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The Event Detection of Serving a Ball in Sports Video

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Abstract

Tennis video's serve events were detected. In other words, athletes area were obtained to calculate particle of athletes area and particle shift in adjacent frame by using background subtraction algorithm. And then tennis video's serve events were inferred, according to specific constraints on serve, through establishing ontology and setting SWRL rules.

***Keywords**: Dominant color, Ontology, SWRL rule*

1. Introduction

In tennis match videos, serving a ball is one of many events. The detection of serving a ball is actually to detect the start and end frames of such episode in the videos [1-3]. Here we use the event detection method whose ideas are based on rules, that is, in the tennis match, when one player is about to serve a ball, he/she must stand in the service area and both fore and back court players must stand in the oblique diagonal place of the court; only after the serving is over, front and back court players can make big movements [4-6]. So the first job is to classify court and non-court frames in tennis match videos; then, fetch court lines of court frames and get the centroid of front and back players, as well as the displacement of front and back players in the two adjacent frames; finally, by creating and formulating the ontology of serving event and SWRL inference rules, fulfill the purpose of serving a ball detection in those videos [7-8].

After classification of court frames and non-court frames of tennis video frame images, it's easily found that each section of consecutive court frames starts with serving a ball; and the basic standard about defining the service event is both front and back court players stand in the service area and their displacement in the anterior and posterior frame is very small. As long as in the two adjacent frames, one player in the front or back court displaces a big step, it's thought that the service of a ball is over and it goes to next episode. In short, to improve the efficiency, once the service is over, it will directly read in the following consecutive court frame sequence, with nothing done to the subsequent court frames [9-10].

2. Acquisition of Attribute Values

2.1 Extraction of Player Area

Here we need only to extract players at the serving moment. During serving a ball, shots are generally long-distance views and lens doesn't shake too much. Based on that feature, we propose using the background subtraction method mentioned in [11] to fetch player area, in the following steps:

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(1) Image preprocessing: use Gaussian filter to smooth and eliminate noises of images as for the goal of enhancing player area;

(2) Background generation and update: every time when reading successive court frame sequence, use the first frame in the sequence as background; then update background with background renewal method;

$$B_{n+1}(x,y) = (1-\partial) * B_n(x,y) + \partial * image(x,y) \qquad (1)$$

(3) Extraction of player area: use the idea of background subtraction method to fetch player area, in the equation (2);

$$M(x,y) = \begin{cases} 0 & if\ |I(x,y) - B(x,y)| < TH \\ 1 & if\ |I(x,y) - B(x,y)| < TH \end{cases} \qquad (2)$$

(4) After treatment: using background subtraction method to extract player area will cause some noise points; to remove those unnecessary ones, utilize morphological method to treat $M(x,y)$.

Figure 1 is a diagram of the experimental results, In Figure 1 (a) is the original image, Figure 1 (b) is to generate the background map, Figure1 (c) is extraction for athletes regional map.

(a) Original (b) Generation Background (c) Extracted Athletes

Figure 1. The Background Subtraction Method to Extract the Results of Athletes

2.2 Centroid Extraction and Displacement Acquisition

For the convenience of the subsequent calculation, we need to get the centroid of player area as follows:

(1) For the extracted pictures of player areas, use connected region calculation method to find out such regions and mark them;

(2) Employ geometrical distance calculation method to obtain the centroid of connected regions; the formula is shown in formula (3):

$$x_c = \frac{\sum_{x}^{m-1} \sum_{y}^{n-1} x * g(x,y)}{\sum_{x}^{m-1} \sum_{y}^{n-1} g(x,y)}$$

$$y_c = \frac{\sum_{y}^{n-1} \sum_{x}^{m-1} y * g(x,y)}{\sum_{y}^{n-1} \sum_{x}^{m-1} g(x,y)} \qquad (3)$$

(3) After the centroid of both front and back court players, compute by Euclidean distance the displacement of such centroid in two adjacent frames; the formula is shown in formula (4) $d = sqrt(\sum_{i=1}^{n}(x_{i1} - x_{i2})^2 + \sum_{i=1}^{n}(y_{i1} - y_{i2})^2)$ (4)

3 Detection of Serving a Ball Based on Rules

In the paper, the detection of serving a ball is implemented with the use of ontology for semantic analysis of low-level features. The approach of using ontology is identical to those steps in Chapter III, *i.e.* utilize protégé as tool to create model of ontology, building its class, attribute as well as class-related units; then, make SWRL rules; lastly, use Jess derivation engine to deduce start and begin frames of ball service in tennis video court frame sequence.

3.1 Creation of Ontology

3.1.1 Creation of Class

According to requirements of recognizing service actions in the tennis videos, we created seven classes of glossaries and meanings. It is shown in Table1.

Table 1. The Vocabulary and Comparison Table of class

Vocabulary	Word meaning
MatchCourt	Space frame
LServeAreaOfP1	Before the athletes left service area
RServeAreaofP1	Right front players tee
LServeAreaOfP2	Left tee backcourt players
RServeAreaofP2	Right tee backcourt players
Event	The current site frame
ServeEvent	Service event

When front and back court players in the current court frame locate in the service area, it's believed that the frame is one belonging to serving a ball event. The service area in the graph is the region among the back of end lines, central mark and the presumed extended lines of side lines where players are standing when a ball is ready for delivery, instead of the region in the tennis court. We create classes with the Protégé tool. It is shown in Figure2.

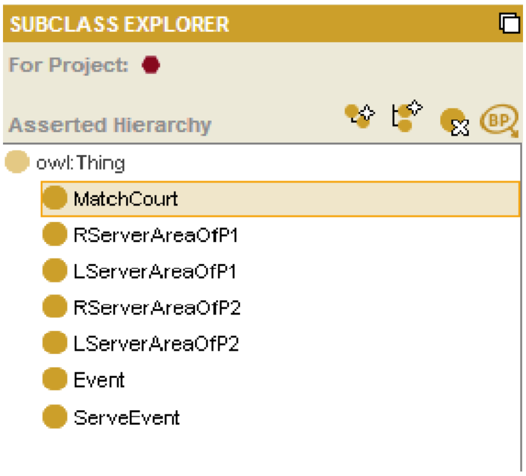

Figure 2. The Establishment of Class

3.1.2 Build of Attributes

As per derivation requirement, we defined sixteen attributes. It is shown in Table 2, Table field refers to the property belonging to the class.

Table 2. The Definition of Attribute

Attribute	Field	Semantic	Type
bxPlayer	MatchCourt	Backcourt player athletes particle x coordinates	float
bxPlayer	MatchCourt	Backcourt player athletes particle y coordinates	float
bxsServiceLine	MatchCourt	The back end and left the singles borderline x coordinates	float
bxsServiceLine	MatchCourt	The back end and the right's borderline x coordinates	float
byServiceLine1	MatchCourt	The back end y value minus the threshold value of T1 coordinate	float
byServiceLine2	MatchCourt	The back end y value minus the threshold value of T1 coordinate	float
bPShift	MatchCourt	The back end y coordinate values and threshold values of T2	float
fxPlayer	MatchCourt	Backcourt players displacement	float
fxPlayer	MatchCourt	Frontcourt athletes particle x coordinates	float
fxsServiceLine	MatchCourt	Frontcourt athletes particle y coordinates	float
fxsServiceLine	MatchCourt	The front end and the left's borderline x coordinates	float
fxsServiceLine1	MatchCourt	The front end and the right's borderline x coordinates	float
fxsServiceLine2	MatchCourt	Frontcourt y to the T3 threshold value coordinates	float
fPShift	MatchCourt	Frontcourt y coordinates and threshold value of T4 Frontcourt athletes displacement	float
sxCenterLine	MatchCourt	The back midline point coordinates x	float
exCenterLIne	MatchCourt	The front line spot coordinates x	float

In protégé built attribute tools, it shown in Figure 3.

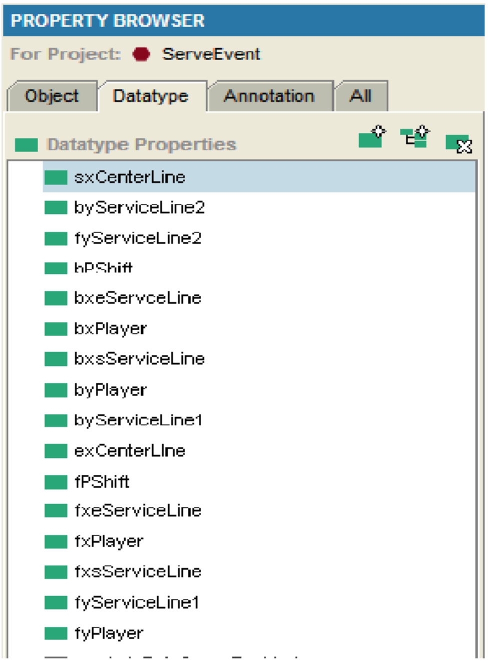

Figure 3. The Establishment of Property

3.1.3 Build of Single Units

We built two units like matchCourt unit in MatchCourt class and event unit in Event class. We created units with Protégé tool. It is shown in Figure 4.

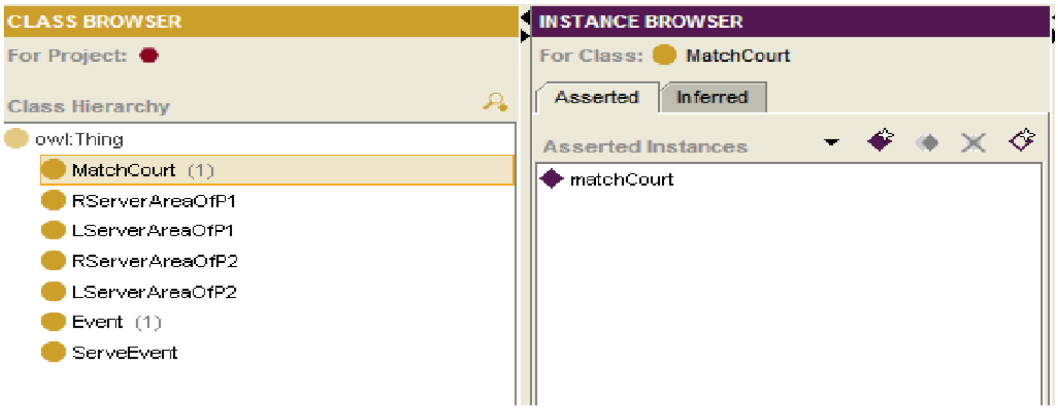

Figure 4. The Establishment of Individual

3.2 Formulate of SWRL Rules

By fetching the tennis court lines of each single court frame, we can get bxsServiceLine, bxeServceLine, byServiceLine1, byServiceLine2, fxsServiceLine, fxeServiceLine, fyServiceLine1, fyServiceLine2, sxCenterLine, exCenterLIne attribute value. Then with background subtraction method, we can get Player attribute value. By computing the Euclidean distance between centroids of bxPlayer, byPlayer, fxPlayer fyPlayer in the anterior and posterior frames, we can have bPShift, fPShift attribute value.

In the tennis competition, serving a ball should follow these rules:

(1) The server should stand in the area among the back of end lines, central mark and the presumed extended lines of side lines. Here players are expressed in their own centroid points. So the coordinate value of server's centroid x axis should exist between middle mark and side lines x axis coordinate; the coordinate value of

server's centroid y axis undulates around end line's y axis coordinate due to different standing postures and ways of serving a ball. The front court server's centroid y coordinate value changes in the range [end line y coordinate -45, end line y coordinate +10]; the back court server's centroid y coordinate value varies in the range [end line y coordinate -30, end line y coordinate +5];

(2) The receiver should stand in the area among the back of end lines, central mark and the assumed extended lines, which is diagonally opposite to the server; so the receiver's centroid x axis coordinate value should be between the central mark and side line x axis coordinate value; receiver's centroid y coordinate value fluctuates around end line y coordinate value, however the changing range is smaller than that when a ball is served;

(3) Either server or receiver will make big displacement only if the ball is already delivered. By computing the displacement of plentiful adjacent frames' centroids, we can get the centroid displacement range of the front and back court players during serving a ball, which is respectively [0, 10] and [0, 7]. After the service is done, the front court players' displacement quantity is bigger than 15 and back court players' is bigger than 10. Based on the above rules, we set up SWRL rules to deduce the service episode.

3.2.1 Definition of Variables

Here we defined three categories of totally nineteen variables. The connotation of each variable is shown in Table 3.

Table 3. The Variable and the Meaning Table

Variable name	Meaning
?m，?n	The MatchCourt class corresponding to the individual
?e	The Event class corresponding to the individual
?bx，?by……?sx，?ex	BxPlayer properties,... SxCenterLine, the exCenterLIne property value

3.2.2 Build of IMP Rules

With the use of SWRL rules, we built six another rules as to infer the service episode from tennis video court sequence. The rules and implications are put in Table4.

Table 4. Serve Event Rules

Meaning	SWRL regular expressions
In front of athletes in the right service area and the displacement is less than the threshold T1	MatchCourt(?m) ^ fxPlayer(?m, ?fx) ^ fyPlayer(?m, ?fy) ^ fxeServiceLine(?m, ?fxe) ^ exCenterLIne(?m, ?ex) ^ fyServiceLine1(?m, ?fys1) ^ fyServiceLine2(?m, ?fys2) ^ fPShift(?m, ?fp) ^ swrlb:greaterThan(?fx, ?ex) ^ swrlb:lessThan(?fx, ?fxe) ^ swrlb:greaterThanOrEqual(?fy, ?fys1) ^ swrlb:lessThanOrEqual(?fy, ?fys2) ^ swrlb:lessThan(?fp, "+T5+") → RServerAreaOfP1(?m)
Backcourt the athletes in the left service area and the displacement is less than the threshold T2	MatchCourt(?n) ^ bxPlayer(?n, ?bx) ^ byPlayer(?n, ?by) ^ bxsServiceLine(?n, ?bxs) ^ sxCenterLine(?n, ?sx) ^

	byServiceLine1(?n, ?bys1) ^ byServiceLine2(?n, ?bys2) ^ bPShift(?n, ?bp) ^ swrlb:greaterThan(?bx, ?bxs) ^ swrlb:lessThan(?bx, ?sx) ^ swrlb:lessThanOrEqual(?by, ?bys2) ^ swrlb:greaterThanOrEqual(?by, ?bys1) ^ swrlb:lessThan(?bp, "+T6+") → LServerAreaOfP2(?n)
Service event	Event(?e) ^ RServerAreaOfP1(?m) ^ LServerAreaOfP2(?n) → ServeEvent(?e)
In front of athletes in the left service area and the displacement is less than the threshold T1	MatchCourt(?m) ^ fxPlayer(?m, ?fx) ^ fyPlayer(?m, ?fy) ^ fxeServiceLine(?m, ?fxe) ^ exCenterLIne(?m, ?ex) ^ fyServiceLine1(?m, ?fys1) ^ fyServiceLine2(?m, ?fys2) ^ fPShift(?m, ?fp) ^ swrlb:greaterThan(?fx, ?ex) ^ swrlb:lessThan(?fx, ?fxe) ^ swrlb:greaterThanOrEqual(?fy, ?fys1) ^ swrlb:lessThanOrEqual(?fy, ?fys2) ^ swrlb:lessThan(?fp, "+T5+") → LServerAreaOfP1(?m)
Backcourt the athletes in the right service area and the displacement is less than the threshold T2	MatchCourt(?n) ^ bxPlayer(?n, ?bx) ^ byPlayer(?n, ?by) ^ bxeServceLine(?n, ?bxe) ^ sxCenterLine(?n, ?sx) ^ byServiceLine1(?n, ?bys1) ^ byServiceLine2(?n, ?bys2) ^ bPShift(?n, ?bp) ^ swrlb:greaterThan(?bx, ?sx) ^ swrlb:lessThan(?bx, ?bxe) ^ swrlb:lessThanOrEqual(?by, ?bys2) ^ swrlb:greaterThanOrEqual(?by, ?bys1) ^ swrlb:lessThan(?bp, "+T6+") → RServerAreaOfP2(?n)
Service event	Event(?e) ^ LServerAreaOfP1(?m) ^ RServerAreaOfP2(?n) → ServeEvent(?e)

Establish the rules in Protégé. It is shown in Figure5:

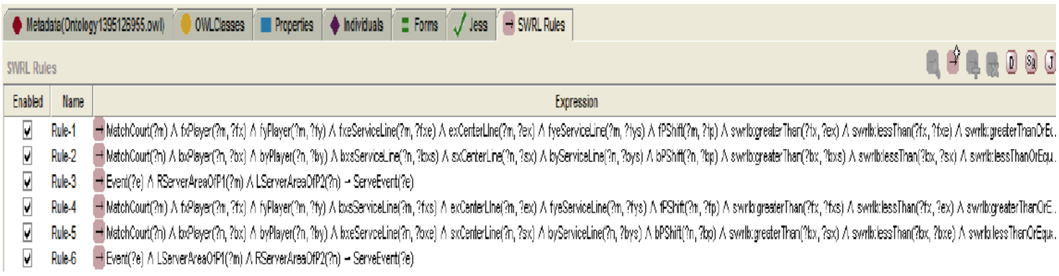

Figure 5. The Establishment of SWRL Rules

3.2.3 Rule Deduction and Representation

Inference results are represented by the motion of units. In the paper, each court frame image stands for one unit. Figure 6 is illustration of inference results. Firstly, it infers that front court players stand in the right service court; meanwhile, it infers that back court players at this frame stand in the left service court; hence, the current frame is correctly judged one of service sequence frames.

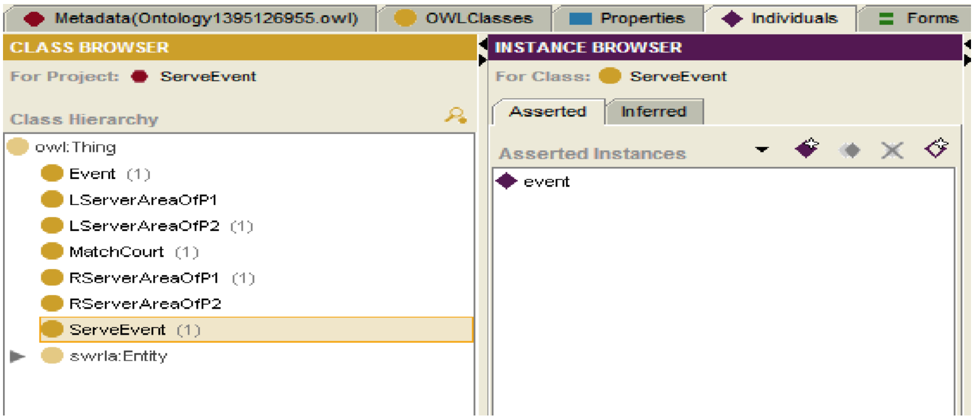

Figure 6. Deduction and Representation

4. Experiment Design and Discussion

We utilized three tennis match videos as experimental data to discern service episodes. Figure 7 shows one group of graphs extracted from one section of the whole service event after derivation. Table5 lists out experimental results of the proposed method here, which are statistical Figures under the condition of assuming both the recall and precision rate at 100%. The service episode's recall ratio, precision rate and the accuracy rate of boundary location are defined like the following equation:

$$\text{Precision}\ \frac{\text{detect the correct number of service events}}{\text{detect the actual number of service events}} \times 100\% \qquad (5)$$

$$\text{Recall} = \frac{\text{detect the correct number of service events}}{\text{In the video the actual number of event service}} \times 100\% \qquad (6)$$

Experimental results suggest that the service action recognition algorithm here can discern accurately the service event. We regarded the first frame of a series of successive court frames as the initial frame of one service episode. The frame in which the front or back court players moved a big step was considered as the end frame of such episode; and nothing was done to the following court frames; instead, we read in the next set of court frames and recognized service episode. In this case, both the recognition speed and the precision rate were improved. However, during the TV broadcasting of some tennis matches, occasionally there was continuous play of two sparring incidents, *i.e.* no inter-cut of non-court frames. In this case, the proposed algorithm didn't detect the second service event, leading to missing detection. In the later period of serving a ball, there were certain lens motions, which led to wrong calculations of players' displacement. The end frame of serving a ball was falsely discerned, as a result the accuracy rate of boundary location became higher.

5. Conclusion

In the paper we discussed about how to detect the service event in tennis videos. For that objective, we proposed classifying tennis video frames to court frame and non-court frame. The first frame of each set of consecutive court frames was regarded as the initial frame of such event, as to enhance the recall and precision rate. Besides, we used protégé to build ontology and SWRL rules for inferring the ball service episode.

Table 5. The Experimental Results

Video sequence	check number	number of positive detection	False number	Missing number	Recall	Precision
1	32	32	0	0	100%	100%
2	29	28	1	1	96%	96%
3	35	32	0	3	91%	100%

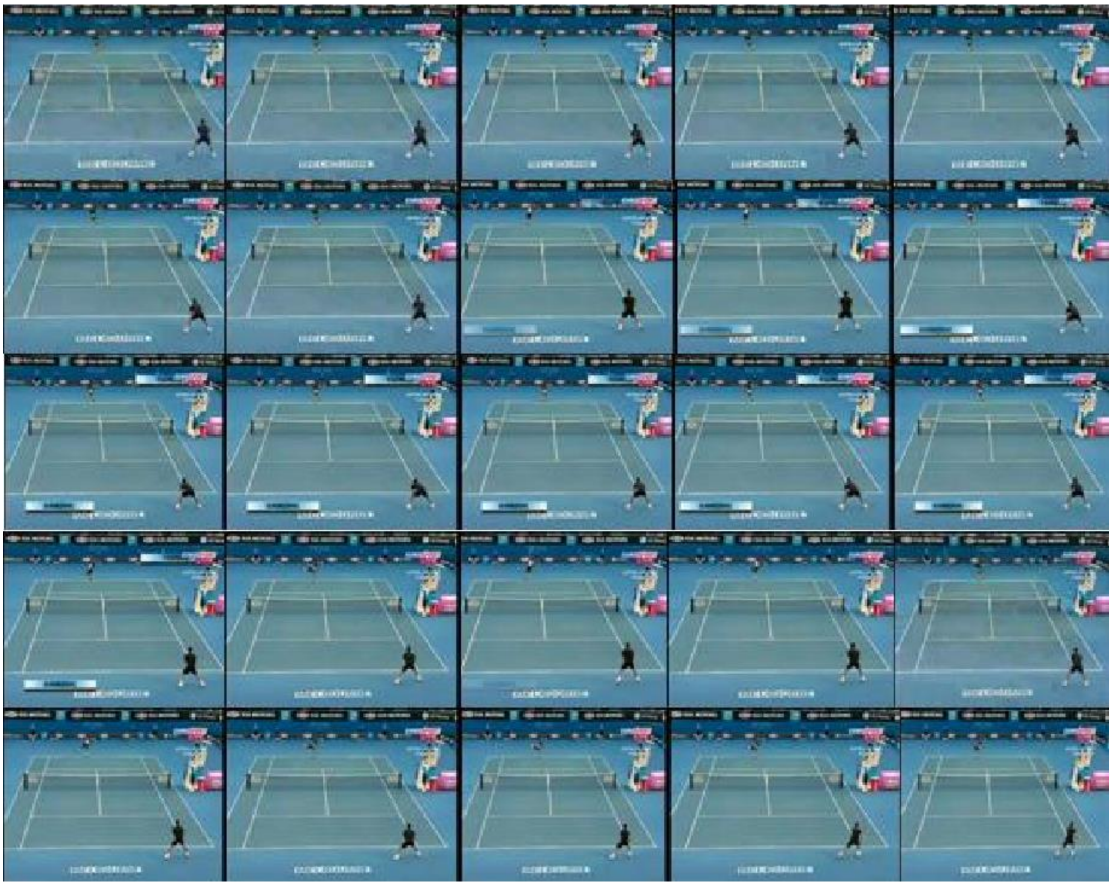

Figure 7. Service Event Graph

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