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Research on Scoreboard Detection and Localization in Basketball Video

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Abstract

With the development of multimedia technology and the appearance of information highway, the storage and transmission of digital video has become a less difficult issue. Various sport games bring the explosive expanding of sport video, therefore, efficient analysis of sport video is necessary. An algorithm of detection and location for scoreboard is proposed. Firstly, the template of scoreboard is built using multi-dimensional correlation, it involves the location and the detection parameter. Then the scoreboard is located by the template matching.

Keywords: *Sport video analysis, Location of scoreboard, Scoreboard detection*

1. Introduction

In the basketball match videos, scoreboard is an important indicator. It provides not only scores and team logo as well as playing time. In this case, by studying scoring board, we can get the team name and grades of two involved parties. Also, based on the change of their scores [1-3], we can judge two-pointer, three-pointer as well as penalty shot, for the goal of describing specifically the contest shots. Currently there are some representative research achievements regarding the scoreboard and license plate [4-5]. But very few papers focused on the positioning of scoring board in the basketball match videos. Hence, the work here has practical significances [6-7]. The detection and locating of scoring board is the first step to the ongoing studies [8-9]. The result of positioning affects directly the accuracy of subsequent results. The main concern in the paper is positioning of scoreboard [10].

2. Analysis of Features of Frame Images Having Scoreboard

In the basketball video sequence, we conduct deep investigation of frame images with scoreboard. This is important to the detection and orientation of scoring board.

2.1. Analysis of the Board Features

In one basketball match video, the board is artificially incorporated into the specific frame images [11-12]. It has the following attributes:

(1) The scoreboard is completely the same, of regular shape and in a fixed position in frame images;
(2) It shows scores, team logo and national flag of two sides and the playing time;
(3) The board contains many image detail components, of which high-frequency components are abundant.

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2.2. Extraction of Frame Image Edges

The traditional methods for extracting image edges fulfill the purpose by fetching from high-frequency components of images. Differential operation is a main method to detect and fetch edges. Usually two kinds of differential operation are adopted:

(1) first-order differential operation, typically Robert operator, Sobel operator and PreWitt operator;

(2) second-order differential operation, like Gauss-Laplacian operator.

We'll introduce some common edge detection operators and compare their performance.

2.2.1 Edge Detection Operators

1. Robert operator, renamed crossover gradient operator. The calculation formula is as follows:

$$R(x,y)=\sqrt{f_x^{\,2}+f_y^{\,2}} \qquad \begin{cases} f_x = f(x,y)-f(x+1,y+1) \\ f_y = f(x,y+1)-f(x+1,y) \end{cases} \tag{1}$$

The corresponding template is:

$$f_x=\begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix} \qquad f_y=\begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix} \tag{2}$$

2. Sobel edge detection operator. The calculation formula is as follows:

$$S(x,y)=\sqrt{f_x^{\,2}+f_y^{\,2}}$$

$$\begin{aligned} f_x &= [f(x-1,y-1)-2f(x-1,y)+f(x-1,y+1)]-[f(x+1,y-1)-2f(x+1,j)+f(x+1,y+1)] \\ f_y &= [f(x-1,y-1)-2f(x,y-1)+f(x+1,y-1)]-[f(x-1,y+1)-2f(x,y+1)+f(x+1,y+1)] \end{aligned} \tag{3}$$

The corresponding template is:

$$f_x=\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \qquad f_y=\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \tag{4}$$

3. PreWitt operator, whose calculation similar to Sobel operator. The corresponding template is:

$$f_x=\begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \qquad f_y=\begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \tag{5}$$

4. Gauss-Laplace operator, a linear second-order operator; different from gradient operators, it has rotation invariance, meeting sharpening requirements of image edges in different directions. The calculation formula is as follows:

$$\nabla^2 f(i,j) = f(i+1,j) + f(i-1,j) + f(i,j+1) + f(i,j-1) - 4f(i,j) \tag{6}$$

The corresponding template is:

$$f = \begin{bmatrix} -2 & -4 & -4 & -4 & -2 \\ -4 & 0 & 8 & 0 & -4 \\ -4 & 8 & 24 & 8 & -4 \\ -4 & 0 & 8 & 0 & -4 \\ -2 & -4 & -4 & -4 & -2 \end{bmatrix} \tag{7}$$

2.2.2. Comparison of Operator' Performance

Perform gray processing of Figure 1(a) to get Figure 1(b). Utilize the above operators to extract edges in Figure 1 (b). Resultant images are shown in Figure 1(c-f).

(a) The Original Image

(b) Gray Image

(c) Robert Operator

(d) Sobel Operator

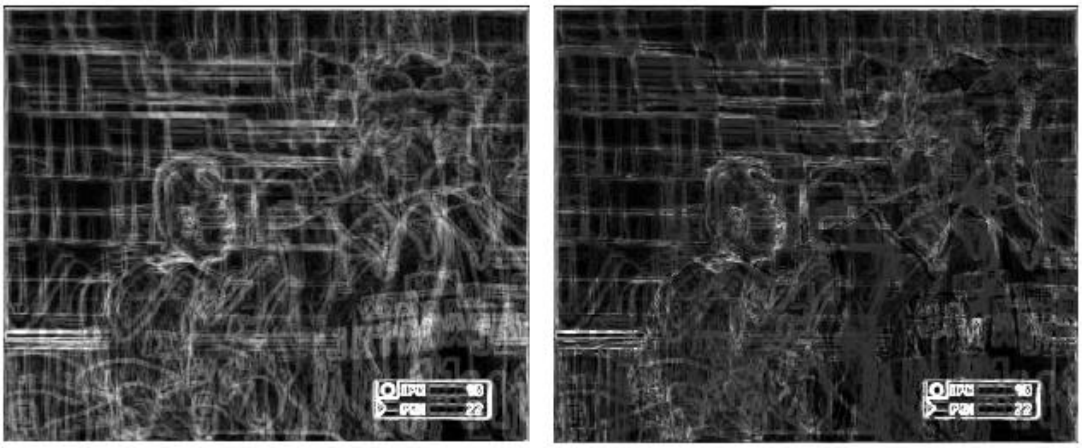
(e) Prewitt Operator (f) Gauss Laplacian Operator

Figure 1. Comparison of Treatment Results of Edge Detection Operator

2.3. Multi-Dimensional Relativity Analysis of Frame Images with the Board

In frame sequence of videos with scoring board, the board area is constant; while other areas will change along with different images in neighboring frames. So, we make multi-dimensional relativity analysis of frame images which contain the board. Firstly we give the concept of a virtual frame edge image.

The edge image of the virtual frame uses the present frame as initial frame and selects the next n-frame images to form backward frame time domain window. Then, by averaging the edge images to which each frame in the window corresponds, a new image is obtained, which is called virtual frame edge image $f_x(x,y)$. Figure 2(a) is the virtual frame edge image of Figure 1(a).



(a) The Virtual Frame Edge Image (b) Multidimensional Correlation of Specific Image

Figure 2. The Analysis Results Graph of Multidimensional Correlation

According to formula 7, by using image $f(x,y)$ after extraction of current frame edges to subtract the relative virtual frame edge image, we get multi-dimensional relativity image $f_c(x,y)$

$$f_c(x,y) = \left| f(x,y) - f_v(x,y) \right| \tag{7}$$

Further on, we implement specific counter-color processing of the above multi-dimensional relativity treatment result and have the result as seen in Figure 2 (b). It's seen that after multi-dimensional relativity treatment, the gray features in scoreboard area are noticeable, with bigger value than those in other areas.

3. Algorithm for Detecting and Locating the Scoring Board

3.1. Overall Thinking of the Algorithm

The detection and positioning algorithm includes two steps:

(1) Build scoreboard template;
(2) The detection and location algorithm based on template matching. In the period of making such template, it's required to perform edge extraction of frame images containing the board and make multi-dimensional relativity analysis; then, calculate the gray mean of the board position and area to get relative parameters and thus build the template. In the detection algorithm based on template matching, the first is to do edge extraction and multi-dimensional relativity analysis; then identify whether the current frame has scoreboard based on template matching, locate the board in frame images which include scoring board and export images of the frame. There, control parameter C_ρ is employed to suggest if the board detection and location template is created. Algorithm diagram is shown in Figure3:

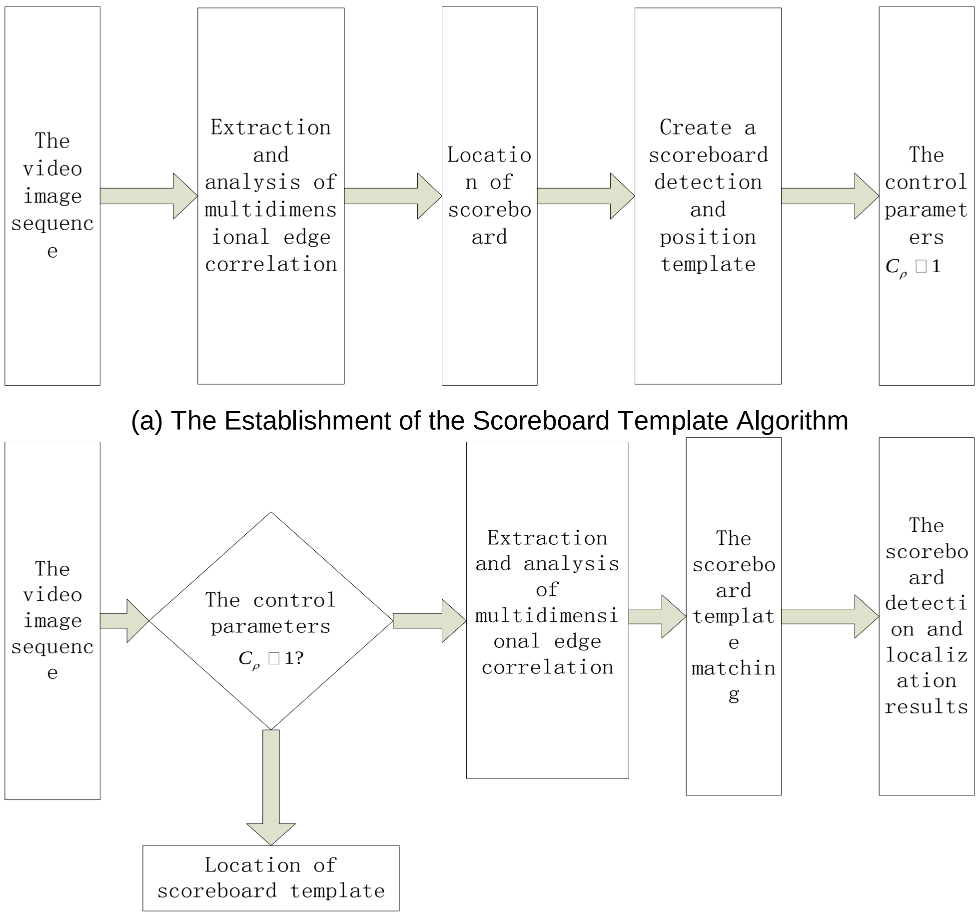


Figure 3. The Scoreboard Detection and Localization Algorithm

3.2. Edge Extraction and Multi-Dimensional Correlation Analysis

Make the present frame image $f_i(x, y)$. Firstly, choose Sobel operator to perform edge extraction of the frame image; then, fetch multi-dimensional correlativity images. The idea is described as follows:

(1) According to formula 8, calculate the relative virtual frame image of the current frame image;

$$f_v(x, y) = \frac{1}{n}\sum_{i=1}^{n} f_i(x, y) \tag{8}$$

(2) Calculate the gray differential image ($f_{GSi}(x, y)$) between the current and its virtual frame image and get the biggest value (Max_PG)

(3) According to the formula (9). Implement specific counter-color treatment of the differential image $f_{GSi}(x, y)$ and get $f_{MDi}(x, y)$ for binarization. The results are shown in Figure4.

$$f_{MDi}(x.y) = (1.0 - (f_{GSi}(x, y) * 1.0) / \text{Max\_PG}) * \quad f_v(x, y) \tag{9}$$

Figure 4. The Multi-Dimensional Correlation Analysis of Binarization Results

3.3. Positioning of Scoring Board

The locating of scoreboard includes rough positioning and precise positioning.

3.3.1. Coarse Positioning

In normal cases, the scoreboard locates in one of the four boundary areas in video frames, which are top left corner, low left corner, top right corner and low right corner. The rough positioning is to determine the board belongs to which area.

To reduce computational amount and increase algorithm speed, we scan the left and right area 1/5 above and below the screen of multi-dimensional relevance image and calculate the regional gray summation S_{gi} of each region. The area with the biggest gray summation S_{gi} is the board's coarse positioning area A_{cl}. The precise positioning will be implemented in the area. It is shown in Figure 5.

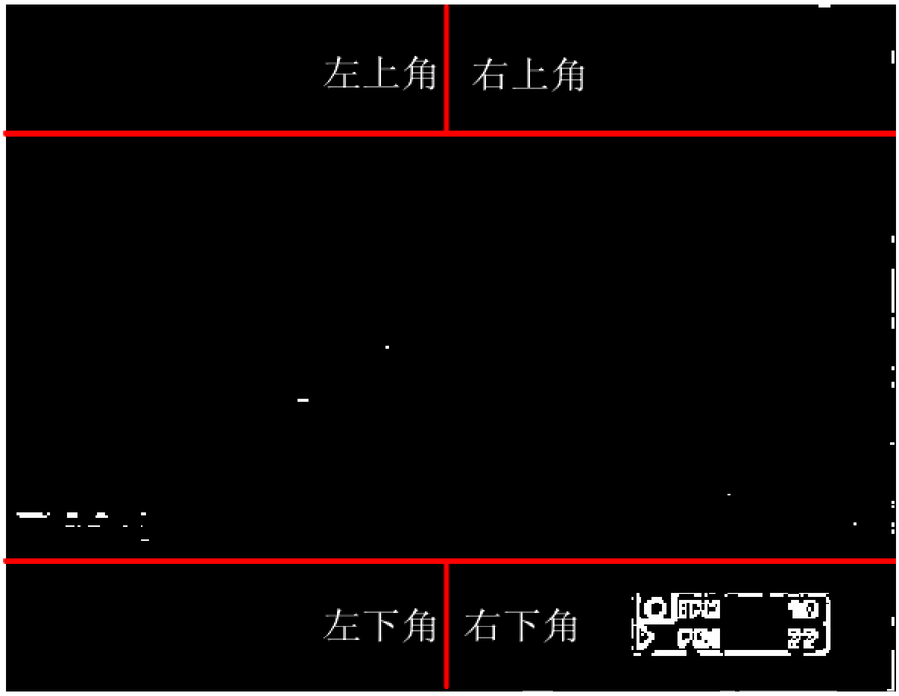


Figure 5. The Scan Area of Rough Location of Scoreboard

3.3.2. Accurate Positioning

In the rough positioning area A_{cl}, we use two different bi-directional windows sliding vertically and horizontally to position accurately the scoreboard and get the coordinate of its position. Hereunder is introduction of the idea:

(1) According to width and height of coarse positioning area A_{cl}, determine the size of windows sliding in horizontal and vertical directions as well as the sliding length L; then according to gray area mean in the coarse positioning area, determine the threshold C_{AGM} of gray mean in the window area;

The window size and sliding length in horizontal and vertical directions are defined by formula 10:

(2) In rough positioning area, slip the window horizontally from left and right side (make window sliding length L_{ρ}) and calculate the gray mean AGM_L and AGM_R of corresponding window area;

(3) If $AGM_L > C_{AGM}$, it's considered that the left window slides to the left side of the board; stop moving to the left window and record its coordinate X (X_L) as that of the board's left point; otherwise, continue step 2; do the same for the right window till the coordinates X in both the left and right side are determined;

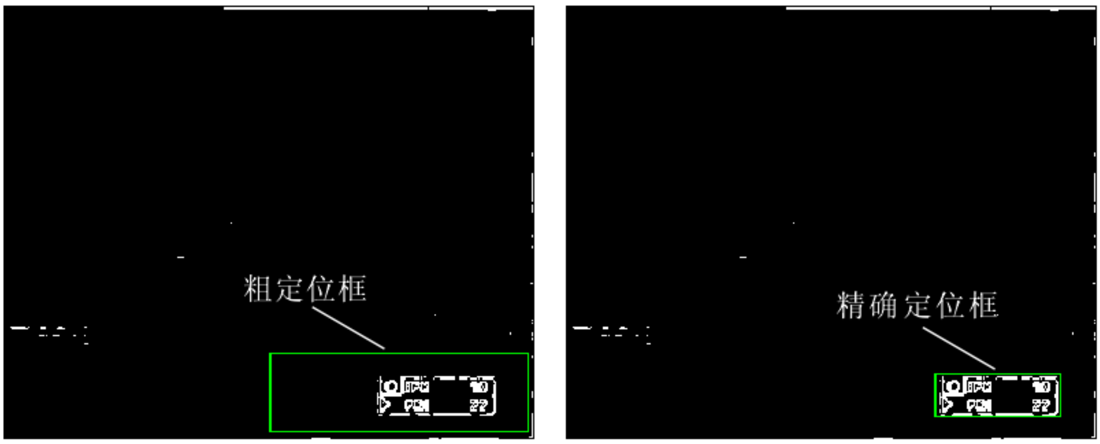
$$\begin{cases} W_p = W_{Acl} / Hscale \\ H_p = H_{Acl} \\ W_v = W_{Acl} \\ H_v = H_{Acl} / Vscale \\ L_P = W_p / 5 \\ L_v = H_v / 5 \end{cases} \quad (10)$$

(4) Similar to what's done in the horizontal direction, use the window gliding up and down to get the coordinates Y (Y_T, Y_B) of both the upper and lower end;

(5) Based on the four coordinates (X_L, X_R, Y_T, Y_B) obtained above, we can confirm the positioning window of the scoring board; since the results have deviations, we need to correct them;

(6) Correction of location parameter According to step length $L_\rho(L_v)$ of two-way gliding window in horizontal/vertical direction, let the coordinates X(Y) in both sides close to the middle by $L_\rho / 2(L_v / 2)$ pixel dots to complete the correction of positional parameter;

Till now, we can locate accurately scoring board area. It is shown in Figure 6.



(a) Coarse Localization Results of Scoreboard
(b) Accurate Location Results of Scoreboard

Figure 6. Location of Scoreboard Results

3.4. Creation of Scoring Board Template

The template contains location and detection parameters, expressed as:

$$Model\_SB = \{Pos, P_c\} \quad (11)$$

After the scoring board is positioned, the gray value aggregation S_g and acreage S_a of its area can be easily defined. According to equation (8), the gray mean of its area is reached. After the template is established, set control parameter $C_\rho = 1$.

3.5. Detection and Position of Scoreboard Based on Template Matching

This section discusses the utilization of built template to detect and locate the board in all video frames. The idea is described as:

(1) According to the location parameter in the template, position the area of candidate scoreboard in current frames;

(2) Calculate the candidate area's gray area mean AGM ;

(3) If $AGM > P_c$ (detection parameter), it's decided that the frame images have scoring board; output the position of the board; otherwise, they don't have.

4. Experimental Results and Analysis

We chose the 22nd FIBA Asia Championship Japan VS Philippine for testing. Four typical videos were selected as testing data.

4.1. Experimental Results of Scoreboard Detection

We tested all four videos as to find out the scoring board. Experimental results are listed in Table1. The initial results indicate that with the proposed algorithm, the accuracy rate of detection can reach up to 98.08%.

Table 1. The Scoreboard Detection Results

Video clips (frame)	The total number of the scoreboard	Detection of the scoreboard number	The correct detection rate
Video clips 1 (500)	380	360	98.20%
Video clips 2 (1400)	756	750	97.15%
Video clips 3 (900)	789	779	98.76%
Video clips 4 (900)	567	560	97.90%
Average	------	-------	98.09%

4.2. Experimental Results of Scoreboard Positioning

To explain, we chose from the four videos the first image which contains the frame sequence of the board. The positioning results are presented in Figure 7.

From the above picture, we learn that the method here has good precision of positioning the scoring board, with an error of about two pixels.

5. Conclusion

Regarding the features of scoreboard in the basketball game, we applied multi-dimensional correlation to analyze the frame images of the board. On the basis of rough positioning of the board, we utilized two-way sliding window to achieve accurate positioning, acquiring location coordinates and relative gray area mean. When two parameters were obtained, we built the template as to detect and locate the board. By template matching, we found out if score board exists in the video frame sequence. The results proved the effectiveness of the board detection and positioning.

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(a) Video Clips 1 Location Results

(b) Video Clips 2 Location Results

(c) Video Clips 3 Location Results

(d) Video Clips 4 Location Results

Figure 7. Location of Scoreboard Results

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