Abstract—Player classification method based on the tradition histograms lacks color spatial information, which leads to low classification performance, and, in addition, it needs priori template information. According to this, a novel player classification algorithm based on digraph was proposed in this paper. Firstly, the candidate players were extracted through the main color under the HSV Model Space of Color and equal-area rectangle partitioning strategy was adopted to partition the image. Secondly, HSV color space was quantified in each block and color histogram was extracted as color features. Thirdly, the distance among images was calculated according to the color features and the digraph was generated based on the distance matrix. Finally, the player classification was implemented by classifying the vertexes of digraph.

Experimental results show that the proposed method, without priori template information, is an effective way of classifying the players positioned around the classification boundary with an average classification accuracy of 98.82%. Compared with traditional method, the proposed method has a remarkable promotion on classification effect.

Keywords—player classification; HSV color space; histogram; digraph

I. INTRODUCTION

Accurate classification of the players plays an important role in the intelligent processing of soccer video. As a key step to target tracking and semantic analysis in soccer video, player classification is the technical basis of high-level semantic analysis including the offensive way analysis, the offensive intentions of both sides, and abnormal event detection, etc.

When identifying player’s team, Kawashima, Yoshino and AOK in [1] adopted the histogram back-projection, while Seo, Choi, Kim and Hong in [2] proposed the Color vertical distribution method. However, both lost part of the color spatial information and had poor robustness of discrimination. Reference [3] introduced an approach which took full advantage of the color information aiming at identifying player’s team by comparing the correlation of normalized color histogram between players and templates.

II. PRETREATMENT WORK

A. Soccer Stadium Extraction

Since soccer field occupies most part of the area in one video frame and the players are all in the stadium, the non-stadium area need to be got rid of at first. The stadium we concern is always green in the soccer video as shown in Fig. 1(a), so the stadium can be acquired by analyzing the statistics of the main color [5].

The main color can be extracted by the following steps:

- Select $N_{frame}$ frames of soccer video as the samples. In order to improve the reliability of the main color extraction and ensure the video frame contains a certain percentage of the stadium, set $N_{frame}=50$ in this paper.
- Under HSV color model, three component peaks ($H_{peak}$, $S_{peak}$ and $V_{peak}$) can be obtained by HSV histograms of the $N_{frame}$ frames.
- The dominant field color is described by the mean value of each color component ($H_{mean}$, $S_{mean}$, $V_{mean}$), which is computed around respective histogram peaks.
Soccer field pixels in each frame are detected according to the distance between the color of a pixel and the mean color. The field region is defined as those pixels \( p_i \) having

\[
\text{distance} \left( \text{color of } p_i, H_{\text{mean}} \right) < T_{\text{color}}
\]

where \( T_{\text{color}} \) is pre-defined threshold and its optimum value for a particular video can be adjusted to obtain the best result. The result of stadium extraction in soccer video frames is shown in Fig. 1(b).

**B. Player Images Extraction**

In terms of the result of stadium extraction, the players are separated out as noise at the same time. To get the player images, the extraction result of stadium is firstly dealt with morphological processing algorithm and then the connected area is extract as candidate player. The real players as shown in Fig. 2(a) can be obtained according to the shape of a player and the distribution of the pixels. The sample is extracted from the part corresponding to original image that the external rectangle of a player contains, and segmentation result is shown in Fig. 2(b).

### III. Classification Method Based on Histogram

Before classification, the player template which is chosen interactively as the typical player from one frame of the soccer video is got in advance during pretreatment. The similarity is measured between the players and templates to identify player’s team [6, 7], the main principles are as follows.

**A. Histogram Normalization**

The H-component histogram of HSV is obtained from each candidate player and template and then normalized in the following way.

\[
N_{\text{pixel}} = \sum_j S(x_j)
\]

The normalization of \( S(x_j) \) is defined as follow:

\[
h(x_j) = \frac{S(x_j)}{N_{\text{pixel}}}
\]

where \( N_{\text{pixel}} \) denotes the number of pixels with value \( x_j \) , and

\[
N_{\text{pixel}} = \sum_j S(x_j)
\]
Then the histogram feature of the image is constructed as:

\[ H = [h(x_1), h(x_2), \cdots, h(x_n)] \]  

(4)

B. Similarity Measurement

The Euclidean distance is often used as the similarity measure between two histograms. Team which the player belongs to is determined by finding the minimum distance according to the similarity between candidate player and the template. The Euclidean distance among histograms is defined as follow:

\[ \text{dis}(a, b) = \sqrt{\sum_{i=0}^{n} (h_i(x_i) - h_b(x_i))^2} \]  

(5)

IV. PLAYER CLASSIFICATION ALGORITHM BASED ON DIGRAPH

A. Color Space Selection and Quantization

There are many kinds of color model, such as RGB space and HSV space, etc. There is great difference between RGB model and human eye perception, therefore the similar color in RGB space does not mean the similar color in human eye vision, so it does not conform to the characteristics of human perception. HSV color space, which is close to the human visual characteristics, consists of three components: hue (H), saturation (S), and value (V). Furthermore, converting from RGB to HSV is a simple calculation of nonlinear transformation. So HSV color space model is adopted in our work to analyze soccer video frames, and, considering the subjective visual perception characteristics of human, color quantization algorithm in [8, 9] is adopted to make non-uniform quantization of the three components in HSV color space. Firstly, hue is divided unevenly into red, orange, yellow, green, cyan, blue, and purple as shown in Fig. 3. And then non-uniform quantization is carried out in HSV color space.

Specific quantization steps are as follows:

- When \( v \in [0, 0.2) \), it belongs to black area, and let \( l = 0 \);
- When \( s \in [0, 0.2] \cap v \in [0.2, 0.8) \), it belongs to gray area, and let \( l = |(v - 0.2) \times 10 | + 1 \);
- When \( s \in [0, 0.2] \cap (0.8, 1.0] \), it belongs to white area, and let \( l = 7 \);
- When \( s \in (0.2, 1.0] \cap (0.2, 1.0] \), it belongs to color area, and \( l \) is calculated by the following ways:

\[ H = \begin{cases} 
0 & h \in (330, 360] \cup [0, 22] \\
1 & h \in (0, 45] \\
2 & h \in (45, 70) \\
3 & h \in (70, 155] \\
4 & h \in (155, 186] \\
5 & h \in (186, 278] \\
6 & h \in (278, 330] 
\end{cases} \]  

(6)

\[ S = \begin{cases} 
0 & s \in (0.2, 0.65] \\
1 & s \in (0.65, 1] 
\end{cases} \]  

(7)

\[ V = \begin{cases} 
0 & v \in (0.2, 0.7] \\
1 & v \in (0.7, 1] 
\end{cases} \]  

(8)

\[ l = 4H + 2S + V + 8 \]  

(9)

As a result, the color space is divided into 36 kinds of color based on this quantitative model, which reduces the computational complexity. In addition, this kind of non-uniform quantitative method can make the color space approximate to the person’s subjective visual perception.

B. Partitioning Strategy of the Image

Since the method of traditional color histogram only makes use of the statistics of image color without considering color spatial distribution, there could be a serious error of classification when the images have the similar color histograms but different color distributions. To make full use of the color spatial information, the image is divided into blocks before statistic calculation of histogram [10]. Generally, the partitioning strategy is dividing the image into \( M \times N \) blocks averagely.

Dividing the image into two blocks of top and bottom is on the basis of the player’s position in the image in order to highlight that the players’ dress color can be distinguished. To consider the influence of the dress color, the weights for sub-blocks need to be set in advance and the sum of weights...
is 1. Partitioning strategy of rectangular block will not destroy the scaling invariance of color histogram.

C. Digraph Generation

The Euclidean distance method is adopted to measure the similarity of color features. First of all, the distances between each pair of blocks are calculated, which will be calculated into weighted sum as the distance between two images. Finally, for the sample set which has $M$ samples, a $M \times M$ distance matrix can be constructed to generate a digraph according to the steps as follows:

- Take sample set as vertex set.
- Take the $n$ values from the minimum values of distance between the current sample and the other samples. If the value is less than the threshold $T$, then there exists a directed edge which emits from current sample.
- Traverse all the samples and repeat above step.

D. Classification Algorithm Based on Digraph

By analyzing the in-degree and out-degree of each vertex and the relationship among the vertexes, vertexes of the digraph can be classified into two teams [11]. Schematic diagram of the algorithm is shown in Fig.4, and the algorithm is described as follows:

1. Step 1 Calculate the in-degrees of each vertex, if the value is more than the pre-defined threshold $t$, the vertex will be added to the initial clustering center set $C$, the isolated vertex is allocated to the referee set $R$.

2. Step 2 Make a clustering for the clustering center set $C$:

   2.1 If two vertexes satisfy the symmetry, namely there is a directed edge from vertex $b$ to vertex $c$ and a directed edge from vertex $c$ to vertex $b$ ($<b, c>$ and $<c, b>$), then vertex $b$ and vertex $c$ are allocated into the same category.

   2.2 If the vertexes satisfy the transitivity, namely vertex $b$ and vertex $c$ meet symmetry, additionally, vertex $c$ and vertex $d$ meet symmetry, then $b$, $c$ and $d$ are allocated into the same category.

3. Step 3 If the vertex $b$ of set $A$, the rest of vertexes, and the vertex $c$ of set $C$ meet the symmetry, let $b$ join the category which $c$ belongs to and delete $b$ from set $A$.

4. Step 4 If $A$ is a non-empty set, calculate the total in-degree from vertex $b$ of set $A$ to each of $N_{class}$ categories. When there is only one category that the value of the total in-degree is not equal to zero, the vertex will be allocated into this category and then delete the vertex $b$ from set $A$.

5. Step 5 If $N_{class}$ $>2$, calculate the total in-degree from one category to another. Merge the two categories whose total in-degree is the maximum value and let $N_{class} = N_{class} -1$. Repeat Step 5 if $N_{class}$ $>2$.

6. Step 6 Repeat Step 3 and Step 4. If a new vertex of set $A$ is allocated and the in-degree of the new vertex is not equal to 0, repeat Step 6.

7. Step 7 Handle the rest vertexes of set $A$:

   7.1 If $A$ is a non-empty set, the vertexes join the category to which has a higher total in-degree from the vertexes and delete the divided vertexes.

   7.2 If $A$ is still a non-empty set, the vertex $b$ of set $A$ join the category that a vertex belongs to which has been classified and is closer to the vertex $b$.

8. Step 8 Output classification results.

V. EXPERIMENTAL RESULTS

The dataset we used for experiment is composed of 22 videos about the 2014 World Cup football match including 516 players and 35 referees in total. Comparison experiment is conducted using the traditional color histograms and the color histograms based on color features proposed in this paper.

We randomly select two frames in each soccer video as samples, and there are 44 groups in total. Experimental results are listed in Tab. I.

In the experiment based on proposed method, the referees could be classified automatically with a recall ratio of 100% and precision ratio of 97.22%.

The template is crucial to the latter two methods which may lead high error. The accuracy of the traditional color histograms reaches at 91.33% while the color histograms based on proposed color features is 95.38%. It can be
concluded that considering the spatial distribution information of color can improve the classification accuracy.

<table>
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<tr>
<th>Method</th>
<th>Statistics</th>
<th>Template</th>
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<tr>
<td>Proposed method</td>
<td>98.82 %</td>
<td>No</td>
</tr>
<tr>
<td>Color histograms based on proposed color features</td>
<td>95.38 %</td>
<td>YES</td>
</tr>
<tr>
<td>Traditional color histograms</td>
<td>91.33 %</td>
<td>YES</td>
</tr>
</tbody>
</table>

It can be seen from TABLE I that the proposed method with an accuracy of 98.82% has better performance than the other two. Since the method which does not rely on template any longer makes full use of color spatial information and the correlation among images and it can classify the players positioned around the classification boundary in an effective way, the classification results are more reasonable and more accurate.

VI. CONCLUSION

In this paper, a novel approach is proposed to classify the players in soccer videos. The player images were divided into blocks by adopting rectangular partition strategy after the color space quantification of HSV model. And a digraph was generated according to the distance matrix calculated by the color feature of histogram statistics in each block. In our approach, player classification was implemented by classifying vertexes of digraph. Experimental results show that the approach could classify the players positioned around the classification boundary in an effective way and it has better adaptability and performance without templates.

In order to satisfy the demand of player tracking and team behavior analysis, the further research will focus on classification among the players that may exist shade.

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Certificate for Participation

Conference Chair: Prof. Qingsheng Zhu


International Information Technology and Artificial Intelligence

This is to certify that [Student Name], from [Institution Name], has attended and delivered an oral presentation in 2014 IEEE 7th Joint

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<th>Accession number:</th>
<th>20152701002129</th>
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<tr>
<td>Authors:</td>
<td>Sun, Shi-Bai¹, Cui, Rong-Yi¹</td>
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<tr>
<td>Part number:</td>
<td>1 of 1</td>
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<tr>
<td>Issue date:</td>
<td>March 20, 2015</td>
</tr>
<tr>
<td>Publication year:</td>
<td>2014</td>
</tr>
<tr>
<td>Pages:</td>
<td>459-463</td>
</tr>
<tr>
<td>Article number:</td>
<td>7065092</td>
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<td>Language:</td>
<td>English</td>
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<td>Document type:</td>
<td>Conference article (CA)</td>
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<tr>
<td>Conference date:</td>
<td>December 20, 2014 - December 21, 2014</td>
</tr>
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<td>Chongqing, China</td>
</tr>
<tr>
<td>Conference code:</td>
<td>112457</td>
</tr>
<tr>
<td>Publisher:</td>
<td>Institute of Electrical and Electronics Engineers Inc.</td>
</tr>
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Number of references: 11

Main heading: Classification (of information)

Controlled terms: Algorithms - Artificial intelligence - Color - Directed graphs - Graph theory - Graphic methods - Video streaming

Uncontrolled terms: Classification accuracy - Classification algorithm - Classification boundary - Classification performance - digraph - histogram - HSV color spaces - Partitioning strategies

Classification code: 716 Telecommunication; Radar, Radio and Television - 716.1 Information Theory and Signal Processing - 723 Computer Software, Data Handling and Applications - 741.1 Light/Optics - 921 Mathematics - 921.4 Combinatorial Mathematics, Includes Graph Theory, Set Theory

DOI: 10.1109/ITAIC.2014.7065092

Database: Compendex

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