Algorithms for contour detection in agricultural images

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Abstract. Contour detection requires a more extensive use of them in agriculture. However, processing by experts on the basis of such images, including subjective visual observation of the field area, takes a lot of time and energy. One of the important parts of the image processing process is the problem of determining the contour of the object in the image, through which the objects in the image are extracted, that is, segmented. This research work is devoted to the comparative analysis of contour detection methods, and the presented methods were first tested on the basis of the original image and images whose contours were separated by experts. The test contour was performed based on the contour images extracted by the expert and the contour images generated by using the methods, and the comparison of the results was performed by the pixel comparison method. Based on the obtained results, an approach of applying the appropriate method depending on the quality of the image is proposed.

1 Introduction

Today, on the basis of satellite images of agriculture, important information about the condition of agricultural fields and crops is being formed quickly and qualitatively. Experts spend a lot of time and effort on such tasks. This, in turn, leads to a delay in the decision-making process. Usually, such problems are solved by automating image processing and recognition.

One of the important steps in image processing is image segmentation, and many approaches to image object segmentation have been developed. However, due to the large number and size of satellite images, their analysis requires large funds. In this case, it is desirable to perform segmentation by determining the contour of the object, and this is an important part of image processing, in which the contour is determined based on the presence of boundary lines of the object in the image [1]. The main goal of contour detection is to minimize the amount of data processing from images. The correct and complete extraction of contours when determining the boundaries of the object in the image depends on the image being free of various noises and distortions and having a normal level of contrast. Because

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the presence of noise in the image leads to the formation of false contours, and the insufficient contrast of the image leads to the contours not being clear and complete. In order to overcome such problems, it is recommended to apply pre-processing algorithms such as image contrast enhancement [2-4] and noise reduction algorithms [5].

Today, researchers have developed many methods and algorithms for contour separation, but in the process of image processing, a specific general method for determining the contour of an object in an image has not been developed, and this is one of the main problems of image processing.

The image can distinguish the outline of the object based on the change in brightness [6]. In this case, the image is considered as a two-dimensional function, and the point gradient is calculated in the vertical and horizontal directions. This is determined by special derivatives of the two-dimensional function, through which the change in image brightness is determined. In this research work, gradient Sobel, Preuitt, Roberts, Scharr, Orhei, Kitchen-Malin, Kayalli and Kenny, Robinson, LoG (Laplacian of Gaussian), DoG (Difference of Gaussian) methods of contour separation are evaluated, and based on them, the optimal method of contour separation compared to the point comparison algorithm is determined.

2 Methods

Suppose we are given a set of T_o-original images and their corresponding T_o^k contour expertly extracted images, as well as u_i contour extraction filters and a set of B image comparison criteria. For the original image $t_o \in T_o$ and the corresponding contour $t_o^k \in T_o^k$ for the image separated by the expert, the contour image t_i generated by applying the filter u_i to the image t_o is defined as follows:

$$t_i = u_i\left(t_o\right),\ i = \overline{1,11} \tag{1}$$

In this case, the filters used to determine the contour of the object in the image were designated according to the period of development as follows: u_1 − Roberts, u_2 − Prewitt, u_3 − Sobel, u_4 − Robinson, u_5 − LoG, u_6 − DoG, u_7 −Canny, u_8 − Kitchen-Malin, u_9 − Scharr, u_{10} − Kayalli, u_{11} − Orhei.

Evaluation of the effectiveness of the selected filters by comparing the image t_o^k and the image t_i obtained by applying the filters is determined as follows:

$$b_i = \frac{\left|t_o^k \cap t_i\right|}{\left|t_o^k\right|} \cdot 100\%,\ i = \overline{1,11} \tag{2}$$

Where $b_i \in B$, $|t_o^k|$ − is the number of contour image pixels, $|t_o^k \cap t_i|$ − is the number of pixels at the intersection of t_o^k and t_i images.

In this approach, the larger the value obtained by (2), then the filter corresponding to this value is considered the most effective, that is:

$$u_{opt} = \max_i\{b_i\}, i = \overline{1,11} \tag{3}$$

3 Computational experience and results

The most reliable way to evaluate the result of the method of delineation of image objects is to compare the image with the exact contour image. In this research work, 100 sample images from the BSDS500 image collection provided on the website www.kaggle.com were used for computational experiments, where the original and corresponding contour images were formed by experts.

BRISQUE [7], a well-known benchmark for image quality assessment, was used to determine a suitable effective method for image object contour segmentation depending on image quality. 400 new images were created by adding 100 sample images from the given BSDS500 image set and adding different effects to them, and a base of 500 images was formed. The quality of the images in the base was divided into 5 categories of images according to the BRISQUE value, i.e. T_o^1-Best, T_o^2-Good, T_o^3-Medium, T_o^4-Poor and T_o^5-Bad (Table 1).

Table 1. Image classification results by BRISQUE value.

Image base	Image quality	Range of classification	Image number
T_o^1	Best	(0;21)	83
T_o^2	Good	[21-41)	15
T_o^3	Medium	[41;61)	97
T_o^4	Poor	[61;81)	227
T_o^5	Bad	[81;100)	78

Sample images from T_o^1, T_o^2, T_o^3, T_o^4 and T_o^5 image sets are shown in the Figure below.

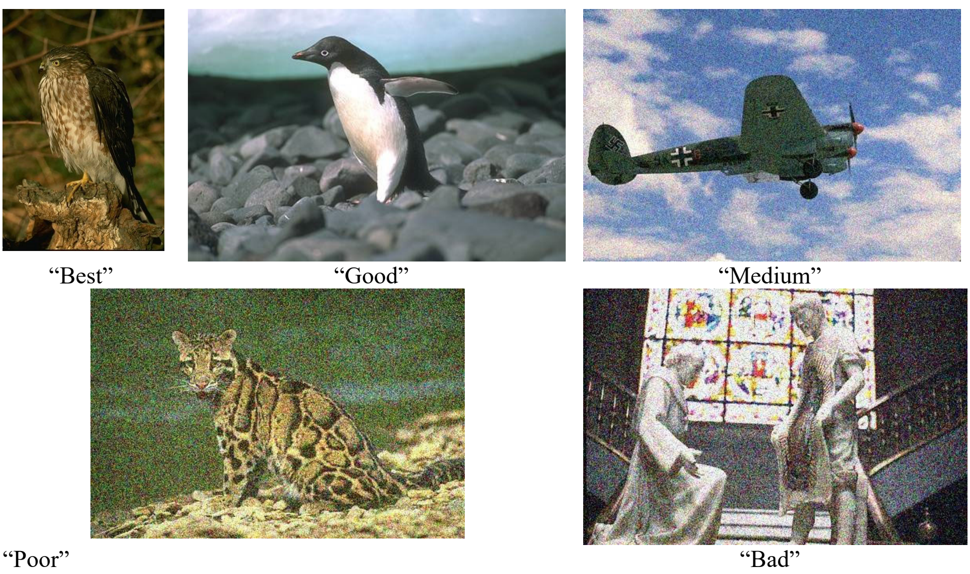

Fig. 1. A set of images T_o^1, T_o^2, T_o^3, T_o^4 and T_o^5 are sample images.

Contour segmentation was performed by applying the above-mentioned u_i, $(i = \overline{1,11})$ filters to the segmented category images. The Figure below shows a sample image obtained by applying the filters to a set of T_o^1 images.

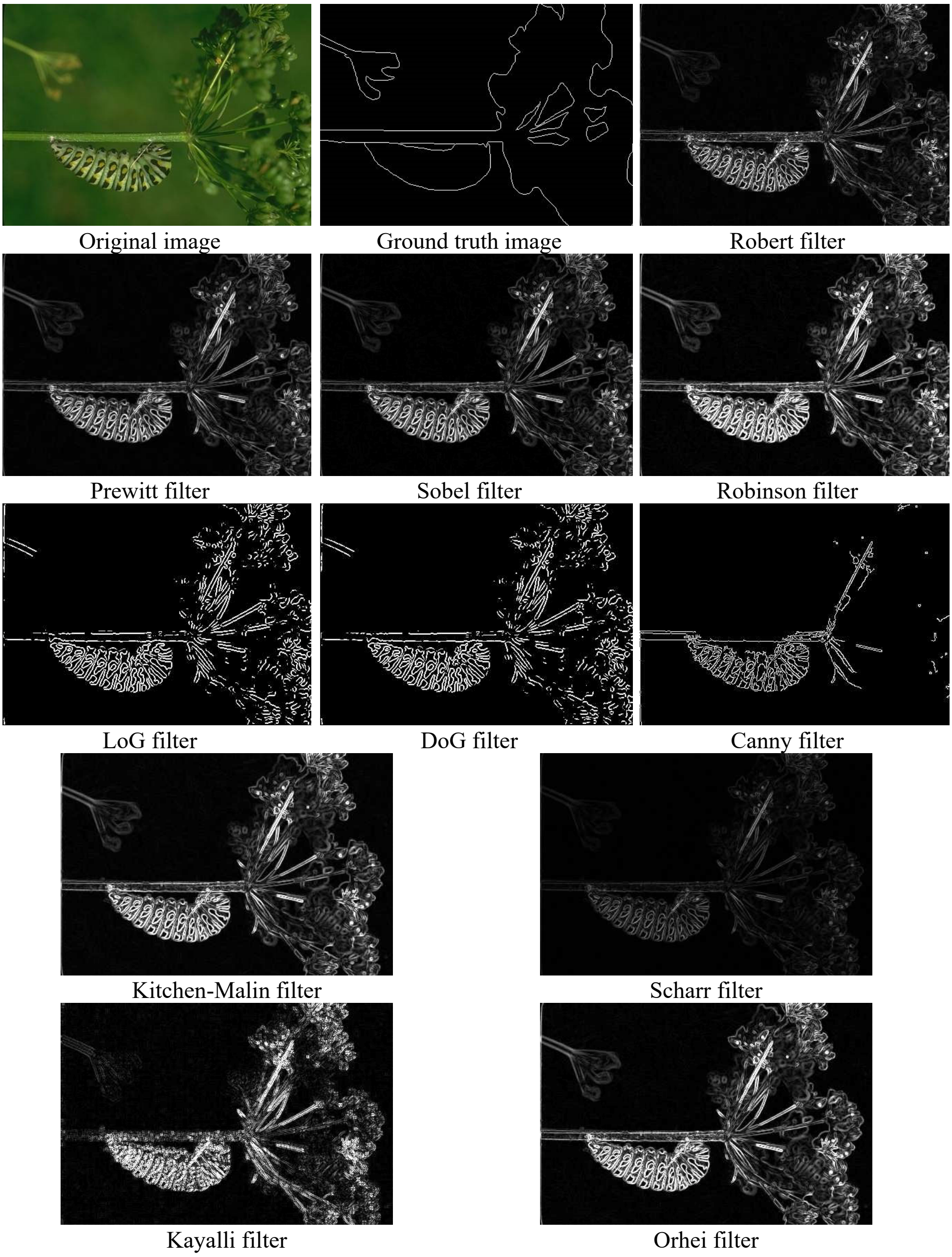

Fig. 2. Samples of the original image and the image with the filter applied.

The results obtained from the application of filters were evaluated by formula (2) and the average values of the evaluation were determined, the obtained results are presented in Table 2.

Table 2. Results of applying filters.

Filter name	Average values of filters (2) by formula %				
	T_o^1	T_o^2	T_o^3	T_o^4	T_o^5
Robert [8]	41.86	36.21	26.35	14.92	13.48
Prewitt [9]	42.35	39.59	36.01	20.91	18.07
Sobel [10]	45.93	44.19	**42.51**	22.01	14.13
Robinson [11]	46.22	39.05	35.10	21.56	17.07
LoG [12]	35.65	35.94	34.30	**26.95**	18.01
DoG [13]	41.56	36.37	34.61	26.79	19.64
Canny [14]	27.57	18.10	24.15	21.94	18.26
Kitchen-Malin [15]	63.65	35.73	33.70	22.31	**19.66**
Scharr [16]	**82.65**	42.91	29.99	17.85	16.62
Kayalli [17]	49.33	**55.92**	14.42	15.09	12.99
Orhei [18]	59.42	38.91	31.81	15.98	15.10
Maximum value	**82.65**	**55.92**	**42.51**	**26.95**	**19.66**

According to Table 2, it can be seen that the use of u_9 −Scharr filter for T_o^1 image set, u_{10} −Kayalli filter for T_o^2, u_3 −Sobel filter for T_o^3, LoG, DoG and Kitchen-Malin filter for T_o^4 image set are effective. However, for the T_o^3 and T_o^4 image sets in this study, the efficiency rate below 50% does not meet the requirements for image object contour separation. Therefore, it is recommended that these images be pre-processed. It can be seen that the accuracy is extremely low in the T_o^5 image set. Therefore, for this category of images, the filters mentioned above do not provide the expected results.

The proposed approach was also tested on the satellite image dataset SIRI_WHU_Dataset. The number of satellite image samples is 73. However, there are no expert images of their outline. The set of satellite images was first evaluated according to the BRISQUE criterion, and then an appropriate object contour separation filter was applied depending on the value of this criterion. Sample images obtained by applying the filters to a set of satellite images are shown in the Figure below (Figure 3).

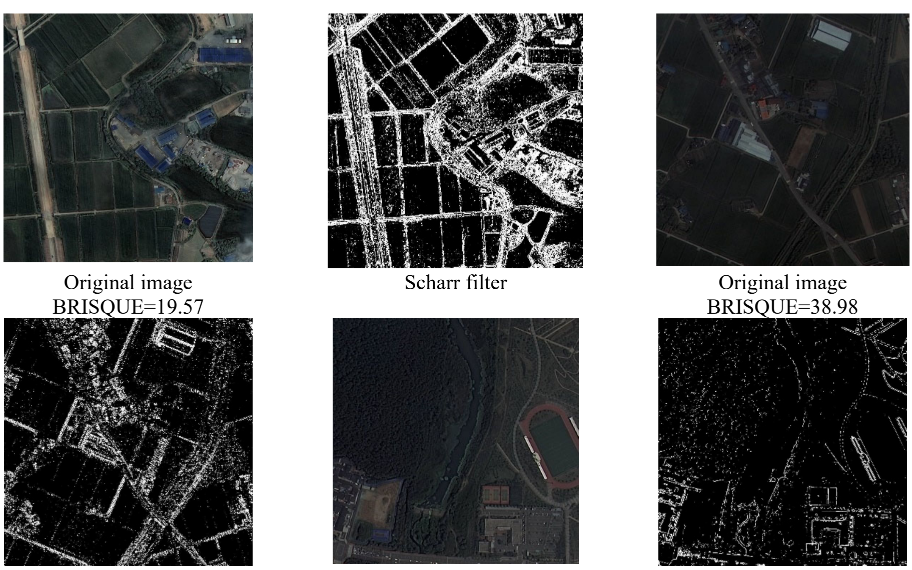

Fig. 3. Results of applying filters to a satellite image.

The obtained results showed that the application of contour separation filter corresponding to the set of satellite images according to the BRISQUE value is effective in separating the contours of field areas.

4 Conclusion

Automation of satellite image processing allows to obtain fast and reliable information about cultivated areas and their types of crops in agriculture. However, the large number of images and the large size of satellite image sets complicate data analysis. In order to reduce the amount of processed data, it is necessary to use contour separation of image objects. Therefore, in this research, the issue of object contour detection during image processing is studied. In this, a total of 11 filters were used in the calculation experiment. Initially, the experiments were carried out on the BSDS500 image database with contour images separated by an expert. All filters selected for the obtained images were tested. The image contour created as a result of the applied filters was evaluated by an expert in terms of pixel compatibility with the extracted contour image. Based on the results of computational experiments, the following rule was developed to apply the appropriate contour separation method based on the BRISQUE value for image quality assessment:

- if $0 < B_r < 21$, then the Scharr filter is used to separate the contours of image objects;
- if $21 \leq B_r < 41$, then the Kayalli filter is used to separate the contours of image objects;
- if $41 \leq B_r < 61$, then the Sobel filter is used to separate the contours of image objects, or the image is re-sent to the preprocessing process;
- if $61 \leq B_r < 81$, then one of the Kitchen-Malin, DoG or LoG filters is used to separate the contours of the image objects, or the image is sent to the preprocessing process;
- -if $81 \leq B_r < 100$, then the given methods for extracting contours of image objects are ineffective.

The above proposed approach has also been tested for a set of satellite images. The obtained results showed that the application of the proposed approach in satellite images provides a more complete coverage of field contours.

The above-mentioned methods of delineation of image objects are important in automating the analysis of satellite image sets, allowing field experts to quickly obtain valuable information for cropland monitoring.

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