International Journal of Computer Science and Applications,

Vol. 7 No. 3, pp. 18 - 32, 2010

STRUCTURE BASED FEATURE EXTRACTION IN BASKETBALL ZONE-DEFENSE STRATEGIES *

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Abstract: This paper proposes a framework for structure-based feature extraction in basketball zone-defense strategies. Firstly, a graphical representation for key-frames extracted from zone-defense video clips is introduced, where each key-frame is expressed in terms of a zone-defense graph, representing the positions of defenders and the ball. Secondly, defense-lines are defined and extracted from zone-defense graphs for each zone-defense strategy, based on which, a 10-dimentional feature vector with respect to the defense-lines is introduced to characterize the structure relationships. Experiments have been conducted for basketball zone-defense strategy detection on both simulated and real-life basketball zone-defense video database, which demonstrate the validation and practicability of such a structure based feature characterization, and, in particular, its robustness with respect to the disturbance of local transformation of subprime nodes in the graphs.

Keywords: Feature extraction; Graphical representation; Structure relationship; Video clip detection; Basketball zone-defense.

1. Introduction

Video detection is one of the hottest research topics in Content-based Video Retrieval and attracted more and more attentions. [Qi *et al*. 2007] proposed optimized multi-graph-based semi-supervised learning (OMG-SSL) algorithm in a regularization and optimization framework. A temporal reasoning method was proposed for events annotation in news video in [Marco *et al*. 2008]. As a popular worldwide media, sport video has become an increasingly important and active research area in video/image processing and pattern recognition including feature extraction, shot segmentation, event or highlight detection, and semantic annotation and so on. [Gong *et al*. 1995] presented an automatic system for parsing TV soccer program by domain knowledge, feature analysis and model matching techniques. [Babaguchi *et al*. 1999] Proposed an event

* This research is supported in part by National Nature Science Foundation of China (No. 60772122).

based video indexing for football games achieved by the idea of intermodal collaboration which takes into account of the semantic dependency between multimodal information streams including visual, auditory and text. [Chang *et al*. 1996] extracted the information in soccer video by an integrate speech understanding and image analysis algorithms. [Rui *et al*. 2000] presented a highlights extraction approach for baseball games on set-top devices in noisy environment. [Xu *et al*. 2001] proposed a grass-area-ratio based algorithm for soccer video segmentation. [Pan *et al*. 2001] proposed an automatic event detection and sports program summarization method based on detecting slow motion replay segments. [Efros *et al*. 2003] proposed a new motion descriptor to recognize human actions at a distance in soccer based on smoothed and aggregated optical flow measurements over a spatio-temporal volume centred on a moving figure. [Luo *et al*. 2003] presented object-based analysis and interpretation for baseball video based on automatic video object extraction, video object abstraction, and semantic event modelling. [Urtasun *et al*. 2005] presented a novel motion tracking approach in golf. [Bagdanov *et al*. 2007] proposed the multimedia ontology for soccer video detection.

A number of approaches have been proposed for basketball video analysis, including shot classification, scene recognition and event detection. [Tan *et al*. 2000] presented a camera motion based annotation and classification tool using the low-level information available directly from MPEG compressed basketball videos. [Nepal *et al*. 2001] proposed a goal detecting method in basketball videos by combining feature extraction techniques with domain specific knowledge. [Zhou *et al*. 2000] proposed a supervised rule based basketball video classification system after investigating the use of video content analysis and feature extraction and clustering. [Kim *et al*. 2002] proposed a semantic information extracting mechanism for basketball video sequence using audio and video features. [Xu *et al*. 2004] proposed an audio keywords generating approach for basketball video based on low-level audio features and applied audio keywords together with heuristic rules to event detection. [Kim *et al*. 2005] presented a summarization method for basketball videos. [Perse *et al.* 2009] proposed trajectory-based approach to the automatic recognition of complex multi-player behavior in a basketball game.

However, few of them focused on zone-defense detection, which is essential and crucial in basketball games. On one hand, the defensive coach needs to layout the zone-defense strategy and check whether the team is playing in the right strategy or not all the time; on the other hand, the offensive coach also needs to know which zone-defense strategy the defenders are adopting.

Zone-defense is a common strategy adopted in basketball games. It is different from man-to-man defense in that, instead of guarding a particular player, each zone defender is responsible for guarding an area on the court (or "zone") and any offensive player that comes into that area. Zone defenders move their position on the court according to where the ball moves. Zone-defense can disrupt the opponent's offensive plan by means of protecting the paint area and forcing the opponent to shoot from outside. In addition, changing defenses from man-to-man to various can make the offense off-balance and confused.

In particular, feature extraction is one of the most significant tasks plays a basic and essential role in Zone-defense detection. The original approach is the common features such as color, texture and shape. It's noted that they are not competent due to the distinct structure character in zone-defense strategies. Graphic representation has been investigated for zone-defense detection. Graph matching (GM) algorithms and their improved variants have been well applied to match graph patterns [Zheng *et al*. 2009 and

Ma *et al*. 2007]. However, the efficiency and accuracy of most graph matching algorithms depend very much on the tested graphs constructed according to the expectation or artificial criteria, rather than real-life applications [Zheng *et al*. 2009], which in turn means most graph matching algorithms are sensitive to the outliers or local bias such as the translation of subprime notes in the graph. [Chin *et al*. 2005] proposed a Spatial-Relationship (SR) based approach to describe the position relationship between defenders. However, it relies on the accuracy of identification of each defender, which is hardly achievable.

Generally speaking, the defense-lines and the structure relationship between defense-lines play a crucial role in team sports, such as basketball, football, volleyball and so on. Therefore, analysing the structure relationship between defense-lines plays an important role in basketball zone-defense strategy detection. Therefore, in this paper, a structure-based feature descriptor in terms of a 10-dimentional feature vector is proposed for zone-defense strategy. The basic idea is to describe the distinct structure relationship between defense-lines based on the graphical representation of key-frames.

In what follows in this paper, the graphical representation of key-frames in basketball zone-defense videos is introduced in section 2. Section 3 elaborates the structure-based feature extraction in basketball zone-defense graphs and the corresponding algorithms. Based on the extracted structure features, section 4 designs the actual algorithm for the overall basketball zone-defense detection system. Experimental results are provided, analyzed and evaluated in section 5, demonstrating the good performance of proposed feature descriptor. Finally, section 6 provides a brief summary and concludes the paper.

2. Graphical Representation in Basketball Zone-defense Video

Videos can be organized at different levels for various research purposes. In this paper, basketball videos are organised in terms of clips. Each clip represents a certain round of offense (or defense) and is denoted as a list of images, or the so-called key-frames sequence $I = [I_1, \ldots, I_n]$, which consists of the key-frames extracted one per 2 seconds from the clip. We premise that:

(1) The defenders have adjusted to their best defensive positions at the moment when the ball is just to be passed or dribbled;

(2) As the zone-defense strategy is to defense the offensive opponent to attack into interior playfield, we only consider the key-frames when the ball is in the midfield, the wing and the corner as key-frames.

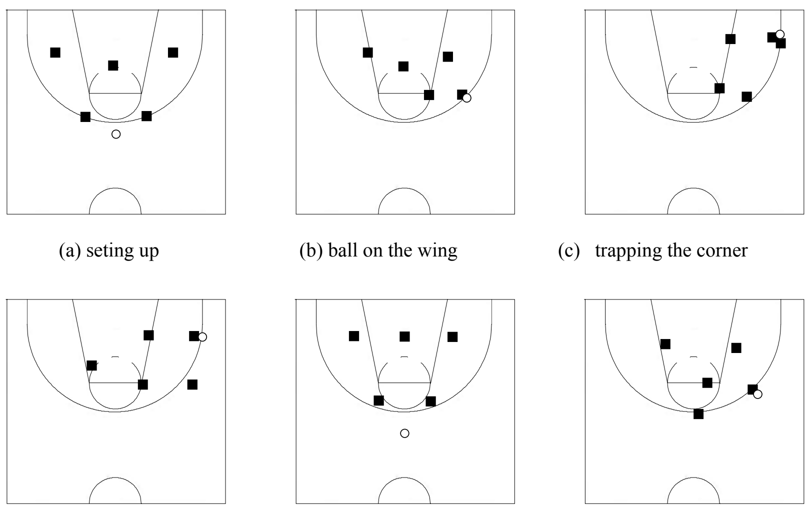
The metric position detection of defenders and the ball is implemented similarly as in [Assfalg *et al*. 2003]: The ball's position, which is either in the midfield, in the wing, or in the corner, is obtained from its motion described in terms of camera motion, which in turn, is captured by image motion estimation algorithm [Baldi *et al*. 1999]. As for defenders position, in the first place, the defend side and offensive side are distinguished by the colour difference of sportswear; template matching and projective transformation are then implemented to determine the metric position of defenders [Assfalg *et al*. 2003].

Each key-frame I_i ($i = 1, \ldots, n$) can be described by its corresponding six-note graph G_i structured by the 5 defenders' position (horizontal and vertical coordinates) plus the ball's position. Following the conventional notations in graph theory, we represent a zone-defense graph as $G = \langle V, E \rangle$, where V and E denote the set of the notes (defenders' position) and the set of edges respectively, and $E \subseteq V \times V$. In particular, here, $|V| = 6$.

Assuming V = {V_b, V_1, V_2, V_3, V_4, V_5} has been ascending ordered by the Euclidean distance to the ball (V_b).

Zone-defense can be divided into various strategies, including 2-3, 1-3-1, 1-2-2, 3-2, 2-2-1, 2-1-2 and 1-2-1-1 zone-defense strategies, where the first three strategies, which have been noted as the most typical ones employed in actual basketball games, are focused in our paper.

A standard zone-defense graph database of these 3 typical zone-defense strategies (2-3, 1-3-1 and 1-2-2 zone-defense) is constructed and populated with graph data corresponding to some of the pictures illustrated on two basketball coaching web sides. For instance, a typical round of 2-3 zone-defense can be expressed as Fig. 1 where 5 squares and the circle denote the 5 defenders and the ball respectively.



(a) seting up (b) ball on the wing (c) trapping the corner

(d) denying pass from corner to wing (e) defending high post (f) ball reversal, opposite post out

Fig.1 A typical round of 2-3 zone-defense strategy

Table 1. The number of standard zone-defense graphs

Ball's position \ Zone-defense	2-3	1-3-1	1-2-2
Midfield	4	3	2
Wing	4	12	7
Corner	6	6	2
Totally	14	21	11

Table 1 below shows the detailed number of zone-defense graphs we have currently collected as standard zone-defense graphs for each strategy in different ball's position. Analogously, only the three typical zone-defense strategies and only the key-frames when the ball is in the midfield, the wing and the corner are considered.

Fig.2 shows the flow chart of basketball zone-defense detection system. For each test zone-defense video clip, it is decomposed into a sequence of key-frames. Each key-frame is represented by a zone-defense graph as mentioned above and matched with the graphs in the standard zone graph database. The global distance with each standard zone are then obtained according to the graph-sequence that is the most similar one (has the smallest distance) to the test graph-sequence, which in turn, provide matching results to confirm which zone-defense strategy does the test key-frame sequence belong to.

It is worth pointing out that, in the framework presented in this paper, zone-defense key-frames are transferred into zone-defense graphs by means of graphical representation. However, instead of using conventional graph matching algorithms, a structure-based feature extraction algorithm, which will be discussed in detail in next section, is proposed to measure the similarity between zone-defense graphs.

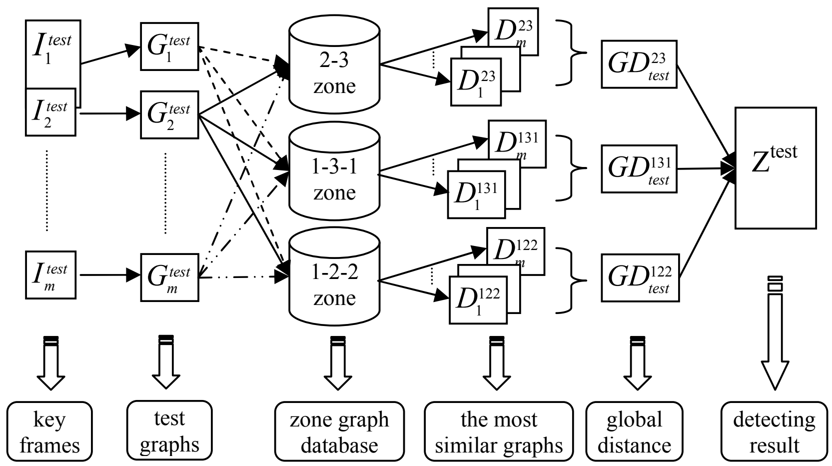


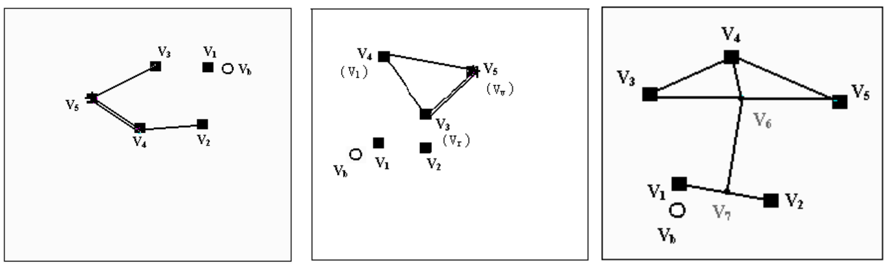
Fig.2 The flow chart of basketball zone-defense detection system

3. Structure-based Feature Extraction in Basketball Zone-defense Strategies

Different zone-defense strategy has different number and type of defense-lines in basketball, For instance, there are two defense-lines in 2-3 zone-defense strategy. Generally, we define that the 2 defenders in the front line construct the first defense-line and the rest 3 defenders construct the second defense-line. In addition, different zone-defense strategy, as what it's named, has its own typical defense-line. For instance, the typical defense-line of 2-3 zone defense strategy is the second defense-line. We shall define the structure-based features to describe the structure relationship between defense-lines. The angle formed by the typical defense-line in each zone-defense strategy is named corresponding character-angle, the definition of which is crucial to the extraction of the other structure features.

3.1. ***Structure-based Features in 2-3 Zone-defense Strategy***

In standard 2-3 zone-defense strategy, normally, we define that the 2 defenders closest to the ball construct the first defense-line; and the rest 3 defenders construct the second defense-line which is defined as the 2-3 character line. The angle formed from the 2-3 character line is defined as "2-3 character-angle" and denoted by shorthand writing as CA_{23}. There are two folds regarding the definition of CA_{23}:



(a) a counterexample (b) another counterexample (c) a general example

Fig.3 Zone graph examples in 2-3 zone-defense

(1) Which 3 notes construct CA_{23}?

Normally, CA_{23} is composed of the 3 defenders farthest from the ball. However, in some zone graphs, CA_{23} may not exactly be constructed by the 3 defenders farthest from the ball by common sense from human understanding of zone-defense strategies. For instance, in Fig.3 (a), assume that V = $\{V_b, V_1, V_2, V_3, V_4, V_5\}$ has been ascending ordered by the distance to the ball (V_b) and V_3 and V_2 have an approximately same distance to the ball. Obviously, the CA_{23} should be constructed by V_2, V_4 and V_5, which is more reasonable according to common sense than that constructed by the farthest 3 notes (V_3, V_4 and V_5).

In other word, if the difference between the distances from the third and forth farthest notes to the ball is smaller than a given threshold, then the one forming a larger angle with the segment constructed by the farthest two notes will be taken to form the character line. The algorithm is described as following:

If $(\left|\overline{V_2V_b} - \overline{V_3V_b}\right| < \delta)\ \&\ (\angle(V_2, \overline{V_4V_5}) > \angle(V_3, \overline{V_4V_5}))$

$$CN_{23} = \{V_2, V_4, V_5\}$$

Else

$$CN_{23} = \{V_3, V_4, V_5\}$$

End.

---

where δ=0.05 (the distance of diagonal of half-court is normalized to 1), CN_{23} denotes the set of notes constructing CA_{23} and $\angle(X, \overline{YZ})$ represents the angle between note X and segment YZ which is defined as:

$$\angle(X,\overline{YZ})=\begin{cases}\angle XYZ, & |XY|>|XZ| \\ \angle XZY, & \text{else}\end{cases} \tag{1}$$

(2) Which one is the vertex of CA_{23}?

For the reason of simple description, without losing the generality, we assume CN_{23} = {V_3, V_4, V_5}, as shown in Fig.3(b) and arrange {V_3, V_4, V_5} into {V_l, V_v, V_r} in clockwise order with respect to the ball, where l, v, r $\in$ {3, 4, 5}. In general, node V_v is then taken as the vertex of CA_{23} while V_l, V_r are the end-points of CA_{23}. However, if Angle<V_v, V_b, V_l> (or Angle<V_v, V_b, V_r>) is smaller than a given threshold, and $|V_lV_b|<|V_vV_b|$ (or $|V_rV_b|<|V_vV_b|$) then V_l (or V_r) will be re-taken as the vertex of CA_{23}. For instance, in Fig.2, CN_{23} = {V_3, V_4, V_5}. Assume that V_4, V_5 and V_3 are in the clockwise order with respect to the ball. V_3 should be defined to be the vertex of CA_{23}, which is more reasonable than regarding V_5 as the vertex of CA_{23}. The algorithm is described as following:

```
If (∠V_l V_b V_v < θ) & (|V_l V_b| < |V_v V_b|)
        CA_23 = ∠V_v V_l V_r
Else
        If (∠V_r V_b V_v < θ) & (|V_r V_b| < |V_v V_b|)
                CA_23 = ∠V_v V_r V_l
        Else
                CA_23 = ∠V_l V_v V_r
        End
End
```

where $\theta=\pi/12$ and we appoint CA_{23} as the obtuse angle if its vertex is biased towards the ball compared with its two end points.

The first 4 structure features with respect to CA_{23} are correspondingly defined as below (As for a general example illustrated in Fig.3(c), $\overline{V_1V_2}$ is the first defence-line and V_3, V_4, V_5 construct the second defence-line, and V_6, V_7 are the midpoints of $\overline{V_3V_5}$, $\overline{V_1V_2}$ respectively):

I. $CA_{23}=\angle V_3V_4V_5$: Character-Angle of 2-3 zone-defense.

As explained earlier, this angle characterises the defenders' positions on the character line of 2-3 zone-defense.

II. $FSA_{23}=\angle(\overline{V_7V_6},\overline{V_3V_5})$: Angle formed by the first and the second defense-lines.

where $\angle(\overline{XY},\overline{ZW})$ denotes the angle formed by segment $\overline{XY}$ and segment $\overline{ZW}$ that is no bigger than π/2. It characterises the structure relationship between the first and the second defense-lines.

III. $BCA_{23}=\angle(\overline{V_4V_6},\overline{V_3V_5})$: the bias of the CA_{23}.

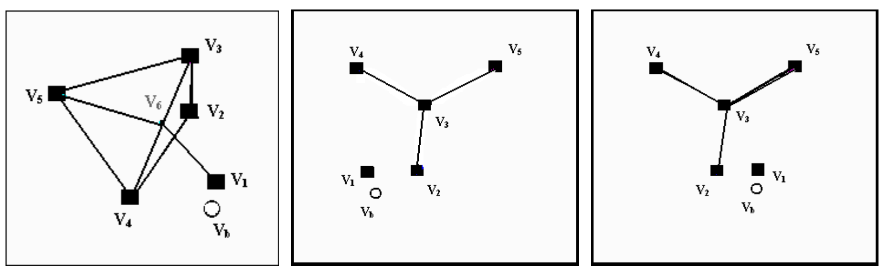
which is an angle presents the bias of the vertex on second defense-lines of 2-3 zone-defense.

IV. $RFSA_{23}=(|V_1V_2|/|V_3V_5|)\ \angle\ (\overline{V_1V_2}\ \overline{V_3V_5})$: restricted FSA_{23}.

which denotes the restricted angle of the first and the second defense-lines of 2-3 zone-defense. The shorter of $\overline{V_1V_2}$ comparing with $\overline{V_3V_5}$, the angle of segment $\overline{V_1V_2}$ and segment $\overline{V_3V_5}$ has less effect to zone graphs. So it's reasonable to take into account a coefficient to the angle.

3.2. *Structure-based Features in 1-3-1 Zone-defense Strategy*

In 1-3-1 zone-defense, the defender nearest to the ball constructs the first defense-line. The second defense-line is constructed by 3 defenders, presenting the basic character of 1-3-1 zone-defense, which is defined as the 1-3-1 character line. The angle formed from the 1-3-1 character line is defined as "1-3-1 character-angle" and denoted as CA_{131}. The key point here is to define the vertex and two end points of CA_{131}.



(a) $CA_{23} < \pi$ (b) $CA_{23} > \pi$ case 1 (c) $CA_{23} > \pi$ case 2

Fig.4 Zone graph examples in 1-3-1 zone-defense

Based on CA_{23} as what we have extracted, there are two cases to define CA_{131}: (Here, we also use V_1, V_2, V_3, V_4 and V_5 to denote the 5 defenders, and assume V_1 is the nearest defender to the ball, $CA_{23} = \angle V_3V_5V_4$ in Fig.4(a) and $CA_{23} = \angle V_4V_3V_5$ in Fig.4(b) and (c)). If the corresponding CA_{23} is smaller than π (as shown in Fig.4(a)), then CA_{131} has the same two end-points (V_3 and V_5) as that of CA_{23}, and the vertex of CA_{131} is the node (V_2) from the rest 3 which is neither the closest to the ball nor the vertex of CA_{23}; otherwise (as shown in Fig.4(b) and (c)), CA_{131} will have the same vertex as that of CA_{23}, and the node which is neither on the 2-3 character line and nor the closest to the ball will be taken as one of the two end-points of CA_{131} where the other end-point is one of the two end-points of CA_{23} which will ensure that CA_{131} divides the rest two nodes sit on each side of the 1-3-1 character line, respectively.

The detection algorithm is expounded below:

If $CA_{23} = \angle V_3V_5V_4 < \pi$

$CA_{131} = \angle V_3V_2V_4$

Else $CA_{23} = \angle V_4V_3V_5 \geq \pi$

case 1: $V_1 \in area(V_2V_3V_4)$

$CA_{131} = \angle V_2V_3V_4$

case 2: $V_1 \in area(V_2V_3V_5)$

$$CA_{131} = \angle V_2V_3V_5$$

End

End

Where, $area(V_2V_3V_4)$, $area(V_2V_3V_5)$ and $area(V_4V_3V_5)$ denote 3 plane areas divided by the beam $\overrightarrow{V_3V_2}$, $\overrightarrow{V_3V_4}$ and $\overrightarrow{V_3V_5}$. Obviously, V_1 cannot belong to $area(V_4V_3V_5)$.

The next 3 features with respect to CA_{131} are defined below (As for a general example illustrated in Fig.4(a) and assume V_6 is the midpoint of segment $\overline{V_3V_4}$):

V. $CA_{131} = \angle V_3V_2V_4$: Character-Angle of 1-3-1 zone-defense.

which characterises the defenders' positions on the character line of 1-3-1 zone-defense analogously.

VI. $FSA_{131} = \angle(\overline{V_1V_6}, \overline{V_3V_4})$: Angle formed by the first and the second defense-lines.

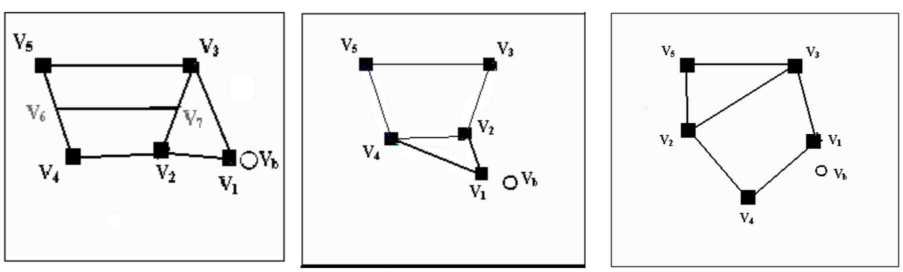
which characterises the structure relationship between the first and the second defense-lines of 1-3-1 zone-defense.

VII. $STA_{131} = \angle(\overline{V_5V_6}, \overline{V_3V_4})$: Angle formed by the second and the third defense-lines.

which characterises the structure relationship between the second and the third defense-lines of 1-3-1 zone-defense.

3.3. *Structure-based Features in 1-2-2 Zone-defense Strategy*

In 1-2-2 zone-defense, the defender closest to the ball forms the first defense-line. As the examples shown in Fig.5, assume that V_1 is the closest defender; $\angle V_4V_2V_3$ is the CA_{131}. If $\angle V_4V_2V_3$ is equal or larger than π (Fig.5(a) and (b)), the vertex of CA_{131} and the nearer one to the first defense-line of the two end-points of CA_{131} construct the second defense-line; the rest two defenders construct the third defense-line. Otherwise (Fig.5(c)), the two end-points of CA_{131} construct the second defense-line and the rest two defenders construct the third defense-line. The first and the second defense-lines present the basic character of 1-2-2 zone-defense, which define the 1-2-2 character line. The angle formed from the 1-2-2 character line is defined as "1-2-2 character-angle" and denoted as CA_{122}.



(a) $CA_{131} \geq \pi$ case 1 (b) $CA_{131} \geq \pi$ case 2 (c) $CA_{131} < \pi$

Fig.5 Zone graph examples in 1-2-2 zone-defense

The algorithm is described as following (CA_{122}, SDL_{122} and TDL_{122} denote the Character Angle, the second defence-line and the third defence-line of 1-2-2 zone-defense, respectively):

If $\angle V_4V_2V_3 \geq \pi$

case 1: $|V_1V_3| < |V_1V_4|$

$CA_{122} = \angle V_2V_1V_3$, $SDL_{122} = \overline{V_2V_3}$, $TDL_{122} = \overline{V_4V_5}$

case 2: $|V_1V_3| \geq |V_1V_4|$

$CA_{122} = \angle V_2V_1V_4$, $SDL_{122} = \overline{V_2V_4}$, $TDL_{122} = \overline{V_3V_5}$

End

Else

$CA_{122} = \angle V_3V_1V_4$, $SDL_{122} = \overline{V_3V_4}$, $TDL_{122} = \overline{V_2V_5}$

End

The last 3 features with respect to CA_{122} are defined as below (assume that $CA_{122} = \angle V_2V_1V_3$, $SDL_{122} = \overline{V_2V_3}$ and $TDL_{122} = \overline{V_4V_5}$, V_6 and V_7 are the midpoints of segment $\overline{V_4V_5}$ and segment $\overline{V_2V_3}$ respectively as shown in Fig. 5(a)):

VIII. $RCA_{122} = (\min(|V_1V_2|, |V_1V_3|) / \max(|V_1V_2|, |V_1V_3|)) \angle V_2V_1V_3$.

Here, we add a coefficient to take into account the effect from the movement of node V_1 along the circle formed from V_1, V_2 and V_3.

IX. $RSTA_{122} = (|V_2V_3| / |V_4V_5|) \angle(\overline{V_2V_3}, \overline{V_4V_5})$.

It's with respect to the restricted angle of segment $\overline{V_2V_3}$ and segment $\overline{V_4V_5}$ and reflects the structure relationship between the second and the third defense-lines of 1-2-2 zone-defense.

X. $BST_{122} = \angle(\overline{V_6V_7}, \overline{V_2V_3})$.

which reflects the bias between the second and the third defence-lines of 1-2-2 zone-defence.

The feature vector is constructed by the above 10 features with respect to those 3 typical zone-defense strategies:

f = {CA_{23}, FSA_{23}, BCA_{23}, $RFSA_{23}$, CA_{131}, FSA_{131}, STA_{131}, RCA_{122}, $RSTA_{122}$, BST_{122}}

The feature vector is not only listed by the 10 components one by one, but also has internal relationships. The features of one typical zone-defence also reflect the structures relationship in other typical zone-defences.

4. Video Detection System of Basketball Zone-defense Strategy

According to the structure-based features extracted above, the test basketball zone-defense video clip with n key-frames (that is, n zone-defense graphs) can be represented by a $n \times 10$ feature matrix $F_{clip} = \{f_1, f_2, ..., f_n\}'$ and a ball's position vector $ball_{clip} = \{ball_1, ball_2, ..., ball_n\}$, where $f_i = \{f_{i1}, f_{i2}, ..., f_{i10}\}$ and $ball_i$ denotes the feature vector and the ball's position of the *i*th key-frame of the detected clip respectively. Analogously, the 3 standard zone-defense databases are represented by 3 corresponding feature matrices with their ball's position vectors respectively. For instance, the standard

2-3 zone-defense database is represented by $F_{23} = \{f_1^{23}, f_2^{23}, ..., f_{14}^{23}\}'$ and $ball_{23} = \{ball_1^{23}, ball_2^{23}, ..., ball_{14}^{23}\}$.

Firstly, compute the similarity between test clip and standard 2-3 zone-defense strategy.

Step 1: For each $f_i \in F_{clip}$, compute the Euclidean Distance(which has been experimented that performs better than other two famous distances Mahalanobis distance and Manhattan distance in our case) between f_i and each feature vector with the same ball position as f_i in standard 2-3 zone graph database:

$$ED(f_i, f_{z_j}^{23}) = [d_{ij}^{23}] \ . \tag{2}$$

where $ball_i = ball_{z_j}^{23}$, $z_j \in \{1, 2, ..., 14\}$, $j = 1, 2, ..., n_p < n_{23}$, and n_p is the number of the graphs with the same ball position as G_i^{test} in 2-3 zone graph database.

Step 2: Determine the distance between f_i and 2-3 zone-defense strategy.

$$D_i^{23} = \arg\min_j([d_{ij}^{23}]) \ . \tag{3}$$

Step 3: Compute the global distance between the test clip and 2-3 zone-defense strategy:

$$GD_{\text{test}}^{23} = \sum D_i^{23} \ . \tag{4}$$

Secondly, in terms of the same procedure, we define the global distance between the test clip and 1-3-1 zone-defense strategy as:

$$GD_{\text{test}}^{131} = \sum D_i^{131} \ . \tag{5}$$

Thirdly, we define the global distance between the test clip and 1-2-2 zone-defense strategy in the same manner as:

$$GD_{\text{test}}^{122} = \sum D_i^{122} \ . \tag{6}$$

Finally, the zone-defense strategy pattern of the test zone-defense video clip is defined as:

$$Z^{test} = \arg\min(GD_{\text{test}}^{23}, GD_{\text{test}}^{131}, GD_{\text{test}}^{122}) \ . \tag{7}$$

5. Experimental Results

The system has been tested with both simulated and real basketball zone-defense videos. Firstly, we formulated 40 simulated zone-defense video clips (key-frame sequences), where the scenario and the defenders' position of each video clip were constructed by the professional coaches according to their rich experience. We also collected about 1 hour of the real basketball zone-defense videos, including 112 clips containing 3 to 8 key-frames each as listed in Table 2. According to the detection system illustrated in Fig 2, each clip denotes once defense with a particular zone-defense strategy.

Table 2. The number structure of test data

	Zone-defense strategy	Total clips		Total key-frames
Simulated	2-3	20	40	145
	1-3-1	20		161
	1-2-2	20		128

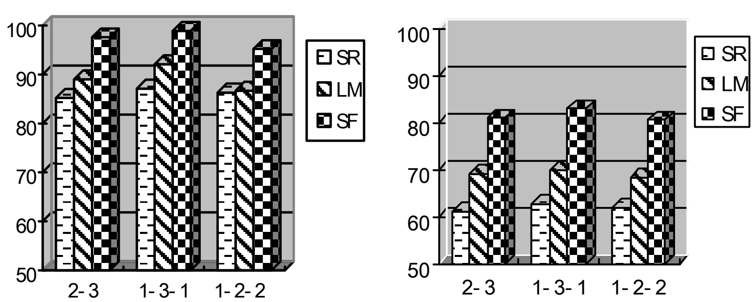
Real-life	2-3	52	112	286
	1-3-1	31		221
	1-2-2	29		169

There are few systems focused on feature description of basketball zone-defense graphs. Here, we compare the algorithm proposed in this paper with LM-based algorithm [Zheng *et al*. 2009] and SR-based algorithm [Chin *et al*. 2005]. Table 3 below reports the detection result of each algorithm on both simulated and real-life data. Here detection results of "Correct MPD (Metric Position Detection)" are the results detected on the test clips with correct MPD. Generally speaking, the detected rate in simulated data is higher than that in real-life data for each approach. In particular, compared with the other approaches, as shown in Table 3, the structure feature (SF) based algorithm can detect more video clips in both simulated data and real-life data. This is due to the fact that the structure feature (SF) based algorithm takes into account of the structure relationship between defenders where it is neglected or inadequately dealt with in other algorithms. The results are more satisfied with regard to correct MPD since the correct MPD of defenders may lead much more likely to the correct detecting results.

Table 3. Detection result of 3 algorithms on different data

Database		**Video clips**		**Correct MPD**	
	Results	Test	Detected	Test	Detected
Simulated data	SR	40	35	38	34
	LM		36		35
	SF		**37**		**37**
Real-life data	SR	112	70	91	69
	LM		78		74
	SF		**91**		**85**

Fig.6 shows the detecting precision comparing with the other two algorithms in both simulated data and real-life data on each zone-defense. From Fig.6, one can see that the SF-based detecting method has the highest detecting precision in both simulated and real-life data, where the SR-based approach performs worst due to its inadequate dealing with the structure relationship between defenders.



(a) Simulated data (b) Real-life data

Fig.6 Detecting precision for each zone-defense pattern with different methods

It's frequent for defenders to have some translational motion comparing with the standard position in standard zone graphs. So the translational motion of the farthest defense-line from the ball in each zone-defense graph, which is regarded to have least influence to the global strategy, is added to the test video clip as a disturbance to test the robust of proposed approach. For each note V on the farthest defense-line in each zone-defense, we add the disturbance α as:

$$V^{'} = V \pm \alpha(\cos\beta - \sin\beta) \ . \tag{8}$$

where α denotes the movement distance of note V to V' and β denotes the angle between α and the x-axis (the mid-field line) as shown in Fig.7.

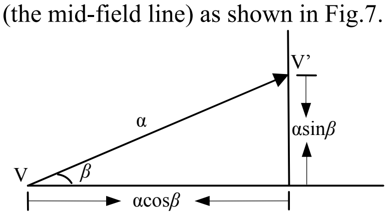
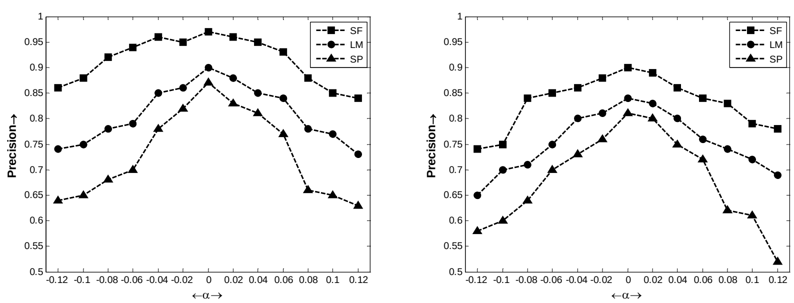


Fig.7 Disturbance of the node on the farthest defense-line

Fig.8 shows the efficiency in each zone-defense with different disturbance. In order to eliminate the interference of the error from position detection, the statistics were calculated on the data with correct MPD.



(a) Simulated data (b) Real-life data

Fig.8 Precision influence with disturbance in each method

The precision comes down with growing disturbance in every method. But the SF-based method drops much slower than the other two and still has a tolerable performance even with a high disturbance, which demonstrates that the SF-based method is robust for the detecting system.

6. Conclusions and Future Work

In this paper, a structure-based feature descriptor describing the structure relationships between defense-lines has been proposed for video clip detection in basketball zone-defense. Comparing with other methods, the structure-based feature descriptor has a robust performance in both simulation and real-life applications especially when disturbance exists. It is reasonable and validly to describe the structure relationship between defenders in basketball zone-defense strategies. It is robust for the disturbance deriving from translational motion of defenders on subprime defense-lines.

For the future work, we shall extend the approach proposed in this paper to other team-work sports such as football, volleyball, etc., to describe the corresponding structure relationships. It is crucial to develop the corresponding metric position detection algorithms on zone-defense graphs which are very influential in the detection system. In addition, it seems reasonable and realistic to adopt clustering approaches and algorithms to develop generalized method(s) for various kinds of both existing and possible future zone-defense strategies. This remains also as future work.

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