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資訊化之籃球運動攻守戰術教學與訓練系統（Ⅱ）

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執行單位：淡江大學體育組

中　華　民　國　95　年　12　月　15　日

資訊化之籃球運動攻守戰術教學與訓練系統（Ⅱ）

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Abstract

This paper aims to develop a simulation system for teaching and training in basketball defensive and offensive strategies. Respectively, defensive and offensive strategies can be described by editing video recording from basketball games into some desired clips for analyzing and storing in a database. In this paper, we utilize spatial-temporal relationships to describe the local defensive movements and evaluate the offensive motions of the basketball players in a game by using a dynamic programming method. Our proposed system will automatically capture tracks of the defensive and offensive movements made by the basketball players in video clips. As a result, basketball coaches and players can learn various defensive and offensive strategies within the shortest period of time by looking at the analysis from our system. The system is expected to become a computerized education aid to basketball teaching and training, and to replace the unscientific and stereotyped system in such kind of activities.

***Keywords**: Basketball defensive and offensive strategies, Spatial Relationships, Dynamic Programming, Computerized education, video technology*

1. Introduction

Basketball is a well-known sport. And it is quite popular all over the world. In this paper, we aim to develop a simulation system for teaching and training the basketball coaches and players about the defensive and the offensive strategies [1, 2]. We utilize the spatial-temporal relationships [3] to describe the defensive strategies, and apply dynamic programming to evaluate the offensive strategies. Both in defense and in offense strategies, basketball players have to react according to their opponent's movements [4, 5, 6]. The success of a team depends on the degree of teamwork. In order to help the players learning key points of defense and offense, a coach must have sufficient and professional knowledge to point out the training topics directly. Therefore, it plays an extremely important role in the basketball field [7, 8, 9, 10, 11] that coach collects and analyzes the information of opponent teams to map out corresponding tactics in advance.

When it comes to basketball tactics, what we basically understand is no more than the concepts of space, ball, and players (offensive is as well as defensive). How to move? When to dribble? And when is the correct time to pass the ball to teammates? If we can utilize a computer assisted teaching module, with the theories of basketball tactics installed, we are confident that the establishment of a simulated system concerning basketball tactics will facilitate the coach's preparation work. Fig. 1 shows the processing flow of our proposed Basketball Strategy Simulated System. First, we shoot the game with Bird's eye view. The video source could be collected from TV or other ways, if the video clips are suitable for our system. Next, we edit the video and select the suitable clips. We are not going to select the video clips with too complexity tactics due to the goal of constructing the concept for the players. The system will extract the content information from clips via system interface. Content information would be treated as features which can be used for tactical estimating. According to the estimated results, we can discuss with the Specialists and Coaches for establishing standard defensive and offensive strategies. All the other strategies can compare to the standard strategies for analyzing and constructing correct basketball concepts.

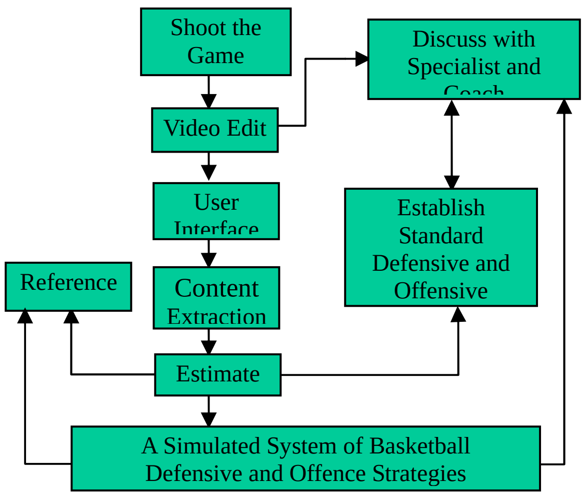

Fig. 1. The processing flow of Basketball Strategy Simulated system

2. Player Tracking and the computation of Spatial Relationships

Tracking objects in an image sequence has been discussed in many papers [12, 13, 14]. The method we utilized to track objects is similar to the concept that discussed in [15]. However, the paper [15] treats two or more objects as one object when the objects are extremely close to each other. In our system, we discriminate objects as individuals, and use the colors of sportswear to distinguish one team from the other. Then, we extract the trajectories and movements of the players from the video which is recorded from an overhead view as shown in Fig. 2. The purpose of filming game from an overhead view is to avoid the heavy collision of players brushing past one another. In analyzing a sequence of players, players are represented by using silhouette images. In this paper, we used Spatial-Temporal Relationships to describe the local defensive movements in a basketball game. Since each silhouette image needs to be assigned to a unique number initially, it will help us to conveniently identify the spatial relationship between each object. According to Fig. 3, we can define 12 spatial relationships among each defensive player. The spatial relationship can be appropriately applied to basketball defensive strategy. Then, we reconstruct a spatial relationships table that represents a unique ID number for each spatial relationship as shown in Table 1.

Fig. 2. To Film the basketball game from an overhead view

Here we put emphasis on the 12 spatial relationships defined in Fig. 3. We do not consider the other relationships, such as "A is up right side of B and close to B" due to object A and object B are team partners and they are too close. In this paper, spatial relationships are used to evaluate defensive strategies such as "2-3 local defensive", "3-2 local defensive" or "2-1-2 local defensive". Fig. 4 shows the topologies of these defensive strategies and they would be the standard defensive strategies which are stored in the database.

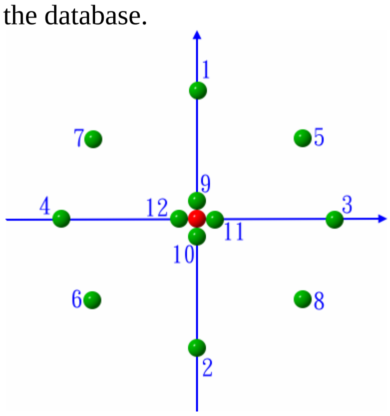

Fig. 3. The distribution of 12 spatial relationships

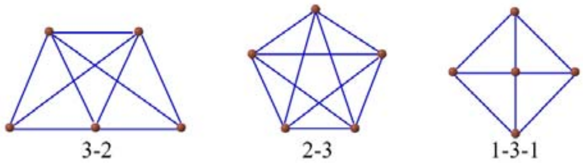

Fig. 4. Three topologies of defensive strategies

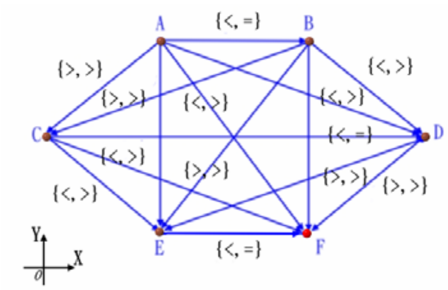

Fig. 5. The topology of defensive stragies based on the spatial relationship

In Fig. 5, there exist six objects A, B, C, D, E and F. A to E are players and F is the basketball stand which plays a role as benchmark. Generally, the topology for a defensive strategy does not vary dramatically in an image sequence, since a team enforces a defensive strategy with certainty. Each relationship has its own ID number and the relationship sets can be represented by the matrix for each frame, since different defensive strategies have different spatial relationships. As the topology shown in Fig. 5, the spatial relationships can be represented by the 6X6 SP matrix as follow.

$$
\begin{array}{c} \\ SP_i^j = \end{array}
\begin{array}{c}
\begin{array}{cccccc} A & B & C & D & E & F \end{array} \\
\left|\begin{array}{cccccc}
0 & 4 & 5 & 7 & 1 & 7 \\
0 & 0 & 5 & 7 & 5 & 1 \\
0 & 0 & 0 & 4 & 7 & 7 \\
0 & 0 & 0 & 0 & 5 & 5 \\
0 & 0 & 0 & 0 & 0 & 4 \\
0 & 0 & 0 & 0 & 0 & 0
\end{array}\right|
\end{array}
\begin{array}{c} \\ A \\ B \\ C \\ D \\ E \\ F \end{array}
$$

This matrix represents the spatial relationship for the i^{th} frame of video clip *j*. For our system, we have *n* *SP* matrixes, since we choose *n* frames from every chip equally. The set of *SP* matrix can be represented as follows.

$$SP^j = \{SP_1, SP_2, \ldots, SP_i, \ldots SP_n\}$$

We can calculate the similarity among different defensive clips. The distance *dist* between SP matrixes of each frames of different clip is obtained according to Table 2. The scores are modified with time, and Table 2 shows the final result of scores.

$$dist_{(i)} = SP_i^j \Leftrightarrow SP_i^k \quad 1 \le i \le n \qquad \text{-------}\mathbf{(1)}$$

SP_i^j : *The spatial matrix of* i^{th} *frame of clip j*

SP_i^k : *The spatial matrix of* i^{th} *frame of clip k*

For example, if the spatial matrix of i^{th} frame of clip k is shown as follow:

$$SP_i^k = \begin{array}{c} \begin{array}{cccccc} A & B & C & D & E & F \end{array} \\ \left| \begin{array}{cccccc} 0 & 4 & 5 & 2 & 1 & 10 \\ 0 & 0 & 5 & 7 & 5 & 1 \\ 0 & 0 & 0 & 4 & 7 & 2 \\ 0 & 0 & 0 & 0 & 5 & 5 \\ 0 & 0 & 0 & 0 & 0 & 4 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{array} \right| \end{array} \begin{array}{c} \\ A \\ B \\ C \\ D \\ E \\ F \end{array}$$

Then $dist_{(i)}$ between SP_i^j and SP_i^k is

$$\begin{aligned} dist_{(i)} &= (0+0+9+0+4) \\ &+ (0+0+0+0) \\ &+ (0+0+9) \\ &+ (0+0) \\ &+ (0) = 22 \end{aligned}$$

Table 1. 12 spatial relationships

ID	Relationships	Judgments(X，Y)
1	A is on the top of B	(=，>)
2	A is under of B	(=，<)
3	A is right side of B	(>，=)
4	A is left side of B	(<，=)
5	A is up right side of B	(>，>)
6	A is up left side of B	(<，<)
7	A is bottom left side of B	(<，>)
8	A is bottom right side of B	(>，<)
9	A is on the top of B and close to B	(=，m)
10	A is under of B and close to B	(=，mi)
11	A is right side of B and close to B	(mi，=)
12	A is left side of B and close to B	(m，=)

Table 2. The distance between each spatial relationship

ID	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	0	6	6	6	3	9	3	9	5	1	5	5
2	6	0	6	6	9	3	9	3	1	5	5	5
3	6	6	0	6	3	9	9	3	5	5	1	5
4	6	6	6	0	9	3	3	9	5	5	5	1
5	3	9	3	9	0	12	6	6	8	4	4	8
6	9	3	9	3	12	0	6	6	4	8	8	4
7	3	9	9	3	6	6	0	12	8	4	8	4
8	9	3	3	9	6	6	12	0	8	4	4	8
9	5	1	5	5	8	4	8	8	0	4	4	4
10	1	5	5	5	4	8	4	4	4	0	4	4
11	5	5	1	5	4	8	8	4	4	4	0	4
12	5	5	5	1	8	4	4	8	4	4	4	0

And the similarity ***SoD (Similarity of Defensive)*** between two defensive clips j and k is shown as follows:

$$SoD = \frac{1}{\sum_{i=1}^{n} dist_{(i)}} = \frac{1}{\sum_{i=1}^{n} (SP_i^j \Leftrightarrow SP_i^k)} \quad \text{-------}\mathbf{(2)}$$

According the value of ***SoD***, we are able to find the similar defensive strategies in the database. The system supports a GUI to display the active similar defensive clips. This mechanism helps coaches to find the standard defensive technique for teaching and they could learn the usage frequency of the defensive strategy by the opponent.

3. Extraction of Offensive Strategy

Since offense is complex and various as compared with defensive strategies, Spatial-Relationship is not suitable on extraction of offensive strategies. We should track the trajectories of the players in the game. Each trajectory is composed of serial coordinates. These coordinates are consecutive points which can be subdivided into series of vectors. After getting the serial vectors, we can compare the trajectories between two different clips. The purpose of comparison is to find the similar tactics. When the players are tracked, their bodies regions are segmented out by using color predicate, which is generated by the images of clothes. The players in a small sequence of images of performer are labeled for generating the color predicate; the system then labels the incoming pixels as the color of clothes based on the predicate. Morphologic operations are used to group the incoming pixels into region. Each region of the player is given a unique number in its own clip. Then we have five objects in each clip and each object has its own number. The existing purpose of the ID numbers is to compare the trajectories to the corresponding objects which have the same ID number in the other clips conveniently.

There are three steps of comparison which we descript as follow:

Normalization:

Some factors such as camera focus may cause the size of a trajectory different to its corresponding trajectory. The difference might be increased, although they are the same in the real world or the same with spectator’s view. For this reason, normalize is necessary. We should put the trajectory into a fix bounding, and modify the size of trajectories to the max that is suitable for the bounding box. The algorithm is shown as follow.

We suppose that the trajectory T has sequence points.

$$P_T = \{p_0, p_1, p_i, ..., p_n\}$$
$$p_0 : (x_0, y_0),$$
$$p_1 : (x_1, y_1),$$
$$p_i : (x_i, y_i),$$
$$\vdots$$
$$p_n : (x_n, y_n)$$

P_T is the set of p_i, and $\{p_0, p_1, p_i, ..., p_n\}$ are the coordinates of a trajectory. We reconstruct a $2 \times n$ matrix P according the coordinates of the trajectory T.

$$P = [p_0 \ p_1 \ p_i .... p_n] = \begin{bmatrix} x_0 & x_1 & x_i & \cdots & x_n \\ y_0 & y_1 & y_i & \cdots & y_n \end{bmatrix}$$

Next, we construct a 2x2 matrix MS.

$$S = \begin{bmatrix} \alpha & 0 \\ 0 & \alpha \end{bmatrix} \cdots\cdots\cdots (3)$$

α is the rate of size between the bounding box and the trajectory. If the new point is $P_i^{'} : (x_i^{'}, y_i^{'})$, then

$$p_i^{'} = \begin{bmatrix} x_i^{'} \\ y_i^{'} \end{bmatrix} = \begin{bmatrix} \alpha & 0 \\ 0 & \alpha \end{bmatrix} \begin{bmatrix} x_i \\ y_i \end{bmatrix} = [\alpha x_i \ \ \alpha y_i] \quad 0 \le i \le n \cdots\cdots (4)$$

$p_i^{'} : (\alpha x_i, \alpha y_i)$ is a new point of $P^{'}$, and we can get all of the points of $P^{'}$ as follow:

$$S \times P = \begin{bmatrix} \alpha & 0 \\ 0 & \alpha \end{bmatrix} \begin{bmatrix} x_0 & x_1 & x_i & \cdots & x_n \\ y_0 & y_1 & y_i & \cdots & y_n \end{bmatrix}$$
$$= \begin{bmatrix} \alpha x_0 & \alpha x_1 & \alpha x_i & \cdots & \alpha x_n \\ \alpha x_0 & \alpha y_1 & \alpha y_i & \cdots & \alpha y_n \end{bmatrix} = P^{'} \cdots\cdots\cdots (5)$$

Interpolation:

The frames of each chip may be different, since the time of executions may be different for each tactic. It means the player may run in the same path many times with different timing. So the trajectories have varied quantity of coordinates due to the frames to vary in amount. It will lead the fault in the results of comparison, and the system would make the error judgment for the same tactics with the above reasons. However, we do not consider the timing factor. Our purpose merely aims to find the different offence strategy models. It is necessary to interpolate the coordinate points, and the amount of points would be closer for two corresponding trajectories.

The way to interpolate the amount of tracking points in two tracks is described in [16]. However, [16] considers coordinate information in three dimensions. For our system, we just considered the trajectory information in two dimensions.

Comparison of Tactical Trajectories

For the comparison of trajectories, we use dynamic programming. The coordinates of trajectories are consecutive points which can be subdivided into series of vectors instead of the absolute coordinative points. Since getting the absolute coordinates, we can compare the vectors between the trajectories which are the players' running paths. Comparison between two players' running paths is based on *Dynamic Programming*, which solves problems by combining the solutions to sub-problems and is typically applied to optimization problems. It is a pattern matching approach widely used in the field of Bio-information, Security, Image Processing, and so forth [17, 18, 19, 20, 21, 22]. The method is shown as follow. Assuming we have two video clips K and T with 5 offensive players.

$K=(k1,k2,\ldots,kl\ldots,k5)$, $T=(t1,t2,\ldots,tl,\ldots,t15)$

l is one of the 5 players. Assume l is the player of K clip has n points, and of T clip has m points.

$kl=(kl_1,kl_2,kl_3,\ldots,kl_i\ldots,kl_n)$, $tl=(tl_1,tl_2,tl_3,\ldots,tl_j\ldots,tl_m)$

Vectors of kl and tl are $\overrightarrow{V_{kl}}$ and $\overrightarrow{V_{tl}}$

$kl_1= (x_{l1}, y_{l1}), kl_2= (x_{l2}, y_{l2})\ldots kl_n= (x_{ln}, y_{ln},)$

And

$tl_1=(x'_{l1}, y'_{l1}), tl_2= (x_{l2}, y_{l2})\ldots tl_n= (x'_{lm}, y'_{lm})$

$$\overrightarrow{V_{kl}} = (\overrightarrow{v_{kl1}}, \overrightarrow{v_{kl2}}, ...\overrightarrow{v_{kl(n-1)}})$$
$$= \{(x_{ln} - x_{l(n-1)}, y_{ln} - y_{l(n-1)}),$$
$$(x_{l(n-1)} - x_{l(n-2)}, y_{l(n-1)} - y_{l(n-2)}), ...$$
$$(x_{l(i+1)} - x_{li}, y_{l(i+1)} - y_{li}), ...$$
$$(x_{l2} - x_{l1}, y_{l2} - y_{l1})\}$$

Let n-1 be a, so $\overrightarrow{V_{kl}} = (\overrightarrow{v_{kl1}}, \overrightarrow{v_{kl2}}, ...\overrightarrow{v_{kli}}, ...\overrightarrow{v_{kla}})$

$$\overrightarrow{V_{tl}} = (\overrightarrow{v_{tl1}}, \overrightarrow{v_{tl2}}, ...\overrightarrow{v_{tl(m-1)}})$$
$$= \{(x'_{lm} - x'_{l(m-1)}, y'_{lm} - y'_{l(m-1)}),$$
$$(x'_{l(m-1)} - x'_{l(m-2)}, y'_{l(m-1)} - y'_{l(m-2)}), ...$$
$$(x'_{l(j+1)} - x'_{lj}, y'_{l(j+1)} - y'_{lj}), ...$$
$$(x'_{l2} - x'_{l1}, y'_{l2} - y'_{l1})\}$$

In the same way, let m-1 be b, and we got $\overrightarrow{V_{tl}} = (\overrightarrow{v_{tl1}}, \overrightarrow{v_{tl2}}, ...\overrightarrow{v_{tlj}}, ...\overrightarrow{v_{tlb}})$

The distance $d(\overrightarrow{v_{kli}}, \overrightarrow{v_{tlj}})$ between the vector v_{kli} of kl and v_{tlj} of tl is $d(\overrightarrow{v_{kli}}, \overrightarrow{v_{tlj}}) = \left\| \overrightarrow{v_{kli}} - \overrightarrow{v_{tlj}} \right\|$ which be calculated based on Dynamic Programming. ϑ is the included angle of $\overrightarrow{v_{kli}}$ and $\overrightarrow{v_{tlj}}$. Dynamic Programming method calculates $d(\overrightarrow{v_{kli}}, \overrightarrow{v_{tlj}})$ according to matching matrix $m(\overrightarrow{v_{kli}}, \overrightarrow{v_{tlj}})$. The calculation steps and optimal structure are given as following:

$$1.\ m(\overrightarrow{v_{kli}}, \overrightarrow{v_{tlj}}) = d(\overrightarrow{v_{kli}}, \overrightarrow{v_{tlj}}) \quad (1 \le j \le b)$$

$$2.\ m(\overrightarrow{v_{kli}}, \overrightarrow{v_{tl1}}) = d(\overrightarrow{v_{kli}}, \overrightarrow{v_{tl1}}) + m(\overrightarrow{v_{kl(i-1)}}, \overrightarrow{v_{tl1}}) \quad (2 \le i \le a)$$

$$3.\ m(\overrightarrow{v_{kli}}, \overrightarrow{v_{tlj}}) = d(\overrightarrow{v_{kli}}, \overrightarrow{v_{tl1}}) + \min \begin{pmatrix} m(\overrightarrow{v_{kl(i-1)}}, \overrightarrow{v_{tlj}}) \\ m(\overrightarrow{v_{kl(i-1)}}, \overrightarrow{v_{tlj-1}}) \mid if\ 0^o \le \vartheta \le 2^o \\ m(\overrightarrow{v_{kli}}, \overrightarrow{v_{tl(j-1)}}) \end{pmatrix}$$

$$(2 \le i \le a) \quad (2 \le j \le b)$$

$$4.\ d(kl, tl) = \min \{ m(\overrightarrow{v_{kli}}, \overrightarrow{v_{tlj}}) \mid 1 \le j \le b \}$$

The distance between the two trajectories of K and T clips is $D(K,T) = \sum_{l=1}^{5} d(kl, tl)$, since each clip has 5 players. And the similarity between clips K and T is given as follow:

$$Similarity = \frac{1}{\sum_{l=1}^{5} d(kl, tl)}$$

According to the $Similarity = \frac{1}{D(K,T)}$, we could find the similar trajectory motions.

In this section, we used Dynamic Programming to evaluate the similarity between trajectories. The serial data are vectors instead of absolute coordinate points. The same motions of different coordinate value with the same curvature are considered as the same. For example, for the two motions in the plane show in Fig. 6, their curvatures are the same, but in different position. The purpose of comparing trajectories is to find the representative of a team tactic. That representative information can be the education materials for teaching in basketball training. It can help coaches and players to understand the antagonists' tactic, and distinct from traditional training model.

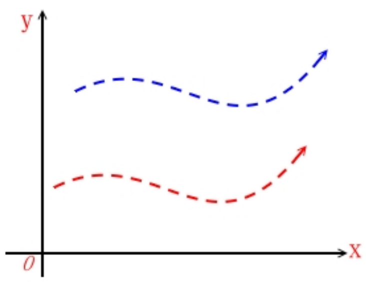

Fig. 6. The motions are with the same curvature, but in different position

4. Experimentation and Result

In our system, we need camera installation and proper clip editing, since we will evaluate the defensive and offensive strategies. We should pre-edit the video and cut out the suitable clips which we want. The average time period of each clip is 20 seconds. However, the number of frames is probably different among clips which would impede comparison between defensive and offensive strategies. To solve this problem, we should choose enough average frames to make sure that each clip has an equal or close amount of frames. We also need to interpolate the points and to scale for trajectories on comparison of offensive tactics. The Fig. 7 shows the GUI and the results of a query. We experimented with a desktop PC of Pentium-4 3.0 GHz. In this system, we marked the objects by using color perdition in the first sequence frames (3 to 5 frames) first before extracting the locations, and tracking the trajectories of the players in the video as shown as the Fig. 6. The upper right side of Fig. 7 shows the defensive locations of the players. After extracting the locations, the system will record the spatial relationships of every frame into the database, and then we can query for the similarity of defensive strategies from the database. In the same way on offensive strategies, they can be queried and extracted in the system, and the offensive strategies should be recorded in the database as well. The coordinate information extracted from the video will transform into animation. Accordingly, the display of the animation objects will remain its continuity. The objects in the animation move synchronously, which are unlike the traditional approaches that independently move or draw the objects on the white board step by step. Presently, our database has 361 specimens of the video clips. We'll keep on collecting and filming the basketball games for expanding the number of specimens to be stored in the database.

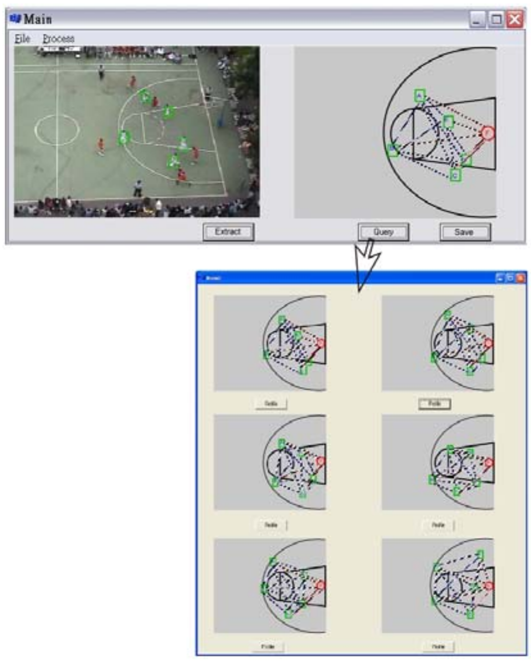

Fig. 7. The GUI and query results

5. Conclusion and Future work

In this paper, we track movements of players in a basketball game video sequence and record the location of the defensive motions as well as tracking players' offensive motions. After extracting the locations in continuous frames, we utilize spatial-temporal relationships to define the players' relationships for evaluating basketball defensive strategies. We also adopt a dynamic programming method to compare the offensive trajectories. Our proposed system can retrieve the similar defensive and offensive strategies efficiently. It will help coaches and players to learn how to carry out the tactics via continuous frames. Without marker pens and colored magnets to demonstrate specific tactics, the coaches still can teach players learning various defensive and offensive strategies within the shortest time. In the near future, we will combine and analyze the defensive and offensive tactics to find the break solutions between the defensive and offensive tactics. In this paper, we studied the information of the defensive and offensive tactics independently. However, a ball game includes offense and defense which are both crucial to win or lose. Without doubt, it is necessary to develop the matching mechanism on defensive and offensive tactics. In addition, by using another program to position correct defensive reactions, coaches can evaluate players' understanding towards the specific tactics from their chosen defensive positions and moves.

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May 15, 2006

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