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Applying Second Order Least Square Regression Technology to Estimate Region Area

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Abstract. *A new method which is applied to estimate the area of region by using least square technology is proposed in this paper. The original image is captured by an unmanned aerial vehicle (UAV) and then applying image processing technology to do the preliminary image procedure. Based on the number pixels of the measurement region, the system can estimate its area. However, the height of UAV is hard to control in different place, therefore, the size of captured images will have a little different. It will cause some errors of the total pixels of image. In this paper, the second order least square regression technology is applied to modify this problem. Before the estimation procedure, an UAV is used to get many images of region area for training this algorithm. It captures a group of images for the same area from different height by every ten meters. In image processing process, edge detection and morphology are used to find the range of the interest region, and then count the number of pixels of it. Based on the experimental results, the proposed algorithm can estimate one unknown area accurately.*

Keywords: Least square technology, Unmanned aerial vehicle, Area estimation, Image processing

1. **Introduction.** The traditional method of measuring land area is using spacing gauge or distance measuring equipment to calculate the area by manual. The traditional measurement methods are convenient, but there are some limits such as the weather condition, the shape of place, terrain effects, etc. The science is made good progress now, therefore there are some methods can greatly improve the efficiency of the measurement. For example, there are aerial photogrammetry, global positioning system (GPS) measurement, and sputnik photo. If we use aerial photogrammetry or GPS measurement, that can save manpower and time. Remotely piloted vehicles (RPV) [1-3] have been actively developed and used in recent years. Some advanced countries have applied them to military aspects, such as enemy position detection and coastal investigation monitoring.

There are many applications in the non-government institution also, such as the exploration of urban development, road traffic analysis, and disaster area relief investigation. For example, some researchers used the unmanned aerial vehicle (UAV) to monitor the area of mangrove forest recently, the crop area estimation from UAV transect and MSR image data using spatial sampling method, and evaluating the uncertainty of area estimates derived from fuzzy land-cover classification are investigated in [10-11]. The main advantage of using unmanned aerial vehicle to capture images is less susceptible to terrain. It can accord user's operation to capture from various angles and heights to obtain more diversified information. Compared with the traditional methods, the user can remotely control unmanned aerial vehicle in a safe place to capture image of the dangerous area, and get the information of the area effectively.

In this study, an image method is applied to estimate the area of region by using lease squire regression technology is proposed. The system uses the original image of place captured by UAV, and then applies image processing technology to measure its area. The height of UAV is hard to control when it captures the images. So, the size of images will have a little difference, and the total pixels of image will have some difference, which may cause the measurement errors. In this paper, the second order least square regression technology is applied to modify this problem. Before the estimation procedure, an UAV is used to get many images of region area for training this algorithm. It captures a group of images for the same area from different height by every ten meters. In image processing process, edge detection and morphology are used to find the range of the interest region, and then count the number of pixels of it. The area of land can be estimated by this algorithm accurately.

The land area is often affected by the land boundary, which will have estimation error comparing with the actually area. For example, in order to estimate the farm area, growth area and production capacity will affect the estimation results. If the method can calculate the actual area of planting area, it will be able to more accurately estimate the production of each crop. If the unmanned aerial vehicle can be used to estimate the land area, the estimation result will be more accurate. But the unmanned aerial vehicle can only be estimated at a fixed height and the height is usually with some vibration which is hard to control. This paper proposes an accurate method to measure a region area of field by using aerial images. The method uses the UAV to collect the image of the grass ground area in each height interval and use the image processing to calculate the connected region pixels in the region of interest. That will obtain the relation of different height and pixels of the real area. The least squares regression line can be derived by using this data so that we can estimate the unknown region area of field if we know the height of the aerial image.

This study proposes to use unmanned aerial vehicle to capture multiple sets of aerial images, and collect images ranging from 70 to 120 m height. Every 10 meters collects 50 groups at same height and same area of the regional image. The system uses the lens distortion normalization and select the region of interest to be processed. Through the color component conversion of the original input RGB color image is converted to gray Intensity image, histogram equalization and edge detection [4-7]. After the number of pixels in the acquisition area, we can get the relation between the different height and pixels of the real area. The distribution of the relationship is obtained according to the height. In order to estimate the distribution of each set of relational data, the second order least square method is proposed to find the regression line. The comparison experimental results by using other approach are also conducted.

2. **Image Processing Technology.** General image usually uses RGB color space. If it directly processes of this image, it needs to spend a lot of computing time. So the system will convert RGB color image to grayscale image and then conduct the image process. Another problem, the image using RGB color system is easy influenced by shadow or ambient illumination changes. In this paper, the HSV color system is proposed, which

can reduce these influence. HSV color space [6-7] contains three components, in which H represents the hue, S represents the saturation, and V represents the brightness. The hue element usually thinks of as color like red, green or others. The saturation is the ratio of colorfulness to brightness which is just gray scale. The value is for color lightness like the light green or dark green. After applying the color space conversion algorithm, the system obtains a relative image with reference background. The image contains RGB or HSV three components, which will increase the computation burden. Therefore, it will do binarization process and let the picture become a gray image. The grayscale image uses a non-linear scale of 8 bits for each pixel, and each pixel is represented by a value from 0 to 255 to represent the changing pixel between black and white, where 0 is black and 255 is white. It can reduce two-thirds of the amount of information, so it can significantly reduce the computation time of image operations. The conversion formula is shown in equation (1)

$$Y = 0.299R + 0.587G + 0.114B \tag{1}$$

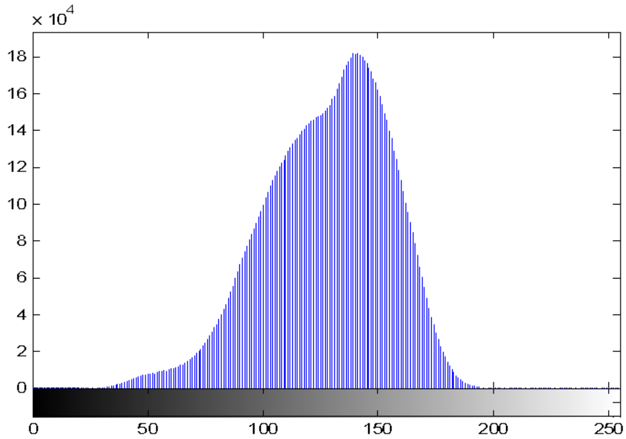
R, G, and B represent red, green and blue components of the pixels in the RGB color image. Y is the gray scale value of image pixel. After the image is become grayscale, the environmental factors will lead to different image quality, especially in the outdoor image. The image enhancement is used to solve this problem, which involves histogram equalization and edge sharpening processing [8-9, 12-13]. The results obtained by equalizing the histogram, it can be observed that the histogram distribution is more evenly distributed between 0 and 255 grayscale intensity. The image is more obvious than the original gray scale image, and the contrast and brightness are significantly improved.

Histogram equalization using the probability distribution makes the grayscale image brightness equalize to the new brightness value. For example, if the original histogram distribution of an image is narrower such as low contrast image, the system uses the program to make its distribution of the gray scale of the luminance become uniform. Then the image is become high contrast and the brightness of is increased. The bright part is also reduced its brightness and makes the image more clearly. Through the histogram equalization, it can make the subsequent image processing program more accurate. Figure 1 (a) is the original grayscale image and Figure 1 (b) is its histogram distribution. The horizontal axis of the histogram represents the gray value of the pixel intensity and the vertical axis is the number of pixels. According to the histogram distribution, the grayscale pixel distribution is relatively uneven, so the overall image is dark. Therefore, the image features are not clear. Figure 2 shows the results obtained by equalizing the histogram. Compared with Figure 1 (b), it can be observed that the histogram distribution is more evenly distributed between 0 and 255 grayscale intensity. The image is more clearly than the original gray scale image and the contrast and brightness are significantly improved. The image features shown in Figure 2 are more suitable for following process.

After the histogram is equalized, the contrast of the image is obviously increased. The results of the following edge detection need more accurate, so the image needs further edge enhancement process. In this paper, the Un-sharp Masking method [4-6] is applied in edge sharpening to enhance the edge. The concept is to subtract a fuzzy image from the original image to adjust the numerical scale, Therefore, the output image will become clearer and to achieve the edge of the enhanced effect. It can improve the accuracy of the following process. Figure 3 shows the original input image and edge enhancement image. The edge-enhanced image is clearer in this Figure.

The purpose of edge detection is to detect the point where the most obviously brightness changes in the image. They are usually the boundary of the object and the background. The gray scale image converted by the original image contains many irrelevant background

(a)



(b)

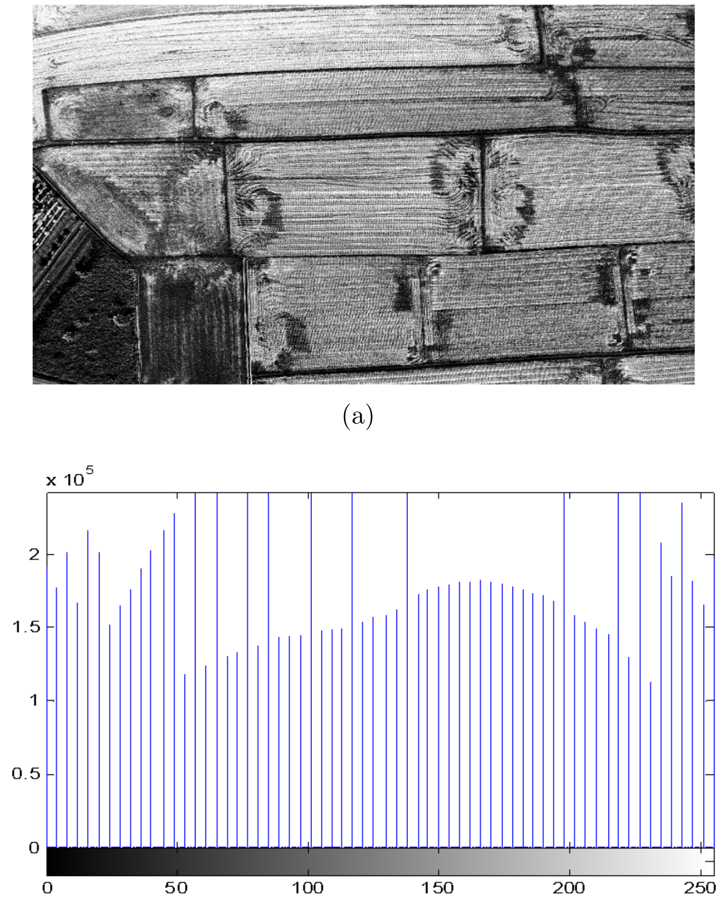
FIGURE 1. (a)Original grayscale image, (b)Histogram distribution

noise. The edge detection method can be used to detect if it is possible to detect the location of the block. Common edge detection methods include Sobel edge detection, Prewitt edge detection, and Canny edge detection method. The principle of the image based on the size of the gray scale difference and gradient degree of change determines the greater gap on behalf of its neighboring pixels. There are more obvious bright and dark changes. These positions are usually the object and the background of the border, so you can use this principle to detect the image of the edge of the object. In this paper, the Canny edge detection method is used to detect the edge of the block. The steps are to filter out the noise by using a 3 * 3 Gaussian filter, and then calculate the lateral and longitudinal differential approximation for each pixel. The gradient size and direction are shown in equation (2). Following by non-maximum suppression of the gradient is shown in equation (3). The purpose of this step is to make the blurred boundary clearer. According to this method, the edge component in the image can be detected.

$$G = \sqrt{G_x^2 + G_y^2} \tag{2}$$

$$\Theta = \arctan\left(\frac{G_y}{G_x}\right) \tag{3}$$

Morphology [7-9] processing is often used in target detection, noise removal, block segmentation, and skeleton boundary capture. The principle is based on the mathematical theory of the collection. The operation is to use mask in the image of the pixels as a shift



(a)

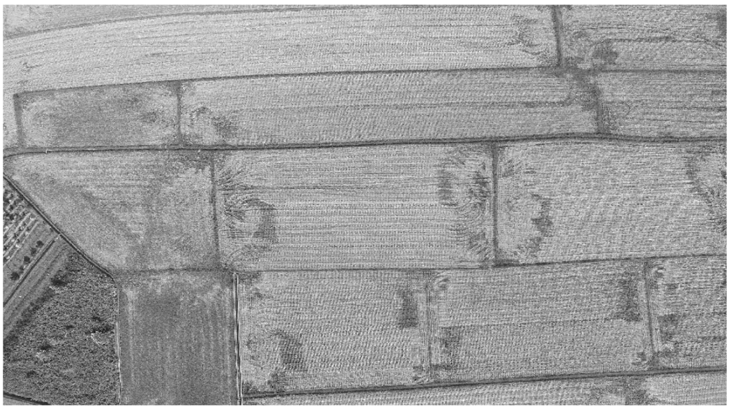
(b)

FIGURE 2. (a)Equilibrated grayscale image after equilibrated process, (b)Histogram distribution after equilibrated process

operation. This mask is also known as the structural element. The user can set the size and shape of the structural element. According to different morphological algorithms, different treatments are made to achieve image segmentation and recognition purposes. The basic operations are erosion, dilation, opening and closing. Many of the applications of morphology can be deduced based on these basic operations to perform advanced image processing. In addition, applying morphology to image processing which can simplify image data and maintains the basic outline of the graph.

3. **Experimental Results.** The images used in this experiment are captured by an unmanned aerial camera. In this experiment, a surface land area is selected to be estimated. The area of the crops grown in the area cannot be obtained correctly because the land is divided by the boundary. In order to do the comparison, the area of the crop is measured by the range wheel first. Based on the measurement, the real area is 1760 square kilometers. Then the unmanned aerial vehicle is used to collect the images, and the image processing technology is applied to obtain the land image. The region of interesting (ROI) is set to be the expected estimation area. Then the number of pixels can be calculated. Based on the preliminary results, the land area can be obtained. In order to obtain more accurate estimation result, the second-order least square regression algorithm is applied. Figure 4 (a) shows the original image of the expected estimating land, and Figure 4 (b) is the area of interesting to be estimated.

(a)



(b)

FIGURE 3. (a)Original input image, (b)Edge-enhanced image

After calculating the number of pixels in each image, we can get the relationship between the height and the number of pixels representing the actual area. As shown in Figure 5, the horizontal axis is the height and the vertical axis is the ratio of actual area to the pixel number. Since the distribution of each set of relational data is nonlinear, the least square method is proposed in this study. Using the least square method, the error of the estimation can be reduced. The equation of second order least square line is shown in Eq. (4)

$$y = a_0 + a_1 x + a_2 x^2 \tag{4}$$

Where y corresponds to the ratio of the area to the number of pixels, x is the height of UAV, which are defined as follows:

$$Y = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix}, X = \begin{bmatrix} 1 & x_1 & x_1^2 \\ 1 & x_2 & x_2^2 \\ \vdots & \vdots & \vdots \\ 1 & x_n & x_n^2 \end{bmatrix}, A = \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} \tag{5}$$

Then apply the following formula to obtain the equation of regression line.

$$A = \left(X^T X\right)^{-1} X^T Y \tag{6}$$

In this research, images of ranging from 70 to 120 m height are collected. Fifty regional images of the same area at same height are collected for each 10 meters. Through the image processing, the number of pixels for detection area is obtained. After the number

(a)

(b)

Figure 4. (a)Original input image, (b)Edge-enhanced image

Table 1. Estimation result using the proposed method

Real area	Average estimation error	Average percentage error
1760 m^2	22.8 m^2	1.30%

of pixels in the acquisition area, we can get the relation between the different height and pixels of the real area. In order to estimate the distribution of each set of relational data, the second order least square method is proposed to find the regression line. The principle of the least square regression line can be used in Eq. (4) to calculate the sum of the value, and then get the regression line equation. The second-order least square regression line is shown in Figure 5.

Based on equations (4) to (6), the equation of regression line can be obtained. In the experiment, the regression line equation is used to estimate the area of the specific area at different heights. In this experiment, the height of UAV is set to be 100 m high. The estimation result of land area by using the second order least square regression line method is shown in Table 1.

The comparison with other approaches which are without using the least square regression line and using first order least square method is shown in Table 2. Based on the experimental results, using the proposed method can estimate the region more accurately.

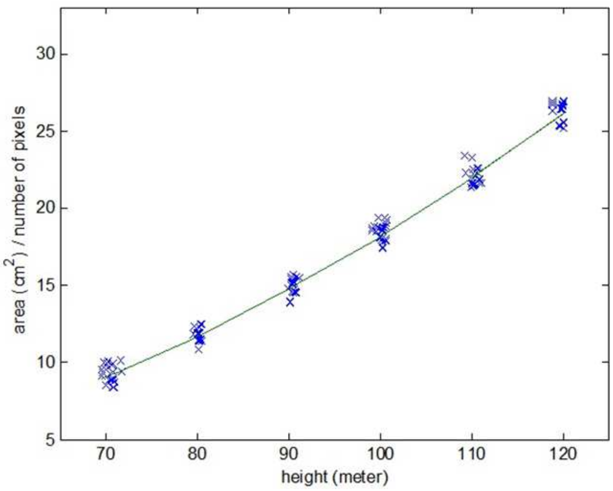


FIGURE 5. The regression line of relationship between the number of pixels and the area

Other algorithm	Average estimation error	Average percentage error
Without regression line	116.1 m^2	6.59%
Using first order regression line	61.2 m^2	3.48%

4. **Conclusion.** In this paper, an image processing technology is proposed to estimate the land area. Firstly, the image information is collected by UAV, and the area of the region can be estimated by image processing algorithm. The image processing technology includes that color space transformation, image enhancement, edge detection, and morphology. In order to obtain more accurate estimation, the second order least squares regression algorithm is proposed in this paper. After training the second order regression line which can be used to estimate other unknown area. Therefore, the proposed algorithm has the advantages which are simple system design, convenience and low cost. Based on the experimental results, the average estimation error is about 1.3% by using the proposed in this study, which is better than other algorithm's.

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