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Character-Angle based Video Annotation

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***Abstract*—A video annotation system includes clips organization, feature description and pattern determination. This paper aims to present a system for basketball zone-defence detection. Particularly, a character-angle based descriptor for feature description is proposed. The well-performed experimental results in basketball zone-defence detection demonstrate that it is robust for both simulations and real-life cases, with less sensitivity to the distribution caused by local translation of subprime defenders. Such a framework can be easily applied to other team-work sports.**

I. Introduction

VIDEO annotation, as an efficient technique to compensate the 'semantic gap' problem between high level concepts and low level descriptors, has been attracted more and more attentions [2][8]. Sport video, as a popular worldwide media, has become one of the most important and active research topics in video/image processing and pattern recognition [4][7].

Zone-defence is a common strategy adopted in basketball games. It is different from man-to-man defence 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-defence 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 defences from man-to-man to various zones can make the attacking off-balance and confused.

On one hand, the defensive coach needs to layout the zone-defence strategy and check whether the team is playing in the right formation or not all the time; on the other hand, the offensive coach also needs to know which zone-defence formation the defenders are adopting.

In what follows in this paper, the organization of basketball zone-defence videos is introduced in section 2. A character-angle-based graphic features descriptor is particularly proposed and illustrated in section 3. Section 4 addresses the determination rules of zone-defence strategies. Experimental results are provided, analyzed and evaluated in section 5, demonstrating the efficiency of the proposed system. Finally, section 6 provides a brief summary and concludes the paper.

II. Clip Organization of Basketball Zone-defence Video

Videos can be organized at different levels for various research purposes. In the framework proposed in this paper, basketball videos are organised in terms of clips. Each clip represents a certain round of attacking (or defence) and is denoted as a list of states, or the so-called state-sequence : $SS = [S_1, \ldots, S_n]$, which consists of the frames extracted one per 2 seconds from the clip.

The metric position detection of defenders and the ball is implemented similarly as in [1]: 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 [3]. 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 [1].

Each state S_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-defence 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 distance to the ball (V_b).

A standard zone-defence database of 3 typical zone-defence formations (2-3, 1-3-1 and 1-2-2 zone-defence) is constructed and populated with graph data corresponding to some of the pictures illustrated on two basketball coaching web sides [5][6]. Table I below shows the number of graphs for each formation in different ball's position.

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TABLE I.
THE NUMBER OF STANDARD ZONE -DEFENCE GRAPHS

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

For each detected zone-defence video clip, it will be decomposed into a state-sequence and each state will be represented by a zone-defence graph as mentioned above. Finally, the defence strategy can be detected by matching its graph-sequence with the standard zone-defence graph database.

III. THE CHARACTER-ANGLE BASED DESCRIPTOR

The problem of matching temporal patterns, including time series and state sequences, can be transformed into conventional graph matching problem [9][10]. 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 [10]. Also, many graph matching algorithms are sensitive to the outliers or local bias such as the translation of subprime notes in the graph.

Different zone-defense strategies in basketball, as what it's named, have their own typical defense-lines. For instance, the typical defense-line of 2-3 zone defense strategy is the second defense-line (normally, the 2 defenders in the front line construct the first defense-line and the rest 3 defenders construct the second defense-line.). In this paper, a set of features based on the Character-Angle (formed by the typical defense-line) of each zone-defense formation are proposed to describe the structure relationship between defense-lines. The algorithm is expounded as below :

A. 2-3 CA and Correlative Features

In standard 2-3 zone-defence strategy, we define that the 2 defenders closest to the ball construct the first defence-line; and the rest 3 defenders construct the second defence-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) Which 3 notes construct CA_{23}? b) Which one is the vertex of CA_{23}?

a) 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-defence strategies. 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. For instance, in Fig. 1, assume that V_3 and V_2 have an approximately same distance to the ball. Obviously, the 2-3 CA 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).

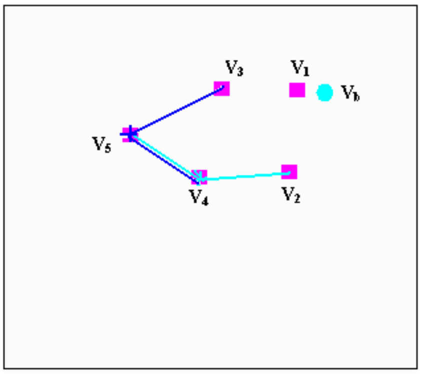


Fig. 1 A typical example of 2-3 zone-defence

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 CN_{23} denotes the set of notes constructing CA_{23} function representing the angle between note X and segment YZ which is defined as:

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

δ=0.05 (The distance of diagonal of half-court is normalized to 1).

b) 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}, 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 ∈ {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,

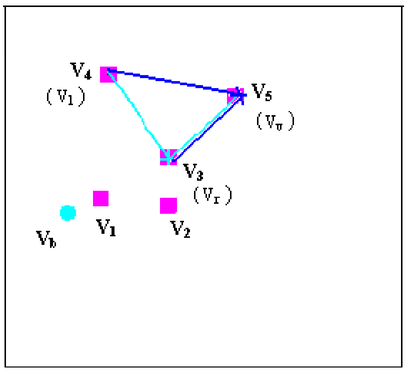


Fig. 2 Another typical example of 2-3 zone-defence

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 $(\angle V_lV_bV_v<\theta)\&(|V_lV_b|<|V_vV_b|)$

$CA_{23} = \angle V_v V_l V_r$

Else

If $(\angle V_r V_b V_v<\theta)\&(|V_r V_b|<|V_v V_b|)$

$CA_{23} = \angle V_v V_r V_l$

Else

$CA_{23} = \angle V_l V_v V_r$

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.

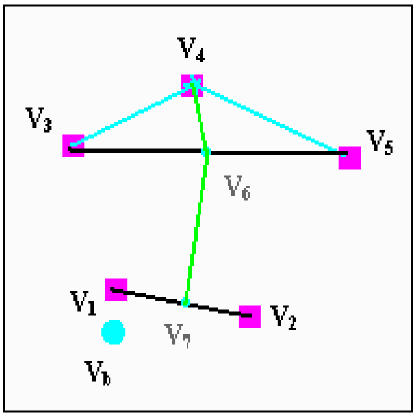


Fig. 3 First 4 features based on CA_{23}

The first 4 features with respect to CA_{23} are correspondingly defined as below (As for example, as illustrated in Fig. 3, $\overline{V_1V_2}$ 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):

1) $CA_{23} = \angle V_3V_4V_5$

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

2) $FSA_{23} = \angle(\overline{V_7V_6}, \overline{V_3V_5})$,

where $(\overline{XY}, \overline{ZW})$ 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 defence-lines.

3) $BCA_{23} = \angle(\overline{V_4V_6}, \overline{V_3V_5})$

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

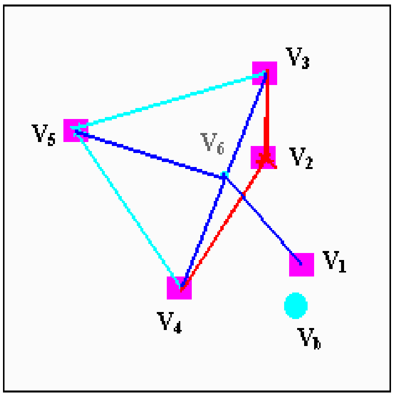
4) $RFSA_{23} = (|V_1V_2|/|V_3V_5|)\ \angle\ (\overline{V_1V_2}, \overline{V_3V_5})$.

which denotes the restricted angle of the first and the second defence-lines of 2-3 zone-defence..

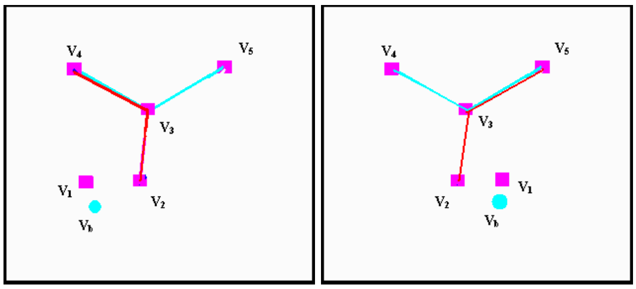
B. 1-3-1 CA and Correlative Features

In 1-3-1 zone-defence, the defender nearest to the ball constructs the first defence-line. The second defence-line is constructed by 3 defenders, presenting the basic character of 1-3-1 zone-defence, 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 points here are to define the vertex and two end points of the angle.

Based on CA_{23} as what we have extracted, there are two cases to define CA_{131}: If the corresponding CA_{23} is smaller than π (as shown in Fig. 4 (a)), then CA_{131} has the same two end-points as that of CA_{23}, and the vertex of CA_{131} is the node from the rest 3 which is neither the closest to the ball nor the vertex of CA_{23}; otherwise (Fig.4(b)), 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 its 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.



(a) $CA_{23} < \pi$



case 1 case 2

(b) $CA_{23} \geq \pi$

Fig. 4 1-3-1 CA detection based on 2-3 CA

The detection algorithm is expounded below (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, $C_{23} = \angle V_3V_5V_4$ in Fig. 4 (a) and $C_{23} = \angle V_4V_3V_5$ in Fig.4 (b)):

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

$$CA_{131} = \angle V_3V_5V_4$$

Else

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 (Assume V_6 is the midpoint of segment $\overline{V_3V_4}$):

5) $CA_{131} = \angle V_3V_2V_4$.

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

6) $FSA_{131} = \angle(\overline{V_1V_6}, \overline{V_3V_4})$

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

7) $STA_{131} = \angle(\overline{V_5V_6}, \overline{V_3V_4})$.

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

C. 1-2-2 CA and Correlative Features

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

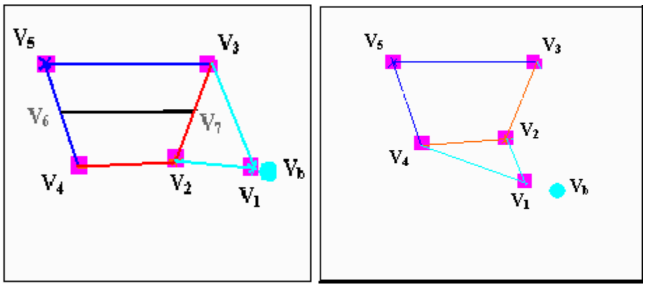
The algorithm is described as following (CA_{122}, SDL_{122} and TDL_{122} denote the Character Angle, the second defence-line and the third defence-line, respectively):

If $\angle V_3V_5V_4 \geq \pi$

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

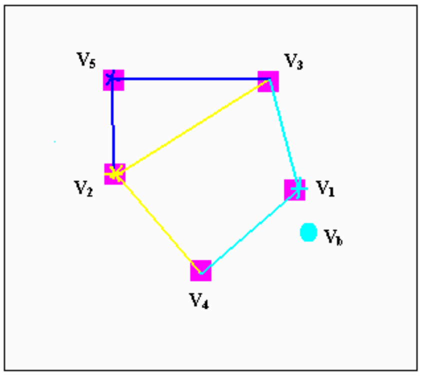
$$CA_{122} = \angle V_2V_1V_3$$

$$SDL_{122} = \overline{V_2V_3}$$



case 1 case 2

(a) $CA_{131} \geq \pi$



(b) $CA_{131} < \pi$

Fig. 5 1-2-2 CA detection based on 2-3 and 1-3-1 CA

$$TDL_{122} = \overline{V_4V_5}$$

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 $TDL_{122} = \overline{V_4V_5}$ as shown in case 1 of Fig. 5 (a)):

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

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.

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

which denotes the restricted angle of the second and the third defence-lines of 1-2 - 2 zone-defence.

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

which reflects the bias between the second and the third defence-lines of 1-2-2 zone-defence and V_6 and V_7 are the midpoints of segment $\overline{V_2V_3}$ and segment $\overline{V_4V_5}$ respectively.

The feature vector is constructed by the above 10 features with respect to those 3 typical zone-defence 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.

IV. Zone-defence Strategy Determination

According to the character-angle based features proposed here, the test clip with n states can be represented by a $n\times10$ 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 state of the detected clip respectively.

Firstly, compute the similarity between detected clip and standard 2-3 zone-defence strategy.

Step 1: For each $f_i \in F_{clip}$, compute the Euclidean Distance between f_i and each feature vector with the same ball position as f_i in standard 2-3 zone graph database:

$$ED(f_i, f_{z_j}^{23}) = [D_{ij}^{23}]. \quad (1)$$

where $ball_i = ball_{z_j}^{23}$, z_j $\{1,2,...,14\}$, $j = 1,2,...,n_p < n_{23}$, 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-defence strategy.

$$SD_i^{23} = \arg\min_j([D_{ij}^{23}]). \quad (2)$$

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

$$GD_{test}^{23} = \sum SD_i^{23} \quad (3)$$

Secondly, in terms of the same procedure, we define the global distance between the test state-sequence and 1-3-1 zone state-sequences as:

$$GD_{test}^{131} = \sum SD_i^{131}. \quad (4)$$

Thirdly, we define the global distance between the test state-sequence and 1-2-2 zone state-sequences in the same manner as:

$$GD_{test}^{122} = \sum SD_i^{122} \quad (5)$$

Finally, the zone-defence formation pattern of the test zone-defence video clip is defined as:

$$Z^{test} = \arg\min(GD_{test}^{23}, GD_{test}^{131}, GD_{test}^{122}). \quad (6)$$

V. Experimental Results

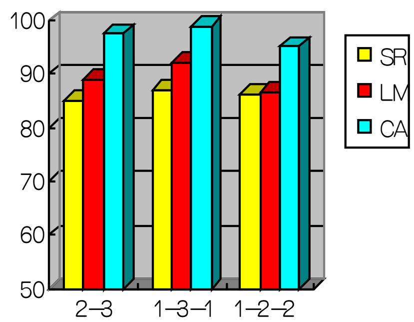
The system has been tested with both simulated and real basketball zone-defence video clips. We formulated 40 clips (state-sequences) provided by the professional coaches and collected about 1 hour of the real basketball zone-defence videos, including 112 clips containing 3 to 8 states each.

There are few systems focused on feature description of basketball zone-defence graphs. Here, we compare the algorithm proposed in this paper with LM-based algorithm [10] and SR-based algorithm [4].

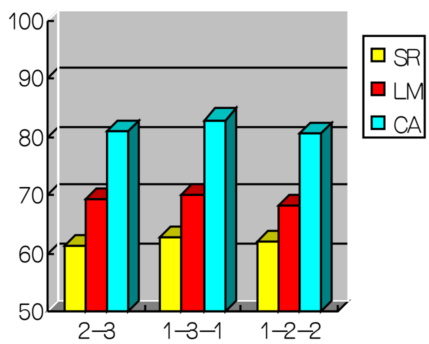
Table II reports the detection result of each algorithm on both simulated and real-life data. Here detection results of "Correct MPD" are the results detected on the test clips with correct MPD. It's clear that character-angle based algorithm has the highest efficiency especially with regard to correct MPD (metric Position Detection).

Table II.
Detection result of 3 algorithms on different data

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



(a) Simulated data



(b) Real-life data

Fig. 6 Detecting precis ion for each zone-defence pattern with different methods

Fig. 6 shows the detecting precision comparing with the other two algorithms in both simulated data and real-life data on each zone-defence. It's clear that the CA-based detecting method has the highest detecting precision in both simulated and real-life data.

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 defence-line from the ball in each zone-defence graph, which is regarded to have least influence to the global formation, is added to the test video clip as a disturbance to test the robust of proposed approach. For each note V on the farthest defence-line in each zone-defence, we add the disturbance α as:

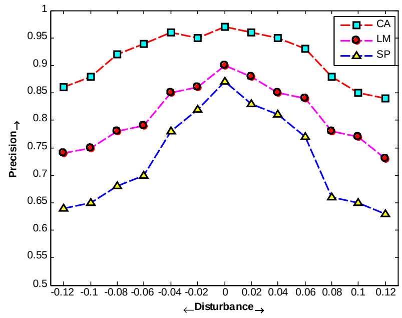
$$V^{'} = V \pm \alpha(\cos\beta - \sin\beta) \tag{7}$$

where α denotes the movement distance of note V vertical to segment $\overline{V_b V}$ and β denotes the angle between α and the x-axis (the mid-field line).

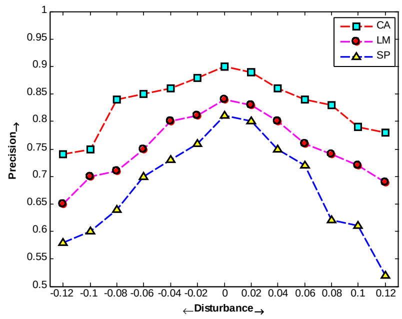
Fig. 7 shows the efficiency in each zone-defence with different disturbance. In order to eliminate the interference of the error from position detection, the statistics were calculated on the data with correct MPD.

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

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



(a) Simulated data



(b) Real-life data

Fig. 7 Precis ion with distribution in each method

VI. Conclusion and Future Work

In this paper, we have presented a framework for basketball zone-defence detection. A set of character-angle based features was proposed to describe the zone-defence graph. It can describe the structure relationship between defender-lines for basketball zone-defence, and has a robust performance in both simulation and real-life applications especially when disturbance exists.

As the future work, we shall extend this framework for other team-work sports such as football, volleyball, etc., and develop the corresponding metric position detection algorithms.

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