Basketball Event Recognition Technique using Deterministic Finite Automata (DFA)

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***Abstract*— Recently, many researchers and sport managers are trying to analyse the movement of sports players by combining sports and ICT technology, and to change the contents of the game using these analysis results. In the case of basketball, leading companies such as STATS Sports are focusing on tracking the players and analysing the players' movements. However, the recording of sports events such as shoot, foul, and rebound resulting from the players' movements is made entirely by the manual work of the recorders. In this paper, we propose a technique to automatically extract events generated by players or judges in basketball games. Experiments have shown that it is possible to automatically extract events by tracking players and referees and analysing the predefined motion of players and referees.**

***Keywords*— Deterministic Finite Automata (DFA), Basketball, Event Recognition**

I. INTRODUCTION

Recently, many researchers and sport managers are trying to analyse the movement of sports players by combining sports and ICT technology, and to change the contents of the game using these analysis results. Leading companies as shown in Table 1 are focusing on tracking the players and analysing the players' movements [1][9].

TABLE 1. MAJOR COMMERCIAL SPORTS ANALYSIS SYSTEM

Products	Sports	Special features
TRACAB	Soccer	Video-based real-time 3D player tracking technique created using rocket tracking technology
Viper (Statsports)	Soccer, Basketball	Sensor-based technology to measure player's speed, acceleration, maximum speed and heart rate during sports game
Prozone	Soccer	Player tracking and real-time game analysis based on big data
Club Portal	Soccer	Real-time player tracking and handwriting input based event extraction
Hawk-Eye	Soccer Tennis	Goal line out detection based on high-speed multi cameras
SportVision	Baseball	Player/Ball recognition and tracking in MLB by using the composition of radar and video-based tracking technology
FreeD	Baseball	3D play motion reconstruction by using high speed multi cameras

However, in case of basketball, the recording of sports events such as shoot, foul, and rebound resulting from the players' movements is made entirely by the manual work the recorders. The game information recorded by professional recorders and analysts is written in analytical reports and utilized by the team manager or coach.

In this paper, we propose a basketball event recognition technique based on pattern matching. It is possible to extract events in real time for the live basketball game and to extract events from recorded video.

The composition of this paper is as follows. In section II, we discuss the related works. In section III, we describe the proposed event recognition technology in basketball game. Section IV shows the experimental results of the proposed method. Finally, we conclude the results of this research in section V.

II. THE PREVIOUS WORK

Previous techniques for recognizing events in sports videos were primarily audio-visual content analysis. Most of them are used for broadcasting, and all events are extracted by manual work. The study described in [2] is a study to track objects (players, referees) from video input from fixed cameras, but does not focus on recognizing events.

Another paper focuses on the automatic generation of basketball videos by cutting out the most optimal video from videos input from multiple cameras [3]. In event recognition studies, [4] is a study of motion recognition on web video. There is an event that can recognize an event only by motion. They mainly studied motion related to basketball shooting. It works well on unconstrained datasets like UCF-50, but it only records for very limited motions.

Another study on event detection is performed by identifying the motion of objects. However, this study is not applied only to sports but it is applied to various aspects and is not specialized in sports events [5].

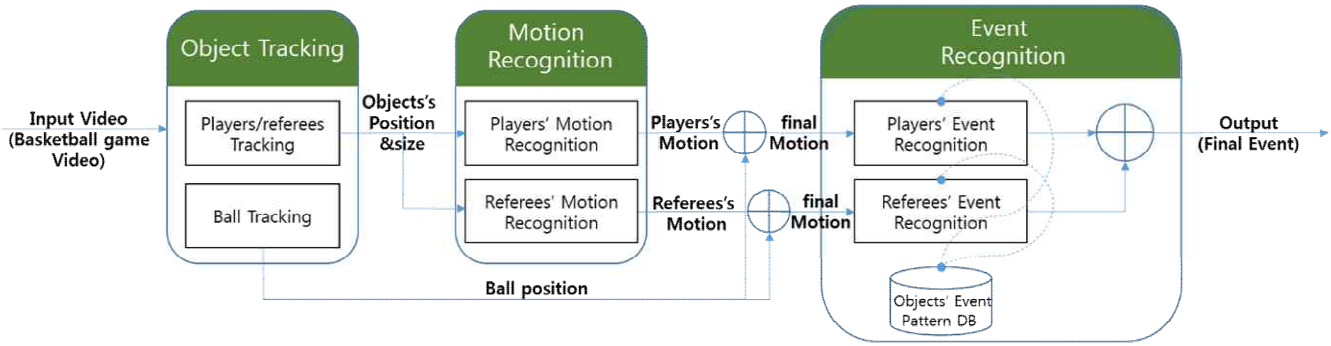


Figure 1. The conceptual diagram of the proposed event recognition system

For example, objects include 'vehicle', 'road', 'bread', and 'plates', and human actions include 'pulling', 'slicing', and 'spreading'. Similar research has been done in soccer also. For example, [6] was a sound-based event recognition study conducted by analysing whistling of referees or loud sounds.

Many of the above studies are not specific to sports and are difficult to use for recognizing sporting events or simply for tracking players/referees. In this paper, we have developed a system that can recognize event automatically, not the recorder, by analysing the position or motion of the players or referees.

III. THE PROPOSED METHOD

The conceptual diagram of the proposed basketball event recognition system is shown in Fig. 1. As shown in the figure, the proposed basketball event recognition system starts with object tracking. In other words, it starts from tracking all the objects (such as 10 players and 3 referees and a ball) that can be seen in a basketball game.

Because multi-object tracking is another area of research, in this paper, we begins with the assumption that tracking of objects in the basketball arena is good. First, we track players, referees and ball and the positions and sizes of each object are output. Based on this, we can recognize the motion of each object except the ball.

When the motion of each object is recognized, the event is extracted by combining the position of the ball and the motion of each object. And we defined the motion of each object based on the tracking of each object as follows.

The event recognition module recognizes the event considering the continuous motion and position of each recognized object and the position of the ball, and can generate the event pattern as shown in Table 2 below.

TABLE 2. MOTIION DEFINITION OF OBJECTS RELATED TO EVENTS

Referees	
Motion	Related events
One arm high	Foul, 3 point shoot(try)
Two arms high	3 point shoot(success)
Arm point	foul
Arms cross	Replacement
Ball pass	Foul, free throw
Walk	-
Run	-

Players	
Motion	Related events
One hand shoot	2 point shoot, 3 point shoot, free throw
Two hands shoot	2 point shoot, 3 point shoot, free throw
Lay-up shoot	Lay-up shoot
Free throw	Free throw
Dunk shoot	Dunk Shoot
Blocking jump	Block
Standing without ball	-
Walking without ball	-
Running without ball	-
One hand pass	Pass, assist
Two hands pass	Pass, assist
Dribble	-

The event recognition module is configured to recognize the event in consideration of the motion, position, and position of each object by previously defining and storing the conditions under which the above-described event occurs in the event pattern DB.

TABLE 3. EVENT RECOGNITION PROCESS EXAMPLES

Event	**Event Recognition Process Example**
2 point shoot	Player shoot (one hand, two hands) motion or player layup shoot motion → catch player position → referee motion(success or not – wave hand stretching two fingers) → 2 point shoot
3 point shoot	Player shoot (one hand, two hands) motion → → catch player position → referee motion (3 point line – one arm high) → referee motion(success or not-two arms high) → 3 point shoot
Dunk shoot	Player dunk shoot motion → referee motion(success or not – wave hand stretching two fingers) → Dunk shoot

Free throw	Player free throw motion → Free throw
Rebound	Player shoot motion(layup shoot, shoot, dunk shoot, free throw) → player catch the ball(grasp ball position) → referee motion(no motion related to point) → Rebound
Assist	Ball pass → success shoot → Assist
Foul	Referee motion(One arm high and point player with another hand) → Foul
Steal	Ball position(player) → Ball position(Player belonged to another team) → referee motion(on motion related to foul or point) → Steal(player intercepting the ball)
Block	Player shoot motion → blocking jump (opposing team) → referee motion(no motion related to foul) → Block
Turn over	Ball position(player) → Ball position(Player belonged to another team) → referee motion(on motion related to foul or point) → Turn over(player snatched the ball)

As shown in Table 3, it can be seen that the event is derived by the transition of the motion. If each defined motion is defined as the state of the object, it can be represented by the DFA (Deterministic Finite Automata) of each object as shown in Fig. 2, 3.

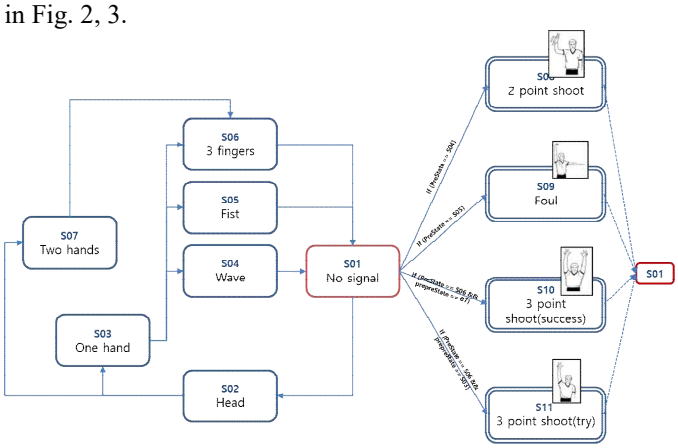


Figure 2. DFA of the referee

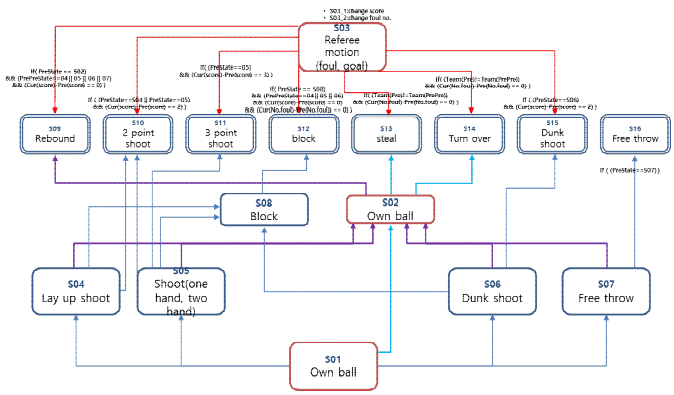


Figure 3. DFA of the player

IV. EXPERIMENTAL RESULTS

For the experiment, two games were selected from KBL (Korean Basketball League) 2016-2017 taken at 4K 30 fps, and the camera was installed at the centre of the basketball court. Figure 4 is a snapshot of the basketball game video. In addition, [7] and [8] were implemented and used for tracking and motion recognition of players / referees. We also used the DFA of the players and referees to recognize the event, and performed recognition experiments for three events (free throw, foul, 3 point shot) among various basketball events. The most influential factor in recognizing various events is tracker and motion recognition performance.

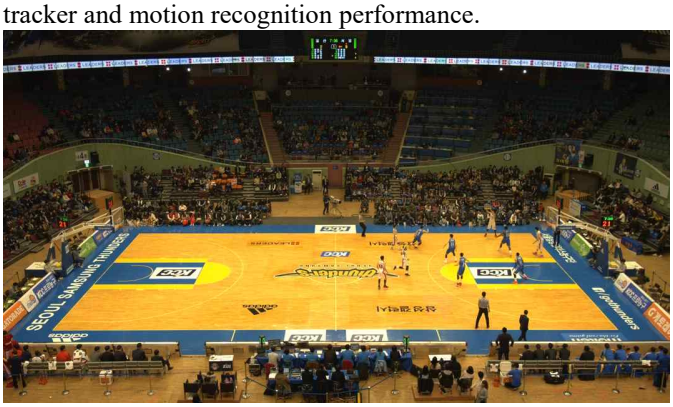
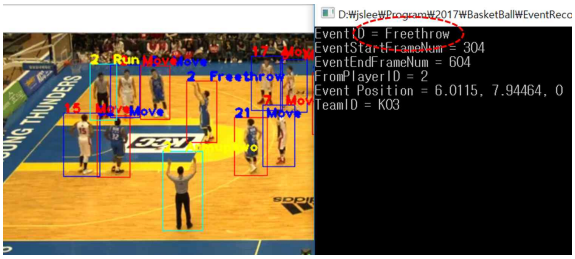
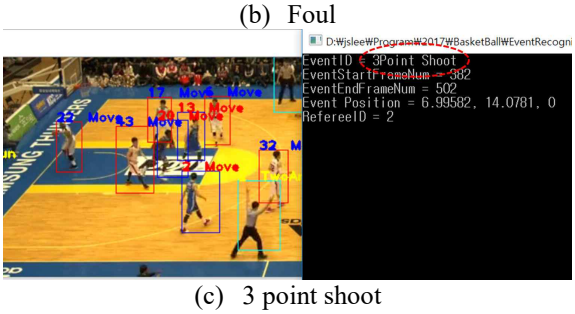


Figure 4. Snapshot sample of the KBL 2016-2017 for the experiments



(a) Free throw

(b) Foul



(c) 3 point shoot

Figure 5. Example of basketball event recognition result. (a) free throw, (b) foul, (c) 3point shoot

Figure 4 is snapshots showing the recognition results for each event. The tracker has an accuracy of about 63%, and the motion recognizer has a recognition rate of about 40%. In this paper, we use ground-truth for tracker and motion recognition because it significantly degrades the performance of event recognition. Through experiments, it is confirmed that the designed event recognition module can accurately extract the event if only the performance of the tracker and the motion recognition module is ensured.

V. CONCLUSIONS AND FUTURE WORK

In this paper, we propose automation of event-dependent event extraction by combining sports and ICT technology. Based on the reliability of the tracker and the motion recognition module, the performance of the designed event recognizer is excellent. In addition, we could confirm that more events could be scaled up if the various patterns of events were clearly defined. However, we can see that a robust tracker is needed to overcome the reflection of the light of the basketball court and the many occlusion among the players and to track the rapid movement of objects. We also found that a robust motion recognizer is needed to recognize the same motion even if the players' motions are slightly different for the same motion. In the future, we intend to concentrate on the multi object tracker and motion recognizer based on these knowledges.

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