Goal Detection and Opponent Avoidance Algorithm for Wheeled Robot Soccer using Color Filtering and Contour Extraction

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Abstract—**This paper proposed a goal detection and opponent avoidance algorithm for robot soccer using color filtering and contour extraction. The paper presented a robust and simple algorithm based on an image captured by robot soccer to recognizing and locating a goal and avoiding from the opponent. The proposed algorithm used a color filtering in the HSV color space to distinguish and detect goal from the background image. The detected goal was then extracted using contour extraction to ensure the detection result. To reduce the noise, the morphology filter was applied to the detected object. The opponent robot was also detected by using HSV color filtering. The opponent robot has a designation color team that is different with our robot team. In order avoiding from opponent robot after detecting its color, we used ping sensor to detect the distance between robots. In the certain distance, our robot could avoid collision with an opponent robot with moving to the left or right side of the opponent robot. The experimental result showed the satisfactory result in detecting goal and avoiding an opponent. The goal successfully was detected from 1.5 m until 8.5 m distance from our robot. The robot successfully avoided the opponent robot in the distance of 40 cm. The robot moved to the right, or left side depended upon the opponent position.**

Keywords—goal detection, color filtering, contour extraction, opponent avoidance

I. Introduction

Indonesia Robotic Contest (IRC) is an annual event for academic, researcher and scientists to develop and build a robot and compete with other contestants' robot. This event is a good chance for academic, researcher and scientists to show their creativity in robot technology. The IRC has four contest categories. One of them is wheeled soccer robot category. The rule of the competition is based on the rule of the International RoboCup Middle Size League (MSL). The winning team is the team who has more score to the other team goal. In order to be the winner that has many scores, the robot has to design to have the capability to kick the ball to the opponent goal. This capability is determined by the capability of the robot to detect the ball and the opponent goal by using the camera mounted on the robot. Another rule that has to be considered is the robot is prohibited to hit or to fall down the opponent robot. If it happens, the robot can get the yellow card. Moreover, it becomes a red car if the robot makes the opponent robot become malfunction. The robot should be out from the soccer field.

According to two challenges above, some of the researchers have already built and developed some algorithm to overcome the problem. Dayanand et al. [1] proposed an object detection and tracking based on color. They used the gray level and binary image to detect the object. They compared to adjacent frames to determine the matching object using Euclidian distance. The object was then tracking using contour extraction. The proposed method would fail to detect the object when the object color is similar with another object color. Hussin et al. [2] proposed a method for object detection from the complex background image. They used color processing as preprocessing stage before detection. The Circular Hough Transform (CHT) was used for shape detection. The method would determine the candidate of the object and find the circular pattern with the given radius within the image by collecting the maximum voting. Because the method using a grayscale image, it is difficult to detect an object with similar color with others. The CHT could not precisely detect the circular object when they connected to another object. Reference [3] proposed a robust detection of white goal based only the Y channel image instead of color segmentation using color filtering to determine and characterize goal position and the horizontal crossbar. The algorithm successfully implemented on the real robot in the field and showed the ability to detect white goal. However, the algorithm depended up on the well-detected field boundary. So if the detection stage failed, then the entire algorithm would fail. Cano [4] designed a video processing algorithm for detection of a soccer ball with the arbitrary color pattern. The research was performed for developing wheeled RoboCup. He used YUV color conversion to detect the ball by taking the Y channel. By using Canny edge detection, the ball edge detection was done. To improve the detection result, he implemented CHT to detect the round ball. The proposed method was time-consuming so it is not suitable for real-time application and the use of CHT is not recommended to detect the small ball in diameter. Woering [5] used goal detection to determine humanoid soccer player position. The method did not only focus on detecting the contrary or own goal but also finding the relative position of the robot to the goal. They used HSV color space as initial detection of the goal. To extract the goal boundary, they used Boundary Object Function (BOF). The BOF became the input for the neural network for training and matching step. The restrictions of the method are the difficulties to watch the whole goal in only one frame, and if the robot is too close to goal, the goal cannot be recognized. The others proposed method have a similar method to the above mention methods to detect the object especially goal and the opponent robot. Such as [6], they

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used color based segmentation to detect goal and robot position.

This paper proposed a goal detection and opponent avoidance algorithm using color filtering and contour extraction. The proposed algorithm used a color filtering in the HSV color space to distinguish and detect goal from the background image. The detected goal was then extracted using contour extraction to ensure the detection result. To reduce the noise, the morphology filter was used to the detected image. The opponent robot was also detected by HSV color filtering. The opponent robot has a designation color team that is different with our robot team. In order avoiding from the opponent robot, after detecting the present of the opponent robot, we used ping sensor to detect the distance between robots. In the certain distance, our robot would avoid collision with the opponent robot.

This paper is organized as follows. In section 2, the proposed method is described. The experimental results and discussion are explained in section 3. Moreover, finally, the conclusion is presented in section 4.

II. METHOD

We divided our proposed algorithm into two stage; goal detection stage and opponent avoidance stage. The first stage is done by employing HSV color filtering and contour extraction. The second stage is done by employing HSV color filtering and a ping sensor. The detail of each stage is described as follow. The HSV color filtering is used to distinguish the goal from the background and other objects. The contour extraction is then applied to the detected goal to ensure we detect the real goal contour. Fig. 1 describes the step which will be described in this section. The HSV color filtering is also used to detect the opponent team. So that, the robot can avoid the opponent in a certain distance. The distance itself is detected using a ping sensor.

A. HSV Color Filtering

HSV color filtering is one of the color filterings that is used to distinguish one color to other colors. We can use the filter to distinguish the goal which has color that different with the environment. We used the HSV color filter to detect the opponent robot that has specific designation color.

The color conversion from default RGB color space to HSV color format is described in (1) based on the gravity center law [7].

The advantage of using HSV color space is because this color space more closely aligns with the way human vision perceives color-making attributes. In HSV color space, each hue color is arranged in a radial slice from 0 till 360^o, around a central axis of neutral colors which ranges from black at the bottom to white at the top. Because of this advantage, more researchers use the HSV color than RGB [8-10]. Fig.2 shows a color conversion from RGB to HSV color space.

$$V = \max(R,G,B)$$
$$S = \begin{cases} \dfrac{V - \min(R,G,B)}{V}, & if\ V \neq 0 \\ 0, & otherwise \end{cases}$$
$$H = \begin{cases} \dfrac{60(G-B)}{V-\min(R,G,B)}, & if\ V = R \\ 120 + \dfrac{60(B-R)}{V-\min(R,G,B)}, & if\ V = G \\ 240 + \dfrac{60(R-G)}{V-\min(R,G,B)}, & if\ V = B \end{cases} \quad (1)$$

If H < 0 then H = H + 360. The value of HSV are $0 \leq V \leq 1$, $0 \leq S \leq 1$, $0 \leq H \leq 360$

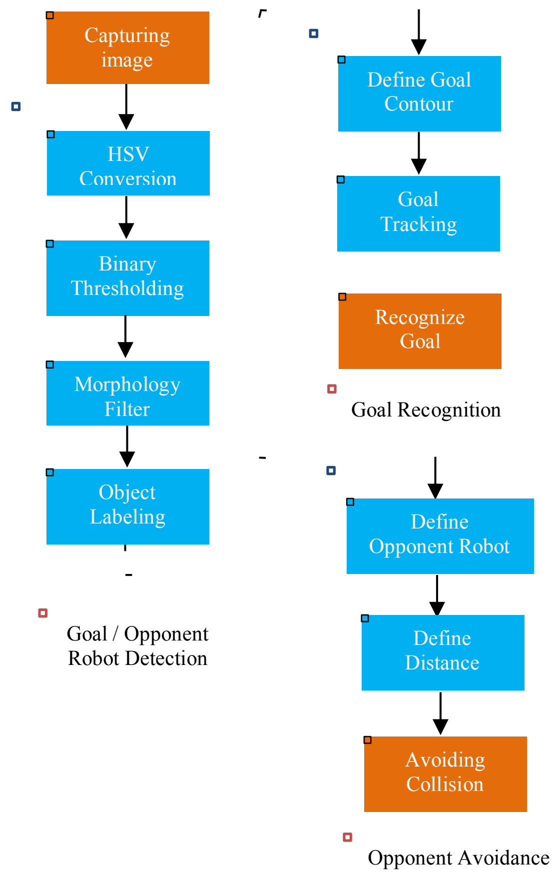


Fig. 1. Entire algorithm flow

B. Morphology Filter

Morphology filter is performed to reduce the noise remained in detected objects [11]. The morphology filters implemented in this paper are dilation followed by erosion.

In dilation, the filter will add the foreground to each background pixel that has foreground pixel in the area of the filter. Dilation adds pixels to the boundary of the detected object and closes the isolated background pixel. Erosion is the opposite method of dilation. This filter will add background pixel to the foreground. Erosion removes isolated foreground pixels.

a. Original image b. HSV Image

Fig. 2. HSV Color Conversion

The morphology filter is implemented using a structure element (SE) matrix or kernel. This paper implemented 3 x 3 SE matrix with the origin at its center as describe on Fig.3

1	1	1
1	1	1
1	1	1

Fig. 3. Fig.3 3 *x* 3 SE

The set coordinate of the SE are:

$$\begin{Bmatrix} (-1,-1), & (0,-1), & (1,-1) \\ (-1,\ 0), & (0,\ \ 0), & (1,\ 0) \\ (-1,\ 1), & (0,\ 1), & (1,\ 1) \end{Bmatrix}$$

To simplify the algorithm, the morphology filter can be described using (2) for dilation and . (3) for erosion

$$f(x,y) = \begin{cases} 1, one\ or\ more\ pixels\ of\ the\ 8\ neighbors\ are\ 1 \\ 0, otherwise \end{cases} \quad (2)$$

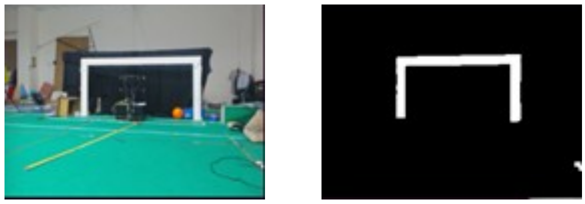
$$f(x,y) = \begin{cases} 0, one\ or\ more\ pixels\ of\ the\ 8\ neighbors\ are\ 0 \\ 1, otherwise \end{cases} \quad (3)$$

C. Object Labeling

In order to distinguish the detected object from other objects, the object labeling is implemented to all objects. In this paper, the connected component labeling [12] is used by employing four neighbors connectivity. By using the labeling threshold, we can define which object will become the detected object. The labeling algorithm is implemented in 8-pixel neighbors' relation. The algorithm is described as follows:

Firstly, from the binary image, we define object pixel as 1 (white) and background pixel as 0 (black). Then the image is scanned from top-left of the image to search the object pixel. The label is done by scanning the image from left to right and comparing label with the neighbor's label in the same line. If the neighbor has the same pixel value, the pixel is labeled as same as the previous label. Next, the labeled image is scanned from top-left to bottom-right by comparing with the four neighbors pixel which has already been encountered in the scan (the neighbors (i) to the left of the pixel, (ii) above it, and (iii and iv) the two upper diagonal terms). If the pixel has at least one neighbor, then this pixel is labeled as same as neighbor's label. On the last scanning, the image is scanned from bottom-right to top-left by comparing with the four neighbors pixel. The labeling result is shown in Fig. 4.

After the connected labeling component, we implemented the goal recognition, and opponent avoidance proses depend on the object detected. If the detected object is the goal, then the next process is goal recognition. Moreover, if the detected object is the opponent, then the next process is opponent avoidance.



a. Original Image b. Image after labeling

Fig. 4. Image after labeling process

D. Goal Recognition

The goal recognition step is performed to recognize the goal contour and the goal position from the detected object. The recognition process is done by employing the contour area extraction from the detected object. The detected contours are stored as a vector of points. We define the goal contour as the largest contour of the detected contours. The goal contour is then tracked by the robot as a target goal. The goal position is determined using the center of mass of the goal contour. Fig. 5 shows an example of goal detection with goal position. The goal position is marked with the red dot, and the goal contour is marked with the blue line.

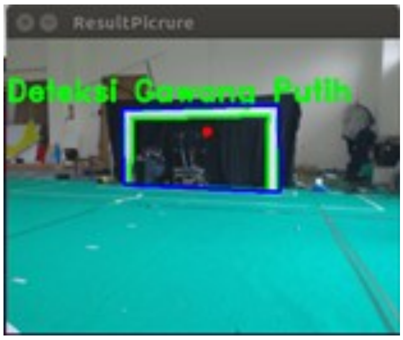


Fig. 5. Goal contour and position detection

E. Opponent Avoidance

The opponent avoidance is done using a ping sensor. The ping sensor is a distance sensor that uses ultrasound as a media to be measured. The ping sensor transmits the ultrasound to the object and receives again the reflection ultrasound from the object. The time interval between transmitting and receiving the ultrasound can be measure become distance between sensor and object. By knowing the distance of the opponent robot, our robot can avoid collision with the opponent robot. When the robot finds the opponent in front of our robot in a certain distance, the robot will move to the left or the right of the opponent. Fig. 6 shows the detected result of the opponent color team of cyan and magenta in the particular distance.

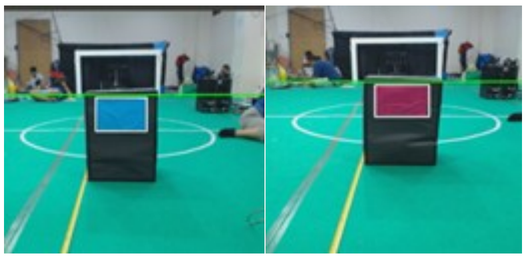


Fig. 6. Opponent Color Detection

III. EXPERIMENTAL RESULT

The experiments were implemented in our robot soccer in the real soccer field for competition as described in Fig.7. The goal has a dimension of 2 *x* 1 m with white color. The field has a dimension of 9 *x* 6 m. The opponent robot has cyan or magenta team color. In this experiment, we implement our proposed method to detect the white goal and to avoid from the opponent collision.

Fig. 7. Soccer field

The goal detection and obstacle avoidance algorithm was implemented into the wheeled robot soccer. Fig. 8 shows the mechanical design of the robot. The robot consists of a camera, ping sensor, mini PC, controller, and motor drivers. Camera and ping sensor as the input device of the system. We used camera C920 Logitech with frame per second (FPS) of 30. The ping sensor was Parallax ping sensor that only needs one signal (SIG). Mini PC and controller is used as the processing devices system. The mini PC was Intel NUC NUC6i5SYH with Intel Core i5 processor. The communications between devices was used a serial cable. While the function of the driver motor is as the motor speed and direction control of the motor. The robot uses three pieces of power window motor and three pieces of Omni-wheel as the mover. Li-Po batteries were used for the robot energy source.

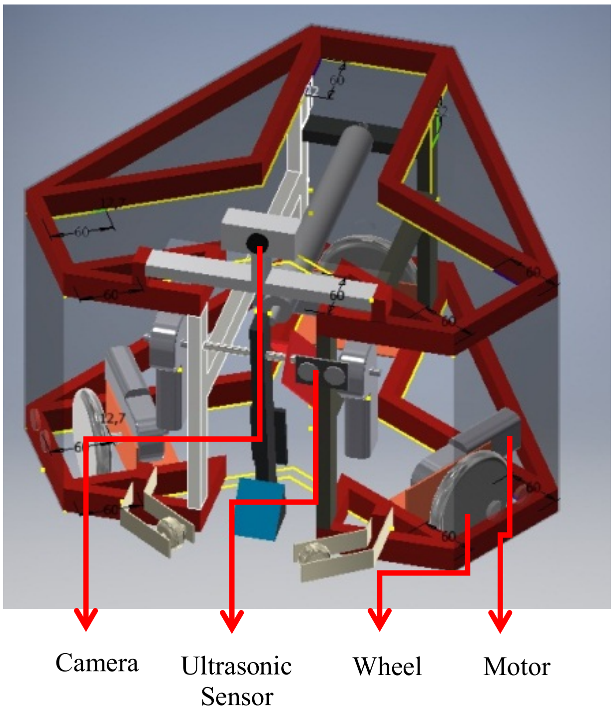


Fig. 8. Mechanical design of the robot

On the first experiment, we detected the goal using our proposed method. The detection results are shown on Fig.9. We have experimented to examine the robot capability to detect the goal on a certain distance. We began the experiment with the closest distance to the goal till the furthest distance to the goal that still could be detected by the robot.

The closest distance could be detected by the robot is 1.5 m. The robot could not detect the goal when the distance to the goal is too close because the camera could not capture the goal image. The maximum distance still can be detected is around 8.5 m. After this distance, the goal contour is too small to be detected. Moreover, it is already outside of the field. The detected goal is marked by the blue rectangle, and the goal contour is marked by the green line.

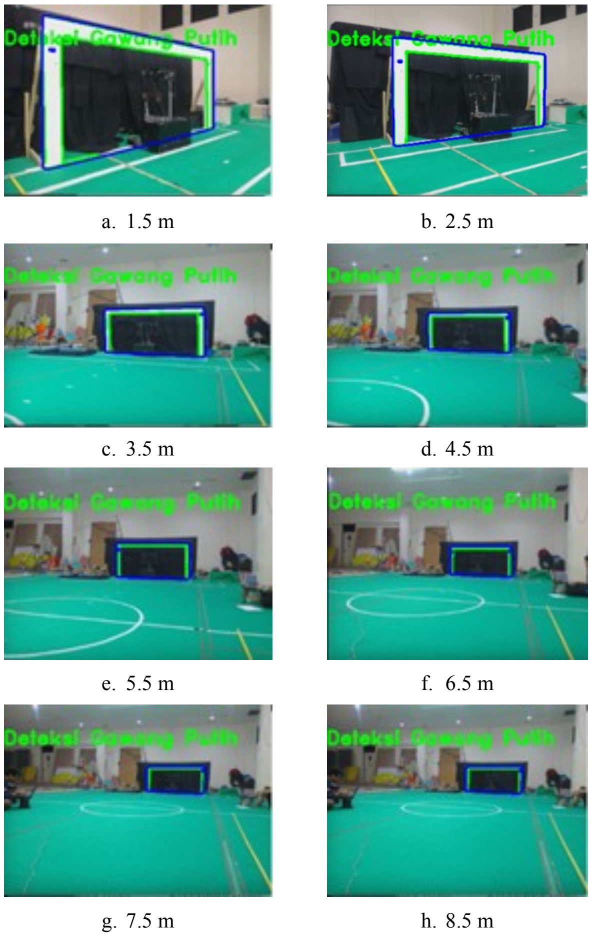


Fig. 9. Goal detection results

On the second experiment, we implemented our method on the robot to avoid the opponent robot. The scenario of the experiment is how the robot moves to the left or right side when there is the opponent robot in front of our robot at a certain distance. We defined the distance when the robot should move left or right is 40 cm. The distance was measured using a ping sensor. To determine when the robot should move left side, right side or forward, we divided the captured frame into two parts; left and right part. The robot will move to the left side if the robot found the opponent robot is on the right part of the captured frame. The robot will move to the right side if the robot found the opponent robot is on the left part of the captured frame otherwise the robot will move forward because of no obstacle in front of the robot. On this experiment, firstly the ping sensor detects the distance between robots. The robot will do the detection task if the distance between robots less than 40 cm. Fig.10 shows the experimental result when in front of robot no obstacle, therefore the robot moved forward. Fig.11 shows the experiment result when the robot moved to the right because there is the opponent in the left side.

Fig. 10. Robot moves forward

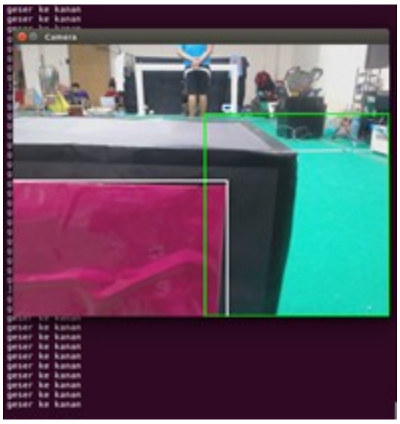


Fig. 11. The robot moves the right side

IV. Conclusion

This paper successfully implemented the proposed method to detect and recognize a goal and opponent avoidance in the real field robot soccer for competition. The HSV color filtering was used to detect goal and opponent robot. The goal contour was recognized using contour detection. The avoidance algorithm was performed by implementing distance measurement using a ping sensor. The goal successfully was detected from 1.5 m until 8.5 m distance from our robot. The robot successfully avoided the opponent robot in the distance of 40 cm. The robot moved to the right, or left side depended upon the opponent position.

However, the algorithm still has limitations especially when the robot is too close to the object; goal or an opponent robot. The robot camera could not capture the whole object image. The algorithm could not recognize a part of the object. These limitations are remaining for our future work.

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