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Vein Visualization System Using Camera and Projector Based on Distance Sensor
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Abstract (1544 Kb)

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Abstract (1571 Kb)

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Improving Field and Ball Detector for Humanoid Robot Soccer EROS Platform

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***Abstract*—Humanoid robot soccer perceives environment mostly through cameras. The performance decrement in our humanoid soccer platform (EROS) is primarily due to the visual perception that is less robust to the RoboCup new rule which specifically reducing color coding in the field. Notable works favorably employ simple color segmentation, image morphology, and blob detector due to simplicity in the implementation and run in real-time for most embedded hardware, while some employ a more advanced supervised learning running in sophisticated hardware to boost detection accuracy. In this paper, a visual perception system consisting of field and ball detection is developed in our platform EROS to address the RoboCup new rule. Color segmentation and image morphology are stacked with a more advanced supervised learning cascade classifier. In this way, the favorable color segmentation and image morphology help to reduce the number of object candidates while the cascade classifier helps to boost the accuracy of detection. Experiments show encouraging result for detecting field and ball position. Our approach has successfully been implemented in practice and achieves remarkably result in Indonesian humanoid robot soccer competition.**

Keywords—Field detector, ball detector, supervised learning, humanoid soccer.

I. INTRODUCTION

RoboCup soccer is continuous research to develop humanoid robots soccer, with the primary goal of being able to win against FIFA's world championship team in 2050. The most important capability of this robot is the ability of robots to understand the game situation in real-time in the real conditions of the soccer field. Every year, the RoboCup soccer league updates the rules of the game to be used, to force participating teams to develop more advanced features for their robots, and to make the competition more similar to the real soccer game [1].

Many changes have been made since RoboCup 2015 to 2017 to the humanoid league rules that significantly affect visual perception, including specifically reducing color coding on objects in the field. The ball is now only determined to be at least 50% white, and the goalpost is now white instead of yellow. The difference in the field with the new rules is shown in Fig.1. Because of this change, simple color segmentation, morphology, and blob detection approaches, which are quite popular in the past [2,3], need further significant improvement.

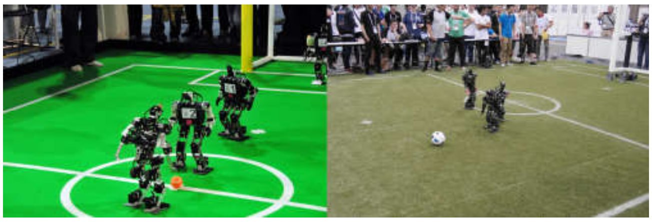


Fig. 1. Difference between old fields (left) and new fields (right) in the RoboCup 2018 rules. The visual preception becomes more difficult and challenging, and the use of simple color segmentation can deteriorate detection.

Existing works on visual perception of humanoid robot soccer have been performed quite significantly in RoboCup community. Color segmentation, morphology, and blob detection are still favorable due to simplicity to implement and able to run in real-time for an embedded platform. The work by [4] introduced adaptive lookup table to address illumination changing in an image. Heuristics approach is introduced by [5] such that the field is the maxima of the weighted histograms of each channel in the image. The work by [6], a color similarity is performed for color classification. Focus on color intensities such as Y channel of YUV has been performed by [7] to solve recent changes in goalpost color. In order to cope with variations in illumination, different heuristics is introduced that can be applied to color histograms. The middle size league (MSL) has used white. A more advanced technique such as supervised learning has been performed [11] and the accuracy is shown quite well for the new rule of RoboCup. However, it requires quite sophisticated embedded platform.

The performance decrement of our humanoid soccer robot platform (EROS) in the past is primarily due to the visual perception system that is less robust to changes in the new rules. An example of a ball detection that is now not fully orange is proven to be quite tricky for detection. The employed color segmentation tends to cause the robot to detect incorrectly between the ball and the penalty point. With this condition, improving detection algorithm for boosting the accuracy and real-time detection to track the ball position in the field are crucial.

Therefore, in this paper, a visual perception system consisting of field and ball detection is developed in our humanoid robot platform EROS to address the new rule in RoboCup. A single monocular camera is used in our approach. Color segmentation and image morphology are stacked with a more advanced supervised learning cascade classifier. In this way, the favorable color segmentation and image morphology help to reduce the number of object candidates while the cascade classifier helps to boost the accuracy of detection. LBP feature is used due to low computational suitable for embedded platform. Experiments show encouraging result for detecting field and ball position. Our approach runs in embedded platform real-time nearly 30fps in the game, if too many objects in the field, it can decrease to a minimum 10fps. Our approach has successfully been implemented in practice and achieves remarkably result in Indonesian humanoid robot soccer competition.

II. Related Works

There have been quite many methods that have been applied by several researchers to detect objects, especially in humanoid soccer robots in the RoboCup community. Efforts have been made to reduce dependence on color classification. For example, Schulz et al. [9] studied to detect spheres by classifying regions with potential neural networks, based on color contrast and brightness features. Similarly, Metzler et al. [10] detection of Nao robots based on color histograms in areas of interest.

More recent works include the work of Houliston et al. [4], which introduces adaptive search tables to overcome changes in image illumination. Schwarz et al. [5] proposed a calibration-free vision system in the standard league platform (standard platform league / SPL), based on heuristics such that the field is the maximum of the weighted histogram of each channel in the image. Härtl et al. [6] show color classification based on color similarity. To overcome the color change of goal in SPL, Cano et al. [7] proposed a method for detecting white lines based on pixel intensity using the Y channel from the YUV color space.

Object detection systems using convolutional neural network (CNN) have been proposed in the soccer humanoid robot. Albani et al. [11], this system is applied to NAO robots using CNN to detect players in RGB images and color-based segmentation techniques. The system applied can get 100% accuracy and 11-19 fps when all unrelated processes such as localization, decision-making, and body control are deactivated. Speck et al. [12], a CNN-based system for detecting balls on a proposed image. Two CNNs are used, consisting of three shared convolutional layers, and two layers that are connected independently. Both CNNs can obtain a possible distribution of localization for the ball above the axis of the horizontal and vertical images respectively. Some nonlinearities are tested, with soft sign activation functions producing the best results. From the results reported in Albani et al. [11]; Speck et al. [12], it can be concluded that this object detector cannot be used in real-time by a robot with limited computing resources while playing soccer, without disturbing the other basic processes.

Contributions of this paper include real-time ball detection algorithms and the application of several practical approaches to produce more robust ball detection in humanoid soccer games.

III. System Overview

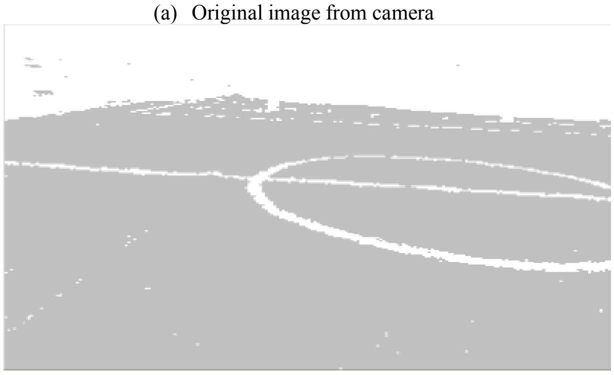
We implement a ball detection system on EROS humanoid robots. EROS is a humanoid robot dedicated to playing football. EROS has a height of 59cm and weighs around 5kg using a single camera which is located in the head like a human. The camera used is a 720p HD camera with 73 wide angles. All detection, decision and control systems are placed inside a robot that allows the robot to move freely in the field. The processor embedded in the robot is an Intel Core i3-5010U 2.10GHz and STM32F407 as a low-level control to access sensors and servo motors. Using 4GB DDR3 memory and SSD as storage. And the entire system run on the ROS (Robot Operating System) Kinetic Kame and Ubuntu 16.04 platforms.

IV. Ball Detection Algorithm

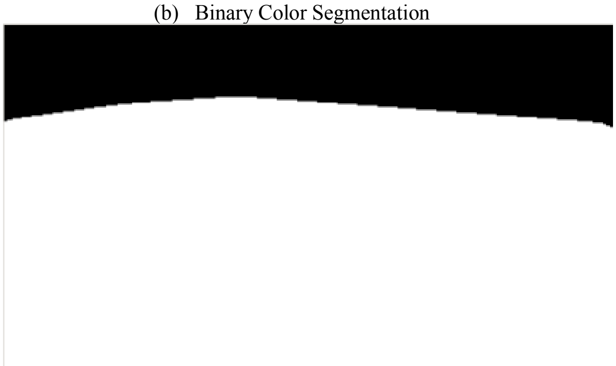
A. Field Detection

The field used in this case is green artificial turf with a height of about 30mm [1]. Because the green color becomes dominant in the field Fig.2(a), color segmentation is quite

(a) Original image from camera

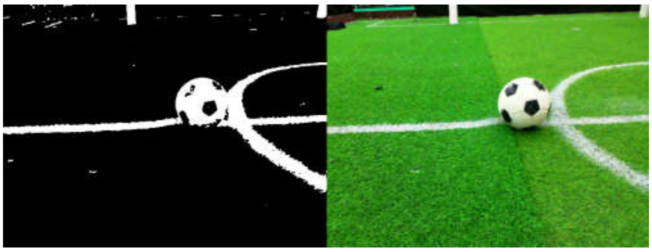


(b) Binary Color Segmentation

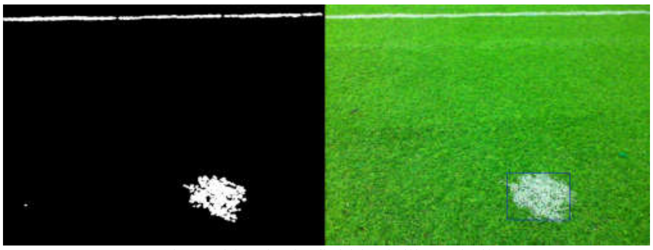


(c) Convex Hull algorithm from binary color segmentation

Fig. 2. Field Detection in EROS Humanoid Robot



(a) White contour of ball and line fused causing ball undetected



(b) White dot in field look like a ball

Fig. 3. Previous vision in EROS Robot

good to use in this case. In this study, we tried to change the color space to YUV to get an approach to color space in humans that are not so susceptible to changes in brightness [8]. However, the green color produced from artificial turf is hollow-cavities so that when image processing is carried out there is noise that requires us to add morphological methods to reduce the existing noise.

The morphology applied includes dilatation, erosion and closing. After getting a binary color that is close to solid-like Fig. 2 (b), we apply the convex hull algorithm [2] to get the whole field that the camera has captured as in Fig. 2 (a), the magenta line shows the results of the convex hull applied to the field. Accuracy in getting the convex hull value depends on the morphological value applied when performing the noise removal process in detecting the field.

B. *Ball Detection*

After getting the convex hull value from the field, we detected all the pixels in the field. In this case, the object used is the ball. The ball used is a ball that is almost all white and has different motives. Circumstances require that we can adapt to any ball motive. In previous research, the EROS team used a binary image segmentation method that uses HSV color space. We are holding on to the ball, goal, and field. The ball is obtained by the binary segmentation

Algorithm Step to Detect Ball

Input : Head pitch degree *Y* and Camera Raw Data *frame*
Output : Ball position in frame *2DPoint(X,Y) ball*

FX←FieldConvexHull(frame)
YUV2RGB(FX)
if *Y<"desired angle for nearest ball"* ***then***
    ball←detectMultiscale(FX,"near ball parameter")
else if *Y <"desired angle for middle ball"* ***then***
    ball←detectMultiscale(FX, "middle ball parameter")
else
    ball←detectMultiscale(FX, "far ball parameter")
end if

value approach plus the morphological filter, the result is compared to detecting the presence of the sphere in the field by checking the binary segmentation of the field with a certain pixel value to the sphere object.

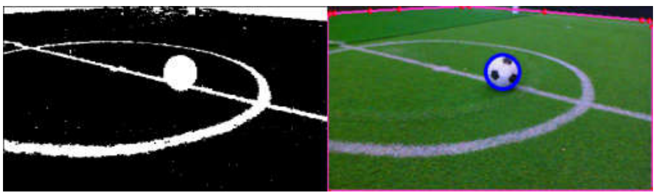
However, the detection of the ball is further disrupted when there is a change in light as well as the higher the error when the object is white (field point, line, and goal) which forms like a ball due to unexpected light reflection as in Fig. 3.

In this case, we tried to use the machine learning method namely the image classifier. We use Local Binary Pattern (LBP) as a type of feature in ball detection. To use LBP, we have to get some positive and negative image samples to train. A positive image is a ball image in all conditions while in the field, and a negative image is not a ball inside or around the field. After getting a number of positive and negative images, positive and negative images are labeled according to the dimensions obtained. After that, positive images are converted into vector shapes. Then do the train with the optimized settings [3] against positive and negative images to get the LBP parameters.

Because machine learning is susceptible to rotation, translation and dilation, we divide the ball object into 3 parameters (far, medium, and close). These three parameters have different training results. For example, to detect a remote ball, the LBP parameter we use is the result of training from a remote parameter and so on. Results from camera raw data in the form of YUV are converted to RGB and the detection algorithm is applied to get the ball position in the field.

V. EXPERIMENTS

Our experiments are performed by using a robot with specifications in the system overview. We analyze the relationship between the number of positive and negative that is used for the accuracy and speed of ball detection in realtime. Optimal results are the greater the accuracy value and FPS. Because to get optimal results, we use original data without any changes in size, brightness, sharpness and so on. The image used is random data classified into positive and negative. Positive data is a picture of balls of all conditions and of different sizes. The closer the ball to the camera, the greater the dimensions of the image. In the first



(a) White contour of ball and line fused and ball still detected

(b) White contour of ball, line and goalpost fused and ball still detected

Fig. 4. Vision using Cascade Classifier in EROS Robot

Fig. 5. Blurry image caused by low FPS when robot is walking towards the ball

experiment, we used 13,000 negative images as control variables to get optimal results from random positive images.

Table 1. Experiment training cascade using LBP features with Negative Image as Control Variable.

Exp.	*Pos/Neg Image*	*Average FPS*	*Detection Accuracy*	*Ball Tracking Accuracy*
1	500/13000	24	44%	50%
2	1000/13000	23	76%	70%
3	2000/13000	20	80%	80%
4	4000/13000	18	100%	92%
5	5500/13000	17	100%	92%
6	7000/13000	15	100%	84%

In Table 1, *Pos / Neg Image* is a positive and negative image used when conducting Cascade Classifier training. *Detection Accuracy* is accuracy in detecting ball images in all conditions while in the field. While the *Ball Tracking Accuracy* is the level of success when the robot is running and tracking to approach the ball. Based on the table, we can conclude that the more features of positive images increase the accuracy value of ball detection, but more features also increase computation and cause FPS to decrease.

When the robot moves with a low FPS, the camera captured image becomes blurry and makes the robot unable to detect the ball. Fig. 5. This results when the FPS goes down, the success rate of the robot in approaching the ball also decreases. Based on the experiment, we conclude that the ideal number of positive images is 4,000-5,000 when the number of images is negative 13,000.

In addition, we tried to see the effect of changing the amount of negative data on the success rate of the robot in approaching the ball shown in table 2.

Table 2. Experiment training cascade using LBP features with Positive Image as Control Variable

Exp.	*Pos/Neg Image*	*Average FPS*	*Detection Accuracy*	*Ball Tracking Accuracy*
1	5000/10000	16	100%	90%
2	5000/13000	17	100%	90%
3	5000/16000	14	100%	84%
4	5000/19000	14	100%	82%
5	5000/21000	14	100%	82%
6	5000/24000	13	100%	82%

In table 2, the greater the number of negative images being trained, the smaller the average FPS value. This does not affect the value of accuracy in detecting it. It's just that when the average FPS value drops, the *Accuracy Ball Tracking* value also decreases. Based on the observed two tables, the ideal number of positive and negative images is around 5,000 positive data and 10,000-13,000 negative data.

VI. CONCLUSION

In this paper, a visual perception system consisting of field and ball detection has been developed in our humanoid robot platform EROS to address the new rule in RoboCup. The combination of the favorable color segmentation and image morphology together with the advanced supervised learning cascade classifier is developed to boost the accuracy while maintaining real-time running in an embedded platform. Color segmentation and image morphology help to reduce the number of object candidates while the cascade classifier helps to boost the accuracy of detection. Experiments show encouraging result for detecting field and ball position. Our approach runs in embedded platform real-time nearly 30fps in the game, if too many objects in the field, it can decrease to a minimum 10fps. Our approach has successfully been implemented in practice and achieves remarkably result in Indonesian humanoid robot soccer competition.

VII. FUTURE WORKS

It is interesting to explore further the developed algorithm using a more advanced supervised learning such as deep learning. Fine tuning methods [13-16] could be applied to increase the accuracy of detection. The challenge is how those approaches can be run in embedded platform.

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