Football Players and Ball Trajectories Projection from Single Camera's Image

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Abstract— **In this paper, we propose a method to track multiple players in a football match video which is captured by a single camera. The camera pans and brings the players and the ball into the view, enabling to record the whole pitch. The players' trajectories in frames and camera movement are obtained to estimate the trajectories on the pitch. Moreover, we propose an effective tracking method for solving occlusion problem by combining Particle Filter and Real AdaBoost Classifier. In ball tracking, we calculate likelihood edge and color feature. The player's points project to pitch by projection transform. Experimental results show the effectiveness of the proposed tracking method.**

Keywords -Object Tracking; Soccer; Particle Filter; HOG; AdaBoost

I. INTRODUCTION

In sports contents, there are many services now. For example, player's activity analysis and reproduction of highlight scenes [1]. In order to put into practice these contents, it is necessary to acquire important information, players and ball from the sports videos. In sports games, the study in football videos has been increased, because football player tracking is a challenging issue, due to factors such as occlusion, camera movements and complicated movement of the players. For the analysis of football videos, we must obtain positional information of players and ball. At the beginning, this works were done manually. But, this way is time-consuming. So we want to track players and ball automatically.

In the previous method, Template matching and background subtraction were the tracking techniques of football players and ball [2]. These methods have some problems. For instance, processing time and tracking accuracy. It is inadequate under complicated situations even though we tried to improve these methods a number of times. So, various cameras are installed on the roof and the video screen of the stadium [3]. We can obtain various videos from different viewpoints, hence player's occlusion decreases in the video and high accuracy tracking becomes possible. But this technique has a problem of few facilities to capture football videos.

On the other hands, tracking method was developing and those techniques were applied for sports video analysis. Specially, Mean-Shift Tracker [4] and Particle Filter [5] brought in great progress. These methods based on object model and center of gravity is moved in the direction where the similarity is high. It is easy to distinguish between object and background. But, if there are many objects and occur overlapping, tracking is extremely difficult. These techniques don't consider the action of crowd. So, the new method was worked out [6]. Particles calculate two types of feature, color and edge. In this calculation, it is hard to lose tracking object. However, this way can't track object we have some similar objects in frames. It is difficult to track football players because of there are many players that wear the same uniform.

To solve these problems, we propose a technique to track the football players and the ball using a single camera. The camera pans and brings the players and the ball into the view, enabling to record the whole match. Player and ball tracks on the pitch can be acquired by horizontally swinging the camera. Therefore, we must track players and ball considering the camera motion and the occlusion.

In players tracking, we use Particle Filter. It is hard to track under the situation that crowd some resemble objects. We attempt to track these situations. We try to resample the center of gravity under complicated situations. In order to track the ball, we try to track combining color and edge histogram.

II. PROPOSED METHOD

Fig.1 shows the flow of the proposed method.

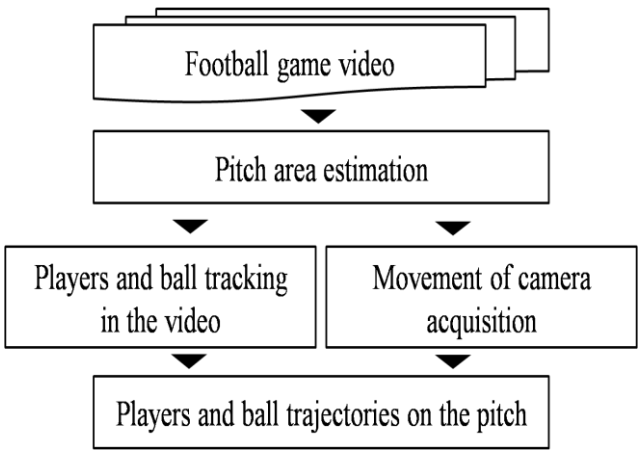

Fig.1 Proposed method

A. Pitch area estimation

In order to restrict to pitch, we estimate lawn area. At first, we converted color space from RGB to HSV to extract lawn area. This lawn area is limited by thresholding Hue and Saturation. Then, we can get upper and lower pitch.

B. Players tracking in the video

We apply Particle Filter [7] to track players and resample center of gravities by Real AdaBoost when overlap players.

Particle Filter is an analyzing method based on presumption. We can set particles that have movement model and likelihood observation and use a number of particles. In these reasons, it is hard to lose sight of the pursuit object, and it is effective for the football player's tracking. The procedure is shown below.

Step.1 Initialization

In this step, arrange particles after specifying player's position. Number of particles are 70.

Step.2 State presumption

Linear uniform motion was applied to the movement model of particle. Moreover, add noise position and velocity to adjust irregular movement that player's turnabout and horizontal camera motion.

$$x_{t+1} = x_t + u_t \Delta t + w_x$$
$$y_{t+1} = y_t + v_t \Delta t + w_y$$
$$u_{t+1} = u_t + w_u$$
$$v_{t+1} = v_t + w_v$$

x, y : Player position
u, v : Velocity
w : Noise
Δ : Delta

Step.3 Likelihood calculation

Model histogram is acquired from player's image. This histogram is compared with color histograms acquired from surround of particles. In order to calculate likelihood, we use the Bhattacharyya coefficient.

$$\mathrm{L} = \sum_{\mathrm{u}=1}^{\mathrm{m}} \sqrt{\mathrm{p_u q_u}}$$
$$\sum_{u=1}^{m} p_u = \sum_{u=1}^{m} q_u = 1$$

L : Likelihood
p, q : Histogram
m : number of histogram bins

Step.4 Initialization

The center of gravity of the object is calculated here. The center of gravity is calculated below.

$$(g_x, g_y) = (\sum_{i=1}^{n} w_i x_i, \sum_{i=1}^{n} w_i y_i)$$

g : center of gravity
w : likelihood
x, y : player position

Although this method is effective for tracking only one player, it is difficult to keep tracking when the objects have similar color features to tracking object. Especially when the players come close or occluded each other, the color-based Particle Filter may perform poorly. As a solution against this problem, we check the positions of the target players by referring the center of gravity for each player, which is calculated by a particle filter, during tracking process. Then, we detect situations that the players move closer and might be occluded each other. In such situations, we apply a Real AdaBoost technique [8] in order to detect the players and resample the center of gravities of a combination of the Particle Filter and Real AdaBoost.

Algorithm of Real AdaBoost is a learning method expansion of AdaBoost [9]. This way can output many weak classifiers and combine these classifiers into strong classifiers. The difference of Real AdaBoost and AdaBoost is weak classifier's output. AdaBoost calculates 0 or 1 by thresholding. But, Real AdaBoost is able to output real number. Then, detection accuracy was uplifted with this algorithm.

Real AdaBoost Learning must set the feature. Here, we apply HOG (Histograms of Oriented Gradients) often used human detection [10]. HOG is acquired brightness gradient and make histogram, it is possible to detect target or not by roughly shape and contour. Players are detected in learning HOG by Real AdaBoost. We extracted 1944 dimensions from player's images.

Decision of occlusion is based on the between player's distances. This distance set don't violate each particle's effective area. This area is judged occlusion. In this situation, we detect football players by Real AdaBoost classifier (Fig.2).

C. Ball tracking in the video

We eliminate not only lawn area but also player's area as a preprocessing flow of ball tracking. We have model histograms that used likelihood calculation. Threshold value is gotten by these histograms. However, we don't erase ball area.

We track ball using Particle Filter the same as players tracking. The likelihood is computed by color and edge histograms. The calculation of the color histogram is in the same way that player tracking. We use HOG feature for the calculation of the edge likelihood. HOG feature between extraction histogram from input image and model histogram can calculate the likelihood by Bhattacharyya coefficient.

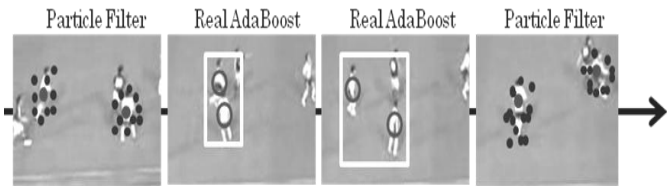

Fig.2 Tracking flow of proposed method

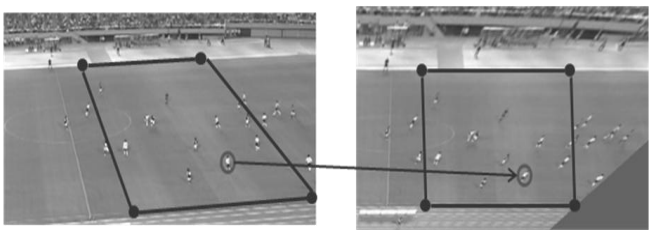

Fig.3 Projection transform

D. Movement of camera

Player points in images project bird's eye view. This transformation projects any quadrangle to any rectangle. This projection transform matrix is calculated four points homology, single camera's image and bird's eye view. Hough transform detects lines and points of intersection. We catch center, side and end lines from pitch. We complement points of intersection in the case of miss extraction.

E. Players and ball trajectories on the pitch

The players and the ball trajectories on the pitch are obtained from trajectories in the football game video and the movement of the camera (Fig.4).

III. EXPERIMENT

We experimented the verification of the player and ball tracking accuracy with the proposed method from the football game video. The video has the frames of 640×480pixels and is taken by 30fps. Moreover, the operation of the camera is only swing motion. We captured football game video in 19:00-21:00 June 20, 2008 in National Stadium. For machine learning, we prepared positive image 3500 frames, negative image 7600 frames. Number of weak classifiers are 50. The computer is consist of Quad Core Intel Xeon 2.66GHz, and memory 3.25GB.

At the beginning, we describe player tracking. We compared proposed method with only Particle Filter method. This experiment verifies tracking accuracy under occluded situations. Moreover, there are two types of situation, the different team and the same team. These are difference in that the uniform's color is the same or not. The success is the situation that don't lose tracking player when overlap each other. Table.1 shows tracking rate, our proposed method and previous method. Color and Edge are ways of likelihood calculation. "Color" calculates only color histogram, and "Color + Edge" calculates combination, color histogram and shape of edge

Table.1 The result of player tracking experiment

	Different team	Same team
Color	98 / 100 (98%)	15 / 100 (15%)
Color + Edge	99 / 100 (99%)	26 / 100 (26%)
Proposed	98 / 100 (98%)	83 / 100 (83%)

In the case of different team occlusion, the tracking rate is high in all method. We can distinguish easily because this tracking is based-on color histogram.

By contrast, we can't track successfully only Particle Filter in the case of the same team occlusion. These methods don't consider other players. So, these accuracies are not high in occluded situation.

We can track players successfully (Fig.6). But, as for a failing situation our proposed method, many players crowd the same place. This is not able to acquire HOG and detect player by Real AdaBoost. To solve this problem, it is thought that change how to give occlusion area.

Next, we explain about ball tracking. We'll show detection rate for all frames (Table.2). By way of comparison, we apply color histogram or HOG for likelihood calculation.

Table.2 The result of ball tracking

	Number of successful frame
Color	741 / 933 (79%)
HOG	656 / 933 (70%)
Proposed Method	921 / 933 (98%)

In the HOG calculation, it is difficult to track when ball and player are close. This is why we can't distinguish edge of players and ball. In the tracking by color histogram, we can't track far player from camera. This is not enough area to take the histogram.

On the other hand, our method calculates likelihood combination of color histogram and HOG. So, we can track continuously by combining two features though it is difficult to track by using only one feature (Fig.5).

However, we can't track under the situation that most areas are hidden because it is difficult to extract feature. In this case, we estimate ball's position and interpolate trajectory by using successful situation back and forth.

IV. CONCLUSION

In this paper, we extracted players and ball trajectories on the pitch from the football game video. Moreover, we tracked combining Particle Filter and Real AdaBoost to solve occlusion problem. In ball tracking, we calculated likelihood by using color histogram and HOG.

To estimate soccer player trajectories on the pitch automatically, we extract projection transform matrix beforehand. In addition, we must estimate 3D ball motion from position of ball in football game video.

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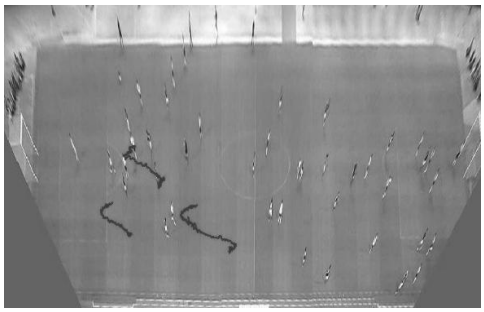

Fig.4 The trajectory on the pitch

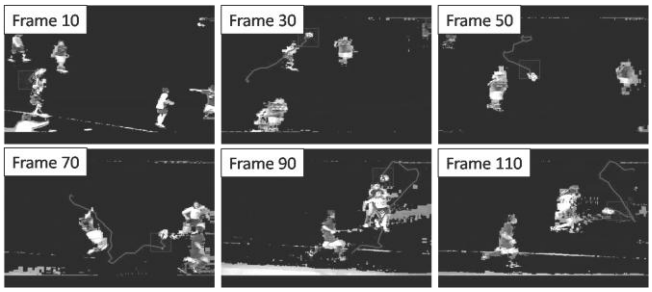

Fig.5 The trajectory of ball tracking

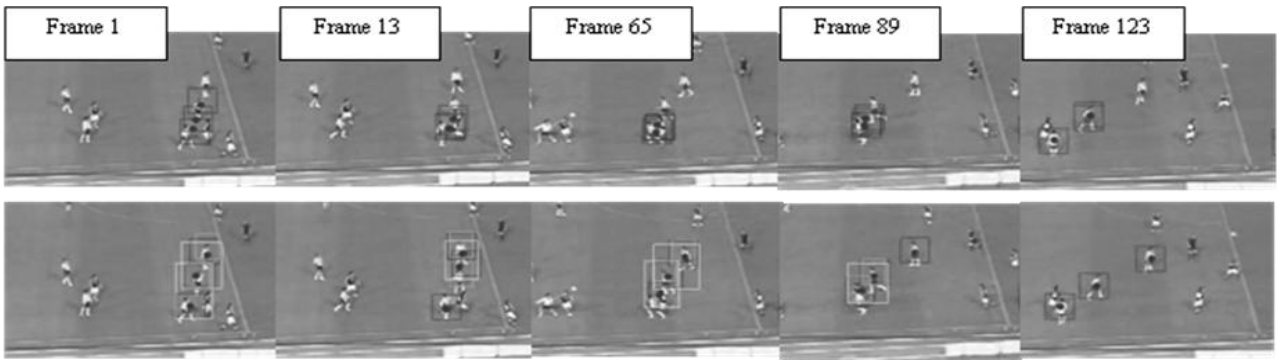

Fig.6 Players tracking under complicated situation