Application of Gait Recognition Technology in Badminton Action Analysis

Yunwei Li, Shiwei Jiang
Hohai University Wentian College, Maanshan City, Anhui Province, 243130, China.

Abstract. In order to improve the quality of teaching, achieve better training results and achieve excellent results in athletics competitions, it is especially important to carry out the analysis of badminton routine teaching and athletic competitions. Gait recognition technology is identified by the individual's unique biological characteristics. With the improvement of computer performance, under the background of the rapid development of big data and artificial intelligence, the video data of badminton is collected by deploying high-performance camera. Video image segmentation, preprocessing, feature extraction, get the badminton player's three-dimensional gait characteristics data. Using the acquired gait data as a sample, a gait-based machine learning model is constructed, and the sample data is trained. Finally, identification information of badminton players is automatically identified, which facilitates the comparison and analysis of different athletes' movement data.

1. Introduction
Badminton is a barrier against the batting of the campaign, mainly reflects the speed and strength of athletes, flexibility and endurance, flexibility and other aspects of the integrated physical fitness. Badminton features the performance of the game no time limit, full of uncertainty, higher explosive requirements, speed and full range of sports. Badminton is an indispensable item in the daily life of modern people in sports competitions, leisure activities and entertainment. Badminton is the focus of all walks of life. The teaching of physical education in badminton programs is getting more and more popular in colleges and universities. To some extent, these factors have played a catalytic role in the rapid development of badminton programs.

Driven by universality and repetition of sports training, teaching practice and athletic competition, badminton has undergone tremendous changes both in technology and tactics. The general improvement of skills has directly led to a significant reduction in athletic competition time and accelerated Rhythm of the game. These new changes have all put forward higher requirements on badminton players' abilities to turn passive into active players, handle key balls and attack continuously. In the process of badminton, it is important to take the initiative to contro [1] as much as possible and seize the opportunity to attack throughout the athletic competition. However, it is more important to handle the frontcourt properly without blindly killing the ball. Badminton sports itself is a contest on the field of control and anti-control, in the current singles and doubles competition, have significantly increased the duplication of control of the ball before the net. Net technology is a powerful weapon to mobilize opponents, especially in competitive games. It is of great significance to analyze the technical action of grid hook ball, diagonal ball and other skills in the competitive game in order to improve offensive competition and create more scoring opportunities.

With the deepening of research and the progress of computer technology, biometrics-based identification technology has attracted the attention of researchers at home and abroad. Gait recognition
technology relies mainly on walking posture for identity recognition [1]. This technology belongs to one of the long-range identification methods, has the advantages of non-contact and low requirement for low pixels [2]. Increasingly the camera technology, the ability to capture the movement greatly enhanced, making gait recognition technology in all areas of application possible, the application of sports training in the study is no exception [3]. In the course of badminton, the camera is set up, the athletes are recorded and the motion video data is collected. Then the original video image is extracted by background subtraction, filtering and other techniques to extract human contour data. State data. Train these data to identify the athlete's identity information, and output the gait data sequence during badminton movement, by comparing and analyzing their respective movement characteristics.

2. Gait recognition process design
Gait recognition technology is composed of biometrics and computer vision technologies. The gait recognition process mainly includes the following steps: motion detection and capture of the human body through the camera; pretreatment of the gait image, background de-noising to the moving body, contour extraction, gait sequence acquisition, etc. The gait feature extraction is the key to gait recognition. It focuses on the selection of feature information for gait recognition and the method of obtaining good recognition results [4]. The features matching, matching sample and step the information in the state library, the final identification work [5-8]. Gait recognition process design shown in Figure 1 below:

Figure 1 Gait recognition overall process

Gaussian weighted gait images of gait images in a single complete cycle are obtained. The gait Gaussian images are obtained, which can correctly reflect the changes of the contour images in the period and highlight the changing features of the gait. Then gait Gaussian chart classification, because the direct classification will face too many dimensions, complex operation, time-consuming and other issues. Through principal component analysis dimension reduction, and then use sparse representation classifier classification. As many as possible zero elements are used to represent the image, the essential information is represented by nonzero elements, and the classifier based on sparse representation is used to reduce the impact on the recognition rate when the image is redundant or noisy, so that the recognition rate is improved.

Three-dimensional recognition and two-dimensional recognition are two existing gait recognition methods. The three-dimensional recognition of the human gait information mostly through the installation of sensors in the joints of the body, a small part of the image obtained. According to the motion information, the 3D motion model of the human body is constructed and classified by classification. The 2D recognition technology mostly obtains the image sequences of the human gait by video capture equipment, and then performs target separation, feature extraction, analysis and judgment, to capture gait based on multi-angle information acquisition and single-angle camera, fixed background recognition.
3. Gait data acquisition and pretreatment

Due to the influence of image acquisition tools or methods, the original image information is hard to be completely reflected in the gait image. Therefore, the input image preprocessing, and then feature extraction, segmentation and matching is particularly important. The main purpose of image preprocessing is to eliminate irrelevant information, restore useful information, make the related information more detectable, simplify the data as much as possible, and improve the reliability of feature extraction and image segmentation, matching and recognition. Preprocessing steps include digitization, geometric transformation, normalization, smoothing, filtering, restoration and enhancement.

Wavelet is the basis of multi-resolution theory analysis. The advantages of the signal representation and analysis at various resolutions are closely related to the theory of multiresolution, which is that the features that are difficult to render under a certain resolution are easily found at other resolutions. There are many ways to interpret the wavelet transform from the perspective of multi-resolution. Wavelet transform has many applications. The application of image processing is one of the applications in many fields. The resolution of the image is determined by the quantization level. The higher the quantization level, the clearer the image, and the higher the resolution.

Noise exists in the entire image processing, therefore, noise reduction is the key operation for gait image processing. No matter what the external conditions, there will always be noise. It is difficult to describe most of the noise with a certain rule, so it is difficult to design a filter that filters out all the noise. In gait images, the noise model can usually be divided into the following categories:

Additive noise model:

\[ g(x, y) = f(x, y) + n(x, y) \]  

Where \( n(x, y) \) denotes a noise signal, \( f(x, y) \) denotes a valid image signal, and \( g(x, y) \) denotes a noise-containing image signal. Generally, this additive noise is caused by the uncertainty of external conditions.

Multiplicative noise model:

\[ g(x, y) = (1 + n(x, y)) \cdot f(x, y) = f(x, y) + f(x, y) \cdot n(x, y) \]  

Generally, system internal factors lead to multiplicative noise. Among them, the image signal directly affects the noise term, and its growth is proportional to the image signal, including the noise of the negative of the negative film and the light quantum noise.

Gaussian noise model:

\[ p(x) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp \left[ -\frac{(x - \mu)^2}{2\sigma^2} \right] \]  

Since most of them can be approximated as Gaussian distributions, such noise models are often used. Its mathematical analysis is better, in many image noise reduction test verification, such noise is often used for related tests.

Common noise reduction method.

Neighborhood mean filter. The neighborhood averaging filter is a linear low-pass filter. In simple terms, the method replaces the value of the unknown point with the average of multiple points in the vicinity, and the number of pixels used to obtain the average needs to be determined according to the specific situation. The formula of this method can be expressed as:

\[ f(x, y) = \frac{1}{M} \sum_{i,j \in R} f(i,j) \]  

Where \( M \) is the number of pixels near the unknown point. When using this method to reduce noise, the mean value of the selected window determines the accuracy of the unknown point value. Generally, the window corresponding to four or eight points near the unknown point is selected.

Median filter.

Median filter is better in image denoising algorithm. This method also belongs to window type noise reduction, which is different from the average value of neighborhood. This method uses the median of each pixel in the window. Determine the size and shape of the desired border, select the border corresponding to four or eight points near the unknown point, count the value of each point in the border to obtain the median, and replace the value with the median.

Threshold noise reduction.
The signal \( f(t) \) is expressed as: \( f(t) = s(t) + n(t) \). Among them, \( s(t) \) is the original input data, \( n(t) \) is the noise data, subject to \( N(0, \sigma^2) \) distribution, that is, the mean is zero and the variance is \( \sigma^2 \).

Taking the one-dimensional input signal as an example, the signal is discretized to obtain a discrete signal \( f(n) \), where \( n \) is a non-negative integer, and the wavelet transform is:

\[
Wf(j, k) = 2^{-j/2} \sum_{n=0}^{N-1} f(n) \varphi(2^{-j} n - k)
\]

(5)

Among them, \( Wf(j, k) \) is a wavelet coefficient, because of the high computational complexity, and because \( \varphi \) does not have a dominant formula, the coefficient is not generally calculated by the above formula. Using the two-scale equation, after this process:

\[
Sf(j + 1, k) = Sf(j, k) * h(j, k)
\]

(6)

\[
Wf(j + 1, k) = Sf(j, k) * g(j, k)
\]

(7)

\( g(j, k) \) is the high-pass filter of scale function, \( h(j, k) \) is the low pass filter corresponding to the wavelet function, \( Sf(0, k) \) is the signal \( f(k) \), \( Wf(j, k) \) is the wavelet coefficient, \( Sf(j, k) \) is a scale factor.

Wavelet reconstruction formula is:

\[
Sf(j - 1, k) = Sf(j, k) * \tilde{h}(j, k) + Wf(j, k) * \tilde{g}(j, k)
\]

(8)

Where \( \tilde{h} \) the high pass filter and \( \tilde{h} \) is the low pass filter in the reconstruction. Through wavelet denoising, the gait image data is pre-processed and the threshold noise reduction method is selected. The main implementation flow is shown in the following figure:

![Wavelet thresholding noise reduction process](image)

Figure 2 Wavelet thresholding noise reduction process

4. Gait data identification technology based on SVM

Many external factors and their own factors will have an impact on the identification of human gait characteristics. In order to further improve the recognition rate of gait characteristics, in the gait recognition technology of badminton action analysis, a combination of dynamic and static methods is adopted to collect the badminton players’ Video data. Statistical pattern recognition to ensure the adequacy of the sample data, to ensure the accuracy of recognition, adequate sample data indispensable. Due to the limited data of badminton gait, many methods cannot achieve the expected results. In solving small samples, non-linear and high-dimensional pattern recognition, SVM support vector machine has obvious advantages and can be generalized to machine learning problems such as function fitting.

The characteristics of SVM mainly include: the principle of non-linear mapping algorithm, the non-linear mapping to high-dimensional space is replaced by the inner kernel function; maximizing the classification margin, distinguishing the optimal hyperplane in the feature space; the support vector is the final training result, plays a key role; a little support vector to determine the final classification results, the number of support vector to determine the amount of computation. In order to avoid over-fitting, we adopt the method of controlling the complexity of the classification model. The model with less data is suitable for SVM, such as straight line, plane and hyperplane.

Select the mode parameter. We extract the two-dimensional space image samples, if the training samples and the classification line is too close, the noise interference is relatively large, only the classification line and the training sample to maintain a sufficient distance, in order to get the optimal induction. To classify the class labels of +1 and -1, you need to rely on training samples to determine the segmentation hyperplane for the maximum classification interval. Set the optimal hyperplane
equation as: \( \mathbf{w}^T \mathbf{x} + b = 0 \); The interval between sample \( \mathbf{x} \) and the best hyperplane \((\mathbf{w}, b)\) is \( \frac{|\mathbf{w}^T \mathbf{x} + b|}{||\mathbf{w}||} \).

select the best sample \( \mathbf{x}_i^* \), normal vectors \( \mathbf{w} \) and \( b \) are satisfied \( |\mathbf{w}^T \mathbf{x} + b| = 1 \): Get standardized hyperplane. The distance between the sample and the optimal hyperplane is: \( \frac{|\mathbf{w}^T \mathbf{x} + b|}{||\mathbf{w}||} = \frac{1}{||\mathbf{w}||} \). The classification interval is: \( m = \frac{2}{||\mathbf{w}||} \). Find \( \mathbf{w} \) to maximum \( m \), \( \mathbf{w} \) substituted into \( |\mathbf{w}^T \mathbf{x} + b| = 1 \), to obtain the value of \( b \). Equivalent to \( j(\mathbf{w}) = \frac{1}{2} ||\mathbf{w}||^2 \) minimum, where, \( y_i (\mathbf{w}^T \mathbf{x}_i^* + b) \geq 1, \forall i \in \{1,2,\ldots,N\} \). The point nearest to the hyperplane \( \mathbf{x}_k^* \) satisfies \( |\mathbf{w}^T \mathbf{x}_k^* + b| = 1 \), the distance from the other plane \( \mathbf{x}_k^* \) to the hyperplane \( \geq 1 \), which is \( |\mathbf{w}^T \mathbf{x}_k^* + b| \geq 1 \). To solve the conditional extreme problem into an unconstrained optimization problem, \( L(\mathbf{w}, b, a) = \frac{1}{2} ||\mathbf{w}||^2 - \sum_{i=1}^{N} a_i \{y_i (\mathbf{w}^T \mathbf{x}_i^* + b) - 1\} \), \( a_i \geq 0 \), find the partial derivatives of \( \mathbf{w} \) and \( b \) in \( L(\mathbf{w}, b, a) \), respectively, and solve at a partial derivative equal to zero, that is, \( \frac{\partial L(\mathbf{w}, b, a)}{\partial \mathbf{w}} = 0 \Rightarrow \mathbf{w} = \frac{1}{2} N \sum_{i=1}^{N} a_i y_i \mathbf{x}_i^* \), \( \frac{\partial L(\mathbf{w}, b, a)}{\partial b} = 0 \Rightarrow \sum_{i=1}^{N} a_i y_i \mathbf{x}_i^* = 0 \), and \( a_i, y_i \) satisfy \( a_i \geq 0, \sum_{i=1}^{N} a_i y_i = 0 \), so as to obtain the optimal solution classification function:

\[
    h(\mathbf{x}) = \text{sgn}(\langle \mathbf{w}^* \mathbf{x} \rangle + b^*) = \text{sgn}(\sum_{i=1}^{N} a_i^* y_i (\mathbf{x}_i^* \mathbf{x} + b^*) (9)
\]

Can solve the optimal classification function.

Choosing a kernel function: The choice of kernel function in a support vector machine is crucial. Gait recognition belongs to the multi-classification problem, and the two-class classification method needs to be applied to the multi-category problem. Support Vector Machine (SVM) method is difficult to apply directly to multi-category classification problems. By combining two-category classification problems in SVM, multi-category recognition problems can be solved. We choose the kernel function as: \( K(x, y) = \exp\left(\frac{-|x-y|^2}{\sigma^2}\right) \). The value of \( \sigma \) is between 0.001 and 0.006.

Select classifier parameters.

Often k-fold cross validation classifier training, can be used to determine the optimal parameters. The basic method is as follows: the training set is divided into two categories: the new training set and the verification set. The new training set selects \( (k-1) \ast n/k \) from \( n \) elements of the original training set, and the verification set is made up of \( n/k \) elements to form the verification set, and the rest as the training set, continue the above operation. When the \( n/k \) elements are Selected, then the operation stopped.

5. Analysis of badminton action based on gait recognition

According to the aforementioned gait feature recognition technology, the gait data information collected during the whole badminton game captured by the camera is input to the system, and the system will intelligently classify the gait information based on the SVM and output the recognition result, so that each Badminton players gait action data, and then expand the analysis of the characteristics of the action. Through the view of the way, from the overall grasp of athlete differences in action, and find out the difference between the score and goal difference. The whole data can also be divided into multiple phases. For example, taking a round as an example, a detailed comparison is made between two or more groups of data at fixed time intervals according to timestamps of data acquisition to compare differences between nodes of the same specific, in order to find the missing side of the lack of action, analyze the score of the key points of this turn to win, the participants targeted specific guidance.

In the gait-based analysis of differences in badminton action, there are two aspects that can be compared: one is to compare the differences and similarities between the complete action of the athlete in competitive competition and the training action in daily training; on the other hand, it is to compare the differences and deficiencies in the movements between losers and winners.

Badminton movement based on gait recognition analysis of the overall design is shown in Figure 3 below:
Figure 3 Badminton action analysis based on gait recognition overall design

The dynamic time warping method is used to compare the complete motion of two types of exercise cycles. Mainly consider the badminton movement before and after the complete difference between the larger, but in the same two action cycle, the same period of time between the point of greater similarity.

Dynamic time warping method. Given two data sequences, the sample sequence \( X = (x_1, x_2, \ldots, x_N) \) and the test sequence \( Y = (y_1, y_2, \ldots, y_M) \), given a sequence of point-to-point distance functions \( d(i,j) = f(x_i, y_j) \geq 0 \), solving the distortion curve is the core of DTW, that is, the correspondence between points and points. We denote \( \varphi(k) = (\varphi_x(k), \varphi_y(k)) \) where \( \varphi_x(k) \) is \( 1,2,\ldots,N \) and \( \varphi_y(k) \) is \( 1,2,\ldots,M \), \( k = 1,\ldots,T \).

Given \( \varphi(k) \), we can solve for the accumulated distance between two sequences: \( d_{\varphi}(X,Y) = \sum_{k=1}^{T} d((\varphi_x(k), \varphi_y(k))) \). Find the most suitable \( \varphi(k) \) twist curve to minimize the cumulative distance, which is the final output of the DTW:\n\[
\text{DTW}(X,Y) = \min_{\varphi} d_{\varphi}(X,Y).
\]

Restrictions. Monotonicity: \( \varphi_x(k+1) \geq \varphi_x(k), \varphi_y(k+1) \geq \varphi_y(k) \), the twist curve cannot be left or back up to avoid the cycle; Continuity: \( \varphi_x(k+1) \leq \varphi_x(k) + 1 \), the twist curve should be continuous to ensure that the points in both sequences are matched; Boundary Conditions Certainty: \( \varphi_x(1) = \varphi_y(1) = 1, \varphi_x(T) = N, \varphi_y(T) = M \), the path must start from the top left and bottom right to end. By calculating the Euclidean distance, the similarity between the two sets of data is determined.

6. Conclusion

Gait recognition technology, as a new biometrics-based remote identity recognition technology, has become a research hotspot in the field of current recognition. As badminton during the fast speed, short-term action, the data acquisition requirements in the image process to have a certain degree of clarity of the pixels, the camera's requirements have increased. Image processing techniques such as noise filtering are relatively mature. The extraction of gait features is essential for image data preprocessing, and the post-processing of image processing needs to be further strengthened. Support vector machines and dynamic time warping algorithm technology is more and more widely used in the classification of gait training data superiority is more prominent in the process of exploring the badminton movement essentials are in place, and other issues have brought a lot of convenience. In the follow-up study, we focus on the automation and intelligence aspects of badminton data analysis, so that the application of artificial intelligence technology in sports is more in-depth.

About the Author

LI Yunwei(1983-), Male, Rongcheng, Shandong, Master, Lecturer, Physical Education and Training.
Jiang Shiwei(1988-), Male, Wuhu, Anhui, Master, Lecturer, Physical Education and Training.

References
[1] Chai Yanmei, Xia Tian, Han Wenying, et al. Research progress on gait recognition [J]. Computer Science, 2012, 39 (6): 10-15.
[2] Chen Yixue, Liu Jiang, Ma Lei. High-speed interpolation of document images based on features [J]. Microcomputer & Applications, 2013, 31 (24): 35-38.

[3] Zhang L, Zhang D, Mou X. FSIM: a feature similarity index for image quality assessment [J]. Image Processing, IEEE Transactions on, 2011, 20(8): 2378-2386.

[4] Shi Xin, Lei Lining, Xiong Qingyu etc. Abnormal gait recognition based on quadratic feature extraction and SVM [J]. Chinese Journal of Scientific Instrument, 2011, 32 (3): 673-677.

[5] Rajagopal A, Dembia C L, Demers M S, et al. Full-Body Musculoskeletal Model for Muscle-Driven Simulation of Human Gait [J]. IEEE transactions on bio-medical engineering, 2016, 63 (10): 1-1.