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# The Smart Goal Monitoring System

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**Abstract.** In the current era of rapid technology development, many researchers compete each other to make an automated and integrated system. Since soccer is a favorite sport of all ages, a goal monitoring system is very needed, especially goal detection. The goal monitoring system generates fair play and avoids human error on soccer match. It will be very useful to help referee work. The system runs through sensor, image processing, and final decision. Sensor as object reader will activate the camera at many angles. Combining Circle Hough Transform (CHT) with real-time Color Ball Tracking produces a progressive method to process ball detection. The referees use collaboration tool to get the information. Hence, the referees can be collaborated each other to decide a goal on the match better.

**Keywords:** Computer Support Cooperative Work (CSCW), Goal monitoring system, Soccer.

## 1 Introduction

Gender is not an obstacle in soccer. Old and young people love this sport. Thousands matches were held, but in fact, there were many mistakes that could not be handled properly. Offside, misconduct, and the goal were the highlighted problems. The referee, who is the key of all decisions, is often less accurate on deciding those issues.

Recently, a less accurate system on soccer happened. A nice goal by Lampard was denied in England's World Cup clash with Germany.

"The ball crashed against the underside of the crossbar before bouncing a yard over the goal-line." [1]

Jorge Larrionda as the referee failed to see the Lampard's amazing goal. This case attracts us to deeply focus on goal monitoring system. This paper provides a preliminary of the goal monitoring system on soccer match.

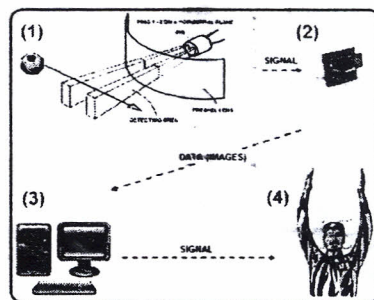
Living in the development era of technology makes everything automated and integrated each other. A case likes Lampard's goal can be discussed more

interested by technology point of view. By seeing soccer's growing and high enthusiasm of supporters, this goal monitoring system can be applied well in Indonesia. We will use the concept of Computer Support Cooperative Work (CSCW) to help the referee.

CSCW is a generic term which combines the understanding of the way people work in groups with the enabling technologies of computer networking, and associated hardware, software, services and techniques [2]. It is a part of Human Computer Interaction (HCI) focused on working groups. One of potential applications for CSCW is procedure processing. It can handle paper-based form, and at the same time, the group can access full summary information about status, whereabouts and over-runs [2].

The reason to apply the goal monitoring system, especially goal detection, is to support fair play on soccer match. It will be used for helping referee work. The referees can be collaborated to decide the best decision. Another reason is to decrease human error. It is natural if the referee makes mistakes. With the existence of this system, both player and referee are advantaged.

The system runs through a sensor that is positioned in-line with the goalpost. The sensor functioned as object reader activates the cameras that are positioned at many angles. Once the cameras active, any object will be captured and sent to the main computer. The image processing will generate the captured object into a result image that clearly shows the ball position. It will be sent to referee field as a signal. The referee can decide the best decision through their collaboration tool. This collaboration tool helps the referees to agree the goal. That is why this research related to CSCW. The system can be called as an automated goal detection system, but the decision is on the referee hand. The system illustration is roughly described as in Fig. 1. There are sensor, camera, computer, and referee. All is integrated and provides an automated system.



**Fig. 1.** (1)Sensor Detects Ball, (2)Camera Captures Ball, (3)Image Processing, (4)Final Decision by Referee

Hence, this paper proposes an automated goal detection through sensor and image processing method in detail. This also proposes an integrated system for all referee. How it works will be discussed in detail on methodology section.



## 2 Related Works

There are many methods or algorithms used for objects detection in soccer which includes players and ball. A software architecture was proposed by Davide *et al.* about ball detection and following based on a stereoscopic vision system. It was able to work in different lighting conditions. The aim was to identify potential arcs in the edge image [3]. The different lighting conditions, such as occlusions, shadows, objects similar to the ball, and real time processing became the important problems. A modified version of the directional Circle Hough Transform with the different lighting was needed. The Circle Hough Transform determined the parameters of a circle when a number of points that fell on the perimeter were known. D'Orazio *et al.* proposed Atherton Algorithm and Modified Atherton Algorithm. Both of them were used for detecting a ball in different lighting condition [4].

The other detection method was from Yu *et al.* It was based on color segmentation and shape analysis in soccer videos. It would detect and locate the players and the ball on the grass playfield. Detecting the shape of an object by using color histogram model was worked to detect the playfield pixels and group them into a playfield region. With the Euclidean distance transform, the players was extracted into skeletons for every foreground blob. Then the transform performed shape analysis [5]. The novel framework by Xinguo *et al.* was not far related with other. Ball candidates were first identified by size, color, and shape, and then these candidates were further verified by trajectory mining with a Kalman filter. It was the most accurate ball detection for broadcast soccer video. The Kalman filter was a tool that can estimate the variables of a wide range of processes [6].

The weakness for each method has been described previously are such as the performance of Atherton Algorithm and Modified Atherton Algorithm. It greatly decreases since the number of points that matches the searched pattern can be very small. Whereas when using the circle detection algorithm, it works very well when a ball passes through in front of the cameras. The ball that comes out of the cameras view always returns a false detection because there is always a peak in the parameter space. Detection based on color segmentation and shape analysis can not detect the ball because the ball's location must be set manually and requires color histogram models to detect player's presence.

The methods were widely used in broadcast video. However, many paper [5,6] proposed the detection based on the soccer ball video. This paper uses a little different method. The detection is applied for the images that have been captured by cameras. The cameras are located inside the wicket. Image processing is needed for the ball detection. This paper combines the method of Circle Hough Transform (CHT) and the real-time color ball tracking to detect a ball. There are many weakness in the Circle Hough Transform in terms of background, shadow and accuracy in detecting. To overcome the weakness, we use Circle Hough Transform to detect the ball as a circle first, then get the shape of an object by knowing the distribution of color by using the real-time Color Ball Tracking.

### 3 Methodology

As discussed before, some cameras are placed inside in the wicket. Each camera has a different capturing time, so there is no delay time to capture the ball. The goal monitoring system has been illustrated clearly in Fig. 1. The sensor has a detecting area to send a signal. If any object passes through the detecting area, sensor will activate the camera. The cameras capture the object immediately and send it directly to the main computer. It will be automatically entered to image processing. The image processing delivers the result detected as a ball. If the result shows the ball crossed the goal line, the system will send a signal to the referees. Every referee has a signal receiving device as collaboration tool to decide the goal.

This goal monitoring system uses 3 steps. The first is grabbing the image, the second is image processing using output from the first step, and the last is final decision system.

#### 3.1 Grabbing the Image

A Passive Infra Red PIR sensor KC7783R is used as switch for the cameras which will capture the pictures of ball [7]. KC7783R PIR is sensor detection functioned normally at 4.7 voltage – 12 volts DC. It will give a high level output between 4.9 to 6 volts. The sensor is positioned in-line with the goalpost. Some cameras will be positioned in some different angles. One camera can be positioned on the corner of the goalpost which leads to the goal line.

The infra red sensor works by detecting a ball passing through the sensor detection area. The sensors will automatically detect the arrival of the ball when the ball past the detection area of the sensor. In other words, if the ball passes the goal line, the sensor will be active. The description of sensor works can be seen in Fig. 2. The camera will be also active as long as the sensor active. Then the camera will grab the image rapidly until the sensor off. The output image will be sent directly to the computer to be processed.

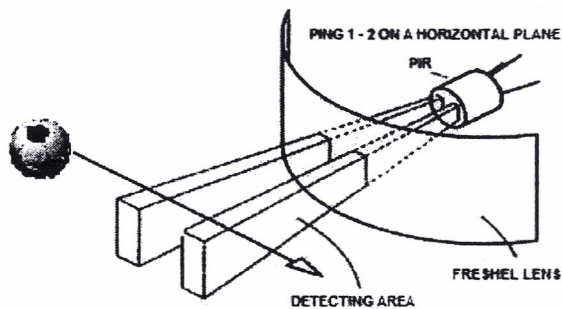


Fig. 2. Sensor System [7]



### 3.2 Image Processing

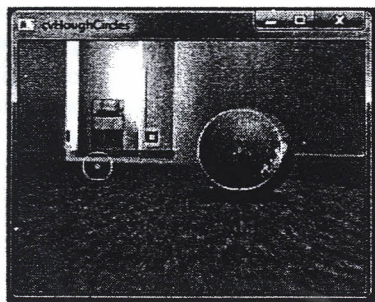
**Hough Transform.** Hough Transform is used for detecting the ball as a circle (amongst other false positives). Hough Transform is also widely used in image analysis, computer vision and digital image processing techniques in terms of extracted features. The purpose of these technique is to find a perfect example of an object in a particular class of shape by the voting procedure.

Circle Hough Transform (CHT) is one part of the Hough Transform method that can retrieve or set on a circular object image. This method transforms the image into the field of Hough.

The algorithm of Circle Hough Transform [8]:

1. Find edges.
2. The hough begin for each edge point.
3. Draw a circle with center in the edge point with radius  $r$  and increment all coordinates that the perimeter of the circle passes through in the accumulator.
4. Find one or several maxima in the accumulator and that is the hough end.
5. Map the found parameters  $(r,a,b)$  corresponding to the maxima back to the original image.

Each element in the image field is transformed into a circular shape in the form of Hough. From the mapping point edge produced by edge detection, the mapping of the Hough space for each parameter circles through each point edge. The result of Circle Hough Transform with false positives that were reduced can be seen in Fig. 3.



**Fig. 3.** Result of Circle Hough Transform [8]

There are some weaknesses when using Circle Hough transform algorithm to detect the ball in the soccer field. The backgrounds on the images have a color that is not evenly distributed or have an uneven color. Therefore, a darker section which is not actually a shadow can be clearly detected. The rate of accuracy in detecting the ball as a circle is still quite low. To overcome these problems, a real-time Color Ball Tracking can be used to detect the ball.

**Color Ball Tracking.** Color Ball Tracking is a system that works to get the shape of an object by knowing the distribution of color. Generally it takes 2 techniques. First is off-line calibration phase the camera's intrinsic parameters and radial distortion. This step purpose is to know the input image distribution color. The approach arranges color balls and acquires a single image. Then there will be image segmentation process to determine the color difference of one object to another. RGB value in each color is converted into one index. The result is shown in Fig. 4.

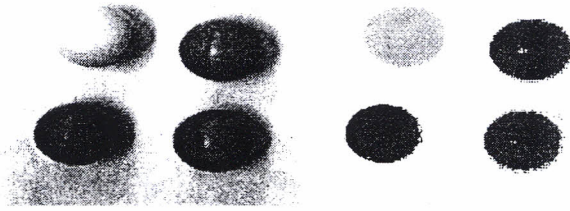


Fig. 4. Input Image and The Result [9]

Then the second step is on-line real-time tracking phase follows where the color classifier is applied to the input images, balls will be detected and 3D positions are returned. Robust estimation of circle parameters and refinement of circle parameters techniques are parts of the input image segmentation. When using these two techniques, we will get the best result of ball detection. The result is shown in Fig. 5.

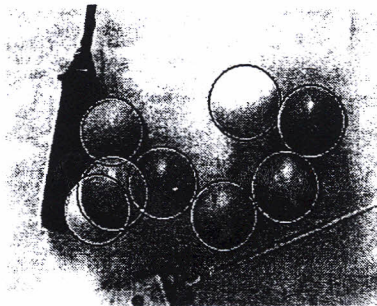


Fig. 5. Result [9]

### 3.3 Final Decision System

The system will check the output of the previous step. If the ball pass through the goal line, the system will send the signal to the referee at field using method from Nedad Pejic [10]. The system includes a signaling device and a signal receiving device. Otherwise, this goal monitoring system only needs the signal

receiving device. It includes a radio-frequency receiver and an actuator device. The actuator device is used to provide an indication thereof.

The steps of this method are generating a radio-frequency signal having a predetermined code, receiving the radio-frequency signal, and generation an indication of receipt. If Nedad uses a vibrator device to generate the indication, this paper uses a sound wave device. This device is connected to the smart earpiece of the referee. This smart earpiece is called as referee collaboration tool.

As the ball detected clearly past the goal line, a radio-frequency signal from the main computer would be generated into sound wave. It will be received by the referees through their collaboration tool.

## 4 Conclusion and Future Work

The advantage of this system is for referee monitoring system. It is expected to help the referee to avoid human error. Hence, the referee can decide the best decision to determine a goal. Since the signal receiving device at final decision step makes all referee connected and receiving a same result just in time, it is a collaboration tool. With the existence of this system, fair play can be well done.

The problem arises when the ball passes through the wicket very fast. The camera can not capture ball at the time. This system could be developed again by using new methods such as detecting the speed of the ball motion. It maybe also be able to detect offside and handball violations. In addition, this system uses only one sensor. Hence, it can be developed by adding more sensors to sharpen the accuracy of the sensor, to send a signal which can make the camera faster to detect the ball presence.

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