Application of An Improved Canny Algorithms Operator in RS Data

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Abstract. When we deploy the seismic line, the data received by seismometer will be affected by ground water bodies. Therefore, we need to extract water bodies by remote sensing image before deploy the seismic line. In this paper, an approach is proposed to extract water bodies. First, use Canny edge detector to extract the edges of the image. Second, based on three features of water body: gray-scale uniformity, edge irregularity and closed regions, this paper uses three means: dual-threshold judgment by gray-scale uniformity, edge irregularity verification based on least square method and closed region verification. During the extraction of water bodies in mountain regions which the topography was complicated, this approach proved to be fairly effective. And the deployment of seismic line was facilitated by this approach.

1. Introduction

Seismic exploration is a major method in petroleum exploration. In the beginning of seismic exploration, the shot points must be located by deploying seismic lines. However, the data received by seismometer will be affected by ground water bodies. So in order to improve the quality of geological data, water bodies need to be extracted. The traditional ways mainly use field exploration and artificial identification, which are time-consuming and exhausting[1]. With the rapid development of remote sensing, we can use remote sensing image to recognize obstructions such as water bodies because it has the feature of comprehensive, macroscopic and intuition[2]. Recently many experts extract water bodies in remote sensing images using band operation. It is because the reflectivity of water bodies in remote sensing image increased sharply in infrared bands. The major researchers are Shih who used Landsat MSS band 7 to extract water bodies[3]. Barton who used AVHRR band 4 to extract water bodies[4]. Lu Jiaju chose TM band 5 to recognize water bodies[5]. Then Mcfeeters proposed normalized difference water index (NDWI) to recognize water[6]. Though these approaches are simple and easy to implement, they rely on multi-spectral images and can’t extract water bodies from optical images. It also has limitations in accuracy and generality and may bring non-water confusion. In this paper, based on the features of water body, we use the Canny detector to extract edge and use dual-threshold judgment by gray-scale uniformity, edge irregularity verification based on least square method and closed region verification to extract water bodies. It has been proved to be fairly effective and accurate.
2. Extract edge using Canny edge detector
Canny edge detector was introduced by John Canny in 1986[7]. He proposed three criteria in detecting edges. First, good detection. There should be a low probability of failing to mark real edge points, and low probability of falsely marking nonedge points. Second, good localization. The points marked as edge points by the operator should be as close as possible to the center of true edge. Last, only one response to a single edge. That is to suppress the false edge. It means that when there are two responses to the same edge, one of them must be considered false.

2.1. Gauss filter
This step is to use Gauss filter to reduce noise. The smooth function of Gauss filter utilize the Gauss function of normal distribution: 
\[ h(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2 + y^2}{2\sigma^2}} \]
\( \sigma \) is the parameter of Gauss filter, controlling the smooth and the denoising level.

2.2. Determine gradient magnitude and gradient direction at each pixel
Calculate each pixel’s derivative at x direction and y direction. Then we calculate the two values’ sum of squares. We call the result gradient magnitude. We can also calculate the orientation of this pixel’s gradient by computing the two values arctangents.

2.3. Non-local maximum suppression
This step is mainly to remove the non-local maximum point of the image. If the gradient magnitude at a pixel is larger than those at its two neighbors in the gradient direction, mark the pixel as an edge candidate because it is a local maximum pixel. Otherwise, mark the pixel as the background.

2.4. Detect edges using dual-threshold
Traverse the image which has been processed by non-local maximum suppression, statistic the gradient of local maximum pixel. According to the statistical results we divide the pixels into two thresholds by a certain proportion. And the two thresholds divide the pixel into three classifications, strong edge pixel, weak edge pixel and non-edge pixel. And we output the strong edge pixel which can be connected and the weak edge pixel which can connect to strong edge pixel as the edge of the image.

3. Water body extraction
Compared with traditional operators such as the Robert, Sobel, Laplacian and so on, the Canny edge detector works definitely better than other operators. For the further extraction of water body in an image, a new operator based on the Canny detector has been proposed. It takes the characters of water body in remote sensing image into consideration, which is Gray-scale uniformity, irregular edge of the water body, and the closure of water region. We can describe the new operator as follow:

3.1. Get the point set of water body that needed confirmation
- Dividing the remote sensing image into many sub-images with certain width and height, we operate each of those sub-images as follows:
  - Get the average grayscale and variance of the sub-image. If the variance is smaller than a certain high-threshold and the central point is not a edge point, then set the central point as a seed and develop an area around it to cover all non-edge points, mark them as area points; if the variance is bigger, then set all points on the sub-image as removed points.
  - Get the average grayscale and variance of the area points. If the variance of one area point is smaller than a certain low-threshold, set this point as a water body point needed confirmation, and set the edge point as the edge of the water body. Meanwhile, if the variance of one area point is bigger than a certain low-threshold, then set all the area points and edge points as removed points.
3.2. Group the edge line of the water body

- Traverse all of the edge points of the water body in the image, and track 8 area of each edge point. If a new edge point is found in one of those 8 area, then mark it and do another tracking based on it. Traversing will not stop until no new edge point will be found, and then line all those edge points, thus getting all of the edge lines.

- Traverse all of the line segments. For two different segments, find two points in one segment. If the distance between at least one point of the segment and the other line segment is smaller than a certain threshold, then group the two line segments.

3.3. Water body varification

- Get corner points of edge line. The process of getting a corner point is that of working out the curvature of point on the edge line. We can achieve it via several ways as follows: Firstly, we have all of the edge lines traversed. For each edge line, set the first point whose curvature is bigger than a set threshold as a corner point. Secondly, go on with detection of the points’ curvatures that follow up. Set the first point whose curvature is smaller than a set threshold as corner point as well. Then turn to step one. In a word, we try to set points, whose curvatures are bigger than a set threshold, of a serial of continuous two points, as corner points. It can be shown as figure 1:

- Fit a straight line via the Least Square method [8]. The Least Square method is one of the mathematic optimization techniques. It provides a best match of function to a serial of data by minimizing the squares of error. To get some unknown true values of points, the Least Square method simply minimizes the squares of error between the true values and values that been figured out. It is commonly used in curve fitting and can be described as follow. When we study the relationship between two variables named x and y, we can get a series of paired data (x1, y1), (x2, y2)…,(xm, ym). Then, we plot those points on the Cartesian coordinates. If those points are lie close to a line, we can get the equation of the line with the help of those points. Viding figure 2.

\[ \text{Figure 1. The corner point} \quad \text{Figure 2. The fitted line by LSM} \]

- Confirm the line segment threshold. What makes the water body different from village and farm is its irregular edge. For a regular image, the ratio of length of lines that fitted by the Least Square method to the total length of edge lines is very big. While for the water body that is irregular, the ratio is small. So, we set a ratio threshold, which helps keep the small ratio area and remove the big ratio area.

- Closed region verification: owing the area of a water body always get its boundary, we take four points of the boundary at the upper left, upper right, below left and below right. And so are another four points of the body. Then the latter four points will be validated weather they
are all contained in the boundary or not. If not, we eliminate this area, otherwise we keep it. And by now we have complete all the validations.

4. Result and conclusion
This approach extracts water bodies based on the Canny edge detector and three features of water bodies. This approach doesn’t rely on multi-spectral image compared with traditional approaches. So it is universal. And from the result, we can see almost all the water bodies are extracted, so it has fairly high accuracy. However, it also has defects because some edges of water body that extracted shrinked to the inside and some water bodies which edges are fuzzy can’t be extracted well, such as Fig. 6. This problem may because the Canny edge detector is not good enough in water body edge extraction, so the next step is to find the best edge detector in water body extraction or revise Canny edge detector to make it better.

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