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Sports Video Evaluation and Three-dimensional Human Motion Simulation of Teenagers in Physical Exercise

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Abstract: *In recent years, teenagers' physical exercise has become more and more important. In pattern recognition, intelligent human-machine interface, virtual reality and other aspects, video technology is the current research focus. Video analysis methods have good application prospects in intelligent monitoring, sports analysis, animation generation, etc. In the experimental part, the new approach of motion target selection based on dynamic background construction put forward in this paper was compared and analyzed with background subtraction method, time difference method and optical flow method in terms of recognition time consumption and false separation rate. 0.95%-1.03% was the fluctuation range of the misclassification rate of the method in this paper, and 1.64%-1.76% was the fluctuation range of the misclassification rate of the background subtraction method; 2.85%-3.06% was the fluctuation range of mis-separation rate of time difference method, and 4.02%-4.16% was the fluctuation range of mis-separation rate of optical flow method. It was not difficult to see that this method can better separate the motion images in sports video.*

Keywords: *Physical Exercise, Video Analysis, Three-dimensional Human Motion Simulation, Sports Training, Youth Groups*

1. Introduction

With the increasingly tense social life, people spend more time on work and study, and have little time for sports and outdoor activities, which has led to the overall decline of the national physique. Youth is an important reserve force for the country in the future, and their health status would directly affect the country's economic development and the successful implementation of sustainable development strategy. People must attach importance to sports in ideology and strengthen sports training from reality. Nowadays, the globalization of sports has emerged all over the world. With the vigorous development of sports, the "New Olympics" movement has also received more and more attention, and sports have become an important social activity in people's daily life.

With the continuous development of society, the research on physical exercise has gradually increased. The goal of Chekroud Sammi R's research was to study the relationship between sports and mental health burden, and understand the impact of sports type, frequency, duration and intensity [1]. Chagas Eduardo Federighi Baisi summarized the suggestions on physical exercise during the COVID-19 pandemic and its benefits to over exercise and health [2]. Moser Othmar detailed the role of physical exercise in improving clinical results, physiological response to exercise, and different nutrition and treatment strategies around exercise [3]. Wegierska Angelika Elzbieta reviewed the recent research on the impact of sports activities on intestinal microbiota, which aimed to determine the potential mechanism that sports may affect the composition and function of intestinal microbiota. He also analyzed whether physical exercise with different work intensities might reflect changes in intestinal health [4]. Lam Freddy MH conducted a study on whether physical activity improves physical performance and quality of life in patients with cognitive disorders and dementia [5]. Although these studies have promoted physical exercise to a certain extent, they have not been combined with the actual situation.

At the same time, video analysis has gradually attracted widespread attention from the academic community. Hendricks Sharief used the method based on expert consensus to establish a consensus group for football league video analysis, and took the development of football league video research as the framework [6]. The aim of Serner Andreas was to perform a standardized video evaluation of a

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range of acute adductor longus injuries in soccer. It was concluded that acute adductor long muscle injury occurs in many situations in football [7]. Kerin Fearghal described the mechanism of hamstring injury of male professional football league players through video analysis [8]. Although these research methods are innovative, a large number of experimental data are needed to prove the reliability of the methods.

This paper analyzed the video-based human motion analysis method, and proposed a new approach to motion object extraction with dynamic background structure. In the video motion tracking technology, the stick graph model was analyzed, and an improved particle filter algorithm was introduced, which is efficient in optimizing the computational efficiency. Next, in the experiment part, the design of 3D human motion simulation was analyzed in detail, including video analysis and human motion analysis. Finally, the effectiveness of the proposed method and system was proved from the experimental data.

2. Video-based Human Motion Evaluation Method

2.1 Motion Segmentation

In the sports training and teaching of teenagers, the functional goal of digital video motion analysis is to make full use of video analysis [9-10]. After the training, an intensive evaluation and contrast of technical actions is a proven method.

Environment model is the premise of human motion analysis based on video. Among them, camera scaling, dynamic generation and updating of environment model are indispensable. In image preprocessing, the background model is established to lay a solid foundation for the next step of motion segmentation.

In the motion analysis of computer vision, in order to obtain three-dimensional (3D) image-based images, the relevant parameters of the camera must be obtained in advance [11]. Therefore, camera calibration is a very important work in the preprocessing process. Generally, based on the existing camera calibration principles, more accurate camera parameters can be obtained through offline camera calibration procedures. In the case of real-time scaling, self-scaling technology can also be used.

The motion in the digital video image of sports action generally includes two types. One is the background movement caused by the camera movement, that is, the overall movement; the motion generated by another kind of athlete's motion is called local motion, and the acquisition of its overall motion parameters is the key and basis for realizing the synthesis of athlete's body motion and motion panoramic image [12].

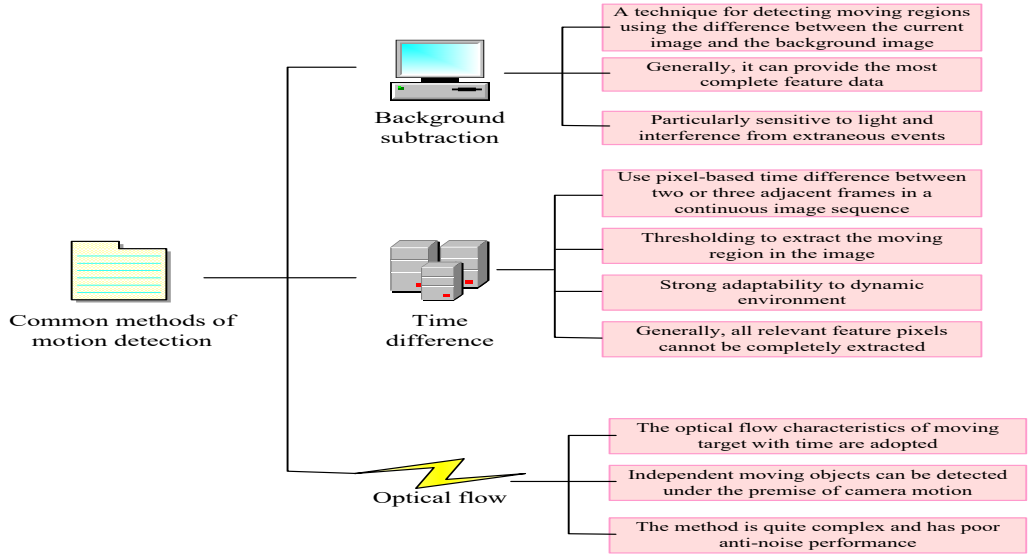

Figure 1. Common methods for motion detection

Video motion segmentation is divided into two aspects, namely motion detection and target classification [13]. The post-processing of motion detection is object classification, that is, extracting the motion region corresponding to the human body from the detected object. Different motion regions

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may be associated with various moving objects. For example, a continuous image taken by a monitoring camera at a traffic intersection may contain pedestrians, vehicles, flying birds, stray clouds, swaying tree branches, etc. Therefore, a better pedestrian tracking and behavior analysis requires an accurate classification of the moving objects.

The presence of factors such as weather, light, shadows, and clutter can make motion detection very difficult. Figure 1 shows several commonly used methods at present.

According to Figure 1, the background subtraction method for moving objects is one of the most frequently used approaches in the current motion segmentation [14]. This method usually offers the most full feature information, but is particularly responsive to the effects of dynamic environments like lighting and uncorrelated events.

The process of background subtraction is as follows:

The background estimation value $Q(\cdot)$ is formed, and the estimation value of the background picture is updated in each subsequent frame.

$$Q(m+1)=\frac{w_s F+\sum_o w_o Q(m-o)}{w_v} \tag{1}$$

Among them, the simplified period of weights w_s, w_o and w_v is taken as 1, that is, when establishing the background, it is assumed that the values of the first frame and other subsequent frames would not be affected by other situations. Moreover, in fact, w_s should be larger than w_o if the light change is considered.

The area of the moving object is subtracted from $Q(m+1)$ for each subsequent frame.

$$O=O_2(x,y)-O_1(x,y) \tag{2}$$

Among them, O is the differential image; O_2 is the original image (red, green and blue color map), and O_1 is the background image.

Time difference method is to use the time difference between two or three adjacent frames, and then use thresholding technology to extract the moving region in the image.

The optical flow method is used to study the motion characteristics of moving objects. It can detect independent moving objects in the presence of camera motion. However, most of the current algorithms are complex and it is difficult to achieve real-time treatment of full-frame video streams with no particular hardware devices.

A motion object selection based on dynamic context construction is shown in Figure 2.

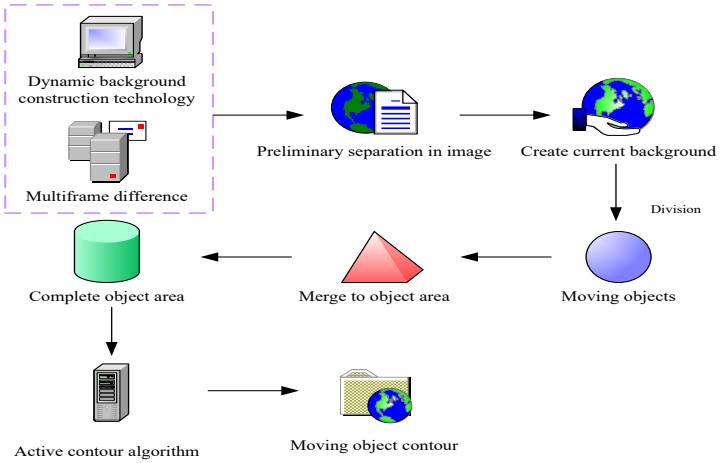

Figure 2. New method of moving object extraction

In Figure 2, first of all, according to the dynamic background construction technology of

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foreground separation, the foreground area is preliminarily segmented by using the multi-frame difference method. On this basis, the static foreground area is extracted using the time sequence information, and the target area is combined with the target area to obtain the entire target area, which overcomes the impact of the irregular movement of the target on the target segmentation accuracy.

The specific target classification is shown in Figure 3.

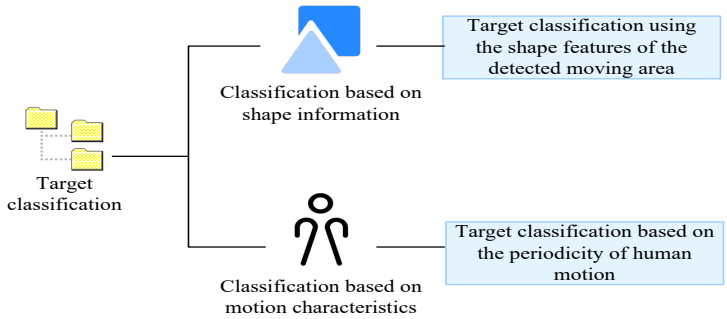

Figure 3. Target classification

These two commonly used classification methods can be applied at the same time, and can comprehensively consider the color, speed and other characteristics of moving objects, so as to obtain more accurate classification results. On this basis, a hierarchical classification algorithm based on time co-occurrence matrix is proposed, which can recognize both target and behavior.

2.2 Motion Tracking

The progress of computer technology has greatly increased the amount of computation that computers can carry. The video processing technology is gradually differentiated and suitable for a variety of different human motion videos. In the past, the research of video processing technology has been divided into forward and reverse. The implementation process of these two plans is completely opposite. The forward calculation method is to build the human skeleton model based on the original image, and then use the computer to collect other video images. Reverse reasoning is to capture human actions in the image, and then build the skeleton model through the capture.

Model-based human motion tracking is currently the most widely used method [15]. The algorithm first constructs the corresponding human body shape according to the actual application requirements, and projects it into the image space when tracking the human motion; after that, using certain evaluation methods or functions, the similarity with the real image data is found. In the model parameter space, by finding the parameters that are consistent with the real image data, after certain conditions are met, the search is stopped, and then it is used as the current motion parameters. This process is a cycle of comprehensive comparison. This method is mainly divided into model selection and model-based tracking.

The selection of suitable manikin is the first issue based on the model. When selecting a model, it is common to consider the type of information provided by the requested model and the constraints required when tracking. The choice of models is varied, which can be represented by a plane stick or a complex 3D human model. For example, in video surveillance, they do not need to obtain the specific position of their bodies. As long as they know where their bodies are, they can use a regional model to describe them. In the case of character animation, it is necessary to have an accurate simulation of each part of the body, since it is necessary to know the specific parameters of each part of the body. From this, it is clear that the model is actually a representation of the information to be obtained by the application, and once the parameters of that model are obtained, all the information needed for that model can be obtained.

Video-based motion detection techniques can be broadly classified into two types: one for formless modeling and the other for form-based. Studies related to morphological models fit better with the human eye's observation and interpretation of the outside world. This method describes the observed object as a prior model, and then continuously corrects it in the follow-up tracking, so that the required attitude and other information can be obtained at any time. The 3D model can obtain accurate human posture parameters, but its calculation cost is very high. This paper used a two-dimensional human model.

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The stick model is the simplest way to express the human body structure. It consists of two parts: point and line. They represent the key point and bone stick model respectively. They can be used to guide the matching of image features, so as to get the posture of the human body and the result of motion capture. Two-dimensional mode is a method of capturing a single visual frequency, which limits the direction and shooting angle of the human body. For example, the most common is the scale prism model parallel to or moving towards the camera.

In this paper, a second-order autoregressive model is used, assuming that each state parameter makes a steady change in acceleration:

$$x_t - x_{t-1} = x_{t-1} - x_{t-2} + \mu w_t \tag{3}$$

T is time; μw_t is a Gaussian distribution, and w_t is subject to zero mean.

When the status transformation of the state vector meets the one-time Markov, the Bayesian filter formula can be used to express the tracking:

$$\begin{aligned} &p(x_t|C_t) = p(c_t|x_t) \\ &\int p(x_t|x_{t-1})p(x_{t-1}|C_{t-1})dx_{t-1} \end{aligned} \tag{4}$$

Among them, x_{t-1} and C_{t-1} are the state vector and observation values before time t. When the motion model $p(x_t|x_{t-1})$ and the observation similarity $p(c_t|x_t)$ are known, the posterior probability $p(x_t|C_t)$ can be calculated recursively by Formula (4).

This paper introduced an improved particle filter algorithm in practical application, which combines the principle of simulated annealing optimization algorithm. In the tracking process, N layers are sampled repeatedly to make the distribution of the similarity function from wide to narrow, and gradually reach the global optimum.

3. 3D Human Motion Simulation Experiment

3.1 3D Human Motion Simulation Design

The motion of human body is a complex and multi-degree-of-freedom motion. Its motion is carried out according to the laws of physics. To make the simulation more realistic, the overall skeletal structure of the human body must be fully taken into account. Therefore, it is very difficult to realize such complex actions. Therefore, it is a challenging work to apply 3D human body simulation technology in physical education. In addition, sports training is also a new training method. First of all, the sports database of excellent athletes has been built by using motion capture technology [16-18]. Next, the movements are corrected by offset mapping and motion stitching techniques. The revised movement is dynamically tested and analyzed, and compared with the training video of athletes[19-21].

(1) Action modification and design

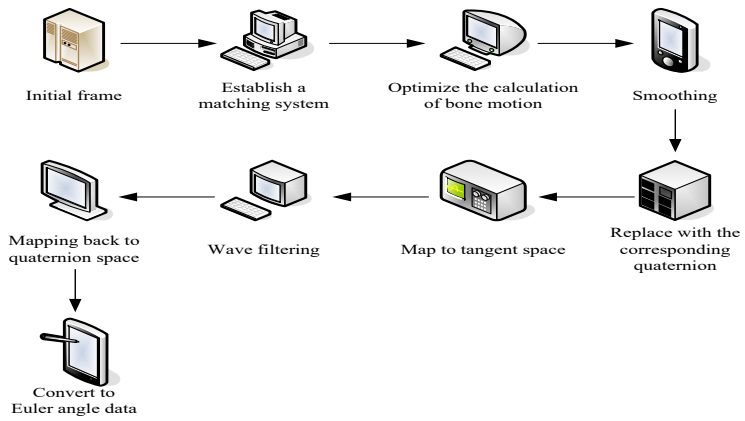

Figure 4. Skeletal motion extraction method

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Motion capture is an effective way to establish a 3D model of technical movements in sports events. The basic principle is to record the object's motion data directly using a sensor tracking device. At present, the main measurement technology is to use optical technology to measure the human surface markers, so as to obtain the most original 3D motion data.

A skeletal motion detection approach using optical techniques to acquire motion data is proposed as shown in Figure 4.

In Figure 4, the initial frame is selected first, and a system of skeletal and virtual tagging points is created to match the movement catch target. According to the principle of minimum distance between virtual marker points and actual marker points, the collected motion data is optimized. Since the optimized motion data has certain noise and the motion curve is unsmooth, it needs to be smoothed. After that, a quaternion linear time-invariant filter is used to filter the smooth motion of the skeleton.

(2) Action arrangement simulation

Based on the case action database, it is convenient to formulate “standard” actions for all technical actions involved by athletes through modification, design and other steps. In gymnastics, it is required to provide a complete set of technical actions, that is, select 10 actions from each technical action and combine them in a certain order. Here, the layout simulation results of the whole set of actions are presented in 3D form, which greatly reduces the danger of training and can help the instructor decide the arrangement of actions.

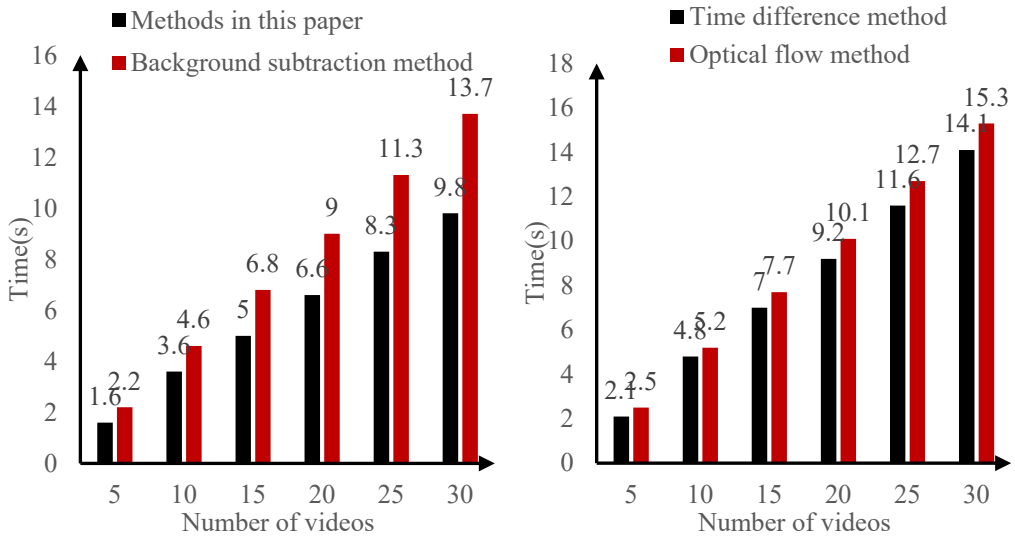
(3) Comparison between simulated actions and training videos

If an interrelated relationship can be established between video and motion data, it can conduct a more comprehensive and in-depth analysis of athletes’ technical actions, so as to better guide athletes’ technical actions.

On this basis, using the method of virtual and real isomorphism, the moving geometric features of the moving object are corresponding to the physical features, that is, through the 3D simulation of the moving object, a virtual camera is constructed to make its viewpoint consistent with the perspective of the camera. On this basis, a specific motion video is simulated on the same screen, and a good effect can be achieved by simulating and analyzing its 3D motion.

Unlike other algorithms, this paper used a 3D reconstruction algorithm based on feature points to obtain the external parameters of the camera. In the process of 3D reconstruction, it is generally necessary to understand the parameters inside the camera. However, the calibration process of camera internal parameters is relatively complex, and the measurement accuracy is disturbed.

3.2 Video Experiment Evaluation



(a) This method and background subtraction method (b) Time difference method and optical flow method

Figure 5. Time consumption of moving object extraction (s)

The new method of moving object extraction based on dynamic background construction in this

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system was compared with background subtraction method, time difference method and optical flow method. In this experiment, different sports videos from a college of physical education were selected as the experimental analysis object. Through statistics, 30 sports videos were selected, each with a resolution of 3840 * 2160 pixels.

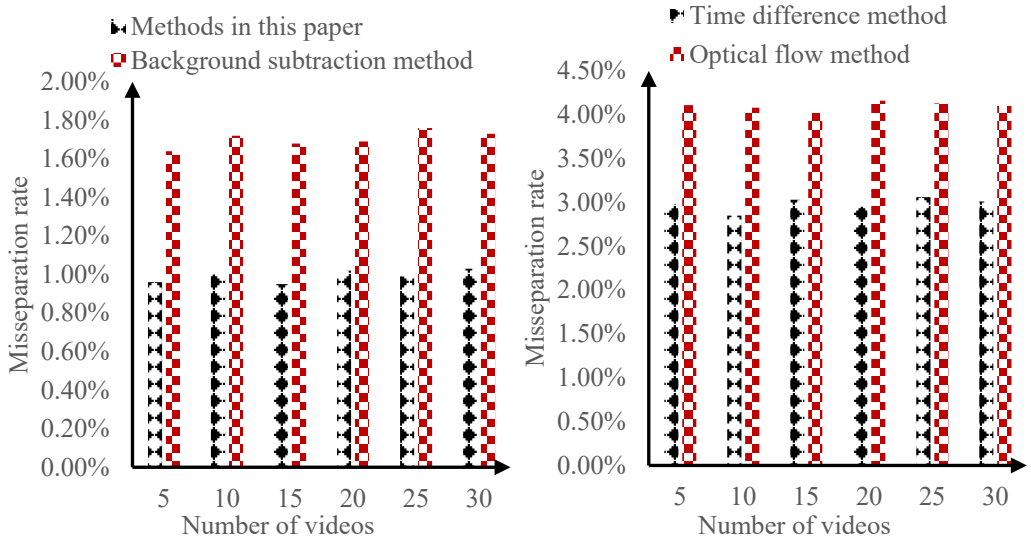
Figure 5 shows the time consuming comparison of the four methods for extracting moving objects under different video numbers.

According to Figure 5 (a), when the number of videos was 5, the time of extracting moving objects by the method in this paper and the background subtraction method was 1.6s and 2.2s respectively; when the number of videos was 10, the time required for the two methods was 3.6s and 4.6s respectively; when the number of videos was 25, the time required for the two methods was 8.3s and 11.3s respectively; when the number of videos was 30, the time required for the two methods was 9.8s and 13.7s respectively.

According to Figure 5 (b), when the number of videos was 5, the time for extracting moving objects by time difference method and optical flow method was 2.1s and 2.5s respectively; when the number of videos was 10, the time required for the two methods was 4.8s and 5.2s respectively; when the number of videos was 25, the time required for the two methods was 11.6s and 12.7s respectively; when the number of videos was 30, the time required for the two methods was 14.1s and 15.3s respectively.

From the data in Figure 5, compared with the other three methods, the method in this paper took the least time and the optical flow method took the most time when extracting moving objects from sports video.

Figure 6 shows the correlation data of the error separation rate of the four methods for extracting moving objects under different video numbers.



(a) Misseparation rate of this method and background subtraction method
(b) Misseparation rate of time difference method and optical flow method

Figure 6. Misseparation rate of four methods

In Figure 6 (a), when the number of videos was 5, the error separation rates of the method in this paper and the background subtraction method were 0.96% and 1.64% respectively; when the number of videos was 10, the error separation rates of the two methods were 1.00% and 1.72% respectively; when the number of videos was 25, the error separation rates of the two methods were 0.99% and 1.76% respectively; when the number of videos was 30, the error separation rates of the two methods were 1.03% and 1.73% respectively.

In Figure 6 (b), when the number of videos was 5, the error separation rates of time difference method and optical flow method were 2.98% and 4.11% respectively; when the number of videos was 10, the error separation rates of the two methods were 2.85% and 4.08% respectively; when the number of videos was 25, the error separation rates of the two methods were 3.06% and 4.13% respectively; when the number of videos was 30, the error separation rates of the two methods were 3.01% and 4.10% respectively.

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From the data in Figure 6, the misclassification rate of the method in this paper fluctuated between 0.95% and 1.03%, and the misclassification rate of the background subtraction method fluctuated between 1.64% and 1.76%; the false separation rate of the time difference method fluctuated between 2.85% and 3.06%, and that of the optical flow method fluctuated between 4.02% and 4.16%. The results obtained by using the method in this paper were more comprehensive and clear, and the error separation rate had not changed significantly, which proved that the method proposed in this paper could better separate the motion image of sports video.

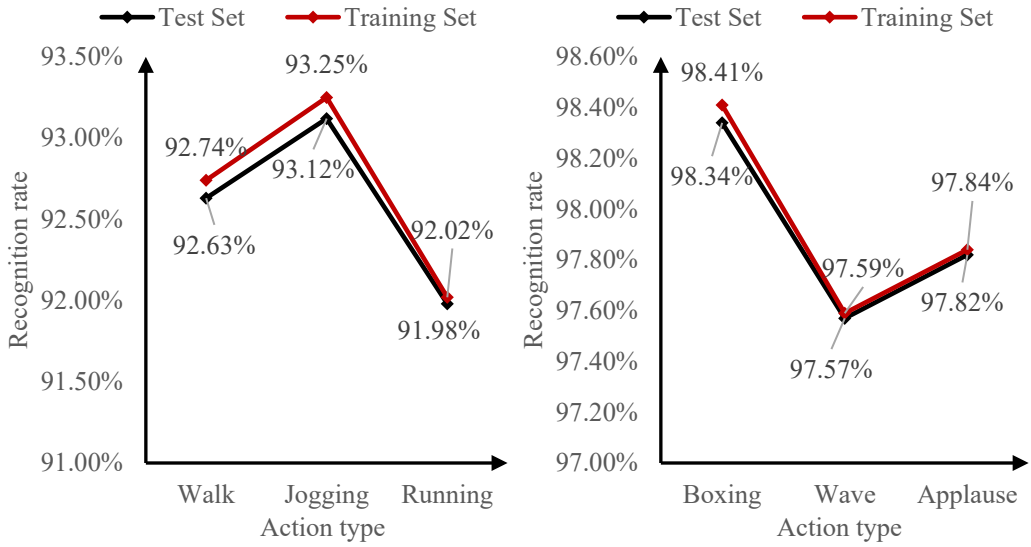
3.3 Human Motion Experiment Evaluation

The following used the method of this paper to identify actions. The database used KTH action library and UCF Sports action library.

KTH action library includes 6 human behaviors, namely walking, jogging, running, boxing, waving and applauding. UCF Sports action library includes 10 human behaviors, including diving, golf, kicking, weightlifting, horse riding, running, skateboarding, pommel horse, uneven bars and walking.

75% of the data in the two action libraries were taken as training data, and the remaining 25% of the training data were taken as test data 50 times of cross detection were carried out, and the action recognition rate took the average value.

The action recognition rate of KTH action library is shown in Figure 7.



(a) Walking, jogging, running *(b) boxing, waving and applauding*

Figure 7. Action recognition rate of KTH action library

According to Figure 7 (a), the recognition rates of walking, jogging and running in the KTH action library test set were 92.63%, 93.12% and 91.98% respectively; the recognition rates of walking, jogging and running in the training set were 92.74%, 93.25% and 92.02% respectively.

According to Figure 7 (b), the recognition rates of this method for boxing, waving and applauding in the KTH action library test set were 98.34%, 97.57% and 97.82% respectively; the recognition rates of boxing, waving and applauding in the training set were 98.41%, 97.59% and 97.84% respectively.

From the data in Figure 7, the recognition rate of this method for actions in the KTH action library was above 90.00%, with a good recognition rate. The method in this paper can well separate the boxing, waving and clapping of KTH. However, the recognition rates of walking, jogging and running were relatively low, which was due to the small difference in the movement range of the key parts of the body of the three movements, resulting in a wrong understanding.

The action recognition rate of UCF Sports action library is shown in Table 1.

According to Table 1, for the action recognition of UCF Sports action library, in the test set and training set the recognition rates of this method for diving were 96.25% and 96.31% respectively; the recognition rates of playing golf were 98.02% and 97.95% respectively; the recognition rates of kicking were 95.16% and 95.20% respectively; the recognition rates of weight lifting were 97.38% and 97.35%

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respectively; the recognition rates of horse riding were 98.62% and 98.60% respectively; the recognition rates of running were 95.18% and 95.21% respectively; the recognition rates of skateboard were 96.92% and 96.94% respectively; the recognition rates of pommel horse were 97.33% and 97.31% respectively; the recognition rates of uneven bars were 95.95% and 95.96% respectively; the recognition rates of walking were 95.01% and 95.03% respectively. The results showed that the recognition rate of this method for different types of behaviors in UCF Sports action library was similar. To sum up, the system designed in this paper has excellent performance in recognition rate, but it needs further improvement.

Table 1. Action recognition rate of UCF Sports action library

Action	Test Set	Training Set
Diving	96.25%	96.31%
Play golf	98.02%	97.95%
Kick	95.16%	95.20%
Weightlifting	97.38%	97.35%
Riding	98.62%	98.60%
Running	95.18%	95.21%
Skate	96.92%	96.94%
Pommeled horse	97.33%	97.31%
Asymmetrical bars	95.95%	95.96%
Walk	95.01%	95.03%

4. Conclusions

With the continuous improvement of life rhythm, the opportunities for teenagers to get sports are also decreasing. The reason why mass sports are difficult to promote is that there is no suitable training method to help teenagers carry out effective sports. In computer vision and pattern recognition technology, human motion analysis based on vision has always been a hot spot. Due to the complexity of human body structure, movements and different shapes, the research in this field is facing unprecedented difficulties and challenges. The video analysis and 3D human motion simulation system designed in this paper has been proved to have certain advantages through experiments, and is worthy of further promotion and application in the future. In the sports training of teenagers, how to make better use of graphic technology for physical exercise is still a problem to be further explored, and further in-depth exploration would be carried out on the basis of the future, in order to achieve more practical breakthroughs in key technology and system development.

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