Goalpost Detection Using Omnidirectional Cameras on ERSOW Soccer Robots

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Goalpost Detection Using Omnidirectional Cameras on ERSOW Soccer Robots

Mochamad Mobed Bachtiar[1], Iwan Kurnianto Wibowo[2], Rakasiwi Bangun Hamarsudi[3]

[1,2,3] *Department of Informatics and Computer Engineering, Politeknik Elektronika Negeri Surabaya, Indonesia*

[1] mobed@pens.ac.id*

[2] eone@pens.ac.id, [3] raka.hamarsudi@gmail.com

Abstract— The ERSOW robot is a soccer robot developed by Politeknik Elektronika Negeri Surabaya, Indonesia. One important ability of a soccer robot is the ability to find the goal in the field. Goal Post is often used as a sign by soccer robots in a match. The mark is a reference robot in the field to be used in determining the strategy. By knowing the location of the goal in a field, the soccer robot can decide to maneuver in the match to get the right goal kick. There are various methods of detecting goals. One of them is to detect goal posts using vision. In this study, the radial search lines method is used to detect the goalposts as markers. Image input is generated from an omnidirectional camera. The goal area is detected on the front side of the goal area. With experiments from 10 robot position points in the field, only 1 position point cannot detect the goal. The robot cannot detect the goal because what is seen from the camera is the side of the goal, so the front side of the goal area is not visible.

Keywords— omnidirectional camera, vision, radial search lines, goal detection, ersow soccer robot

I. Introduction

Robot match is a form of science competition in robot development. One of the biggest robot games in Indonesia is the Kontes Robot Indonesia (KRI). Politeknik Elektronika Negeri Surabaya (PENS), as one of the competent tertiary institutions in the field of technology,, certainly contributed to the robot contest. In one of the contested categories, the Kontes Robot Sepak Bola Indonesia (KRSBI), PENS has a robot named EEPIS Robot Soccer Wheeled (ERSOW).

ERSOW is a mobile soccer robot / wheeled soccer robot made by the PENS robot team to take part in the KRSBI competition. In its making, ERSOW follows the RoboCup Soccer League Middle Size (MSL) requirements, which are the reference of Wheeled KRSBI. Following these references, ERSOW must have an autonomous ability to compete. In an autonomous robot system, the ability to detect a goal post is an important feature. The way to detect it is to use a camera. ERSOW uses omnidirectional cameras as a vision to see the entire field area [1] [2].

The use of omnidirectional cameras as vision robots is more commonly used than conventional cameras. By using an omnidirectional camera that has a more comprehensive view of the view that is 360°, it will be advantageous in analyzing the conditions of the surrounding environment. From the 360 ° image, more information about the area around the robot.

In carrying out the omnidirectional image processing process, various methods have been carried out by various parties. One of them has been done by A.K. Mulya, and his team has researched the detection of goal and ball using the radial search lines method [3]. But in the case used in this research is the use of yellow goal objects as landmarks, where the goal condition is not relevant to the KRSBI match conditions followed by ERSOW who have goal criteria with different shapes and colors.

This research is an attempt to improve the research in the goal detection section. So that the system can be used by ERSOW in field matches that are following the actual KRSBI competition rules. Improvements made are to make a new definition of the characteristics of the goal. The shape of the goal in the race rules is white. By using this method, ERSOW can recognize the goal accurately.

II. Theory

A. Robot ERSOW

ERSOW Robot (EEPIS Robot Soccer on Wheeled) in Figure 1 is a soccer robot type mobile robot that follows the Wheeled KRSBI standard based on RoboCup Middle Size League (MSL) rules. From various systems owned by ERSOW, there are omnidirectional sensors as one of the visualization capabilities in the environment.

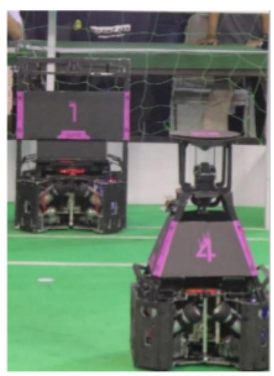

Figure 1. Robot ERSOW

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In addition to the provisions regarding robots, all other properties, such as the field and the goalpost, have also been arranged. With the provisions of the field used is measuring 8 x 12 meters with a width of 6 cm and design the field, as shown in Figure 2.

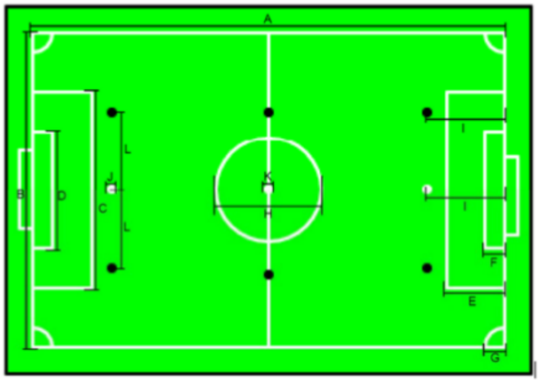

Figure 2. Wheeled Robot Soccer KRSBI Field

B. Radial Search Lines

Radial search lines are a radial pixel reading method that starts from therobot's center to a certain radius and runs for each 0 to 360° in sequence. This search method is built on the Bresenham line algorithm. There is also the location of therobot's center in the omnidirectional subsystem, as shown in Figure 3.

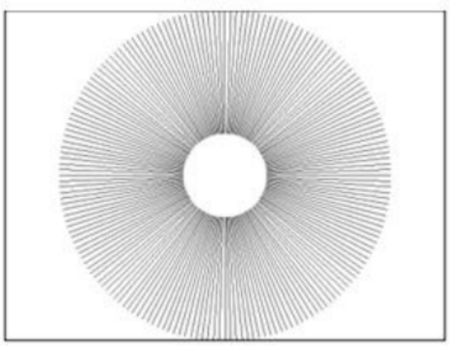

Figure 3. Radial search lines reading pattern

The use of radial search lines aims to speed up the process of object detection, because this approach does not need to process all the pixels in the image, but only the pixel values of the required area [3].

C. Omnidirectional Camera

With a camera configuration that uses an omnidirectional mirror to get an image of a 360° area, this will affect the calculation of the actual distance of the detected object. Therefore the mirror characteristics used need to be modeled. In the omnidirectional mirror characteristics using hyperbole mirrors can be modeled so that the equation (1) is obtained.

$$(f^2 - r^2{a_2}^2)R^2 - (2a_1a_3fr)R + r^2{a_3}^2({a_1}^2 - {a_2}^2) = 0 \quad (1)$$

The modeling of the omnidirectional camera [2][3] is illustrated in Figure 4.

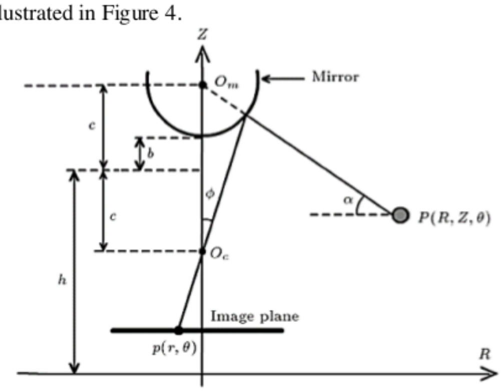

Figure 4. Hyperbole omnidirectional mirror model

Hyperbole mirror equation has the form of the equation *ax + bc + c = 0,* which is converted into a new form so that it is easier to do calculations. The equation can be used to estimate the actual distance between the robot and the goal post that is used as a marker. The equation becomes (2).

$$R = \frac{2a_1a_3fr}{f^2-a_2^2r^2} \pm \sqrt{\frac{a_2^2a_3^2r^2(f^2+a_1^2r^2-a_2^2r^2)}{(f-a_2r^2)^2(f+a_2r^2)^2}} \quad (2)$$

where:

R = real world distance (m)
r = the distance in the image in pixels
f = focal length of the camera
a_1, a_2, a_3 = variable mirror

Omnidirectional camera mirrors have various shapes such as cones (canonical), round (spherical), cylindrical, parabolic (ellipsoidal) and hyperbole (hyperboloidal). The types of mirrors commonly used in omnidirectional cameras are round and hyperbole, as shown in Figure 5. Such a camera structure will produce an omnidirectional image that can display the surrounding environment with a horizontal field of view in the form of a full 360 ° circle. This concept is often used in robot soccer to be a vision of the surrounding environment.

Figure 5. Omnidirectional camera mirror shape

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III. RESEARCH METHODOLOGY

The following research methodology activities in Goalpost Detection Using Omnidirectional Cameras on ERSOW Soccer Robots, Figure 6 describes the system used in this study.

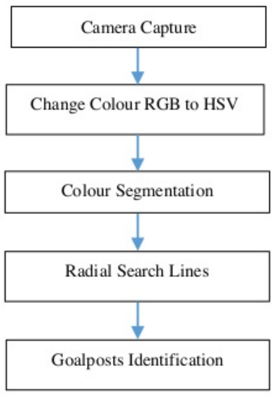
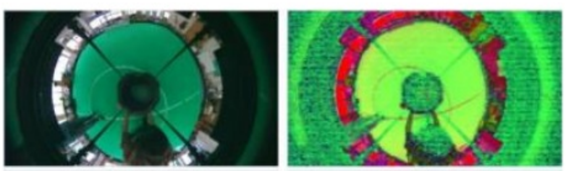


Figure 6. Goal Detection Process Diagram

A. Change of Color Space in the Image

The goal image data obtained from the camera is still in the RGB space color (Red, Green, Blue). RGB color space has the disadvantage that it is difficult to determine the color range in changing or uneven lighting conditions. Therefore the RGB image in Figure 7(a) of the goal is converted into HSV in Figure 7(b).



(a)RGB (b) HSV

Figure 7. Conversion Process Results

After converting image data to HSV color space, the next process is the required color threshold. The two colors identified are green, which represents the color of the field, and white which represents the color of the goalposts in the process Figure 8.

Figure 8. The threshold to search for color ranges using the trackbar

B. Goalpost Detection

Goal detection in Figure 9 is carried out using the radial search lines method. This method is a way to read pixel values radially with a certain angle and distance from the center of the image.

Figure 9. Goalpost

To determine the location of the omnidirectional image center and 0º angle can be determined manually in Figure 10. Where in this study, the center of the omnidirectional image is at (620,380), and the angle 0º is defined to the left of the midpoint of the omnidirectional images. In addition to determining the center of the omnidirectional image, we also need to find out the length of the radial radius of the search lines needed as a reading limit for the omnidirectional image. The radius determines how wide the area of the image that must be read to find the features of the desired object.

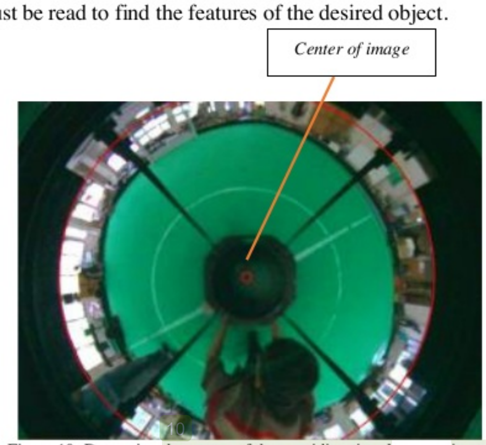


Figure 10. Determine the center of the omnidirectional camera image

After getting the center point of the omnidirectional image and the radius as a search boundary for radial search lines, the next step is to design the radial search lines function on the system by adjusting the image used. The criterion for the radius used is the length of the radius must cover the entire area that needs to be read but must not exceed the image resolution limit. From these criteria, the length of the radius used in this study was 400 pixels. In addition to the radial search lines scanning area, the path of reading radial search lines also needs to be determined. In this system, radial search lines will scan from the outer radius to the inner radius but

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will be limited to a radius of 250 pixels. This is done because the process does not require pixel data at the radius below it. Besides this, it is useful in saving time and process resources in applying the radial search lines method.

In recognizing the goal, the radial search lines will read the color value of each pixel, starting from the angle of 0 to 360° and starting from the outer radius to the inner radius. To find the pixel position, use equations (3) and (4):

$$x_n = 620 - r_n \times \cos\theta \tag{3}$$
$$y_n = 380 - r_n \times \sin\theta \tag{4}$$

where:

xn and *yn* : The pixel coordinates to be read

rn : The length of the radius to be read

To get information about the location of goalposts as markers on the image. In the process, radial search lines will take color information from each pixel in the image according to a predetermined search pattern and identify it according to the color range that matches the color of the goal and the color of the field that has been searched for in the image extraction process. In this system, the color of the goal is identified as a white object that is tangent to green which is located at the farthest point from the center of the omnidirectional image for each degree of the search path, provided that there is no green color at a radius further from the assumed location. Based on these characteristics, determine in finding the goal in the omnidirectional image.

The process of reading pixel values using the radial search lines method, the pixel location configuration, will meet the pixel requirements (*Өn, rn*) = green and pixel (*Өn, rn + 1*) = white. This configuration illustrates the conditions previously explained that the white color outside the green area is part of the goal line. From the reading of these conditions, the pixel coordinates will be saved for further identification to determine the coordinates of the white colour, if the white colour lined up a lot around, it forms a straight line that is certain that the line is the goal line. The white colour of the goal is wider than the colour of the edge of the field.

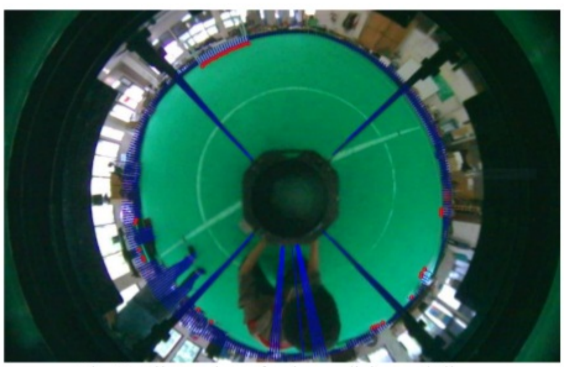


Fig 11. Illustration of using radial search lines

IV. THE RESULTS

After the image is extracted to the HSV space color, this process looks for a range of green and white colors as parameters to determine the identification of the object to be performed. Based on the process of determining the color range value, the HSV color range is obtained as in Table I.

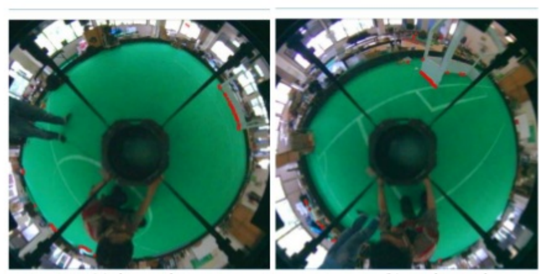
TABEL I

THE RANGE OF GREEN AND WHITE COLORS USED

Color	Min H	Max H	Min S	Max S	Min V	Max V
Green	65	92	114	255	93	235
White	58	108	4	163	97	164

In table 1 is the range of HSV values that have been obtained from an image obtained under certain conditions that are following the image data used in testing this system. The range of HSV values does not guarantee it will always fit all environmental conditions in the field. Many factors affect the condition of the range of HSV values that will be used as parameters to identify objects based on color. Therefore it is necessary to recalibrate in determining the correct range of HSV values for each environmental condition before running this system.

By using the radial search lines method in detecting goalposts according to the criteria described earlier, results are obtained in Figure 12.



(a) detected (b)not detected

Fig 12. Goal detection result using radial search lines

From Figure 12, visible red dots as signs that indicate that these dots are white dots that meet the criteria as determined as part of the goal, the color configuration where pixel *(Өn, rn) = green* and pixel (*Өn, rn + 1) = white*. From the detection process, it is still seen that there are still parts of objects other than the goal that is also detected. But it can also be seen the difference between the actual goal object and other objects that can be considered as noise. In the goal section, it appears that there are more points lined up than the detected noise objects, therefore it can be assumed that the location where there is a collection of points lined up indicates that the section is a goal.

In addition to identifying between the goal area and other objects, the system still has various other shortcomings. This detection process still has some obstacles in detecting the goal where when the robot is on the side near the goal, so the sidewall of the goal is also detected in Table II. Because the

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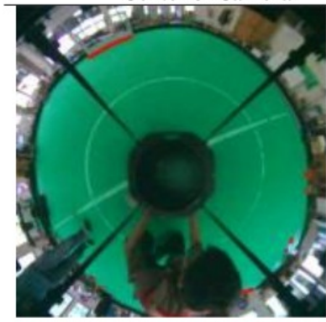
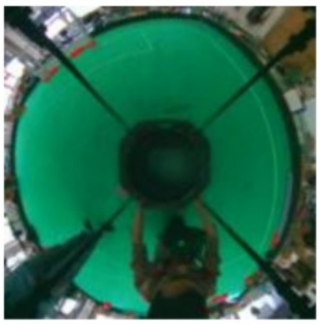
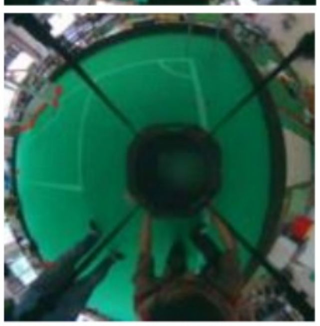
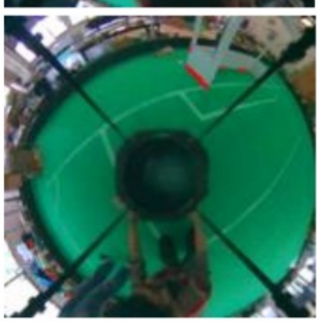
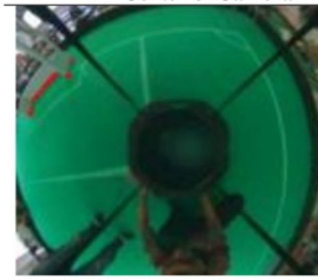
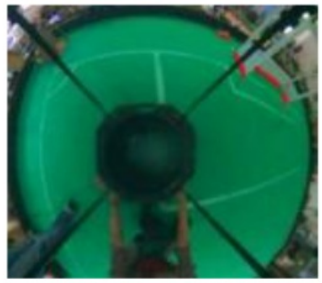
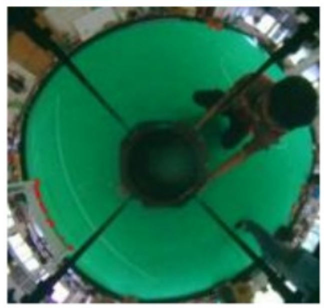
detection of the goal wall side is quite a problem considering the part of the desired goal is the front of the goal. These problems still need to be overcome in determining the toe of the goalpost to be used as a marker.

TABEL II
GOAL DETECTION RESULT FROM VARIOUS POINTS IN THE FIELD AREA

Center of Camera	Information
	Goalpost detected
	Goalpost detected
	Goalpost detected
	The goalpost not detected (goalpost detected from the side)
	Goalpost detected
	Goalpost detected
	Goalpost detected
	Goalpost detected
	Goalpost detected

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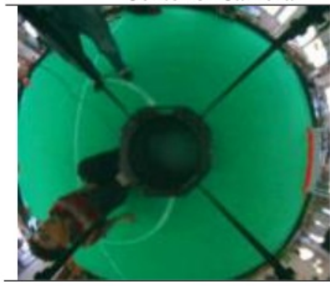
Center of Camera	Information
	Goalpost detected

V. Conclusion

From research on goal detection that has been done, it can be concluded based on the results that have been obtained is the goal detection system using the radial search lines method has advantages in terms of simplicity in reading pixel values. However, this method is very dependent on the declaration or determination of the criteria of the object to be processed. Besides, the use of hyperbole mirror equations as a method of converting distances from omnidirectional images to real distances also has a pretty good level of accuracy provided that the accuracy will decrease as the distance of the goal from the robot is further away. With experiments from 10 robot position points in the field, only 1 position point cannot detect the goal. The robot cannot detect the goal because what is seen from the camera is the side of the goal, so the front side of the goal area is not visible.

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