Automatic recognition method of abnormal behavior in athletes

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ABSTRACT

This paper presents an automatic recognition method for abnormal behaviors in exercising human bodies, including sample image collection and preprocessing. The displacement of shoulder, elbow, wrist, and knee joints of the exercising human body are taken as state variables. A normal exercising human body form observer is designed based on Kalman prediction, along with the design of observation gain for the exercising human body form observer. A threshold for determining abnormal behaviors in exercising human bodies is set. Another set of exercising human body samples, Sample II, is used to test the designed exercising human body form observer. The main advantage of this method lies in its ability to establish a database through the collection of human movements, to predict subsequent movements, and to preemptively determine the trend of any abnormal behaviors so that intervention control can be applied in advance if necessary. Additionally, the robustness of recognition is enhanced through image enhancement, image filtering noise reduction, morphological analysis of images, and edge detection processes in data.

Keywords: Human abnormal behavior, recognition, Kalman prediction, image processing

1. INTRODUCTION

With the rapid development of science and technology and the arrival of the intelligent era, image and video has become an important information carrier[1]. In order to cope with public safety and intelligent scene applications, cameras are used in a variety of scenarios, such as traffic roads, squares, stations, and shops, etc. The original intention is to monitor crowd behavior through 24-hour monitoring, so as to ensure public safety and intelligent unmanned application scenarios.

The use of cameras will produce a large amount of data, the traditional monitoring mode mainly has the following problems: (1) a large number of monitors are required to view the video around the clock, which is easy to make sensory fatigue, resulting in leakage and error detection; (2) shooting 24 hours uninterrupted with multiple cameras generates a vast amount of data, posing difficulties for subsequent searching, so the need to use the computer for auxiliary detection; (3) in public places, with numerous targets to track, manual identification proves challenging[2].

In real scenes, there are often some uncontrollable factors, such as light change, shadow, occlusion, perspective conversion, etc.[1]. The existing abnormal behavior detection method is implemented in practical applications, therefore, improving the robustness of abnormal behavior analysis is a need to solve the problem, which not only can the existing monitoring method not predict human abnormal behavior, but also fails to guide monitoring personnel to intervene early and prevent emergencies.

More importantly, most of the existing monitoring methods can only detect and record the abnormal behaviors that have occurred, but cannot predict the potential abnormal behaviors in advance. This means that in the event of an emergency, the monitoring personnel can only respond passively, and cannot take intervention measures in advance, thus may miss the best opportunity for disposal.

Therefore, to address these problems, this paper aims to propose a new method for automatic identification of abnormal behaviors. This method can not only improve the accuracy and robustness of abnormal behavior detection, but also realize the prediction of potential abnormal behavior, provide timely warning information for monitoring personnel, and help them take intervention measures in advance, so as to effectively avoid the occurrence of emergencies[3]. This is of great significance for improving the public safety level and promoting the application of intelligent scenarios.

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2. OVERVIEW OF HUMAN BEHAVIOR RECOGNITION TECHNOLOGY

2.1 Human behavior recognition technology

Human behavior recognition technology refers to the utilization of external data to identify and analyze types of movement and behavioral patterns. It is the principal method for computers to detect and understand human motion and behavior and represents a fundamental step in behavior analysis[4]. Human activity detection and recognition is a hot topic of research in the field of computer vision[5].

Human behavior recognition technology primarily relies on computer vision, machine learning, and deep learning techniques. It involves analyzing motion patterns in videos, images, or sensor data to extract key features, and then using algorithms to recognize and understand the human behaviors represented by these features.

Prior to recognition, it is necessary to first collect a large amount of image data containing various actions and behaviors. Then, preprocessing procedures such as noise removal, background subtraction, inter-frame difference, and optical flow calculation are carried out on the image data to better extract the main motion features, which are key to delineating people's behaviors from the existing data. These features may include shapes, contours, motion trajectories, velocities, accelerations, etc. Traditional image feature extraction techniques mainly include Spatio-Temporal Interest Point (STIP), Histogram of Optical Flow (HOF), and Motion History Image (MHI)[6]. However, in recent years, with the development of deep learning, more complex and efficient features can be extracted from massive amounts of data. After feature extraction, classifiers or deep learning methods are used for classification and recognition. Traditional classifiers include Support Vector Machine (SVM) and Hidden Markov Model (HMM); deep learning models include Convolutional Neural Network (CNN), Recurrent Neural Network (RNN), and Long Short-Term Memory (LSTM) network[7]. They are widely used in the fields of healthy living, fitness tracking, remote assistance, security applications, and elderly care. In addition, this technology can also be applied in human-computer interaction, intelligent surveillance, Virtual Reality (VR), and Augmented Reality (AR) among other domains.

2.2 Research status of human behavior recognition technology

Research on human behavior recognition technology has made significant progress both domestically and internationally. Human behavior recognition technology primarily relies on advanced technologies such as computer vision, machine learning, and deep learning. In terms of algorithms, traditional behavior recognition methods include those based on template matching, feature description, and model-based approaches. However, with the rise of deep learning technology, behavior recognition methods based on deep learning models, such as Convolutional Neural Network (CNN), Recurrent Neural Network (RNN), and Long Short-Term Memory (LSTM) network, have gradually become the mainstream. These methods can automatically learn complex features from data, improving the accuracy and robustness of recognition.

In the research of human behavior recognition technology, the quality and quantity of datasets have a significant impact on the effectiveness of model training. At present, several large-scale datasets for human behavior recognition have emerged, such as KTH, UCF101, HMDB51, etc. These datasets contain videos of human actions in various complex scenarios, providing a wealth of data support for model training and testing. At the same time, to improve the quality of data, researchers have employed a range of preprocessing techniques to enhance the performance of the models.

Despite the significant progress made in human behavior recognition technology, there are still many issues and challenges. Recognition of behaviors in complex scenarios remains a difficult problem, such as behavior recognition in situations involving lighting changes, occlusion, multi-person interactions, and real-time requirements. These are all significant challenges that need to be addressed in behavior recognition technology.

Regarding domestic and international research, while significant progress has been made in both domains, there are also some differences. Domestic research in human behavior recognition technology started a little later but has developed rapidly in recent years. Some research institutions and businesses have begun to invest a significant number of resources into related research and product development. Conversely, international research in human behavior recognition technology began earlier, resulting in deeper technological accumulation. Moreover, exploration in application scenarios is also more extensive and profound.

3. IDENTIFICATION METHOD OF ABNORMAL BEHAVIOR

The goal of this paper is to address the challenge of using public camera footage to create a database of abnormal human behaviors through computer processing, ensuring the robustness of the data during the process. Specifically, to overcome the issues of delayed recognition and the inability to predict abnormal behaviors of moving individuals present in existing technologies, this paper introduces an automatic recognition method for abnormal behaviors of moving individuals[8].

3.1 Method and system process

The automatic recognition method for abnormal behaviors in moving individuals provided in this paper, and its system diagram, as shown in Figure 1, includes the following steps:

S1: Collection and preprocessing of sample images;

S2: Taking the displacement of the moving human shoulder, elbow, wrist and knee joint as the state variable ($\dot{x}(t)$), the moving human form state space model is determined as: $\begin{cases} \dot{x}(t) = Ax(t) + Bu(t) \\ y(t) = Cx(t) + Du(t) \end{cases}$, where A, B, C and D respectively are the system matrix, input matrix, output matrix and transfer matrix of the system;

S3: Design of normal motion human form observer based on Kalman prediction;

S4: The observation gain L(t) for the moving human body form observer is designed to optimize its performance in tracking and analyzing the motion of the human body;

S5: A judgment threshold for motor abnormal human behavior is established to differentiate between normal and abnormal movement patterns;

S6: A separate set of moving human body form observers is employed to assess the performance of the designed moving human body form observer. If the identification results from the designed observer are accurate, it signifies that the observer is qualified and suitable for application. However, if the identification results are incorrect, the process should revert back to step S4 for redesigning the observation gain of the moving human body form observer.

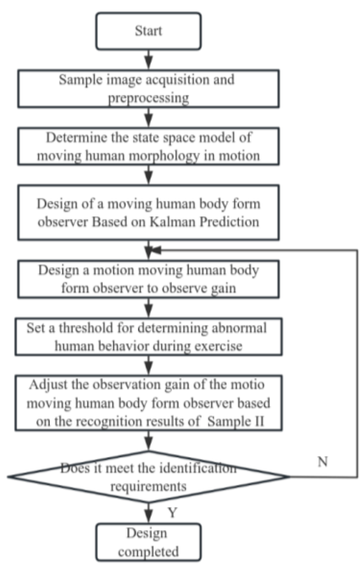

Figure 1. System block diagram of automatic identification method of abnormal behavior.

3.2 Specific examples

(1) Sample image acquisition and preprocessing; image preprocessing for normal moving human sample I. Based on the sample image acquisition and preprocessing methods outlined in Figure 2, which encompass image enhancement, image morphology, and image edge detection[9], the morphological feature matrix, denoted as u(t), is derived from normal moving human samples.

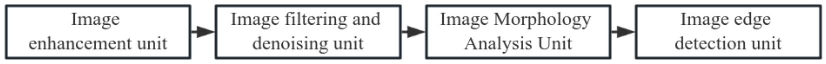

Figure 2. Block diagram of the S1 system.

(2) Taking the displacement of moving human shoulder joint, elbow joint, wrist joint and knee joint as the state variable (x(t)), the expression of moving human form state space model is determined as follows:

$$\begin{cases} \dot{x}(t) = Ax(t) + Bu(t) \\ y(t) = Cx(t) + Du(t) \end{cases} \tag{1}$$

where, A, B, C and D respectively are the system matrix, input matrix, output matrix and transfer matrix of the system[10];

(3) Design of normal motion human form observer based on Kalman prediction;

Based on the Kalman prediction, the moving human body form observer can be determined as:

$$\dot{x}(t) = Ax(t) + Bu(t) + L(t)[y(t) - Cx(t) - Du(t)] \tag{2}$$

$L(t)$ is the observation gain of the moving human body form observer;

(4) The observation gain L(t) for the moving human body form observer is designed to optimize its performance in tracking and analyzing the motion of the human body;

Equation (2) minus (1) The estimation error of available motion human morphological state is:

$$\dot{\bar{x}}(t) = [A - L(t)C]\bar{x}(t) \tag{3}$$

Based on the optimal algorithm, the estimation error matrix of moving human morphology state is defined as:

$$P(t) = \bar{x}(t)\bar{x}^{T}(t) \tag{4}$$

Combining equations (1) and (2), the derivative of the estimation error matrix of moving human morphology state is:

$$\dot{P}(t) = [A - L(t)C]P(t)[A - L(t)C]^{T} \tag{5}$$

Because P(t) is a non-negative fixed matrix, it can be configured in the following form, $\dot{P}(t)$

$$\begin{aligned} \dot{P}(t) = AP(t)A^{T} - L(t)CP(t)A^{T} - AP(t)C^{T}L^{T}(t) + L(t)[CP(t)C^{T}]L^{T}(t) = AP(t)A^{T} - AP(t)C^{T}[CP(t)C^{T}]^{-1}CP(t)A^{T} \\ +\{L(t) - AP(t)C^{T}[CP(t)C^{T}]^{-1}\}[CP(t)C^{T}]\{L(t) - AP(t)C^{T}[CP(t)C^{T}]^{-1}\}^{T} \end{aligned} \tag{6}$$

In order to minimize the estimation error matrix of the moving human morphology state, the selected L(t) should ensure that the last item of equation (6) is equal to 0, so the expression of the observation gain L(t) of the moving human body form observer can be determined as:

$$L(t) = AP(t)C^{T}[CP(t)C^{T}]^{-1} \tag{7}$$

At this time, the estimation error matrix of moving human morphology state is:

$$\dot{P}(t) = AP(t)A^{T} - L(t)CP(t)A^{T}$$

(5) A judgment threshold for abnormal behavior is established, utilizing the motion displacement and speed of the shoulder, elbow, wrist, and knee joints as the primary criteria. Specific thresholds for motion displacement and velocity are set, and any values exceeding these thresholds are considered indicative of abnormal behavior.

(6) A separate group of moving human body form observers is utilized to inspect the performance of the designed moving human body form observer. If the identification results produced by the designed observer are found to be accurate, it signifies that the observer is qualified and ready for application. However, if inaccuracies are detected in the identification results, the process reverts back to step (4), necessitating the redesign of the observation gain for the moving human body form observer.

After the above 6 steps to complete the identification.

4. EXPERIMENTAL VERIFICATION

According to the method process provided in this paper, the surveillance video graph is collected first, 5 frames/s. Then, for the edge detection algorithm, the figure changes the pixel value along the edge, and the pixel value varies greatly along the direction perpendicular to the edge[11]; The first and second derivatives of the gray scale are used to describe and detect the edges. Then the portrait in the background is binarized. According to the algorithm adopted in Computer Engineering, the data is gathered from the human shoulder, elbow, wrist, and knee joints, establishing anchor points for their respective coordinate systems, and subsequently track the coordinate data of each established anchor point. According to the above idea, efficient tracking is realized by locating and tracking multiple targets in the collected picture. The control group collected the coordinates of each anchor point using the behaviors of the normal population as a database, such as walking, squatting, waving, and running in public places. In case of violence, such as chopping, kicking or panic escape of the crowd, the acceleration of the corresponding coordinates will exceed the set threshold and trigger an alarm.

Figure 3 shows the simulation analysis results of the movement abnormal behavior identification using the method of this paper, it can be seen that the human form observer designed by the invention can effectively predict the movement speed and acceleration signal of the human joints, and according to the prediction results of the movement at point A, abnormal behavior will occur, which can guide the monitoring personnel to intervene in advance.

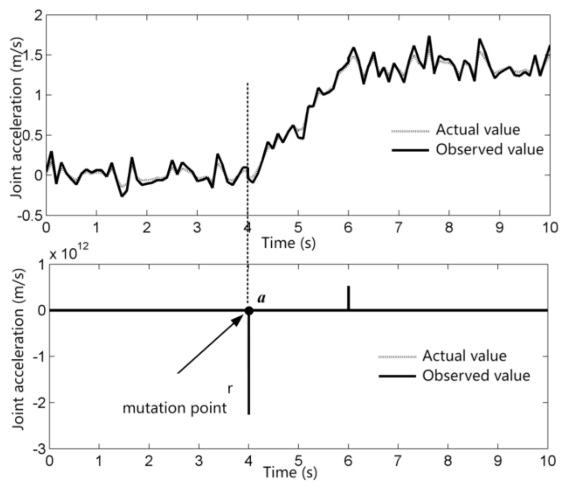

Figure 3. Simulation analysis results.

5. CONCLUSION

The beneficial effects of the automatic identification method of abnormal behavior in the exercise body described in this paper are:

(1) Construction of a database by meticulously collecting an individual’s actions. This database is utilized to analyze and judge the upcoming action, proactively predicting the existence of any trends indicating abnormal behavior. If such a trend is detected, initiate an alarm system in advance to alert of potential concerns.

(2) Enhancement of the stability and accuracy of recognition by implementing processes such as image enhancement, followed by image filtering for denoising, morphological segmentation to distinguish features, and edge detection to outline boundaries within the image.

(3) Multi-target tracking is employed to establish tracking anchors, thereby enhancing the efficiency of identification processes.

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