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Team Formation Mapping and Sequential Ball Motion State Based Event Recognition for Automatic Data Volley

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Abstract

Event recognition is an important topic in the volleyball analysis system Data Volley, in which events are classified by their influence to the progress of the game. Normally analysis on Data Volley system relies on entering event data manually but now methods for automatic data acquisition are in demand. This paper proposes a formation mapping and sequential ball motion state based event recognition method for automatic Data Volley system. The team formation mapping method distinguishes those events with similar ball motion by representing the distribution of players when the event happens. Sequential ball motion state feature improves the recognition result by indicating the status of game progress. Experiments are conducted on game videos from the Semifinal and Final Game of 2014 Japan Inter High School Games of Mens Volleyball in Tokyo Metropolitan Gymnasium. Experiments of the proposed method achieve the average accuracy of 98.51% with an improvement of 10.34%, the average recall of 98.94% with an improvement of 18.5% and precision 97.85% with an improvement of 13.12% comparing to the conventional method.

1 Introduction

Data Volley system is one of the most widely used professional volleyball statistics analysis software. This system helps analyzer manually record the moving condition of ball and players when a hit is performed, which is called event, and give evaluations to each hit. However, due to the prevalence of automatic system, saving manual work become the trend of times in a variety of industries, and recording data manually cannot meet the requirement of efficient sports analysis. Therefore, our research aims at automatically recognizing events, which is the fundamental data for analysis in Data Volley system.

Data Volley focuses on seven basic events, based on some introductions[1] and the volleyball game rules[2], the description of each are summarized and presented in Tab. 1. During the study on the rules and introductions, two main problems for volleyball event recognition come out: the compact rhythm of the game process and the high similarity between some events. For the case like Attack and Block, the interval between two events is so short that the moving conditions of the ball and players only change slightly. For some similar events like Reception and Dig, their happening positions vary a lot and the ways players perform them show little difference.

Table 1. Description of events in Data Volley.

Type	Description
Serve	Serve the ball at the start of one round
Receive	First pass after the ball cross the net
Set	Put the ball in the air to decide attacker
Attack	Attempt to score a point against defense
Block	Interception of the ball coming from opponent over the net
Dig	Prevent ball from hitting the ground after opponent's attack or an emergency
Free Ball	Pass the ball over the net when attack is impossible

Many similar works for event detection and recognition focus on broadcasting video analysis. These works refer to some post-process information like text feature on the screen and inserted audio in work[3]. The discontinuous broadcasting video limits the algorithm to perform automatic sports event analysis. For this case, work[4] proposes a framework using visual feature and audio feature of non-broadcast sports videos. However, this work mainly focus on events with referee's whistle thus doesn't suit our target.

In volleyball game analysis, every hit is a meaningful event, and the motion of volleyball fully denotes when and where the event happens. For this reason, the non-broadcast video is chosen to obtain quantified information. Work[5] proposes a ball state based model and achieves good detection result, but the categories of events, which are Serve, Pass, Spike and Others, doesn't fit that in Data Volley. In this work, Spike has the same definition as Attack while Pass includes the event type Reception, Set and Dig. However, it turns out that the way of classification leads to some weakness in distinguishing events that are classified as Pass from each other or telling apart Attack from Block.

To achieve the target of recognizing events defined in Data Volley, this paper proposes a method using team formation mapping and sequential ball motion state feature. These two features are closely relative to tactical analysis, and that's what Data Volley system classifies the events for. The formation mapping is designed to represent the distribution of players at the moment when an event happens, and this feature reduces the probability of false recognition between similar events. The sequential event feature refers to the ball motion state on former event, thereby improving the ability to distinguish events with small intervals. By combing formation feature and sequential event feature, a better result is achieved. One thing needs to be mentioned is that the event Free ball is not included in the experiment because of the limitation of data set.

This paper is arranged as follows. Section 2 explains the flow of event recognition and details of formation mapping and sequential event feature. Section 3 presents experiment results and analysis and Section 4 gives the conclusion of the whole paper.

2 Team Formation Mapping and Sequential Ball Motion State based Event Recognition

2.1 Framework

The overview of proposed event recognition method and the conceptual difference with the conventional method is shown in Fig. 1.

Firstly, the ball tracking method in work[5], and player tracking method in work[6] are applied to the four-view game videos. In the 3D space with the origin set to the center of the court, the ball trajectories, including position and velocity, and the twelve players' 3D trajectories of positions are obtained. By detecting the ball's hit point, all the events are located by frame.

Afterwards, features of players and ball motion for each event are extracted from player's trajectories and ball trajectories respectively. For this step, we propose team formation mapping to represent the feature of players' position and sequential ball motion state feature to describe the relationship between two time-adjacent events. Details of the two proposals are introduced in the following subsection.

At last, all the features are synchronized by referring to the hit frame then Support Vector Machine[8] is used as the classifier to recognize the event we focus on.

2.2 Team formation mapping

Team formation denotes how the team is organized to strengthen the defensive or offensive activities. Thus, certain positions on the court are filled on different events. To represent this feature, we propose the method of team formation mapping.

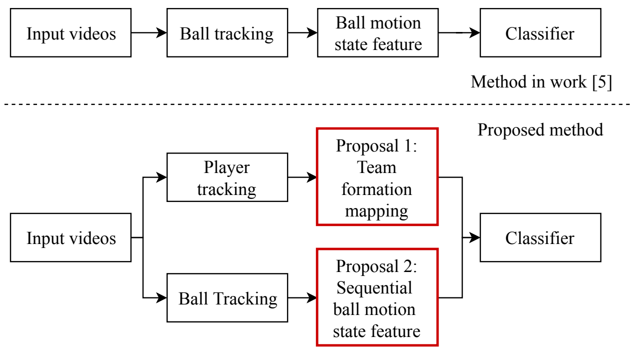

Figure 1. Overview of the conceptual difference between conventional method and team formation mapping and sequential state based event recognition method.

Fig. 2 shows how the players' position is mapped. The court is divided into zones of five rows and eight columns. Inside the sideline and end-line, each zone is a square with sides of 3 meters while the outside area is divided by every 3 meters along the court line. For the mapped matrix, it contains two parts, X-Y plane matrix and Z plane matrix. The element in X-Y plane matrix denotes how many players are in the corresponding zone of the court and in Z plane is the sum of these players' positions in the z-direction.

To make a further explanation, let's define the position of a player in 3D space as $player_i(x, y, z)$, where $i \in [1, 2, ..., 12]$ and the element of the two sub-matrices as $E^{XY}_{a,b}$ and $E^{Z}_{a,b}$ respectively, where $a \in [1, 2, ..., 8]$ and $b \in [1, ..., 5]$. The process of mapping is described as follow.

First, elements in the matrix are initialized to zero.

Then, for the i_{th} player, if $player_i(x, y, z)$ falls in the zone (a, b), the element is calculated by:

$$E^{XY}_{a,b} = E^{XY}_{a,b} + 1, \tag{1}$$

$$E^{Z}_{a,b} = E^{Z}_{a,b} + z, z \in player_i(x, y, z). \tag{2}$$

2.3 Sequential ball motion state feature

During the games, how a player hit the ball directly relates to the former hit. Based on the analysis in[7], the status of volleyball game is divided into three categories: Attack Process, Counterattack Process and Emergency.

Attack Process: A series of events from Serve Reception to set then Spike.

Counterattack Process: A series of events starts from opponent's Attack and ends when the team

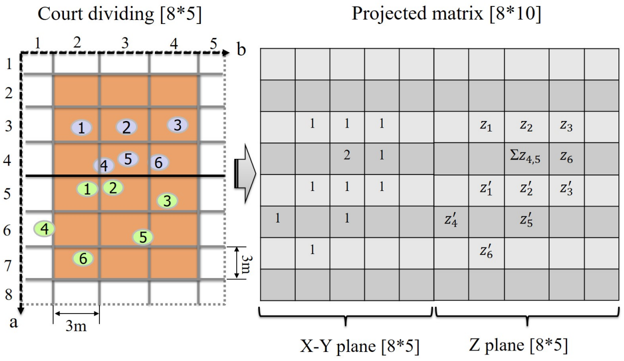

Figure 2. Demonstration of formation mapping method.

returns the ball. In some situation, Block cannot be performed successfully.

Emergency: A receiver or digger failed to control the direction of the ball. Players usually try to dig the ball when the emergency happens.

Comparing with the ball motion feature used in work[5], this work takes the feature of the former event into consideration. The sequential and spatial relationships of the events are summarized in Fig. 3. This figure reveals that the type of an event directly relates to its order. To describe the sequential ball motion feature, we define S_k as the ball motion state of the k_{th} event counting from Serve of each round. P denotes the position and V denotes the velocity in 3D space. So the S_k is defined as:

$$\begin{aligned} S_k = (x_k, y_k, z_k, (v_x)_k, (v_y)_k, (v_z)_k), \\ (x_k, y_k, z_k) \in P, \\ ((v_x)_k, (v_y)_k, (v_z)_k) \in V. \end{aligned} \tag{3}$$

Thus the sequential ball motion state feature S_{seq} for the k_{th} event can be denoted as:

$$(S_{seq})_k = [S_{k-1}, S_k]. \tag{4}$$

For the occasion when the event type is Serve, the former ball motion state are set to zero.

3 Experiment Result

3.1 Experiment environment and data set

The experiment uses the videos of Semifinal Game and Final Game of 2014 Japan Inter High School Games of Mens Volleyball in Tokyo Metropolitan Gymnasium, and views from the four corners of the court are chosen as input. The resolution of all videos is 1920×1080, with the frame rate of 60 frames per second. The implementation of our method uses C++ programming language and OpenCV library 2.4.10.

To meet the requirement of testing all proposed features, some situations like severe occlusion that trajectories were failed to obtain are not included in the data set for the experiment. The overview of the data set is shown in Tab. 2. For the evaluation criteria of the recognition result, we choose precision, recall and accuracy defined in[9].

Table 2. Data sets of events.

	Serve	Receive	Set	Attack	Block	Dig
Semifinal Game	14	23	68	77	33	41
Final Game	10	13	42	41	14	41
Total	24	36	110	118	47	82

3.2 Experiment result and discussion

In the experiment, for each event half of the data is randomly chosen to train the classifier and the other part for testing. Three experiments are conducted and the result of the experiment are shown in Tab. 3. Firstly, tracking methods in [5][6] are applied to our data set to obtain motion data, and the estimation method in [5] is implemented recognizing six kinds of events. Then experiment with proposal 1, the team formation mapping method, is conducted. Finally, proposal 2, the sequential ball motion state feature, is combined with the former two methods for a better result.

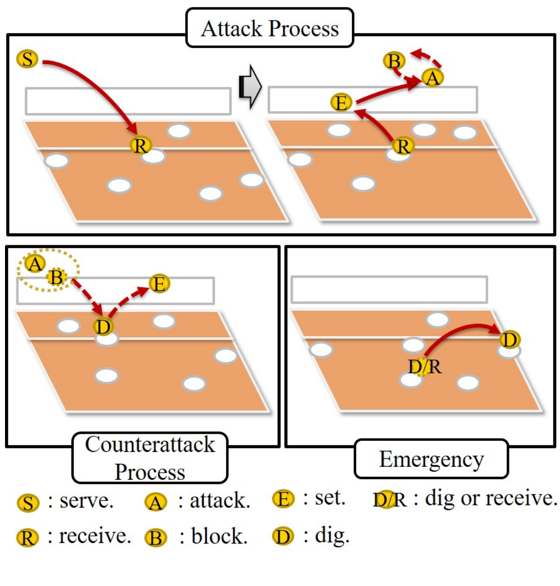

Figure 3. Demonstration of sequential and spatial relationship of events.

Table 3. Experiment results.

Method	Event	Precision	Recall	Accuracy
Conventional work[5]	Serve	100%	100%	100%
	Receive	66.67%	80.00%	86.52%
	Set	86.67%	70.72%	83.87%
	Attack	98.33%	95.16%	96.58%
	Block	77.27%	70.83%	84.62%
	Dig	79.41%	65.85%	77.42%
With proposal 1	Serve	100%	100%	100%
	Receive	82.61%	95.00%	94.38%
	Set	82.61%	89.06%	87.33%
	Attack	98.25%	92.32%	94.02%
	Block	94.44%	70.83%	85.37%
	Dig	89.74%	85.37%	89.25%
Combination of proposal 1 and 2	Serve	100%	100%	100%
	Receive	100%	100%	100%
	Set	93.94%	96.88%	96.00%
	Attack	100%	96.77%	98.29%
	Block	100%	100%	100%
	Dig	93.18%	100%	96.77%

From the test result of method in work[5], we noticed that this work doesn't work well in distinguishing Receive, Set and Dig. The hitting points of these three events distribute over a large area in the court and their features of velocity are also similar for their purposes are the same: put the ball into the air. Besides, the result for Block is relatively low despite its distinct position. Because of the short interval and distance between Block and its former Attack, some cases of these two events are confused. Besides, due to the high speed of the ball after attacker's hit, blocker usually performs poor control on the ball, thus the motion feature of Block doesn't show any distinct pattern.

For the similar events on which ball motion feature doesn't work well alone, a much better result is achieved by combining the team formation feature. This proves that the team formation mapping method offers a good description for players' moving tendency of both teams on the court, which is relative to the purpose of each event. However, this method does not fully solve the problem to distinguish those similar events so we conduct a further experiment.

For the result of combining the two methods, the improvement of each criteria is up to 20% comparing to the work[5]. This experiment also achieves a better result than that with formation mapping, especially for Set and Block. That means the sequential feature has the ability to distinguish events of similar hitting point for the idea of referring to the former event corresponds to the principle for classifying events.

4 Conclusion

In this paper, we propose a team formation mapping feature and sequential ball motion state feature method for event recognition in volleyball games. Team formation mapping represents the players' distribution when the event happens, which reveals the moving tendency of the team. Sequential ball motion state feature describes the relationship between the current event and the former event. By combining these two methods, the experiment result achieves the average accuracy of 98.51% with an improvement of 10.34%, the average recall of 98.94% with an improvement of 18.5% and precision 97.85% with an improvement of 13.12% comparing to the conventional method.

For further research and to achieve the target of automatic Data Volley, detection and evaluation for all events should be realized. Besides, the recognition method should be applied to a video processing system so that the function of automatic Data Volley system can be completed.

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