

## Research Article

# Trampoline Motion Decomposition Method Based on Deep Learning Image Recognition

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The automatic segmentation and classification of an unknown motion data stream based on given motion classes constitute an important research problem with applications in computer vision, animation, healthcare, and sports sciences. In this paper, the scenario of trampoline motions is considered, where an athlete performs a routine consisting of sequence of jumps that belong to predefined motion classes such as somersaults. The purpose of this study was to make theoretical discussions on the turning starting time and starting technique of trampoline somersault based on image recognition and point out that the appropriate turning starting time of trampoline somersault is the event when the spring net of the trampoline recovers and applies force to the human body, and the overturning start exists in the latter half of the take-off action. It is considered that how to obtain the ideal full reaction force of the net facing the human body is the flip starting technique. This work analyzes the key steps and events for trampoline somersaults and the application of artificial intelligence for the recognition of actions in the healthcare and sports fields. The effectiveness of the proposed study is shown through experimental results. The study can facilitate the process of recognition of trampoline somersault.

## 1. Introduction

In recent years, the integration of artificial intelligence with sports field is gradually increasing [1–3]. The use of artificial intelligence to simulate the real sports training has gradually become the key technology to improve the training level of athletes and increase the teaching efficiency of school physical education. It has become a key research topic in sports training and teaching to correct the wrong movements and determine the correct movements [4].

There are great differences between computer image recognition technology and human image recognition. Human recognition is to compare and analyze different images by naked eyes and obtain the corresponding information elements directly. Moreover, the number of images that can be recognized is relatively small, and with the continuous extension of recognition working time, the accuracy of recognition will be affected [5–8]. However, image

recognition technology can solve this problem well, because it will first store a large number of images and then obtain the most intuitive data information through the arrangement and comparative analysis. When people need to identify the results, they can also directly obtain reference. At the same time, the process of image recognition by naked eyes is often very short and cannot save image information for long time. However, image recognition technology has a very long processing flow and can save data for a long time. When the relevant personnel need the image data information, they can obtain it directly from the computer system [9–11].

Worldwide, the training of the trampoline is still in the stage of exploration and experience accumulation. At this stage, according to the performance characteristics of the trampoline and the requirements of competition rules, this paper examines the key link of trampoline somersault, the turning start time and its action technology, and finds out

the corresponding theoretical basis. It has positive practical significance for the athletes to train the trampoline somersault and improve the technical level of the action. Based on the analysis of the image data of the world's elite athletes, performance characteristics, and relevant provisions of the trampoline competition rules, combined with the research results of gymnastics and acrobatic somersault, we theoretically discussed the turning start time and action technology of trampoline somersault. The proposed research can be helpful for the future training of trampoline somersault and development of trampoline. However, the application of artificial intelligence especially computer vision in the field of sports action recognition is more in the experimental state, lacking systematic and clear technical guidance. The innovations of the proposed work are as follows:

- (i) To construct a perfect application framework in the field of sports action correction.
- (ii) To analyze the key steps, and realization ways of artificial intelligence simulation in the sports action correction field in detail.
- (iii) To provide technical guidance for the extensive development of artificial intelligence technology in the field of physical education teaching and sports training.

## 2. Application of Artificial Intelligence and Virtual Reality Technology in Trampoline Action Decomposition Image Recognition

Using artificial intelligence-based systems, users can restore the vision, hearing, touch, force, and motion perception in the virtual environment to the greatest extent. The integration of artificial intelligence technology and modern physical education teaching can visualize the three-dimensional dynamic information observed by computer, which is conducive to the observer and athletes to objectively evaluate the sports action and, finally, optimize and perfect it. After fusion, it can help these sports effectively avoid sports risks, reduce training costs, and eliminate the impact of the weather. In a word, the emergence of artificial intelligence technology can break the limitation of traditional sports on movement correction, simulation training, and other hardware conditions. Moreover, it can optimize the sports and training experience of sports participants at the lowest cost.

At present, there are some researches on the integration of artificial intelligence technology and the sports field. Ma et al. combined the multiperception, interactivity, immersion, and other characteristics of artificial intelligence with some activities in physical education teaching and summarized the application strategies of sports action comparison and remote interaction technology [12, 13]; Xi analyzed the convenience of artificial intelligence for sports teaching field and summarized the defects and improvement schemes of artificial intelligence in the field of sports teaching [14]; Wu further conceived the application methods of artificial intelligence in specific sports such as

football, diving, and trampoline [15]. However, these studies mainly focus on the macro direction and strategy of the application of artificial intelligence and physical education teaching. In addition, they do not conduct in-depth excavation and research on the specific application framework and technology.

*2.1. Characteristics of Trampoline Somersault under the Requirements of Rules.* Trampoline is a recreational and sport exercise device. Compared with gymnastics and acrobatic somersault, the spring coefficient of trampoline somersault is far greater than that of the tumbling board. Therefore, the time of jumping in the air is longer and the turning space is larger. It is much easier to complete the same difficult somersault on a trampoline than on gymnastics and acrobatic flip board. However, with the development of trampoline, the long time and large space of tumbling have brought trampoline athletes not only plentiful flipping space-time conditions but also the challenge of how to complete more difficult movements. In the competition rules, there are more difficult points in the final score of a set of movements. It is an indisputable fact that the movement is characterized by high difficulty and complex technique.

*2.2. Characteristics of Artificial Intelligence Technology.* Thanks to the rapid development of modern sensor technology, the multiperception of artificial intelligence technology has gradually developed from the original vision and jerk perception to a comprehensive perception system with multiple senses such as vision, hearing, touch, movement, and force and can provide users with more comprehensive and real perception environment. Similarly, artificial intelligence enables users to simulate different application scenarios through professional equipment according to their own needs, so that users can communicate, contact, and even create simulation scenarios more naturally and truly. Artificial intelligence can simulate and develop scenarios that are difficult or impossible to achieve in real-life applications. Various scenes can fully activate the human brain's imagination of the outside world and expand the imagination space of human beings. Artificial intelligence equipment can simulate the real scene of the outside world to the greatest extent and help users to truly perceive the virtual world and get familiarity with the environment [16].

*2.2.1. Artificial Intelligence-Based Image Recognition Mechanism.* Image recognition is the capability of a computer system to identify people, places, objects, and actions in images. It uses computer vision techniques with artificial intelligence and machine learning algorithms to recognize images through a camera system. While human and other animal brains recognize actions and objects with comfort, computers-based image recognition requires machine learning algorithms such as deep learning algorithms. Deep learning algorithms can function by use of comparative 3D models, appearances from different angles using edge detection, or components. Image recognition algorithms are

often trained on millions of pre-labeled pictures with guided computer learning. Image recognition works by detecting salient sections called features, which are the areas inside the image that contain the most distinct information about the object or image. The most informative features in an image are selected and localized, while the less informative points are ignored. For this purpose, a classification algorithm is used that takes an image as input and outputs what the image contains. Mostly supervised learning algorithms are used that are trained to learn the differences between image classes. For example, if the goal of an image recognition system is to detect a cat, the image recognition algorithm needs to be trained with hundreds of images of cats and hundreds of images of backgrounds that do not contain any cats [17–19].

*2.2.2. Analysis of the Technical Principle of Image Recognition Technology in Artificial Intelligence.* In artificial intelligence, the technical principle of image recognition technology is to use a computer to process pictures and then extract the discriminant features of the pictures for further processing. Image recognition technology is not complex in the technical principle. If a person is regarded as a computer, so every time people look at each other can be said to have completed an image recognition process, and then people, according to the impression of others in their brain, analyze, search, and memorize other people's information. Computer image recognition process is using the same principle. The only difference is that, in artificial intelligence-based image recognition technology, the image on the computer provides information dependent on the number. According to the principle of image recognition technology, artificial intelligence is combined with a computer algorithm, so that the information of the image can be extracted and analyzed. In the image with large amount of information, the recognition efficiency of image recognition technology may be reduced due to redundant information. Therefore, while analyzing images on computer, we should also find a better, simpler, and more convenient information extraction method to make image recognition simpler and faster.

*2.2.3. Analysis of the Composition Principle of Image Recognition Technology in Artificial Intelligence.* Pattern recognition is mainly used in image processing technology to process different types of plane pictures and three-dimensional pictures, to analyze pictures and objects. Image recognition technology is mainly based on pattern recognition and development of three-dimensional images. In the field of modern medicine and architecture, the use of this technology is more prominent such as to analyze the three-dimensional structure of the human body and examine the health status of patients. In the field of architecture, the traditional building structure is mainly based on the plan. With the development of modern science and technology, architects can use pattern recognition to make the architectural plan stereoscopic and make the architectural image

clearer and more understandable. At the same time, it meets the needs of people not only in the application of image recognition but also in the application of image recognition technology. In our daily life, people's eyes are the best pattern recognizer, so the ordinary pattern recognition technology is doomed to be unable to meet the needs of people's daily life, but after combining with artificial intelligence, pattern recognition has achieved better performance. For example, the analysis and imaging of complex stereo images, artificial intelligence, and pattern recognition can help us process such images more conveniently and efficiently.

*2.2.4. Research on the Process of Image Recognition Technology in Artificial Intelligence.* Human brain image processing is similar to computer image processing. In the computer image processing, the information is obtained first and then converted into a computer readable form and the relevant programs and tools are used to process information. The second step is to store the image. After the image is stored, we can use the image for simple processing, sharpen the important information of the image, and make the image information more prominent. The third step is to extract the relevant information of the image and further process the image according to the keywords and needs of people. On the computer, there are many software programs and methods for processing picture information. People can choose the tools and methods according to their own needs, and at the same time, they can also choose the region and characteristics of the picture for processing. In the development of the computer, the most prominent image processing should be in photoshop (PS), which is a relatively fast and stable software for image processing and also has a very large development prospect. In the PS image processing, you can operate the image arbitrarily as long as you select the processing area, and you can carry out relevant operations on the image. Then the processing process and method of image processing technology in artificial intelligence are very similar to those of the computer processing process. The image processing technology in artificial intelligence also needs to have pictures before the subsequent work of pictures can be carried out. The difference is that the image processing technology in artificial intelligence is more intelligent than the computer processing method. For the technical realization, the image processing technology in artificial intelligence is more convenient, and the operation is more convenient and simpler. It is believed that, in the later stage of the development of science and technology, the image processing technology in artificial intelligence will develop into a processing technology which is more suitable for public use.

Technology has changed the complexity of computer image processing and can also achieve the same versatility, which is very convenient for our daily application [20, 21]. Therefore, a comprehensive analysis of the image processing technology in artificial intelligence [22–26] will be better recognition of technology after the traditional image processing technology [27–32].

### 3. Simulation Experiment and Result Analysis

After getting the 3D reconstruction model provided by the system, the participants can directly see the virtual policy results of their actions. Through communication with the coaches and the comparison of excellent athletes' action completion, this paper analyzes the unreasonable points in their movements, to correct them in future training. Besides, using the established and perfect system to expand the function, an automatic comparison interface can be established to automatically compare the movement changes in the process of a training cycle and the action comparison between itself and other excellent athletes and assist manual analysis of action essentials. First of all, we can collect the technical action images of elite athletes in related fields for three-dimensional reconstruction, to obtain the complete three-dimensional pose data of such athletes. Then, according to the three-dimensional posture data extraction technology provided in this paper, the effective characteristic information of three-dimensional posture data of excellent athletes is quantified. Thirdly, the information obtained from mining is taken as the system standard. In the last, the standard is established. The quasi model database is used to enrich the standard action model in the system database. In this technical condition, the more the number of excellent athletes' technical movements entered is, the more it can help the later users learn from more excellent movements. After comparing with the actions in the database, the system will score the user's action scores according to the scoring system in the competition, so that the users can obtain the evaluation results more directly.

Firstly, the preprocessed image is transformed by scale-invariant feature transformation, and the feature points whose position, scale, and rotation are invariant are detected by the operator. Secondly, the feature points of the detected image are matched by nearest neighbor matching algorithm, and the matching measure is the Euclidean distance between the feature points. Thirdly, to eliminate the error matching caused by the nearest matching two secondly, RANSAC algorithm is used to enhance the consistency of random samples. Fourthly, SFM method is used to filter the data from two-dimensional information to obtain the three-dimensional point cloud structure. Then the matching point pairs between multiple images are used to estimate the parameters of the topological camera and obtain the final three-dimensional structure.

For the application of virtual sports scene simulation, the system application focuses on the interaction between the virtual scene and the real scene of athletes. The immersion of the virtual scene is the key to determine whether the participants can get a sense of reality. Therefore, the application of the virtual scene simulation direction mainly lies in the rendering of 3D reconstruction. Therefore, designers should strengthen the comprehensive analysis and quantification of a certain kind of motion and establish a simulation physical engine based on a huge database. In the process of using the system, the 3D reconstruction technology is used to accurately obtain the technical action data of the user and input it into the simulation physical engine of the system, and the

system will provide feedback on the action of the moving personnel according to the set program.

A complete set of trampoline movements is characterized by its movement and floating upward. The rhythmic connection and transformation between the athletes' movements include two feet take-off, back siph, sitting, and bouncing. As shown in Figure 1, there will be no long pause and intermediate jump in the middle of the whole set of movements. All kinds of forwarding and backward somersaults and turns as well as some nonrotation movements of athletes coordinate with each other to form a complete trampoline action. Team trampoline events require athletes to show a complete set of movements to show the beauty of body posture and the accuracy of technical movements, including the ideal height and control of the body. In a set of actions, not only can there be repeated actions, but also they cannot be interrupted. If there is an interruption, the action after the interruption will not be given points. In the actual competition, the score of trampoline action is mainly divided into skill score, difficulty score, and synchronous score. Among them, the skill score is mainly determined according to the athlete's action completion, while the difficulty score is mainly calculated by the number of turnover cycles of the movement, and the synchronous score is the score of the synchronization of the routine performed by two athletes. As a result, gymnastics trampoline has become a special sports competition, and the development of a competitive sports event on the field is an inevitable result.

The trampoline set consists of 10 single movements. A complete set of technical links should be composed of preparation posture, prejump, last prejump, take-off, completion of overturning action, falling, net touching rebound jump (at the same time, it is the take-off of the second action). In the same way, when the last action is completed, it includes the following links: falling, net touching rebound, jumping, buffer stops, etc., as shown in Figure 2.

From this, we can see that there is an overlapping link in the technical link between each action, that is, the touch net rebound jump link. From the technical aspects of a single action, the task of net contact rebound jump is to buffer the rebound strength. But from the connection movement technical link, this link's task becomes through the lower limb muscle, and the joint's strength flexes and stretches, causes the net surface to produce the maximum distortion, and thus obtains the ideal take-off effect. Generally speaking, it is the end of the previous action and the beginning of the next action. This overlapping part is the main feature and key part of trampoline technique. From this point of view, in the practice of a complete set of movements, we must grasp every link of net contact rebound, so that the buffer of every passive net touch rebound becomes an active and powerful take-off, which is the key problem of an active connection. In the transition from single-action practice to complete set of actions practice, many athletes are often thrown "flying around" by rebound force because they do not grasp this link well and they do not take-off actively. This has a great relationship with the fact that the athletes do not timely change the passive buffer of net rebound take-off into the main dynamic take-off. To solve this problem, the best way is to

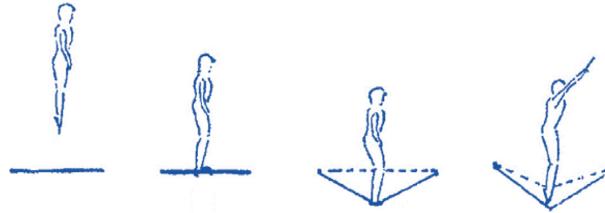


FIGURE 1: Dynamic work diagram of trampoline.

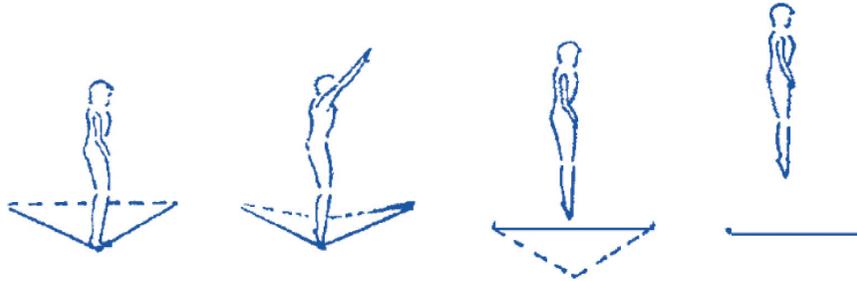


FIGURE 2: Continuous prejump of trampoline.

regard the net touch rebound jump as a part of the actual action in the single-action training. Only when the action is completed can the touch net rebound link be effectively turned into a powerful take-off again. On this basis, it will be easier to practice in sections, that is, to divide the 10 movements in the set into several small segments and practice them separately. Finally, it will be much easier to carry out the whole set of exercises, as shown in Figure 3.

Besides, through the analysis, we also found that there is an inevitable internal relationship between the movements. We can observe the interaction between these movements in training. To sum up, there are two forms of this connection and influence: one is that when a certain action moves forward and backward (longitudinally), it will affect the air trajectory and landing point of the next action, thus affecting the stability of the action. Second, the left and right (lateral) displacement of a certain action will directly affect the stability of the next action. Sometimes the displacement may not be obvious and can be easily ignored, but it has a great influence on the next action, which is enough to cause the failure of the action. This kind of connection and influence is often seen in the usual training.

The reason for the forward and backward displacement is that the athlete is eager to do the action, resulting in forward and backward movement of upper body during taking off. The cause of the left and right displacement may be due to the strength differences between the legs when taking off and the length difference of the legs. Therefore, special attention should be paid to this connection in training. If we only look for the reason from the obvious wrong action itself and do not consider the influence of the previous action, the effect will be very unsatisfactory, such as forward somersault 2 weeks, twist 180 degrees, and somersault 2 weeks. The athlete has a slight forward displacement when doing the front somersault, but the backward somersault obviously moves backward and even falls on the

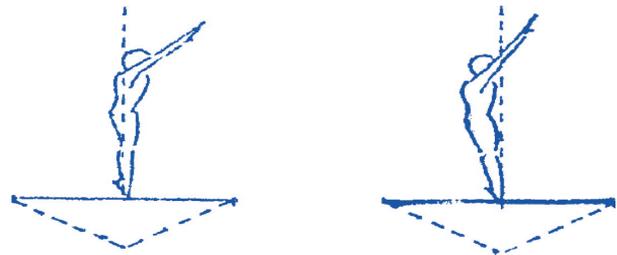


FIGURE 3: Schematic diagram of the last jump of trampoline taking off and doing a somersault.

safety platform. The problem of two weeks of front somersault has appeared. At this time, if the coach only emphasizes the backward somersault and does not consider the internal relationship between the movement connections, the improvement effect will be very unsatisfactory. If the front somersault is improved, try to make the front somersault not having a slight forward displacement, and the problem of backward somersault moving back can be easily solved. The influence of left and right displacement is also the same.

*3.1. Decomposition and Recognition Process of Trampoline Action Based on Image.* The combined morphological operation can eliminate part of the background in the video image, and the morphological features can be well preserved to obtain the silhouette image of the human body, which is very similar to the background subtraction technology. Then the operation formula of combined morphology can be expressed as follows:

$$G(x, y) = F(x, y) \cdot B(x, y) - F(x, y), \quad (1)$$

where  $G(x, Y_1)$  represents the image processed by the combined morphological operation,  $f(x, Y_1)$  represents a

frame image in the original video, and  $G(x, Y_1)$  represents structural elements. Through (1), the area in the original image that is darker than the background and smaller than the size of the result element can be removed. The appropriate structural elements can be selected and the remaining background image can be obtained through the closing operation so that the target extraction can be completed by subtracting it with the original image.

In the video image of human trampoline action, one frame of the image cannot fully describe an action. Generally, it is necessary to extract multiple image features to display human action completely. Due to the difference of action rate, the frame number of each video image may be different even for the same action. To deal with these two kinds of rate changes, considering the characteristics of rate changes, the gray features of each edge image in the same time window are accumulated into the same image, and the features are extracted by using the accumulated edge image to represent the human trampoline action.

The operation flow of cumulative edge image is as follows: a frame of video image processed by morphological gradient operation is represented by  $C(x, Y_1)$ , the edge detection image obtained by using edge detection operator on  $C(x, Y_1)$  is represented by  $E(x, Y_1)$ , which is a binary image, the edge image obtained by multiplying  $C(x, Y_1)$  and  $E(x, Y_1)$  on each pixel is  $I(x, Y_1)$ , and the gray image is represented by  $I(x, Y_1)$ . It means that for the gray information  $s$  on the edge points if the pixels are outside the edge, the gray value is 0; the cumulative edge image is represented by  $H(x, y, t)$ , and its scale is consistent with the size of  $C(x, y, t)$  and inning purpose of obtaining  $H(x, y, t)$  is to accumulate all  $I(x, Y_1)$  in a video image on a certain time window.

For  $H(x, y, T_1)$  initialization, all pixels are set to 0, and the time condition is  $t=0$ ; based on edge detection, edge image  $e(x, y)$  can be obtained on the first frame of the morphological gradient image  $g(x, Y_1)$  of the video time window; the gray image  $I(x, y)$  is obtained by multiplying gradient image  $g(x, y)$  and edge image  $e(x, y)$ ; cumulative previous  $I(x, Y_1)$  and previous frame are compared on all pixels edge image  $H(x, y, T_1)$ ; the gray value of the pixel with larger gray value will be taken as the new value of  $H(x, y, T_1)$  action at the edge detection step until the whole image is complete.

The image operation is completed.

The main idea of this method is to compress the information in the video sequence into a frame image to express the action. The information contained in the accumulated edge image is huge. The formula of accumulating edge image at the point  $FX, Y_1$  can be described as follows:

$$\begin{aligned} I(x, y) &= G(x, y)E(x, y), \\ H(x, y, t) &= \max(H(x, y, t-1), I(x, y)). \end{aligned} \quad (2)$$

The cumulative edge image is to multiply the binary tattoo  $e(x, Y_1)$  and the morphological gradient image

$c(x, Y_1)$  at each pixel to obtain the edge image  $I(x, Y_1)$  with gray information and then accumulate all the edge images into one image, not every binary image into one image. 0 and 1 are the only two gray values of the binary image  $e(x, Y_1)$ . If the pixel value of the binary image  $e(x, y)$  corresponding to the edge image  $I(x, y)$  is 1, then the gray value range at this point is more than that of the binary image.

If the edge image is accumulated for the target image, the image information center already contains more edge information of the image. So it is not necessary to extract the edge features, and the directional gradient histogram can be directly solved at each point of the accumulated edge image.

The calculation of the grid-based directional gradient histogram is to solve the directional gradient of all points in the cumulative edge image. The cumulative edge image is divided into  $l$ e spatial grids, and the histogram vector on each grid is calculated. One of the scale feature vectors is extracted and used as the action feature. The local shape of the target is counted, and then the feature vector of the cumulative edge image is obtained.

*3.2. Trampoline Movement Recognition Based on Dynamic Time Warping.* Action expression has temporal persistence; that is, action can be a set of static actions in a certain period. The movement process of the human body can reflect the changing trend of movement through the change of joint angle curve, which can be called the joint angle time series. The motion characteristics can be defined as follows:

$$\text{Action\_feature} = \{A_1, A_2, \dots, A_M\}, \quad (3)$$

where the time series of a certain joint angle is represented by line vector  $a$ ; the row vector with the number of motion features is represented by  $a$ , and the range is  $1 \leq m \leq 16l$ . If the time-varying one-dimensional signal can be understood, it evolves into the classification problem of time-varying feature data by simple action recognition. From the past data, we can see that when the examinee freely displays martial arts motions, the same movement, it is hard to rule out the potential of being similar to a because of distinct waveforms and amplitudes. Therefore, action recognition is realized by comparing the similarity of time series; that is, Wushu action decomposition judgment is realized by comparing the distance between different length vectors.

The comparison of similarity between curves is the focus of the time series change trend. Because there are uncertainties in the video feedback system and testers, which will lead to data deviation and fluctuation, the following formula is used to smooth the sequence:

$$x_i = \frac{x_1 + x_2 + \dots + x_n + x_{n+1}}{n}. \quad (4)$$

RT is an integer greater than 0. To sum up, this paper extracts the feature vector of martial arts action features in video images by accumulating edge images and then calculates the time series of martial arts actions by using the

dynamic time warping theory. After the martial arts actions to be identified are matched with the reference time series samples, the process of Wushu action decomposition and recognition is completed.

#### 4. Conclusion

The assimilation of artificial intelligence in the field of sports is progressively increasing. The use of AI to simulate the real sports training has regularly become the key technology to improve the training level of athletes and increase the teaching efficiency of school physical education. Human action recognition technology is widely used in healthcare and sports fields. This work proposes an effective recognition method based on image recognition for trampoline decomposition, using morphological gradient operation based on the cumulative edge image. The contour edge image features are extracted and accumulated into an image. The directional gradient histogram of the image is calculated to obtain the image feature vector. The dynamic time warping method is used to calculate the joint action change sequence of different martial arts actions to form a reference sample set. Finally, the test sample is compared with the reference sample to realize the image recognition of the trampoline decomposition action analysis. It is concluded that the proposed method will be beneficial for analyzing and improving the trampoline somersaults of sports individuals. Results of the experiments reveal the effectiveness of the study.

#### Data Availability

The data used to support the findings of this study are included within the article.

#### Conflicts of Interest

The authors declare no conflicts of interest.

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