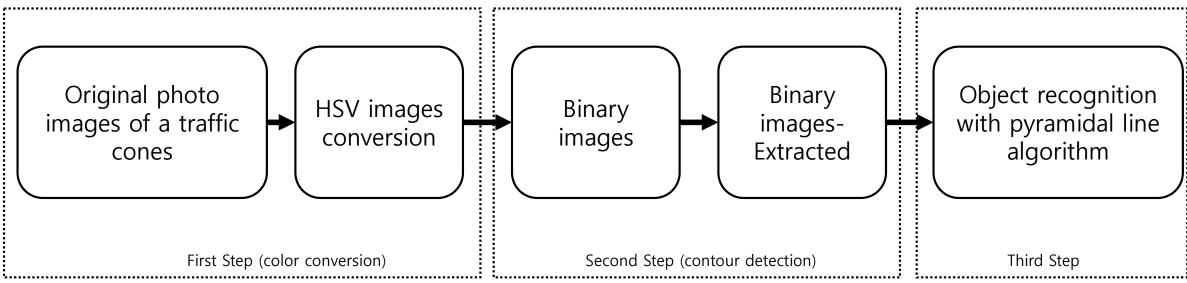

FIGURE 6. Algorithm for Searching Traffic Cone on Microcontroller Side

The process begins with the robot's front and rear cameras taking pictures of the robot's surroundings simultaneously, and the system will combine the two images into one image before detecting traffic cones on the image.

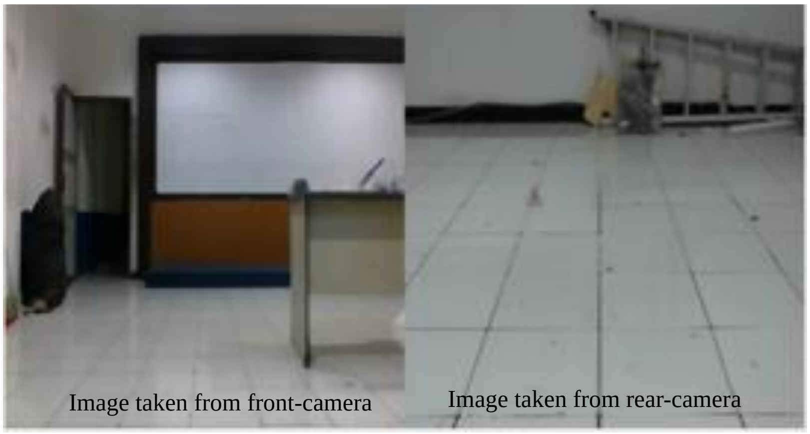

FIGURE 7. Images Taken from The Cameras

In Figure 7 we can see that the image panel on the left is the image from the front camera and on the right is the image from the rear camera. Simultaneously the camera will be rotated 180 degrees to find traffic cone objects around the robot. If one camera can find an object, the system will focus on the camera and turn off the other camera. After that, the search will be carried out again until the position of the object is right in the middle of the camera.

FIGURE 8. Focused System on the Camera that Detecting Object

After both cameras take pictures and send the images to the personal computer, the images will be combined and the image conversion process is carried out in order to detect the traffic cone. First, the conversion will be carried out from the original image which is still in the RGB (Red Green Blue) color space into the HSV (Hue Saturation Value) color space. This is done to improve the accuracy of object searches. In Figure 9 the conversion results will be shown.

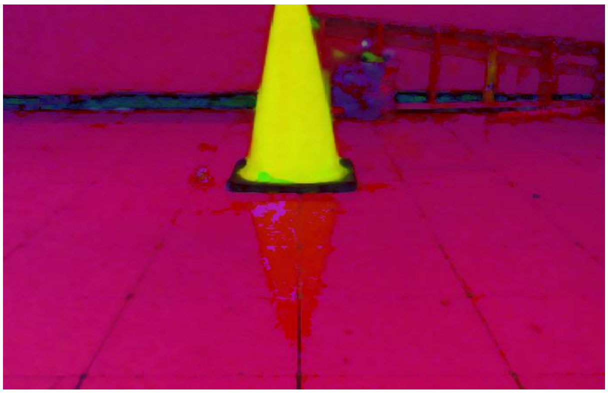

FIGURE 9. Result of the Conversion from RGB image to HSV image

The traffic cones color used in particular study in RGB color value is in Red=255, Green=98 and in Blue=0. HSV is an example of a color space that represents colors as seen by the human eye. H comes from the word "hue" S comes from "saturation", and V comes from the word "value" (Acharya and Ray 2005). To get the values of H, S, V based on the colors in R, G, B in this study, it was obtained using the following formulas:

$$r = \frac{R}{(R+G+B)}, g = \frac{G}{(R+G+B)}, b = \frac{B}{(R+G+B)} \tag{1}$$

$$V = max(r, g, b) \tag{2}$$

$$S = \begin{cases} 0, \ If\ V = 0 \\ 1 - \frac{\min(r,g,b)}{V}, \ If\ V > 0 \end{cases} \tag{3}$$

$$H = \begin{cases} 0, \ If\ S = 0 \\ \frac{60 * (g-b)}{S * V}, \ If\ V = r \\ 60 * [2 + \frac{(b-r)}{S * V}, \ If\ V = g \\ 60 * [4 + \frac{(r-g)}{S * V}, \ If\ V = b \end{cases} \tag{4}$$

From the application of the above formula to the processing system, we get the hue value is 23 degrees, the saturation value is 255 or 100% and the value of the intensity itself is 255 or 100%. Then based on this max value we can determine the range of object color values in detecting orange to anticipate changes in the detected color values if there is a change in light in the detection environment. The range of defined and applied color values can be seen in table 1.

TABLE 1. The range of application of the HSV value

Hue	Saturation	Value
Hmin=0	Smin=209	Vmin=142
Hmax = 23	Smax = 255	Vmax = 255

The image that has been converted into HSV will then be converted back into a binary image by thresholding the parameters of HSV images such as the grayness and brightness, where the purpose of this conversion is to find the boundary of the traffic cone object.

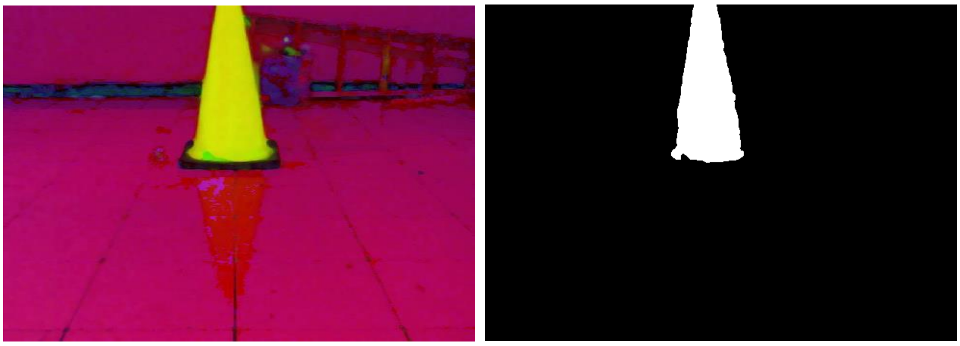

FIGURE 10. Result of the Conversion from HSV image to Binary image

After finding the edge of the object, the largest contour area will be searched. After that, the contour will be divided into 6 parts to later be compared with one another to determine the shape of the object is a triangle.

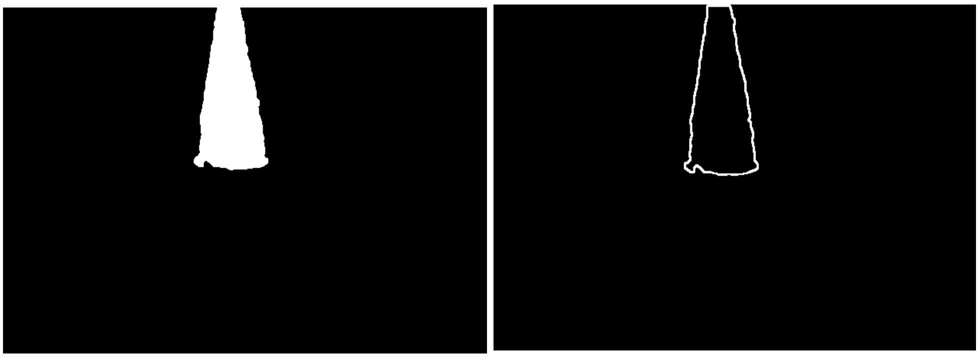

FIGURE 11. Result of the Contour Detection image (right) from Binary image (left)

FIGURE 12. Final Result

In Figure 12, it can be seen that the image that has found its edges will be calculated as high after that the height of the object will be divided into six parts and a straight line will be drawn at each point to calculate the length, then the value of the bottom line will be compared with the line above it and will be compared again with a line above it to the last line. If the length of the line decreases, the system will assume that the object is the object being sought.

Then after completing the conversion process and it is decided that the object is the traffic-cones, then Jelajah V-18 robot will move to the traffic-cones and touch it. Movement direction determined by finding the center points of the traffic cones. The figure 13 shows the movement direction visualized by a line drawn from P1(x1, y1) to P2(x2, y2) in the area. The 0-xy is the coordinate frame of the image. P1(x1, y1) represents the current position of the robot, and P2(x2, y2) represents the endpoint of the movement direction of the robot.

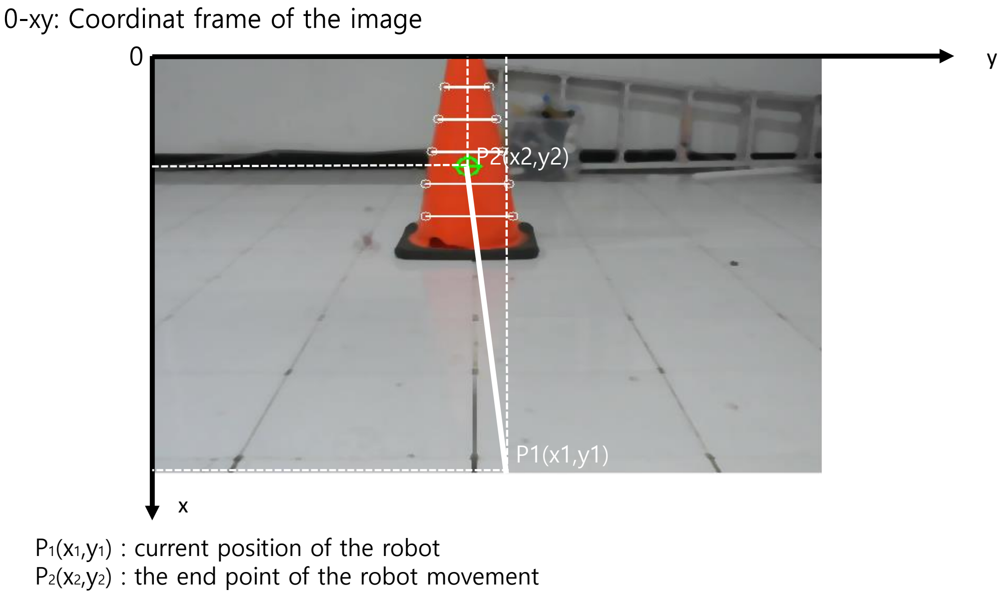

FIGURE 13. Movement Direction Visualized by a Line Drawn from P1 to P2

EXPERIMENTAL RESULT

The test includes the success of detecting objects on the robot being tested in two different parts, first in a room with room light intensity in the 200-500 lux range and the tests carried out only include the success of detecting traffic-cones that are set per 1 meter internal distance with repetitions of 1-7 meters. The test results for this section can be seen in table 2 and the testing process can be seen in Figure 14.

FIGURE 14. Data Retrieval Process in Detecting a Cone

TABLE 2. Data Retrieval Result in Detecting a Cone

Distance	Frame	Percentage of Success
1 Meter	241	100%
2 Meter	310	100%
3 Meter	192	100%
4 Meter	199	100%
5 Meter	192	100%
6 Meter	212	100%
7 Meter	185	35.67%

It can be seen from table 2, the success rate of the system from a distance of one meter to six meters reaches 100% and at a distance from six to seven meters the percentage of robot success is only 35.67%. At a distance of 7 meters the robot is already difficult to determine whether the object is a traffic cone or not. This is probably due to the limitation of the maximum distance that can be obtained.

The second part of the test is carried out outside the room. Where the test covers the functions of the entire system, as previously explained, there are two major parts in robot design, namely the first part is long and short-range navigation, and the second is the part of detecting traffic-cones till touch it. This second test is carried out on a parking area which has a length and width of 300 to 500 meters where there are various kinds of moving and stationary obstacles in it, the starting point of the robot is random and there are 2 to 3 traffic cones are placed at different points and the test is carried out in several different weather conditions. The following is in table 3 the results of tests carried out for all functions of the Jelajah V-18 robot. As we can see on the fifth column the success rate on detecting the traffic cones almost get 100% on cloudy and sunny weather. Failure occurs, as we can see in line 5 and line 14, because the accuracy of the stopping position of the robot is poor, so that the distance between the robot and the traffic cone is outside the detection area. The long-range navigation sensor applied to Jelajah V-18 robot is a GPS that accuracy will be poor in cloudy weather conditions.

TABLE 3. Data Retrieval Result in Navigating and Detecting the Cones

Number of testing	Weather testing condition	Number of cone	Number of Cone detected	Success rate (%)
1	Cloudy	2	2	100
2	Cloudy	2	2	100
3	Cloudy	2	2	100
4	Cloudy	2	2	100
5	Cloudy	3	2	66.6
6	Cloudy	3	3	100
7	Cloudy	3	3	100
8	Cloudy	3	3	100
9	Cloudy	3	3	100
10	Cloudy	3	3	100
11	Cloudy	3	3	100
12	Cloudy	3	3	100
13	Cloudy	3	3	100
14	Cloudy	3	0	0
15	Sunny	3	3	100
16	Sunny	3	3	100
17	Sunny	3	3	100
18	Sunny	3	3	100
19	Sunny	3	3	100
20	Sunny	3	3	100

21	Sunny	3	3	100
22	Sunny	3	3	100
23	Sunny	3	3	100
24	Sunny	3	3	100
Success average				86.10%

CONCLUSION

Based on the detection and searching test stages of objects, it is concluded that the robot can recognize the orange color and triangular traffic cones. In testing indoors with a light intensity of 200-500 lux, the control system can recognize objects up to a distance of six meters with a percentage of success reaching one hundred percent. At a distance of six to 7 meters, the percentage of the system's success in recognizing objects has dropped dramatically to 64.33 percent, and is no longer able to detect and recognize objects at a distance of more than 7 meters. For the future works, we plan to implement the method and combine it with other obstacle sensors for navigating because each sensor type has inherent strengths and weaknesses.

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