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A Primary Study on Gully Erosion Area Estimation Based on Images

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Abstract: We propose in this paper an approach for image-based gully area estimation. Given an image of a real gully, our goal is to automatically detect gully and measure its area. The main challenge in developing such tool is the lack of camera calibration information for the images. In this research, we have presented a novel approach for gully area estimation. A reference with known area was used in gully area estimation instead of camera calibration, which makes it easier to carry out in the outside gully measurement. The image processing algorithm including segmentation, filtering, edge detection and morphological processing was applied in gully identification. The proposed method was evaluated in the experiment environment. The relative error of the estimation is an average of 2.78%. We also give an example of actual gully detection and gully area estimation using this method, which shows that the method is practical and simple. Thus, it will enable to perform real gully area estimation.

Keywords: *Gully erosion, gully erosion area estimation, image processing*

1. Introduction

Gully erosion is one of the most important types of water erosion, one form of accelerated soil erosion and the occurrence of gullies indicates an extreme form of land degradation. In order to determine the environmental impact of erosion and conservation practices, design viable gully control or rehabilitation measures, and development and evaluation of erosion control technology, dynamics monitoring of the gully erosion is crucial.

Gully erosion monitoring methods can be summarized as direct and indirect measurement methods [1]. Traditional tape and erosion pin monitoring are kinds of direct method. Traditional tape monitoring method uses tape to measure the intersection surface parameters of gully erosion such as gully length and the various shape parameters along the gully erosion every certain distance in different time, so that the volume of erosion gully can be calculated, the volume changes along with time is used to determine the rate of soil erosion of gully erosion. This method is in lower cost but is time-consuming, the error is also uncertain. Traditional erosion pin is wildly used for soil erosion monitoring in the development and construction projects. Erosion pins can be implanted in the soil; soil removal can then be determined by frequently measuring the distance from the top of the pin to surface. An increase in distance corresponds to erosion. This method is simple and easy to use. The accuracy compared with the tape measurement is more security. The disadvantage is that the position where the erosion pins are plugged in is prone to collapse or instability. It's easy to lose the monitoring data [2][3]. 3D laser scanning and vision measurement are types of indirect measurement method. 3D laser scanning can get high precision, reflect the surface morphology. But some reasons such as the higher cost of 3D laser scanner, a stable place and visible topography required for the scanner, and the erosion environment restrict the use of the scanner [4][5][6].Vision measurement includes remote sensing monitoring method and GPS monitoring method. Remote sensing monitoring method is widely used in recent years. The different volume of gully erosion is achieved from the remote sensing image interpretation in different periods, then the erosion rate can be gained by subtracting the gully erosion volume from different period. Although remote sensing has the advantage of short –cycle data acquisition, long-term monitoring and higher precision measurement, but compared to other indoor measurement technology, it requires high technology and must cooperate with professional software [7].

GPS technology is a rapid and efficient means for gully erosion research. GPS can position the monitoring point quickly and accurately, determine the geomorphic parameters and extract the regional DEM monitoring information in order to obtain the erosion gully volume. GPS monitoring can obtain high spatial resolution DEM, and plays an important role in gully erosion research [8][9][10]. 3D reconstruction based on images are widely used in computer vision, robotics mapping and medical area [11], but to date, this technology have rarely been used in gully erosion monitoring, some studies are testing and exploring the possibility of these technology in recording of gully morphology [12], estimate gully headcut erosion [13], Measuring 3D coastal change [14], erosion measurement in agricultural fields [15]. A general conclusion of these studies is that it can get similar accuracy to some accurate methods, but more work needs to be done in order to analyze the performance of these techniques. Also this technology needs camera calibration to solve camera model parameters and scene geometry simultaneously, which is difficult to do sometimes.

This study applied this technology to the gully erosion monitoring, but a reference is used in the measurement instead of camera calibration. The method is easily used to outside gully erosion measurement. This method has the advantage of higher precision than the traditional direct measurement methods and lower cost than laser scanning and other modern indirect measurement methods. In this paper, we present our initial research on gully area estimation based on images with a reference, we'll do the 3D measurement of gully erosion later on.

2. Method:

The image-based measurement methods usually need a digital camera calibration in order to calculate its real value. As gully erosion measurement in real environment is very complex, it's difficult to do the camera calibration, thereby we used a reference with a known size instead of camera calibration, which makes it more convenient to be applied in real measurement of gully erosion. The flow chart in Figure 1 shows the proposed image-based gully area measurement method mainly including image acquisition, image processing and real gully area calculation.

2.1 Image Acquisition:

The images of gully erosion can be taken by a common digital camera. Canon EOS 600D and Sony DSC-F717 were used in our experiments. Some images were taken using Sony DSC-F717 with an 850nm infrared filter, which makes the background gray value to be controlled in a certain range, and reduce the difficulty of further image processing. The gully erosion images were taken in natural light in order to ensure the picture with enough contrast and brightness. In order to calculate the area of the gully erosion, a 9 cm^2 squire paper and a toy car were used as a reference instead of camera calibration in the experiment for small size gully erosion measurement; well a car, a lane line or other object with a known size were used as a reference for larger scale gully measurement or real gully erosion measurement, as shown in figure1A, the lane line (the white line) was used as a reference of the measurement.

2.2 Image Processing:

Image processing is to detect the gully erosion and reference in the image including segmentation, filtering, edge detection and morphological processing.

Segmentation: In order to separate the gully erosion from the background in the image, image histogram analysis was used for the gully erosion subtraction. The background was suppressed by setting all the pixels in three color panels that have a value lower than a given value (e.g. for the image in figure 1A: 75 was set for both Red and Green panel, and 70 for Blue panel) resulted in a binary image with only the gully erosion (see figure1B for the segmentation result of figure 1A).

Filtering: After segmentation, there are still some noises in the image. The median filter was used to reduce the noises. The median filter replaces the pixel value with the median of those neighbor values. The median is calculated by first sorting all the pixel values from the surrounding neighborhood into numerical order and then replacing the pixel being considered with the middle pixel value. (If the neighborhood under consideration contains an even number of pixels, the average of the two middle pixel values is used.) Figure 1C illustrates the filtering result of figure1B.

Edge detection: Candy method was used to find the edge of gully erosion in this study. The Canny method finds edges by looking for local maxima of the gradient of image. The gradient is calculated using the derivative of a Gaussian filter. The method uses two thresholds, to detect strong and weak edges. This method is therefore less likely than the others to be "fooled" by noise, and more likely to detect true weak edges. Figure1D shows the result of edge detection for figure1C.

Morphological processing: Since the detected edge is usually discontinuous, the morphological dilation method was first applied on image to close the edge; as dilation method makes the edge wider, the erosion method was then used after region filling in order to get a correct edge; finally, the regions are labeled and the area was calculated by pixel. An example of morphological processing result is shown in figure 1E.

The same procedure was used to reference detection, Figure 1F-I show the corresponding result of the image processing for the reference (a white lane line) in figure 1A.

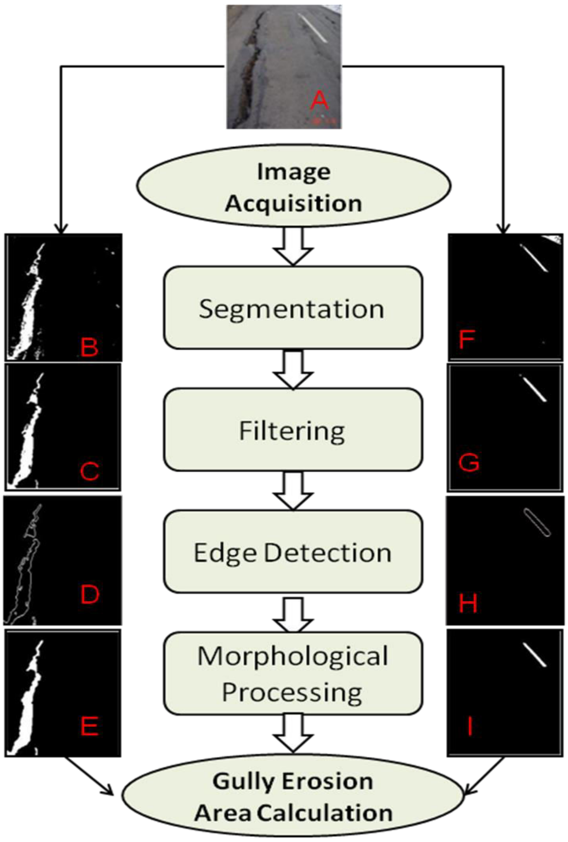


Figure1: Gully erosion measurement method:*(A)the original image ;(B) segmentation of the gully;(C) remove noise with median filter; (D) edge detection;(E)gully area identification; (F) segmentation of the reference (the white lane line);(G) remove noise with median filter; (H) edge detection of the reference;(I) reference area identification*

2.3 Real Gully Erosion Area Calculation:

After image processing, the area of the gully erosion and the reference can be calculated by pixels, and the real area of the erosion can further be computed according the formula (1);

$$S = P \times \frac{S_r}{P_r} \qquad (1)$$

Where S is the real area of gully erosion, Sr is the area of reference; P is the pixel area of gully erosion in the image. Pr is the pixel area of the reference in the same image.

3. Experiments and Results:

Whether the proposed gully erosion area estimation method can be used in real gully measurement or not, the key task is to prove the accuracy of measurement and gully identification principally, accuracy evaluation should be done on real gully area estimation. Because it's difficult to get real gully data for the evaluation, therefore, in this research, we first applied the proposed method in the experiment environment to do the accuracy estimation, then the real gully images were used to verify the performance of our image processing algorithm on the real gully identification. Finally, an example was used to demonstrate how to use our proposed method to estimate the area of a real gully.

Figure 2: *Experiments for gully erosion measurement: the area within the red line was simulated as the gully area in the experiment, and the black car was used as a reference.*

3.1 Accuracy Evaluation of Erosion Area Estimation:

The relative error was used in the evaluation calculated as the formula (2);

$$\varepsilon_r = \frac{M - R}{R} \qquad (2)$$

Where M is measurement area of gully erosion which was computed according to formula (1), R is the real area of gully erosion which was calculated by use of graph paper (for small size) or tape measuring (for larger scale) manually, and ε_r is the relative error.

For small size gully erosion measurement, the gully erosion was manmade by simulating the formation mechanism of the nature gully erosion. A 9 cm2 squire paper was first used as a reference instead of camera calibration. As a car may be possible seen in a scene of real gully erosion measurement, therefore toy cars were also used as a reference in the experiments in order to show the practicability of using a car as a reference in real gully erosion measurements. Because there is no real gully erosion data for the accuracy evaluation at the moment, and it's difficult to find a large gully erosion near the city, a lawn with a known size was simulated as an erosion area as shown the area with red mark line in figure 2, where the black car in the figure was used as the reference for the calculation.

Table1 shows the performance of the proposed method with a comparison to manually measurement. The table has clearly demonstrated that the proposed method can get a higher accuracy the average relative error <3%) for small erosion area estimation. For larger scale area, it's also possible to apply the proposed method to do the estimation.

Table 1: *Accuracy evaluation of erosion measurement*

No.	**Measurement area of erosion** （cm^2）	**Real area of erosion** （cm^2）	**Relative error** (%)
1	33.85	34.93	3.19
2	34.35	35.23	2.60
3	27.37	28.15	2.78
4	26.85	27.53	2.53
5	23.96	24.86	3.76
6	884.63	907.78	2.55
7	8.92	8.57	4.11
8	7.37	7.20	2.43
9	11.98	11.85	1.05
10	9.13	8.87	2.93
11	9.32	9.58	2.68
12	50810	52180	2.70
		Average error =	2.78

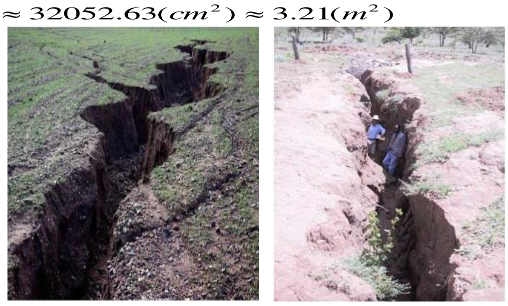
3.2 Real Gully Identification:

In figure 3, we demonstrate our image processing algorithm on real gully identification. Figure 3a-d give the original gully images taken from internet, the corresponding processing results were shown in figure 3e-h respectively according to the image processing algorithm mentioned in section 2.2. The gully can be then identified according to the area in white; their pixel area can also be obtained just counting the number of white pixels. The identification results clearly show the efficiency of our proposed imaging processing method.

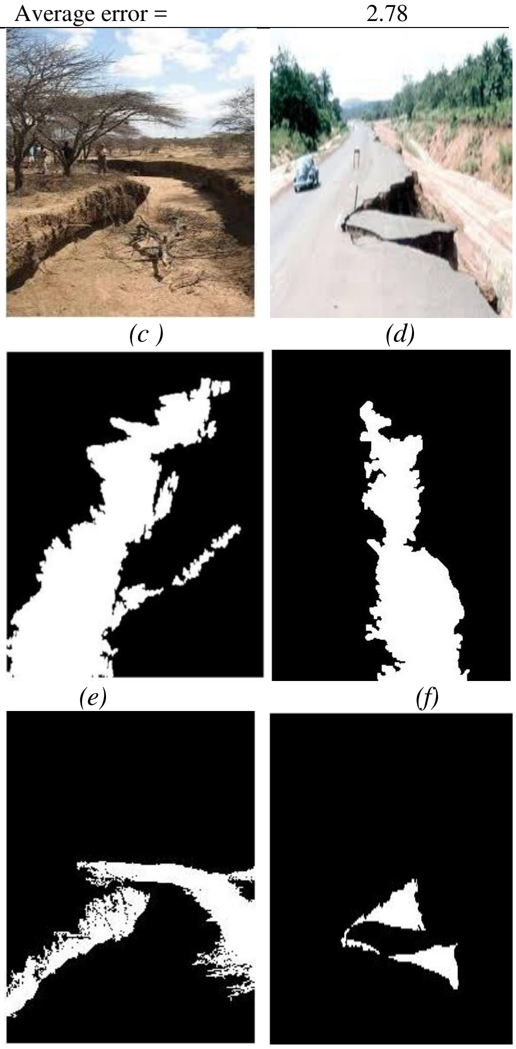
3.3 Example of Real Gully Area Estimation:

Figure 1 shows an example of real gully area estimation. Figure 1A is an image of gully erosion in a road provided by School of Soil and Water Conservation, Beijing Forestry University. There was no any camera calibration information for this image, so we took the white line in the image as a reference, which is a standard white label line with the size of 200cm×15cm. We first applied the image processing algorithm mentioned in section 2.2 on the image to identify the gully and the white line (seen in figure 1I); then their pixel area can be calculated by counting the number of pixels in white area in figure1E, 1I, the pixels area for the gully erosion and the white line are 2436 and 228 respectively; the real area of the gully erosion in the image can be finally estimated based on formula (1) as the following:

$$S = \frac{2436 \times 15 \times 200}{228} \approx 32052.63(cm^2) \approx 3.21(m^2) \quad (3)$$



(a) *(b)*



(c) *(d)* *(e)* *(f)* *(g)* *(h)*

Figure3: Real gully identification: *(a-d) are the original gully images found on internet ;(e-h) are their corresponding gully detection results.*

4. Conclusion:

In this paper, we have presented a novel approach for gully area estimation using images. The proposed approach focuses on gully identification using image processing algorithm. It uses a simple reference with known size in the gully area estimation instead of complex camera calibration. The experimental results show that the proposed method can get a certain accuracy (the relative error is less than 3%) in gully area estimation. The image processing results also show the effective detection of gully in real gully images, thus we believe that the proposed method is able to be used to estimate the real gully area. In the near future, we will evaluate this method for real gully measurements.

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