Recognition method of kicking and stride movements of Taekwondo athletes based on Gaussian mixture model

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Abstract
In order to improve the accuracy of Taekwondo Athletes' motion recognition, a human motion recognition method based on Gaussian mixture model is proposed. This paper decomposes the structure of kicking and stride movement of human Taekwondo athletes to form a group of recognition targets, and investigates the changes of muscle surface under kicking and stride movement of Taekwondo athletes. The Gaussian mixture model is used to collect the short-time feature images of kicking and stride movement of Taekwondo athletes, and the wavelet time-domain features of the images are obtained as the recognition vector space, The experimental results show that the method can effectively identify the movement characteristics and muscle changes of Taekwondo athletes, fully meet the research requirements.
Keywords. Gaussian mixture model; Taekwondo; Action recognition; Wavelet time domain feature

Introduction

Taekwondo is deeply loved by teenagers. With the continuous improvement of Taekwondo Teaching mode, the standard writing requirements of Taekwondo athletes are also higher and higher. Based on this, in order to better analyze the action training effect of Taekwondo athletes, taking the kicking and stride action of Taekwondo athletes as an example, this paper proposes a kicking and stride action recognition method of Taekwondo athletes based on Gaussian mixture model (Guo, Li, and Shao 2017). The performance of Gaussian mixture model needs to consider not only the choice of core functions and parameters, but also the limitation of the number of Gaussian mixture models. Through visual search and Gauss mixture model, we can get effective information, quickly perceive the changes of athletes' muscle structure during movement, and help athletes adjust their thinking and skills in complex environment(Ma et al. 2019). In order to achieve the continuity of action, avoid interfering with the free movement of human body, and ensure the flexibility of kicking and stride action of Taekwondo athletes, the intelligent assistant is combined with the recognition method of kicking and stride action of Taekwondo athletes. The accurate recognition of kicking and stride movement of Taekwondo athletes is a hot research topic at present (Kritikos et al. 2020). By obtaining a typical non-stationary time-varying signal of lower limb muscle changes in the process of kicking and stride movement of Taekwondo athletes, it is often accompanied by lower limb movement noise (Gao et al. 2018). The recognition method of Gaussian mixture model is essentially a multi behavior classification problem. In this paper, a kernel based multi classification support vector clustering simplification method is proposed to improve the accuracy and real-time performance of action recognition.

Recognition of kicking and stride of Taekwondo Athletes

Feature extraction of kicking and stride of Taekwondo Athletes

Using motion capture equipment to obtain human motion data, and according to the topological structure of human lower limbs, a simplified skeleton model of human lower limbs is established, so as to realize the effective extraction of kicking and stride movement characteristics of Taekwondo athletes. The specific structure includes hip joint, left and right fine points, nine joints, left and right knee joints and left and right toe points (Souza et al. 2020). The feature extraction information of kicking and stride movement of Taekwondo athletes mainly includes the spatial position coordinate information of the hip joint at each time point and the relative rotation angle information between the hip joint and its parent node. Based on this, Gaussian mixture model is used to extract the feature information of human lower limb motion, including the extraction of lower limb motion parameter information, the selection of lower limb motion parameter, etc (Xia and Shi 2020). The steps are as Figure 1:

For simple target recognition, the bottom vision can provide enough information by using appropriate matching and recognition algorithm. For complex target recognition methods such as human motion recognition, although the visual information cannot meet the actual needs of accurate matching, the recognition effect is very good (Da Gama et al. 2019). Therefore, the requirement of feature extraction in computer vision is very high. In order to meet the research requirements, based on the results of Taekwondo Athletes' body structure feature collection, in the process of Taekwondo Athletes' kick and stride action feature extraction, we need to further build a mature and fixed signal processing process, carry out

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continuous parameter prediction, and further optimize the Taekwondo Athletes' kick and stride action recognition process (Kim and Lee 2018). The initial muscle signal is preprocessed to extract the muscle feature classification / prediction model output. The specific steps are shown in Figure 2:

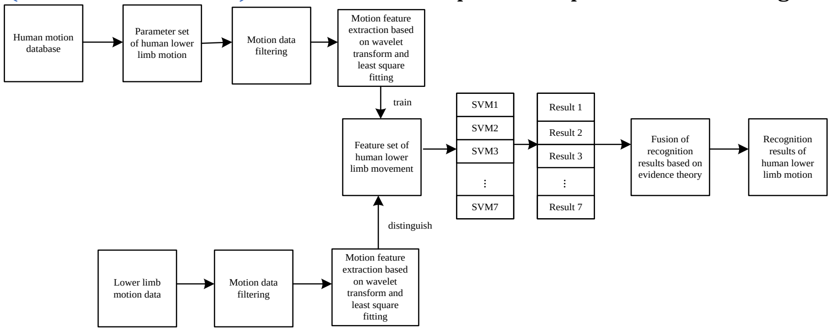


Fig. 1 Information collection of human muscle changes of Taekwondo athletes during kicking and stepping

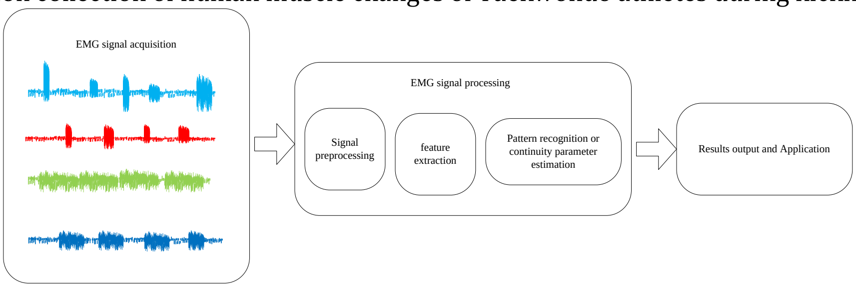


Fig. 2 Information processing steps of athletes' movement

Furthermore, Gaussian mixture model is used to extract multi-dimensional features directly from the basic features, which avoids the extraction of time-frequency features and reduces the dimension loss of time series data (Liu et al. 2018). A software program is developed to collect acceleration signals for the selected data collector, and a set of recognition actions are designed according to its wear condition. Its basic function is to collect data and provide original acceleration signal for subsequent operation (Shin et al. 2016). Its performance depends on the performance of the system to a certain extent. The Figure 3 shows its basic flow.

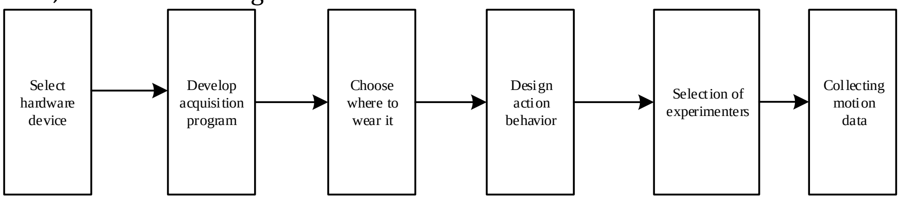


Fig. 3 Optimization of information collection steps of pedaling and stride

In recent years, the research on the recognition of kicking and striding movements of Taekwondo athletes is a hot issue (Gong and Shu 2020). In the process of recognition, it is necessary to combine the non rigid motion of human body, the change of light, the mixture of background, the self occlusion and mutual occlusion between objects, which brings new challenges to the research in this field. Optimization research is carried out to ensure the recognition accuracy.

Recognition algorithm of kicking and stride of Taekwondo Athletes

Gauss mixture model is used to classify and calculate the characteristics of pedaling and stride, and the recognition problem of pedaling and stride is transformed into a classification problem. In order to have good performance of the step recognition method, based on the basic idea of Gaussian mixture model, the optimal spatial decision hyperplane is established to maximize the sample spacing (Yang, Wang, and Chen 2019). Set the given sample (x, y) as the training sample, a is the target classification, k is the target classification number, and b is the input space dimension. The essence of classifying samples with optimal hyperplane is to solve the constrained quadratic programming problem:

$$f(x) = \mathrm{sen}\left(\sum_{j=1}^{L} \alpha_i y, k(x_i, x) + b\right) \quad (1)$$

Furthermore, the nonlinear mapping features of complex pattern classification problem are calculated to obtain a feature space of sufficient dimensions, and a high-dimensional linear separable feature space is generated (Gurbuz and Amin 2019). The best decision-making with the largest mark is found in this space. The classification function of Gaussian mixture model is reconstructed, and the corresponding points and change rules of muscle changes in stepping action are found The feature mechanism is transformed into a special multi class algorithm to construct m binary target sub classifiers, which are gradually transformed into binary classifiers, so as to construct a binary classifier containing multiple binary support vectors (Kurban and Yıldırım 2019). In the process of calculation, including contour A and color gradient B, spatial feature N and other new crown information, similarity calculation is carried out, which is measured by the nearest distance. When the orthogonality and importance of the feature components are the same, the eigenvector algorithm is as follows:

$$D_1 = f(x)\sqrt{\sum_{i=1}^{N}(A_i - B_i)^2} \quad (2)$$

The weight of each component of the eigenvector is further calculated:

$$D_{\text{mahal}} = D_1(A-B)^T C^{-1}(A-B) \quad (3)$$

Assume that matrix d is the sequence of actions to be tested and listed in the example. The elements in the matrix are defined as:

$$D(i,j) = d(i,j) + \min_{p(i,j)} D_{\text{mahal}}\{D[p(i,j)] + T[(i,j)\cdot p(i,j)]\} \quad (4)$$

Furthermore, according to the new control requirements of variable time signal purchase time history, the human-computer interaction method of dynamic outer frame control is adopted, and the time-domain features with less calculation are used as the input features of the classification model, so as to effectively improve the recognition accuracy of the stepping muscle signal (Lossau et al. 2019). In order to solve the problem that the sensor displacement is not sensitive in the process of signal extraction, the motion intention of lower limbs can be recognized effectively (Barshan and Yurtman 2016). The envelope signal of muscle signal is introduced as the representation, and the proportional control strategy is adopted to improve the standard writing of pedaling and stride, which achieves good auxiliary effect. The average absolute value of action recognition signal is calculated.

$$\text{MAV} := \frac{1}{N}\sum_{n=1}^{N}|y(n)|\,D(i,j) \quad (5)$$

The square root algorithm of the amplitude of the recognition signal is:

$$\text{RMS} := \sqrt{\frac{1}{N}\sum_{n=1}^{N} y(n)^2 D(i,j)} \quad (6)$$

The total number of times that the slope sign changes to the opposite state in the muscle signal is:

$$\text{SSC} := D(i,j)\sum_{n=2}^{N-1}\zeta(n) \quad (7)$$

The slope sign change algorithm is as follows:

$$\zeta(n) = \begin{cases} 1, & \text{if } \operatorname{sgn}((y(n)-y(n-1))\times(y(n)-y(n+1))) \\ & \text{and } |y(n)-y(n\pm 1)| \geq \varepsilon \\ 0, & \text{otherwise} \end{cases} \quad (8)$$

In the process of recognition, the gray value of pixels in the background image and the gray value of moving object are directly compared to get the accurate action recognition image. The specific algorithm is as follows:

$$F(x,y) = \begin{cases} 1, & \zeta(n)\left|f_1(x,y) - f_2(x,y)\right| > S \\ 0 & \text{other} \end{cases} \quad (9)$$

Based on the above algorithm, the optimization of action recognition algorithm can effectively remove redundant data and interference information in the recognition process, and ensure the effectiveness of action recognition (Chaudhary and Murala 2019). The algorithm has strong robustness. Although the algorithm complexity is high, it can meet the needs of practical application.

Realization of kicking and stride recognition of Taekwondo Athletes

In the recognition of kicking and stride movements of Taekwondo athletes, the first step is to establish the target set of kicking and stride recognition of Taekwondo athletes. According to the characteristics of human motion mechanics, complex body movement is a general simple movement combined according to certain rules(Meng et al. 2020). Through the effective identification of these simple movements, we can provide clear control ideas for the recognition method of kicking and stepping movements of Taekwondo athletes. Combined with the action decomposition method, the daily lower limb movements such as standing, walking at a constant speed, going up and down stairs are decomposed into seven action segments to determine the recognition target and decompose the action. The details are shown in Table 1.

Table 1 Decomposition of the lower limb movement characteristics of Taekwondo Athletes under the step action

number	Action segment name	Action description
A	Stand up	The main function is to lift the human body.
B1	Walking support	It starts with the heel of the observation leg touching the ground, and ends with the observation of the toe of the leg leaving the ground. Its function is to support the body weight and maintain balance in the

		process of the other leg swinging forward to move the human body.
B2	Walking and swinging legs	It starts when the tip of the observation leg leaves the ground, and ends when the heel of the observation leg touches the ground. The function is to swing forward and guide the body to move when the other leg supports the weight.
C1	Stair support	The function is to guide the human body to move upward and support the weight and maintain balance when the other leg swings.
C2	Go up the stairs and swing your legs	It starts from the observation of the foot leaving the step and ends at the observation leg foot contacting the step. The function is to guide the human body to rise when the other leg supports the weight.
D1	Lower stair support	It starts from the observation leg foot contact step, and ends at the observation leg foot leaving the step. The function is to resist the effect of gravity and maintain body balance when the other leg swings downward.
D2	Go down the stairs and swing your legs	It starts from the observation leg foot leaving the step and ends at the observation leg foot contacting the step. The function is to guide the human body to move down when the other leg supports the weight.

In the process of recognition, each behavior segment is segmented based on a single information source, which affects the efficiency and accuracy of recognition. Because the plantar pressure information can easily and accurately distinguish each action and support action (including standing action), the plantar pressure information is introduced (Park, Chung, and Kim 2019). According to the pressure information, the lower limb movement targets are divided into beating movement and support movement. On this basis, each group of motion is further classified by muscle signal. The recognition features of kicking and stride movements of Taekwondo athletes are usually based on model features, which are mainly applied to the extraction of recognition targets, target recognition and other issues (Wu and Jafari 2018). Most of the models belong to specific geometric models with corresponding positions. In addition to many basic features of the image itself, there is also a very important high-order feature, that is, according to the distribution of tree structure, The "elastic" model can be used to describe the distribution relationship of various parts of the human body. Even if the position of each part of the human body changes during the movement, it can also be described by the "elastic" model. The target recognition of kicking and stride movement of Taekwondo athletes adopts high-level features. When the human body moves forward, one of the lower limbs is the supporting part, and the other lower limb is the part supporting the forward stepping movement. According to the order of contact with the ground, the support stage can be divided into the sole support stage, the foot support stage and the front support stage. Based on this, the standard for determining the phase of kicking and stepping movements of Taekwondo athletes is standardized. The specific contents are as Table 2:

Table 2 Criteria for determining the phase of kicking and stride of Taekwondo Athletes

Gait phase	Is the heel in contact with the ground	Does the toe touch the ground
Heel support	yes	no
Full foot support phase	yes	yes
Forefoot support phase	no	yes
Oscillating phase	no	no

Based on the information in the table above, the step recognition steps of Taekwondo athletes are further optimized. After the recognition program is started, the wireless module nRF24L01 is initialized and the sensor mpu-6050 is accelerated. The A / D sampling port is used to enter the cyclic waiting state. Set the timer to 1 / 60 and the sampling rate is FS = 60 Hz. The motion frequency is generally below 20 Hz, and the sampling frequency of 60 Hz can meet the sampling requirements. Based on this, the processing steps of kicking and stride of Taekwondo athletes are shown as Figure 4:

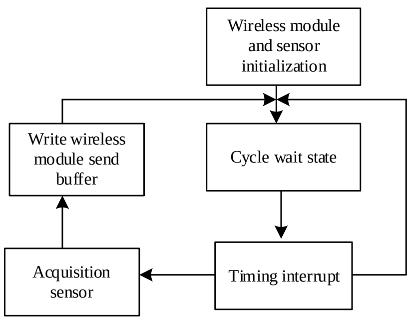


Fig. 4 Steps of kicking and stride of Taekwondo Athletes

After the receiver receives the data, the main control unit of the receiver only forwards the data, that is, the data is sent to the acquisition and processing program of the PC through the serial port. There is no difference in this process. The acquisition processor identifies each frame in the data stream, identifies the frame header and frame serial number, checks whether the data is correct, then displays and identifies, reports errors and stops storing and displaying the data. The specific steps of kicking and stepping action identification of Taekwondo athletes are shown in Figure 5.

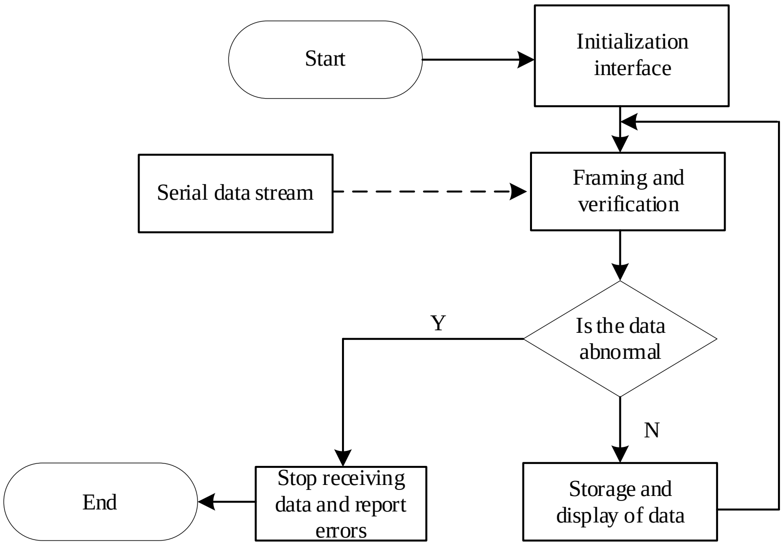


Fig. 5 Recognition steps of kicking and stride of Taekwondo Athletes

A method of behavior recognition based on machine learning is proposed: feature extraction and classification learning. The purpose of training learning classifier is to create a multi value classifier for behavior classification, and finally combine all the judgment results into the recognition, forming the overall framework of human behavior recognition. To select the target and extract the features of the target, we need to extract the features according to the characteristics of the target itself. According to its complexity and feature extraction ability, features can be divided into low-level features, wavelet transform features and high-level features. The final recognition result depends on the description ability of motion features, and also on the accuracy and reliability of classification. In order to ensure the recognition accuracy, the action recognition results are further modified, and the specific steps are as Figure 6:

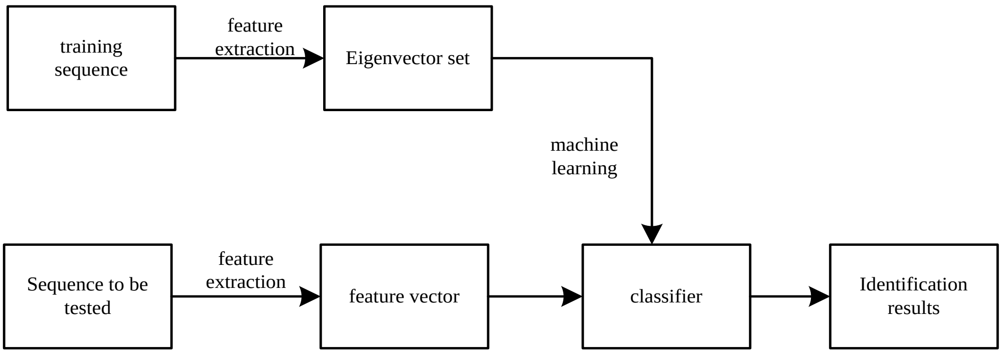


Fig. 6 Recognition and correction of kicking and stride of Taekwondo Athletes

This paper presents a new recognition method of kicking and stride movements of Taekwondo athletes. It can not only extract the essential attribute features of the new method in the image, so as to reduce the dimension of the original data, achieve the purpose of selectivity and characteristics, but also reduce the complexity of feature extraction and improve the recognition ability of kicking and stepping movements of Taekwondo athletes.

Analysis of experimental results

In order to verify the recognition effect of kicking and stride action of Taekwondo athletes, an experiment was carried out. Ghiz72.064 bit processor, 16GB ram and Dx11 card adapter were used in the experiment. This test uses one host, and the configuration parameters are shown in the following Table 3.

Table 3 experimental parameter setting

parameter	index
CPU	IntelCore
processor	64 bit
Video card	NAIDIA

built-in	USB3.0 bus
OS	WIN8.1

Eight sensor modules were designed to identify the joint action of kicking and stride movement of Taekwondo athletes, and combined with more muscle information, 8-Channel data synchronous transmission was realized to ensure the safe and stable transmission of data. In the programming, it involves the configuration recommended by TI company, the setting of website collection module, and the TCP client of wireless network. The experimental data processing process is optimized, as shown in Figure 7.

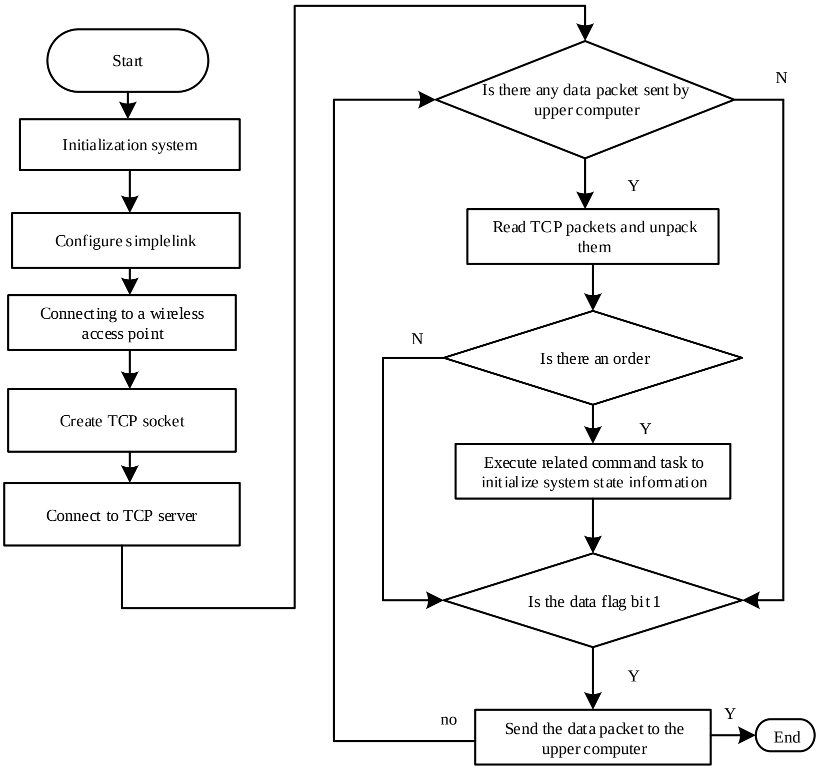


Fig. 7 Experimental data processing flow

In the experimental environment of 50m2 and open indoor space, volunteers can control the beginning and end of data collection. Each group collected 6 groups of data, a total of 84 groups, each group only do one action, according to the intensity of the action and the state of the subjects, do 1-2 minutes in the natural state, as the reference of the experimental data. The details are as Table 4:

Table 4 Comparison of reference data

Action type	Action description	Duration
Walk	You can walk freely in the open space at any time, and you can choose the speed freely	2min
Run	You can run fast in the open space at any time without touching the ground at the same time	2min
Jump	It can take off at any time during the data acquisition period, and the takeoff height can be controlled freely, and the feet can be off the ground	1in
Step by step	Step in place, step frequency and height can be controlled freely	2min
On tiptoe	Lift the heel in place and touch the ground with the tip of the foot. The lifting time and height are controlled freely	1.5
Step back	You can walk backward in the open space at any time, and you can choose the speed freely	2min

Based on the above data for comparative analysis, in order to reduce the frequency of the data acquisition module to send data to the terminal without affecting the real-time data transmission, the benefits of muscle changes under the pedaling and stride action are analyzed. Because the muscle change signal is a continuous sequence signal, in the limb movement, the movement amplitude will increase significantly. During sleep, due to the disorder of the corresponding muscle group, the signal is very weak, so it is necessary to manually click the branching points to obtain a group of branching points. The specific identification results are shown in Figure 8:

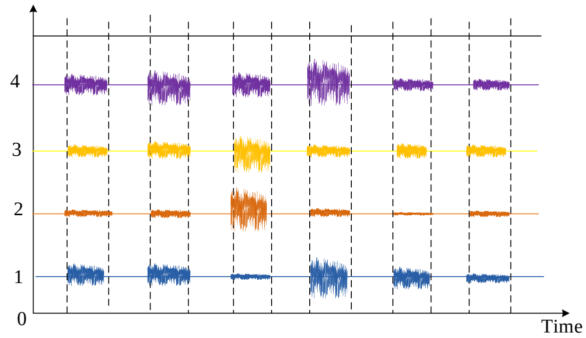
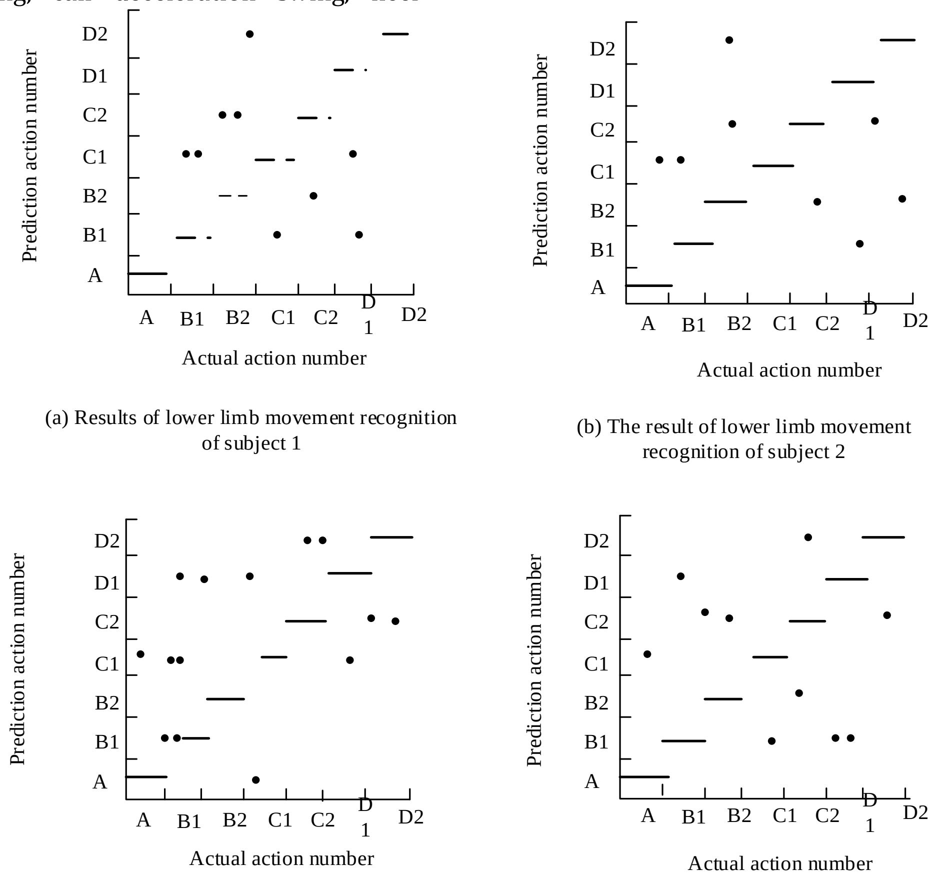


Fig. 8 Lower limb muscle recognition results

On this basis, four macro differences of Kua and other inactivity were selected for classification and recognition, but no detailed analysis was carried out. For example, based on the relationship between the forefoot, heel and the ground, the flat step can be divided into two leg support, forefoot support, calf acceleration swing, calf deceleration swing, heel support, full foot support and other sub movements. The following research focuses on the classification and description of multimodal lower limb movement, and classifies and identifies them to obtain the recognition effect of the continuity of pedal and stride action



(a) Results of lower limb movement recognition of subject 1

(b) The result of lower limb movement recognition of subject 2

(c) Results of lower limb movement recognition of subjects 3

(d) Results of lower limb movement recognition of subjects 4

Fig. 9 Recognition results of the continuity of pedaling and stride

Based on the above research results, it seems that the recognition method of kicking and striding movements of Taekwondo athletes based on Gaussian mixture model has good continuity in the process of English, and the clarity of muscle recognition image can also be changed under the name of you. Further, the experimental analysis is carried out between the traditional method and the principle recognition method under the condition of delay and interference. The test results are shown in table 5.

Table 5 Accuracy comparison results of two methods under recognition delay

Step	Traditional recognition methods				The method of action recognition in this paper			
and	Image	Motion	Dynamic	Accuracy/%	Image	hand	Dynamic	hand

step	acquisition	tracking	identification		acquisition	tracking	identification	tracking
pos1	—	R	R	59	—	R	R	69
pos2	R	—	R	86	R	—	R	94
pos3	R	R	—	70	R	R	—	91
pos4	—	—	R	55	—	—	R	79
pos5	—	R	—	60	—	R	—	71
pos6	R	—	—	40	R	—	—	52
Pos7	R	R	R	100	R	R	R	100

The "-" in the table indicates the delay in the recognition process, which represents the normal R. It can be seen from the table that the recognition accuracy of kicking and stride action recognition method of Taekwondo athletes based on Gaussian mixture model is obviously better than that of traditional methods in complex environment. Therefore, it is confirmed that the recognition method of kicking and stride movements of Taekwondo athletes based on Gaussian mixture model has high accuracy and anti noise ability, which fully meets the research requirements.

Concluding remarks

This paper presents a method of kicking and stride recognition of Taekwondo athletes based on Gaussian mixture model. The motion feature information is collected according to the structure characteristics of human body, and the motion tuckles are decomposed by wavelet. The time frequency eigenvalues are obtained. The eigenvector space of the eigenvalues of the muscle signals of the rectus femoris, the vastus medialis, the two muscles and semitendinosus muscles is established to make complaints about the step movements of Taekwondo athletes. The practice shows that the recognition method of kicking and stride movements of Taekwondo athletes based on Gaussian mixture model is effective, which enriches the recognition method of lower limb movement.

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