Research on Application of Classification Model and Behavior Recognition Based on Support Vector Machine

Liu Tianshu[*1], Fang Jiandong[*2], and Zhao Yudong[*2]

[*1] Inner Mongolia University of Technology, Hohhot, Inner Mongolia, China
E-mail: 1054993721@qq.com
[*2] Inner Mongolia Key Laboratory of Perceptive Technology and Intelligent System, Hohhot, Inner Mongolia, China
E-mail: fangjd@imut.edu.cn

Abstract. In order to effectively monitor whether cows have estrus behavior, a combination of background subtraction and external contour feature extraction of cows is proposed to extract cow targets. Use Support Vector Machine(SVM) model to identify its crawling behavior. Use the background subtraction method to extract the moving cow target from the video, preprocess the extracted cow targets; Realize the simulation design of the extraction function of the two geometric features of the cow's target minimum circumscribed rectangle aspect ratio and centroid aspect ratio; According to the different postures of the cows, an SVM classification and recognition model is established to effectively identify the estrus behavior of the monitored cow. Experimental results show that the proposed method can effectively process the actual video key frames, and the average accuracy of cow behavior recognition can reach 97.5%.

Keywords: Target detection, feature extraction, behavior recognition, SVM

1. INTRODUCTION

The estrus monitoring of dairy cows plays an important role in the precise breeding of dairy cows. The timely detection of estrus of dairy cows is conducive to the timely conception, calving and prolonging the lactation period of dairy cows, thereby improving the economic benefits of dairy cows[1]. The physiological conditions and behavioral characteristics of cows in estrus are different from those in non-estrus. They show restless-ness, increase in activity, and begin to crawl across other cows or accept other cows to crawl across. Most farms use traditional manual observation and rectal detection methods to monitor the estrus of dairy cows, but the detection rate is low, and missed detection is easy to occur. With the rapid development of dairy farming in my country, it is urgent to use information technology to monitor the estrus of dairy cows[2].

At present, in order to solve the shortcomings of manual observation, scholars at home and abroad have adopted the Internet of Things technology to study the detection methods based on activity and body temperature to determine the physiological condition of dairy cows. Hou Yuntao, Ren Xiaohui and others[3,4] use an acceleration sensor on the cow's neck to detect the characteristics of the cow's movement and behavior, so as to understand the physiological condition of the cow. Yin Ling and others[5] analyzed the acceleration data to restore the cow's movement behavior, thereby detecting whether the cow is in estrus. Liu Zhongchao and others[6] used a pressure sensor to collect the pressure information on the back of the cow to determine whether the cow has estrus crawling behavior. Steve Warren[7] uses an electrocardio-graph installed on the cow to automatically measure the heart rate of the cow, and automatically collect, transmit and analyze the cow's physical signs to determine whether the cow is in estrus, but this type of contact sensor collects the cow's physical signs in an invasive manner. Installation in different parts of the cow will produce stress response, which is detrimental to animal welfare, and the cow is in a complex environment, the sensor is easy to fall off and damage, and the signal transmission is easy to be disturbed by noise, which affects the accuracy of judgment.

In response to the above-mentioned problems, research-ers have made rapid progress in the research of animal behavior recognition methods based on machine vision technology. Wu Qian[8] uses the background subtraction method to extract the cow targets from the video through video analysis to detect the cow's step length characteristics to discriminate the cow's limp behavior. Since only using the background subtraction method cow detection target, there will be some false detection region, Zhang Ziru[9] proposed a background subtraction method combining color and texture features to detect dairy cow targets. The size of the outer envelope convex hull of the key connected domain was used as the geometric feature, and the Support Vector Machine(SVM) classifier was used to identify and judge the estrus behavior of dairy cows. However, the selection of the threshold value in the extraction of color and texture information is greatly affected by the environment, and it is prone to false detection. Song Huaibo, Zhang Ziru and others[10] judged the respiration and estrus behavior of cows by extracting the optical flow characteristics of cow motion, but the optical flow information requires const-ant brightness of the background environment, consistent space, and high requirements for video stability, which makes it difficult to extract features. Yang Wei[11] used the support vector machine classification algorithm to identify the porcupine contours in a single background environment and judge the behavior of the porcupine. Xie Zhonghong[12] manually calculated the height and width of the smallest bounding rectangle of the target cow, and the aspect ratio. They used the KNN classifier to determine whether the cow was in heat or not. But the effect of dynamic behavior classification is not obvious. The advantage of unsupervised learning is that human intervention is small. The disadvantage is that it is sensitive to abnormal data of dairy cow behavior. Supervised learning is to train known cow behavior data to build a classification model, and then apply this model to the prediction of new data. Supervised learning has the advantages of strong anti-noise ability and high accuracy of behavior discrimination. The commonly used supervised learning algorithm is support vector machine. Therefore, this paper takes cow estrus behavior as the monitoring object, and detects cow targets based on Gaussian mixture, background subtraction and edge contour extraction, effectively removing irrelevant back-ground. Extract the two obvious geometric features that are not affected by the shooting distance, the aspect ratio and the aspect ratio of the smallest enclosing rectangle of the cow, as feature vectors, and realize the simulation design of the feature extraction function, and use the SVM classifier to train the cow behavior classification network model to identify cow estrus behavior. The system does not require a large amount of data, it can accurately identify the behavior of cows and realize non-contact detection, which has certain practical value.

2. TARGET DETECTION

Moving target detection is the process of identifying and extracting moving targets from background images by processing video images[13]. Moving targets will be affected by factors such as light changes, low contrast between foreground and background, and dynamic backgrounds. In order to detect targets more accurately, fixed cameras Are used for video extraction to effectively avoid the influence of dynamic backgrounds, Gaussian mixture models that are highly adaptable to complex backgrounds are used for background modeling[14], and background subtraction methods are used to detect targets. Background subtraction detection principle block diagram shown in **Fig.1**:

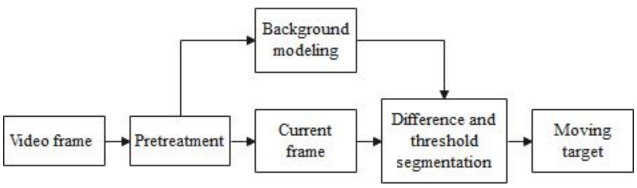

Fig.1 Block diagram of background subtraction method

The main steps of the background subtraction method include background difference and threshold segmenta-tion. The mathematical representation is:

$$\begin{cases} d_n(x,y) = \left|F_n(x,y) - B(x,y)\right| \\ Fr_n(x,y) = \begin{cases} 1, d_n(x,y) \geq T_d \\ 0, d_n(x,y) < T_d \end{cases} \end{cases} \quad (1)$$

In the above formula: (x,y) is the pixel coordinate point of the video sequence image; $d_n(x,y)$ is the diff-erence result between the current frame image and the background image; $Fr_n(x,y)$ is the nth frame image in the video sequence; $B(x,y)$ is the background image; $Fr_n(x,y)$ is the binary image of the extracted target; T_d is the binarization threshold after the background differ-ence.

Since the field only has no cows during the milking time, the grayscale images of the 5 background frames in the video of this time period are used to establish the background model. As shown in **Fig. 2(a)**. Use Gaussian mixture background model for background subtraction target detection. Optimal threshold method to determine the threshold[15]. When the threshold is set to 25, a complete contour of the cow's motion target can be extracted, and the detection result is shown in **Fig. 2(b)**.

(a) Background image **(b)** Processed image

Fig.2 Background subtraction method detection results

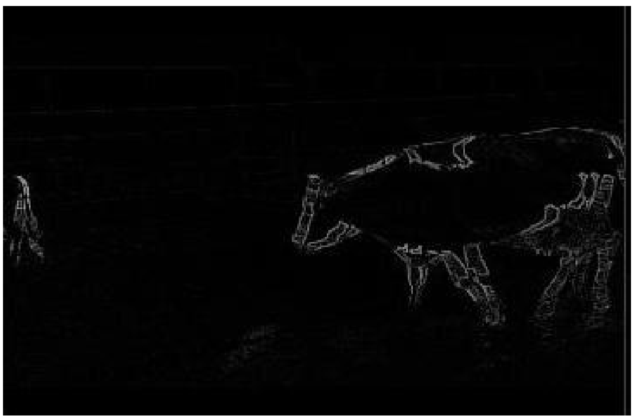

Fig.3 Target detection results

From the binarized image of the moving target, it can be seen that although the area of the moving cow is extracted, there are some extra white pixels around and the outline is not very clear. Therefore, it needs to be processed by morphological processing and Canny edge detection algorithm[16,17] to obtain a complete cow area and a clear outline. The processing result is shown in **Fig.3**.

3. FEATURE EXTRACTION

3.1. Geometric Feature Selection and Description

Since the geometric characteristics of the crawling behavior of a cow in estrus are obviously different from the behaviors of standing, crawling and lying, the geometric characteris-tics of the cow can be used to identify the estrus behavior of the cow. It mainly includes the change of the aspect ratio of the minimum bounding rectangle of the target cow and the change of the aspect ratio of the centroid coordinate.

In order to prove that the change in the aspect ratio of the smallest bounding rectangle and the aspect ratio of the center of mass when the cow is crawling is an important basis for judging the behavior of the cow, the video segment with the crawling behavior will use two-dimensional coordinates to represent the two feature changes. As shown in **Fig.4**.

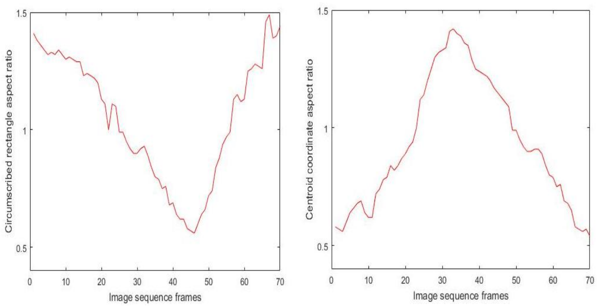

Fig.4 The geometric feature detection diagram of the target image sequence frame

If the change rate of the geometric characteristics of the two adjacent frames is obvious, it means that an action different from the current behavior has occurred. If the change rate between frames is not obvious, it means that the cow has not made a large movement. It can be seen that there are obvious downward fluctuations in the aspect ratio of the circumscribed rectangle in the 0th to 70th frames, and upward fluctuations in the aspect ratio of the center of mass, indicating that the center of mass is high at this time and there is a crawling behavior.

According to the literature[18] for a 2D continuous image $f(x,y)(\geq 0)$, The $p+q$ moment $\left(m_{pq}\right)$ and center distance (μ_{pq}) are defined as

$$m_{pq}=\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} x^p y^q f(x,y)\,dxdy \tag{2}$$

$$\mu_{pq}=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\left(x-\bar{x}\right)^p\left(y-\bar{y}\right)^q f(x,y)\,dxdy \tag{3}$$

where p and q are non-negative integers. For discretized digital images, the above two formulas become:

$$m_{pq}=\sum_{j=1}^{N}\sum_{i=1}^{N} i^p j^q f(i,j) \tag{4}$$

$$\mu_{pq}=\sum_{j=1}^{N}\sum_{i=1}^{N}\left(i-i_c\right)^p\left(j-j_c\right)^q f(i,j) \tag{5}$$

where $\left(i_c, j_c\right)$ are the centroid coordinates, and $i_c=m_{10}/m_{00}$, $j_c=m_{01}/m_{00}$.

It can be seen that the centroid is the 0th and 1st moments. **Fig. 5** shows a positive and negative example of cow behavior. The centroid of the target image is shown in **Fig. 5(c)**, and "*" in the image is the centroid of the target object. **Fig.5(b)** is the minimum bounding rectangle of the target cow. Define the aspect ratio of the minimum bounding rectangle containing the target cow as the ratio between length Y and width X. The calculation formula is as follows:

$$A_r=\left(X_{\max}-X_{\min}\right)/\left(Y_{\max}-Y_{\min}\right) \tag{6}$$

(a) The original image

(b) Target extraction

(c) Centroid mark

Fig.5 Some sample feature mark pictures

Among them, $X_{\max}$ and $X_{\min}$ are the largest and smallest abscissas of the smallest bounding rectangle containing the target cow, respectively, $Y_{\max}$ and $Y_{\min}$ are the largest and smallest ordinates of the smallest bounding rectangle that contains the target cow. Since a cow can be regarded as a rigid object similar to a rectangle, a rectangular frame is often used to frame the target during motion detection. When the cow is standing normally, the length X of the rectangular frame is greater than the width Y, the A_r is a value greater than 1. When the cow has a crawling behavior, the length X of the rectangular frame decreases rapidly, and the width Y will increase appropriately, the A_r will quickly decrease to a value less than 1. Therefore, the A_r can be used to characterize the movement of the target.

3.2. Geometric feature extraction

In order to realize the extraction, processing, display and storage of the collected data, the two geometric feature parameters related to the behavior of the cow are automatically obtained, and the simulation design interface of the feature extraction system function is performed. This

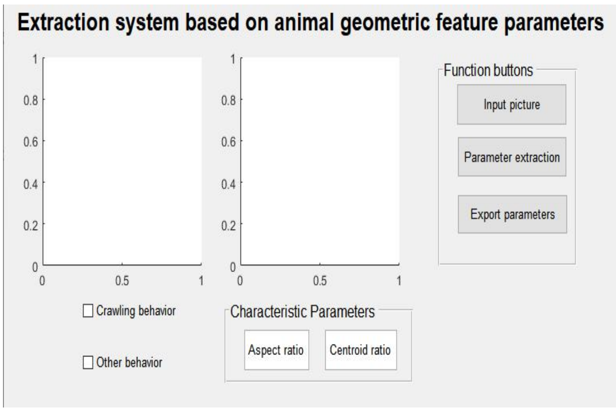

Fig.6 Feature extraction interface diagram

interface is mainly composed of three parts: geometric feature parameter extraction, feature parameter export, and behavior judgment, as shown in **Fig.6**.

Among them, the geometric feature extraction button can extract the smallest circumscribed rectangle of the target cow, and the feature value export button can automatically extract the two parameters of the rectangle aspect ratio and the centroid aspect ratio and automatically store the data in the EXCEL table. The checkboxes for crawling behavior and non-climbing behavior respectively indicate status 1 and 0, and the status tag value is automatically imported into the EXCEL table when the recognition selection is performed. The positive and negative sample processing interface is shown in **Fig.7**. The entire interface completes the automatic data processing, display and storage functions, effectively reducing the complexity of manual feature value marking, extraction, and storage.

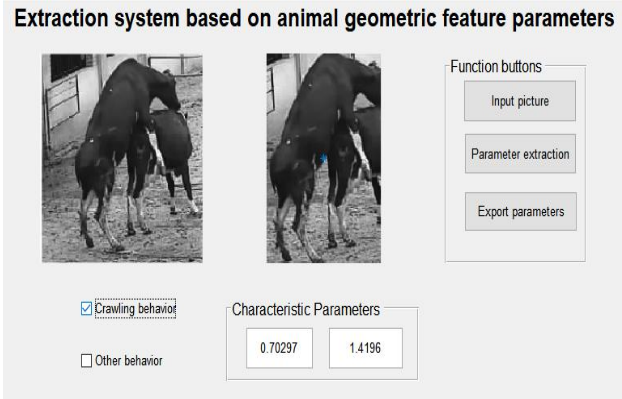

Fig.7(a) Positive sample processing interface

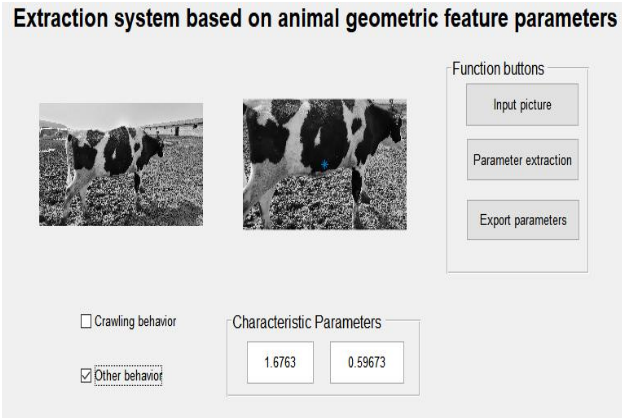

Fig.7(b) Negative sample processing interface

4. BEHAVIOR CLASSIFICATION METHOD BASED ON SVM

4.1. Feasibility Analysis

SVM is a classification method with supervised learning, which is used in statistical classification and regression analysis[19]. SVM has advantages in solving small sample, nonlinear and high-dimensional pattern recognition in classification problems. The core idea of SVM is to construct an interval separation hyperplane on the high-dimensional feature space of the kernel function mapping, and realize the two classification of samples by establishing the hyperplane.

Analyze the applicability of the support vector machine algorithm, and generate a data scatter plot from the collected 260 sets of samples. From the two-dimensional scatter diagram analysis of the data, it can be seen that the clustering effect of data points is obvious, and the difference between crawling behavior and non-climbing behavior is obvious. Because the clustering effect is obvious, support vector machines can be used for classification and recognition. The results are shown in **Fig.8**.

4.2. Building SVM Classifier

Constructing an SVM classifier is to train the SVM classifier using known samples and determine the best parameters of the classifier. The specific steps are as follows:

Step1 : Prepare sample data. The cow's target area includes crawling behavior and non-climbing behavior, and the 2-dimensional feature vector extracted for each target is a sample. The samples are processed through the feature extraction interface, and the climbing behavior samples are defined as positive samples, the label is set to 1, the non-climbing behavior samples are defined as negative samples, and the label is set to 0.

Step2 : Normalization of sample data, Use formula (7) to normalize irregular data to [-1,1][20].

$$p_i^{'} = \frac{2(p_i - p_{\min})}{p_{\max} - p_{\min}} - 1, \quad i = 1,2,3,..., p \qquad (7)$$

In the formula, $p_i^{'}$ represents the data after standardization, p_i represents the data before standardization, $p_{\min}$ represents the smallest data in the feature, $p_{\max}$ represents

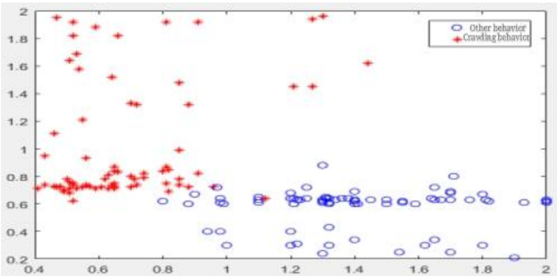

Fig.8 Data scatter plot

the largest data in the feature, and p is the total number of samples.

Step3 : The design of SVM mainly includes the selection of inner product kernel function, the determination of penalty factor and kernel function parameters.

1) The Gaussian kernel function can map samples to any dimension, which is suitable for processing nonlinear sample classification problems. The expression of the Gaussian kernel function is as follows:

$$K(x, x_c) = \exp\left(-g\|x - x_c\|^2\right) \qquad (8)$$

Among them, x , x_c is a sample or vector; g is a hyperparameter, and $\|x - x_c\|$ represents the norm of the vector, also known as the modulus of the vector.

2) The penalty factor C is used to weigh the loss and the weight of the classification interval. The larger the C, the more important the loss. In order to reduce the loss of misclassification, the value of C can be increased contin-uously, which can always achieve the correct classification of sample points, but this will lead to Over-fitting, insufficient generalization ability. On the contrary, the accuracy of classification cannot be guaranteed. There is no uniform formula to guide the value of the penalty factor C and the kernel function parameter g. Generally, the optimal C and g are determined on the training sample data set[21].

Step4 : Train the SVM classifier, and directly train the SVM classifier on the training sample data set, which can be applied to predictive classification of unknown samples.

4.3. Experimental Environment and Data Equations

The experimental environment is a 64-bit Windows 10 operating system, Intel Core i7-10700F CPU , Main frequency 2. 90GHz, memory 16 GB. The moving cow target detection algorithm and behavior recognition algorithm were developed and experimented using MATLAB 2017b.

The experimental data set is divided into two parts: training set and test set. Because the behavior of cows is more complicated, non-climbing behavior mainly collects the standing behavior and crawling behavior of cows from different angles. In the experimental data set, there are a total of 260 cow behavior images in the training set, and the test set is 40 cow behavior images randomly selected from different videos. The behavior distribution of cows in the test set and training set is shown in **Table.1**.

4.4. Experimental Results and Analysis

According to the process and steps of the SVM classification algorithm in Section 3.2, experiments are carried out on the test samples, and the visual classification results of the construction of cow behavior recognition training and testing[22] are shown in **Fig.9** and **Fig.10**.

Table. 1 Caption for table.

Experimental data	Behavior description		Total
	Other behavior	***Crawling behavior***	
Training set	197	63	260
Test set	20	20	40

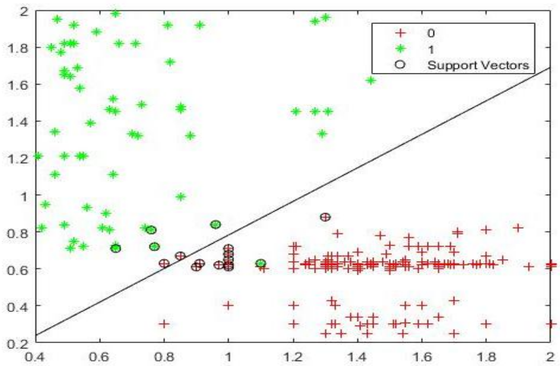

Fig.9 Classification results of the training sample set

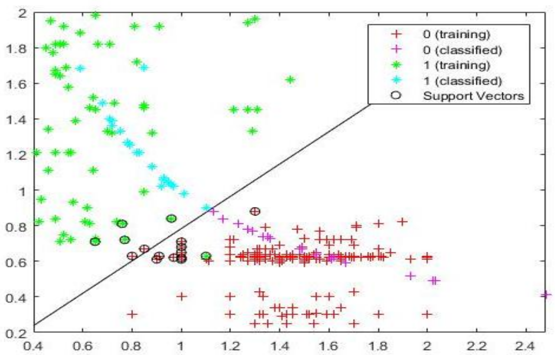

Fig.10 Classification results of the test sample set

The classification result can use the precision and recall : Accuracy refers to the ratio of the number of positive samples to the total number of samples in a given data set; recall refers to the number of positive samples detected by the model accounting for the true mark The ratio of the number of samples. The calculation formula is as shown in (9):

$$\begin{cases} Precision = TP/(TP+FP) \\ Recall = TP/(TP+FN) \end{cases} \quad (9)$$

In the formula,the true sample represents the sample where the detected target category is consistent with the real target category; False Positive represents the sample where the detected target category is inconsistent with the real target category; false negative sample is represented as a sample where the real target exists but has not been detected. The parameters are shown in Table 2:

Table. 2 Schematic diagram of each parameter

	Positive	Negative
IOU＞0.5 （True）	TP	TN
IOU＜0.5 （False）	FP	FN

From equation (9), it can be seen that the accuracy of the method in this paper is 97.5%, and the recall rate is 89.7%. It shows that the method in this paper can realize the recognition of cow's estrus behavior in complex environment, and the recognition result is reliable. The main reason for the misdetection of the algorithm is that the geometric characteristics of the rear view of some standing cows are similar to the geometric characteristics of the crawling behavior. Compared with the SVM prediction[23] method based on the characteristic parameters obtained by the pedometerr, the algorithm has an accuracy rate of 11.70% higher in the conversion of the same sample parameters.

5. CONCLUSION

In this paper, a video behavior recognition algorithm based on geometric features and SVM is proposed to conduct research on cow behavior recognition technology for the purpose of monitoring cow estrus behavior. The SVM classifier is trained to recognize the behavior of cows through the extracted geometric features. Compared with the wearable sensor method, it has advantages in convenience, the algorithm is quick to implement, and the accuracy of cow behavior recognition can reach 97.5%. However, the behavior recognition of the rear view of the cow behavior is not very accurate. You can choose to combine the minimum enclosing rectangle degree or the inclination angle of the circumscribed rectangle for multi-feature fusion recognition to further improve the behavior detection rate of the cow. Provide support for operations such as calving rate.

REFERENCES:

[1] Gu Jingqiu, Wang Zhihai, Gao Ronghua, Wu Huarui. Cow behavior recognition method based on fusion image and motion amount[J]. Transactions of the Chinese Society of Agricultural Machinery, 2017, 48(06): 145-151.

[2] Liu Zhongchao, He Dongjian. Recognition method of cow estrus behavior based on convolutional neural network[J]. Transactions of the Chinese Society of Agricultural Machinery, 2019, 50(07): 186-193.

[3] Hou Yuntao, Cai Xiaohua, Wu Zequan, Dong Zhongge. Research and Implementation of the Recognition Method of Dairy Cow Behavior——Based on Support Vector Machine[J]. Journal of Agricultural Mechanization Research, 2018, 40(08): 36-41.

[4] Ren Xiaohui, Liu Gang, Zhang Miao, Si Yongsheng, Zhang Xinyue, Ma Li. Cow behavior recognition method based on support vector machine classification model[J]. Transactions of the Chinese Society of Agricultural Machinery, 2019, 50(S1): 290-296.

[5] Yin Ling, Liu Caixing, Hong Tiansheng, Zhou Haoen, Kae Hsiang Kwong. Design of dairy cow behavior characteristic monitoring system based on wireless sensor network[J]. Transactions of the Chinese Society of Agricultural Engineering, 2010, 26(03): 203-208+388.

[6] Liu Zhongchao, Liu Yongjun. Design of a wireless monitoring system for cow's estrus crawling behavior based on Android[J]. Heilongjiang Animal Husbandry and Veterinary, 2019(15): 55-59+179.

[7] Steve Warren, Angel Martinez, Timothy Sobering, et al. Electrocardiographic pill for cattle heart rate determination[C]//30th Annual International IEEE EMBS Conference Vancouver, British Columbia, Canada: [s.n.], 2008: 4852－4855.

[8] Wu Qian. Research on extraction of key parts of dairy cows and limp detection based on video analysis[D]. Northwest Sci-Tech University of Agriculture and Forestry, 2019.

[9] Zhang Ziru. Research on the detection method of cow estrus information based on video analysis[D]. Northwest Sci-Tech University of Agriculture and Forestry, 2018.

[10] Song Huaibo, Wu Dihua, Yin Xuqiang, Jiang Bo, He Dongjian. Respiratory behavior detection of dairy cows based on Lucas-Kanade sparse optical flow algorithm[J]. Transactions of the Chinese Society of Agricultural Engineering, 2019, 35(17): 215-224.

[11] Yang Wei, Yu Shouhua. Research on Captive Porcupine Detection and Basic Behavior Recognition Method Based on Machine Vision [J]. Fujian Journal of Agriculture, 2017, 32(09): 1021-1025.

[12] Xie Zhonghong, Liu Yueyi, Song Ziyang, Xu Huanliang. Research on Cow Crawling Behavior Recognition Based on Time Series Movement Features[J]. Journal of Nanjing Agricultural University, 2021, 44(01): 194-200.

[13] Bin Wu et al. Recognition of Student Classroom Behaviors Based on Moving Target Detection[J]. Traitement du Signal, 2021, 38(1): 215-220.

[14] Lv Hongbao and Dong Xinqiu. Target Detection Algorithm for Basketball Moving Images Based on Improved Gaussian Mixture Model[J]. Microprocessors and Microsystems, 2021: 104010-.

[15] Si Haifei, Hu Xingliu, Shi Zhen. Fall recognition method based on background subtraction and feature extraction[J]. Journal of Electronic Measurement and Instrument, 2020, 34(10): 33-39.

[16] Dong Lv and Shenghu Pan. Improved Canny edge detection algorithm based on deep learning[J]. Scientific Journal of Intelligent Systems Research, 2021, 3(2).

[17] Li Jianjun, Sun Yue, Zhang Baohua. Interactive behavior recognition based on sparse coding feature fusion[J]. Progress in Laser and Optoelectronics, 2020, 57(18): 96-104.

[18] Wang Bing, Zhi Qinchuan, Zhang Zhongxuan, Geng Guohua, Zhou Mingquan. Fast algorithm for gray image centroid[J]. Journal of Computer Aided Design and Graphics, 2004(10): 1360-1365.

[19] Diganta Kumar Pathak and Sanjib Kumar Kalita and Dhruba Kumar Bhattacharya. Hyperspectral image classification using support vector machine: a spectral spatial feature based approach[J]. Evolutionary Intelligence, 2021: 1-15.

[20] Wang Lili, Liu Hongbo, Chen Deyun, Feng Qishuai. ECT flow pattern identification based on adaptive and additional momentum BP neural network[J]. Journal of Harbin University of Science and Technology, 2018, 23(01): 105-110.

[21] Xiao Lei. Intelligent recognition of image features based on parameter optimization of support vector machines [J]. Computer Knowledge and Technology, 2020, 16(04): 173-175+177.

[22] Han Kun, Huang Zefan. Falling behavior recognition method based on dynamic characteristics of human posture[J]. Journal of Hunan University (Natural Science Edition), 2020, 47(12): 69-76.

[23] Tan Yi, He Dongjian, Guo Yangyang, Zhang Ziru. Design and implementation of a real-time monitoring system for cow estrus based on Storm[J]. China Agricultural Science and Technology Review, 2018, 20(12): 83-90.