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Colored Ball Position Tracking Method for Goalkeeper Humanoid Robot Soccer

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Abstrak

Robot kiper dalam pertandingan sepak bola robot harus mampu mendeteksi posisi bola dan memblok bola ke gawang. Mengidentifikasi lokasi bola menggunakan visi robot menjadi sangat penting selain gerakan mekanis robot. Makalah ini mengusulkan metode untuk melacak posisi bola berwarna untuk robot kiper. Pertama, gambar yang diambil dengan kamera web, kemudian pentapisan warna berdasarkan model warna HSL dilakukan untuk setiap frame gambar dalam video. Setelah itu, dilakukan pendeteksian gumpalan untuk gambar hasil proses pentapisan dengan pelabelan komponen terhubung terdekat. Gumpalan terbesar dalam gambar mewakili obyek bola. Langkah selanjutnya adalah deteksi posisi bola menggunakan koordinat 9 sel. Koordinat posisi bola diperbarui dalam jangka waktu tertentu dan mengirimkannya ke pengendali robot untuk melakukan gerakan robot yang sesuai. Hasil pengujian menunjukkan sistem telah mampu mendeteksi bola dan posisinya dalam koordinat 9-sel yang dapat digunakan oleh pengontrol robot kiper sepak bola untuk memblokir bola.

Kata kunci: *deteksi bola, sepakbola robot, pelacakan obyek, filter HSL*

Abstract

The goalkeeper robot in a robot soccer game must be able to detect position of the ball and block the ball into the goal. Identifying the location of the ball using robot vision becomes very important in addition to the mechanical motion of the robot. This paper proposed method to track colored ball position for goalkeeper robot. First, image is captured with web camera and then color filtering based on HSL color model performed on each image frame in the video. After that, images from filtering process are detected its blob by labeling nearest connected components. The largest blob in image represents the ball. The next step is detection of ball position using 9-Cells coordinate. Ball position coordinate is updated in some period of time and then sends to robot controller to conduct the robot's movements appropriately. Experiment results show that system is able to detect the ball and its position in 9-Cells coordinate which can be used by goalkeeper robot soccer controller to block the ball.

Keywords: *ball detection, soccer robot, object tracking, HSL filter*

1. Introduction

Colored object detection is one topic that is often discussed in computer vision, particularly in the development vision for the robot. In developing the robot, which is owned limited computing resources, but requires accuracy. Therefore finding an optimal point between accuracy and resource usage should be done. In a robot soccer game, robots must have ability to find position of the ball. The ball usually has particularly specified color and contrast with the color of the field. Robot players must be able to detect the location of the ball to be kicked. Goalkeeper robot must be able to detect the exact position of the ball so that it can block the ball into the goal [1]. Identifying the location of the colored balls using robot vision becomes very important in addition to the mechanical motion of the robot.

Colored ball detection can be done with various methods, such as by detecting a ball through feature detection [2], [3] or by its color [4], [5]. This paper focused on detecting colored ball object for goalkeeper soccer robot purpose. The color in the digital system can be represented in a variety of color models. Image processing hardware in general apply the RGB color model with the consideration of the ease in technical color displaying. Other color model focuses on human's eye perception to the color, like HSV and HSL. HSL color model represents

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color as three components, Hue (H), Saturation (S) and Lightness (L). Hue is an attribute of human perception and can be described as red, green, blue, purple, and yellow as primary hues or any intermediate combinations of the primary hues. The colorfulness of a color is described by the saturation component. Saturation is thus a measure of colorfulness or whiteness in the color perceived. The Lightness essentially provides a measure of the brightness of colors. This gives a measure of how much light is reflected from the object or how much light is emitted from a region [6].

Ball position coordinate can be determined in several ways, such as using the theory of trigonometry to determine the position of the ball. The position is calculated based on the height of the camera and the camera angle [7]. In this study the position of the ball is determined by 9-cells coordinate which maps the position of the object into 9 different positions to be sufficient for use in identifying the position of the ball for goalkeeper robot.

2. Research Method

Method of tracking the position of the colored balls consists of several sequential processes. Beginning with capturing video with camera, then for each frame in the video images, the color filtering based on HSL color space (Hue, Saturation, Lightness) done. The resulting images of the filtering process is then detected its blob, by labeling connected components nearby. The largest blob that has formed represents the detected object. The next step is detection of ball position using 9-Cells coordinate. Ball position coordinate will always be accessed and updated in some period of time through the mechanism of object position updater. Information obtained in the updates will be sent to the robot controller to control the robot's movements appropriately. In general, this method works as shown in Figure 1.

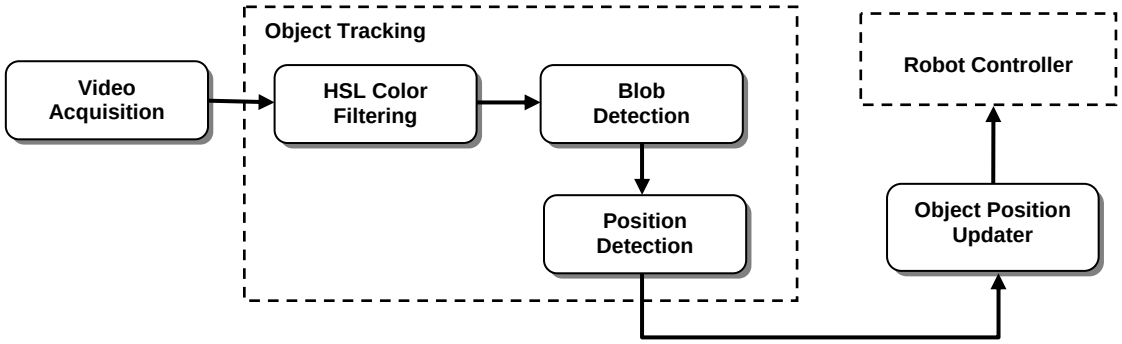

Figure 1. Colored ball position tracking system

2.1. Video Capturing

To track position of the ball, a series of images taken by a video camera is used. Before the video acquisition process, setup of frame size and frame rate images to be taken should be done first. These settings affect the speed and accuracy of detection. Number of frames per second that widely used is 30 frames per second (fps), but can be reduced to speed up the process of image analysis, because it affects to the number of images to be processed. However, this reduction must also consider the accuracy of the analysis, because there may be some missing frames, so need to find optimal values for both. Another setting is the image size, which affects to the internal operation of each pixel in image analysis process. The smaller size of the frame, the fewer pixels is processed and affects to the speed of the process, but also has impact to the accuracy of image analysis

2.2. HSL Color Filtering

Image processing hardware in general, apply the RGB color model with the consideration of the ease in technical color displaying. Color conversion is needed to bridge the two models so the color can processed and displayed correctly. Color conversion from RGB to HSL steps are as follows [6]: r, g, b values are first obtained by normalizing each pixel such that:

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

Accordingly, the *H, S,* and *L* values can be computed as

$$V = max(r,g,b) \quad (2)$$

$$S = \begin{cases} 0 & \text{if } V = 0 \\ V - \frac{\min(,r,g,b)}{V} & \text{if } V > 0 \end{cases} \quad (3)$$

$$H = \begin{cases} 0 & \text{if } S = 0 \\ \frac{60*(g-b)}{S*V} & \text{if } V = \text{r} \\ 60*\left[2 + \frac{(b-r)}{S*V}\right] & \text{if } V = \text{g} \\ 60*\left[4 + \frac{(r-g)}{S*V}\right] & \text{if } V = \text{b} \end{cases} \quad (4)$$

$$H = H + 360 \text{ if } H < 0 \quad (5)$$

In HSL Color filtering, pixels with value are in the specified range value of each H, S and L component, pixels value will not change. Therefore, after filtering, pixels with HSL values in the range specified by value of input parameters will still appear as the original color, while the outside of the range will be replaced with black or with a value of 0. HSL filtering can be expressed as Equation (6)

$$F_{HSL}(p_i) = \begin{cases} p_i, & min_H \le H(p_i) \le max_H, min_S \le S(p_i) \le max_S, min_L \le L(p_i) \le max_L \\ 0, & \end{cases} \quad (6)$$

If HSL value of pixel p_i is between minimum values for each HSL component min_H, min_S, min_L and maximum values max_H , max_S , max_L , value of pi still remain, otherwise p_i is set to value 0 or black.

2.3. Blob Detection

Blob detection performed on images generated from the HSL color filtering. The method used to detect the blob is connected component labeling method [8]. In order to get the largest connected component, each blob is then merged with other blobs that are intersecting each other. This Largest blob is considered to represent an object detected by a specific color, in this case the ball. Blob detection process described in Figure 2 [9].

Then, the center of gravity *CoG* (x_c,y_c) of the connected component is calculated using the Equation (7) [10]

$$x_c = \frac{\sum_{j=1}^{N} x_j}{N} \qquad y_c = \frac{\sum_{j=1}^{N} y_j}{N} \quad (7)$$

Here, in after *CoG* regarded as a point that representing object position in the coordinate of ball position detection

```
Algorithm BlobLabeling
k = 1
 for each pixel in image
  if pixel X is foreground
    if neighbors A,B,C & D are unlabelled
      label pixel X with k
      increment k
    else
       num = neighbor label A,B,C & D with least value
       label pixel X and pixels A,B,C & D if foreground with num
    end if
  end if
done
```

(a)

A	B	C
D	X	

(b)

Figure 2. (a) Blob Labeling Algorithm (b) Label kernel applied to each pixel

2.4. Position Detection

Center of gravity of the detected object will be mapped to a coordinate on the screen. In this research, 9-cells coordinate models is used, which divide the screen into nine congruent squares, each represent specific locations such as on the Figure 3.

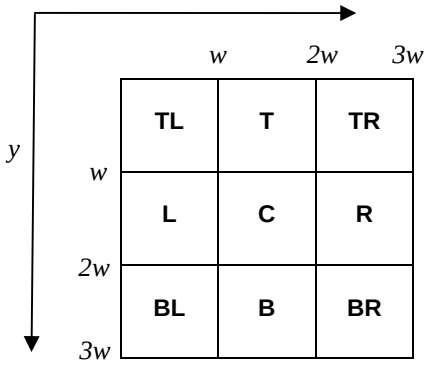

Figure 3. 9-Cells Coordinate: **T**op-**L**eft, **T**op, **T**op-**R**ight, **L**eft, **C**enter, **R**ight, **B**ottom-**L**eft, **B**ottom, **B**ottom-**R**ight, *w* = cell size

If *CoG* is in a particular cell then the object is considered to be in the coordinates of the cell. 9-cells coordinate is used since ball position detection for the goalkeeper in soccer robots which is the defensive one. Therefore with only 9 kind of ball position is adequate to block a ball into the goal. If ball is detected in the Top-Left coordinates then robot controller will be send command to shift to the left and raised his hands, likewise if the ball is detected in Bottom-Right then the robot will move to the right, and so on.

2.5. Object Position Updater

In video image processing, the number of images being processed in a second is in the same number to frame rate. Thus object position detection may change dozen times per second. If the changes are also done to the command to robot, it will need a very responsive robot. It is to be inflexible, therefore independent processes are needed to separates an updating of the robot vision and robot control. The Object Position Updater component designed to separate those processes. It fetched the current object position information from object tracking mechanism in robot vision for some period of time. This component also sends appropriate commands or signals to the robot controller. Updating period used in object position updater is set to be suitable to the robot movement synchronization abilities. Those setting parameters of time period are separated independently for robot vision and robot controller.

3. Results and Analysis

Application for tracking ball position is implemented with MS-Visual C# 2008 using Computer Vision library of AForge [11]. To carry out the color filtering based HSL components using HSLFiltering class. Colors can be filtered by the user input. Program is also featured with tolerance settings for each values of HSL color, therefore the color detected is not necessarily the same exact color selected by the user, but the colors are similar to the corresponding value of the tolerance range that had been input .Blob detection performed using BlobCounter class with minimum width and height is 10 pixels and the maximum width and height is the same size as camera image. Object position updating process in the program implemented using the Timer component, which has OnTick() event to execute commands in specified period of time. Video capturing is performed using Logitech® Webcam C170. Experiments were carried out using light green field and orange, green and blue balls. Two kinds of experiments were carried out which color detection experiments and the position of the ball.

3.1. Ball Color Detection

Ball color experiments were performed by placing three different colors of balls on the field. Then color to be filtered out is selected in the program. After that, program starts to detect a ball which is considered to have color similar to the color selected in the program. Detection results will appear as a red box indicates that is an area with a color closest to the color pixel based on the user's choice in HSL color space. Experiment result can be seen in Figure 4.

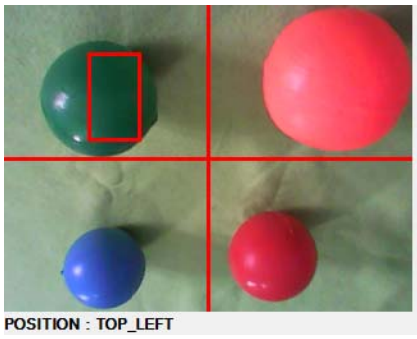

Figure 4. Detection of green ball

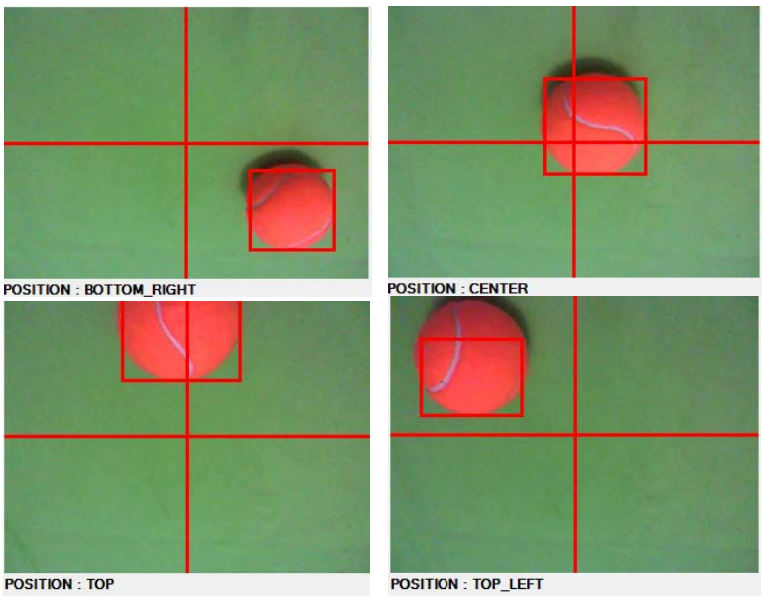

Figure 5. Ball position detection on 9-Cells coordinates

Experiment result shown that the system can distinguish certain color of ball from several color balls. Pixels color cannot be fully detected because the lighting factor that greatly affects to color gradation. Therefore, detection process can only detect some of pixels. Experiment is performed using a color tolerance setting H = ± 5, S = L = ± 0.5 and ± 0.5.

3.2. Ball Position Detection

Experiment conducted by putting orange ball to detect on light green field. Ball is placed at several different positions. An updating period in Object Position Updater is set to 1 second. Experiment results can be seen in Figure 5.

Results in experiment above show that the system was able to detect ball position coordinate in 9-Cells coordinate system. Ball coordinate is determined based on its CoG which is the midpoint of rectangular area of the ball with the color selected.

4. Conclusion

Proposed method can be implemented into an application of colored ball tracking system on the robot. System is able to detect the presence of the ball by a specific color in the HSL color model. Ball position coordinates can be detected by the system in 9-Cellss coordinate for goalkeeper robot soccer to block the ball.

Accuracy of ball detection by its color needs to be improved, especially to prevent color differences due to differences in illumination of the object. Besides, calculation of ball speed will also need to be added to improve the accuracy.

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