DESIGN AND IMPLEMENTATION OF SHEEP TARGET EXTRACTION ALGORITHM BASED ON MACHINE VISION
/
基于机器视觉的羊只目标提取算法设计与实现

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ABSTRACT
In order to improve the quality of sheep foreground object segmentation, images are segmented using the watershed algorithm in combination with a growing region algorithm, and the pixel-by-pixel comparison of segmentation is optimized to reduce the processing time. Compared with other algorithms, the optimized watershed algorithm can achieve more complete target extraction, and its processing time is improved by over 50%. Moreover, the optimized watershed algorithm has the optimal overall image quality indicators. This algorithm can provide a reference for the real-time extraction of the activity state of sheep.

摘要
为改善羊只前景目标分割的质量，结合分水岭算法与生长区域算法对图像进行分割，优化分割的逐像素比较，改进运算时间。改进后的分水岭算法较其它算法目标提取更完整，较其它六种算法处理时间提升 50%以上，各项图像质量指标总体最佳。该算法为实时地提取羊只活动状态提供了一定的借鉴和参考。

INTRODUCTION
Sheep breeding is a vital part of animal husbandry. To meet the development needs, intelligent sheep breeding has become an inevitable trend. Machine identification technology has been increasingly used in the breeding industry to achieve more scientific and convenient management of sheep breeding, which has significantly facilitated the transformation and modernization of the breeding industry *(Ma et al., 2021)*. Target object segmentation is an essential technology in machine vision technology *(Xue et al., 2021)*. The foreground recognition of sheep targets based on image processing technology lays a solid basis for the automatic detection of sheep behaviour while being the premise of this detection, and the image segmentation algorithm can effectively increase the accuracy of foreground target recognition. Thus, the image processing technology was used in this paper to identify the foreground target of sheep in order to analyse the characteristics of different segmentation algorithms.

Extensive research on machine vision technology has been conducted worldwide. *(Qin et al., 2021)*, proposed a cow target extraction algorithm based on correlation filtering and edge detection. The average overlap rate between the targets extracted by the algorithm and the real results was 92.93%, suggesting that the algorithm can be effective in accurate target extraction. *(Zhang et al., 2017)*, proposed a sheep foreground image extraction algorithm based on the superpixel image segmentation algorithm and the FCM clustering algorithm, which extracted the outline of the sheep image and automatically measured the body size parameters. Rare studies have been conducted on image segmentation in the animal husbandry abroad. *(Cao et al., 2021)*, extracted wheat lodging using a hybrid algorithm combining watershed algorithm and adaptive threshold segmentation. *(Muhammad et al., 2018)*, used the optimized HSV and watershed to detect red ripe tomatoes, which shows good application potential in picking robots. *(Chen et al., 2021)* used traditional computer vision to identify livestock at different growth stages. In brief, machine vision technology has been extensively used in the production of the breeding industry, and the sheep breeding industry has been less involved. In this paper, a sheep target extraction algorithm that integrates morphology and watershed algorithm is proposed for sheep target extraction.

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MATERIALS AND METHODS

Image acquisition and processing

The experimental data were collected at the base of Shanxi Agricultural University, Taigu District, Jinzhong City, Shanxi Province, and 10 adult sheep were selected and placed in stalls with a size of nearly 6m×4.2m×2m. A smart camera is used as a shooting tool. Fig. 1 presents a schematic diagram obtained through the system acquisition. Fig. 2 presents a single image collected by shooting. Fig. 3 gives a representative image of four different poses selected from the 188 image data for batch processing.

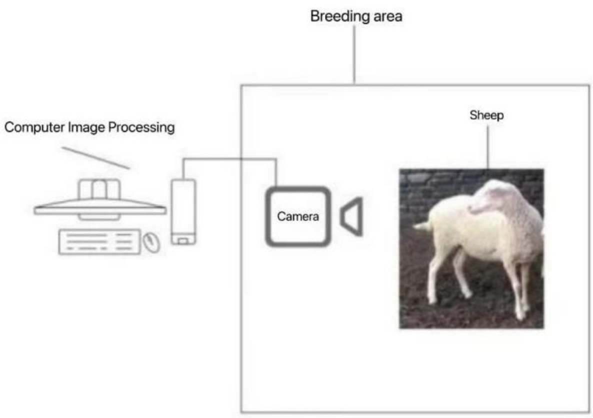


Fig. 1 – Schematic diagram of acquisition system

Fig. 2 – The effect of sheep data acquisition

a) *b)* *c)* *d)*

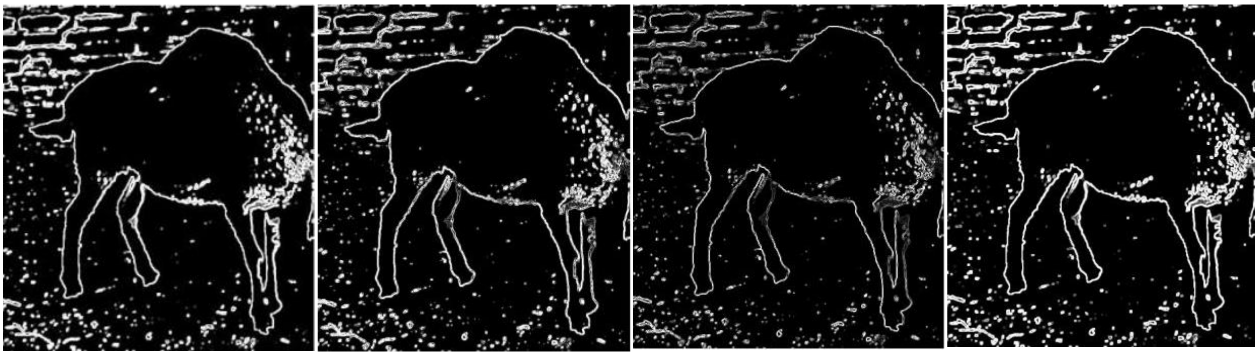
Fig. 3 – Original picture of sheep in four poses
a) Standing; b) Lying on the side; c) Eating; d) Forelimbs bent

When processing an image, the first step is to gray the image, in order to remove the miscellaneous and useless information in the original colour image, simplify the image matrix, and speed up the image processing. The specific operation method of graying processing: read the image, extract the R colour channel grayscale of the colour image, remove a lot of unnecessary information in the colour image, that is, make the RGB values equal, and then the image is converted to gray. When shooting and recording sheep, the original image is too large due to its complex colour and large amount of information, which will reduce the processing speed. The transformed gray image simplifies the matrix in the original colour image, that is, R=G=B, and the equivalent is the gray value. The gray value is 0-255. The gray image is obviously smaller than the colour image, and the processing speed of gray image is faster.

Using linear spatial filtering method, the output pixel is the weighted sum of the input neighbourhood pixels. The use of linear filtering is mainly to improve the image quality, enhance the image recognition, and eliminate a series of interferences such as high-frequency noise. In addition, linear filtering can also enhance the image edge and linearity, and de-blur at the same time. Sobel operator of edge detection is used to convolve the image in vertical and horizontal directions respectively.

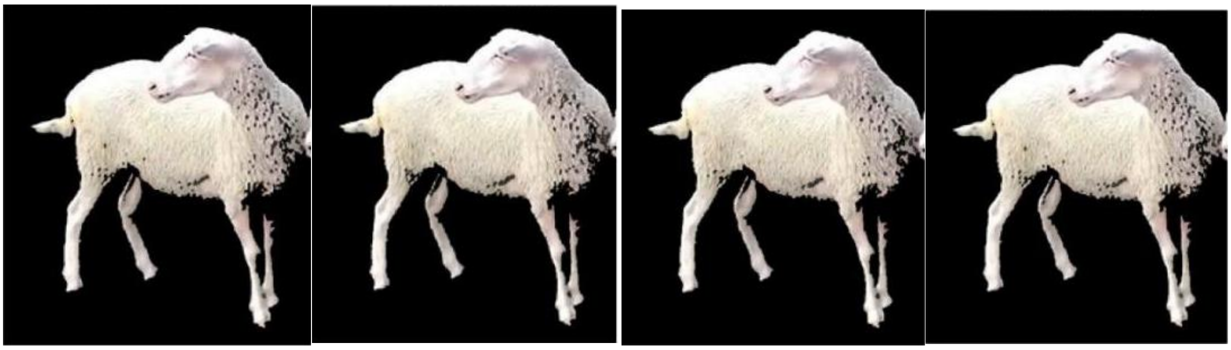
To achieve better segmentation results in the image segmentation process, grayscale processing, linear filtering, gradient transformation, and morphological operations should be performed on the image.

When increasing the segmentation effect, it is considered trying the edge detection operator, and comparing the segmentation effects using the Sobel operator, the Laplacian operator, the Laplacian Gaussian operator, as well as the Prewitt operator. The gradient images based on different operators are presented in Fig. 4, and the final segmentation results are compared in Fig. 5. Comparing the images of the segmentation results of different filtering algorithms, the difference in the segmentation results is very small. The four filtering algorithms have good applicability to the watershed segmentation algorithm, and the filtering effect of the Laplacian-Gaussian operator is the best.



a) b) c) d)

Fig. 4 – Gradient image based on different operators:
a) Sobel operator; b) Laplacian operator; c) Laplace Gaussian operator; d) Prewitt operator



a) b) c) d)

Fig. 5 – Segmentation result graph based on different operators
a) Sobel operator; b) Laplacian operator; c) Laplace Gaussian operator; d) Prewitt operator

Sheep target extraction based on an optimized watershed algorithm

Using the watershed algorithm to process the sheep image shows an advantage that it can process the weak edge perfectly. Moreover, using the method of marking the image for segmentation can reduce the segmentation of the image area with small noise and correct the over-segmentation. The traversal is performed to extract the area where the sheep is located, and then the watershed algorithm is operated to segment the image. Fig. 7(b) illustrates the effect of extracting sheep from the background.

The segmentation result obtained using morphology alone is depicted in Fig. 6(a), which can completely segment the sheep subject, whereas some image data may not be stuck to the background. The segmentation result achieved using the growth region method alone is presented in Fig. 6(b). The sheep subject can be more accurately extracted, whereas there will be noise inside, thus making the segmented sheep target incomplete.

a) b)

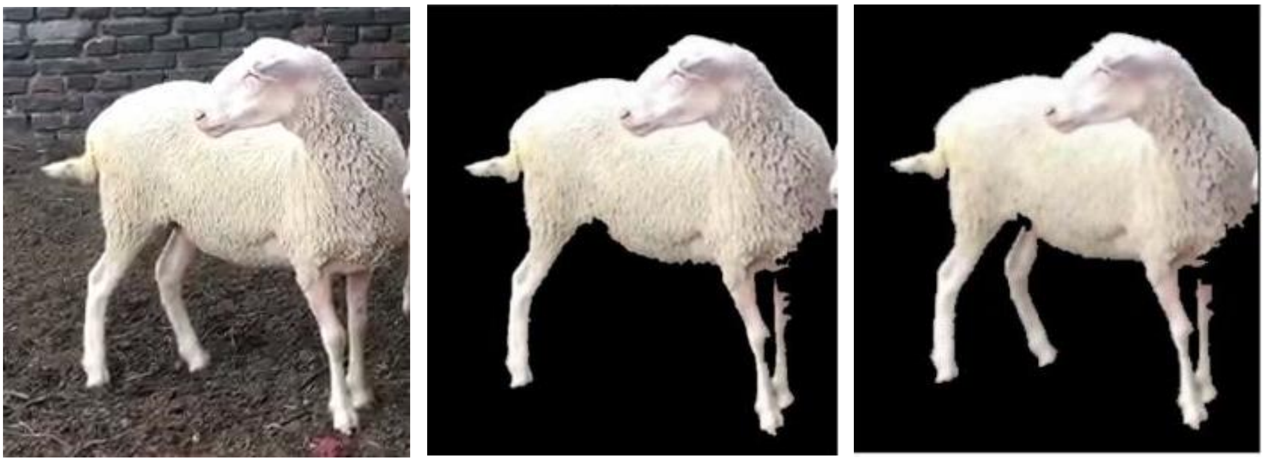
Fig. 6 – Separate segmentation result
a) Morphology; b) Growth area

The overall design idea, combining the advantages and disadvantages of the above two methods, is to use the growing region algorithm to outline the accurate outline of the sheep, then adopt the morphological method to fill in the noise part in the middle of the sheep body, and finally combine the largest area object extracted using the two methods to extract the final sheep part.

(1) Local adjustment. Morphological algorithms do not just use simple erosion and dilation, but use composite operations (e.g., erosion, dilation, negation, reconstruction, and local maxima) to further refine the segmentation results. The morphological operations aiming to remove non-target boundaries are conducted.

(2) Specific combination process. Sheep segmented by morphological and growth area methods are treated in three categories below: (a) the part divided by both algorithms: directly judged as the sheep part; (b) the part judged as sheep by morphology and judged as noise by growth area method is judged as sheep; (c) Finally the extracted largest area object is used to extract the final sheep.

The comparison of segmentation results according to the above watershed algorithm and the optimized algorithm is shown in Fig. 7. Compared with the watershed algorithm, the optimized algorithm is more complete in target extraction, which proves the effectiveness of the optimized algorithm for target extraction, which further improves the image processing results and improves the accuracy.



a) *b)* *c)*

Fig. 7 – Comparison of results before and after improvement

a) Original drawing; b) Watershed algorithm; c) Optimized watershed algorithm

Batch time optimization

To further select the optimal algorithm for sheep extraction, the maximum inter-class variance method (OTSU), the wavelet algorithm, the support vector machine (SVM), the optimal histogram entropy method (KSW), the global threshold method, and the optimized watershed algorithm are used to process batch images of 188 sheep image data. The pixel-by-pixel comparison in the process of judging sheep is optimized by the built-in function, and the cycle is reduced by vector calculation in the process of calculating the average assessment index. Moreover, the processing time reduces significantly.

Fig. 8 presents a flow chart of extracting sheep targets before and after time optimization.

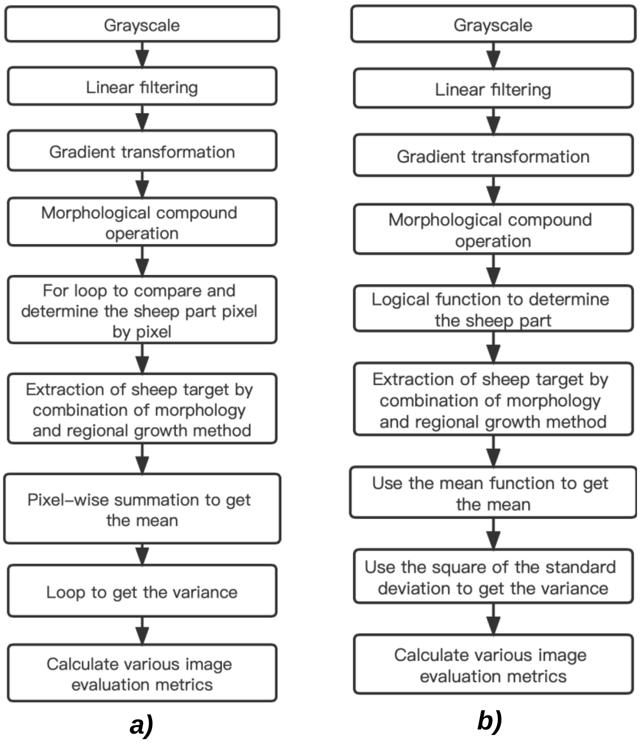


Fig. 8 – Flowchart of extracting sheep targets before and after time optimization

Assessment indicators

Reasonable assessment of image quality has a very important application value, so the quality of the generated segmentation results is assessed through an objective assessment *(Huang et al., 2021)*. Based on the assessment indicators of a single image feature, the following six are selected:

(1) *Mean*. It is the arithmetic mean of the luminance values of all pixels in the image, and the calculation method is expressed in Equation (1).

$$\mu = \frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} P(i,j) \tag{1}$$

where:

$P(i,j)$—pixel value at point (i,j);

$M \times N$—size of image.

(2) *Standard deviation*. It expresses the degree of dispersion of pixel gray levels from the image mean *(Zhang et al., 2014)*, which is written as Equation (2):

$$\sigma = \sqrt{\frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} (P(i,j) - \mu)^2} \tag{2}$$

(3) *Information entropy*. Image entropy is a vital indicator to measure the richness of image information. The size of the entropy value indicates the average amount of information involved in the image. The information entropy of an image is defined as Equation (3):

$$E = -K \sum_{i=1}^{n} p_i \log p_i \tag{3}$$

where:

K—A proportional constant corresponding to the chosen unit of measurement;

p_i—The probability that the gray value of a pixel in the image is i.

(4) *Spatial frequency*. It can indicate the overall activity level of an image space, including spatial row frequency RF and spatial column frequency CF, which are respectively defined as Equation (4) and Equation (5):

$$RF = \sqrt{\frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} [P(i,j) - P(i,j-1)]^2} \tag{4}$$

$$CF = \sqrt{\frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} [P(i,j) - P(i-1,j)]^2} \tag{5}$$

The spatial frequency is the root mean square of RF and CF, which is written as Equation (6):

$$SF = \sqrt{CF^2 + RF^2} \tag{6}$$

(5) *Variance*. It can indicate the dispersion of the gray level of the respective pixel in the image relative to the average gray level. It can also be used to assess the amount of image information to a certain extent. It is calculated as Equation (7):

$$D(X) = E\left\{[X - E(X)]^2\right\} \tag{7}$$

(6) *Contrast*. It is the ratio of the black and white of the image, i.e., the gradient level from black to white. The larger the ratio, the more gradient levels from black to white will be, and the richer the color expression will be. It is calculated as Equation (8):

$$C = \sum_{\delta} \delta(i,j)^2 P_{\delta}(i,j) \tag{8}$$

where:

$\delta(i,j) = abs(i-j)$—The grayscale difference between adjacent pixels;

$P_{\delta}(i,j)$—The distribution probability of the grayscale difference between adjacent pixels.

RESULTS

Comparison of the effect of segmentation algorithms

Through the comparison of wavelet transform, OTSU algorithm, SVM algorithm, optimal histogram entropy method and global threshold method, the optimal improved watershed algorithm is obtained. As depicted in Fig. 3, the images of four postures of upright, side lying, eating, and forelimb bending are selected for the representative analysis. The OTSU algorithm should be implemented on the targets to be processed respectively, and the effect is relatively poor. Fig. 9 illustrates the extracted image. Since the wavelet transform is a frequency domain operation, it is not sensitive to noise, and Fig.10 presents the segmented image. The SVM algorithm adopts the regional segmentation method to distinguish the image into foreground and background images. Subsequently, the feature vector is extracted as the SVM training sample for the image segmentation, as illustrated in Fig. 11. As depicted in Fig.12 the optimal histogram entropy method performs segmentation by maximizing the entropy of the segmented image *(Cheng et al., 2018)*. The global threshold method is an iterative process, and the segmentation results are illustrated in Fig.13.

a) *b)* *c)* *d)*

Fig. 9 – OTSU algorithm

a) Standing; b) Lying on the side; c) Eating; d) Forelimbs bent

a) *b)* *c)* *d)*

Fig. 10 – The wavelet transform

a) Standing; b) Lying on the side; c) Eating; d) Forelimbs bent

a) *b)* *c)* *d)*

Fig. 11 – The SVM algorithm

a) Standing; b) Lying on the side; c) Eating; d) Forelimbs bent

a) *b)* *c)* *d)*

Fig. 12 – KSW algorithm

a) Standing; b) Lying on the side; c) Eating; d) Forelimbs bent

a) b) c) d)

Fig.13 – Global threshold method

a) Standing; b) Lying on the side; c) Eating; d) Forelimbs bent

a) b) c) d)

Fig. 14 – Watershed improvement algorithm

a) Standing; b) Lying on the side; c) Eating; d) Forelimbs bent

Compared with other algorithms, the optimized watershed algorithm (Fig.14) handles noise better while more effectively outlining the foreground target area making it more obvious.

Time comparison of segmentation algorithms

For multiple image data, the time average comparison is shown in Table 1 after 7 segmentation algorithms. Compared with other algorithms, the optimized watershed algorithm achieves an improvement rate of higher than 50%, which suggests that the optimized watershed algorithm is highly applicable to batch processing time.

Table 1

Comparison of the mean time of batch image processing

Segmentation algorithm	Operation hours [s]	The improvement rate of the processing time of the optimized watershed algorithm compared with different algorithms [%]
OTSU algorithm	0.4530	59.38%
Wavelet transform	1.0156	81.88%
SVM algorithm	0.4491	59.02%
KSW algorithm	0.6306	70.82%
Global threshold method	0.4253	56.73%
Watershed algorithm	1.1307	83.73%
Watershed improvement algorithm	0.1840	0%

Comparison of image quality indicators for segmentation algorithms

Table 2 presents the average comparison of different image quality indicators of 188 images after segmentation using six algorithms. To be specific, the segmentation effect of wavelet transform is relatively poor, which results in a completely black state, so some image quality indicators of the wavelet transform result are invalid. The analysis of different quality indicators in Table 2 reveals that the smaller the standard deviation and variance of the target extraction results, the wider the gray distribution of the image will be; the larger the information entropy, the richer the information involved in the image will be; the smaller the mean, the lower the brightness will be; the smaller the spatial frequency, the smaller the overall activity level; the smaller the contrast, the less colour expression. In general, the assessment indexes of the segmentation results based on the optimized watershed algorithm are better than those of other algorithms in terms of target extraction.

Table 2

Image quality assessment

Segmentation algorithm	OTSU algorithm	Wavelet transform	SVM algorithm	KSW algorithm	Watershed algorithm	Watershed improvement algorithm
Mean	65.2505	69.0906	65.4993	109.9486	60.6109	54.8811
Standard deviation	85.1338	46.9962	81.5149	98.7614	83.4112	78.2767
Information entropy	0.8585	0.3567	3.1449	1.3190	0.7987	3.0794
Spatial frequency	51.8825	25.3765	51.6625	63.7363	52.6317	32.2580
Variance	85.1331	46.9958	84.5142	98.7606	83.4105	78.2761
Contrast	0.0661	0.0250	0.0628	0.0649	0.0596	0.0349

CONCLUSIONS

The watershed algorithm is prone to over-segmentation. Accordingly, the watershed algorithm is usually combined with different algorithms to increase the processing effect when used to process images. In this paper, a growing region algorithm is introduced into sheep target extraction, and a sheep target extraction algorithm is developed based on a combination of the watershed algorithm. As revealed by the experimental results, the optimized algorithm achieves the optimal recognition for the sheep foreground target, and the segmentation results are more complete. The segmentation results are compared with those of the OTSU algorithm, the wavelet transform algorithm, SVM, the KSW method, and the global threshold method through image quality assessment, and the overall assessment index is the best, suggesting that the optimized algorithm can be effective in accurately extracting sheep targets. The optimized algorithm exhibits high applicability. For batch image processing of multiple images, the average processing time is 0.1840 s, marking an increase of higher than 50% than the processing time of the other six algorithms.

The optimized watershed segmentation algorithm improves the quality of target extraction, simplifies, and accelerates the processing of sheep images, and has promotion value in agriculture and animal husbandry. Machine vision technology has been used in all walks of life, and its extensive application has significantly improved the living standard of human beings. With the improvement of productivity and automation level, machine vision will play wider roles.

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