

An Improved Elbows Detection Algorithm for Underwater Blurred Images

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Abstract—In order to reduce the influence of noise pollution, shadow, biofouling and disruptors on elbows detection failure rate, an underwater pipeline detection algorithm was proposed. To improve the detection accuracy of underwater pipeline, two aspects of research were presented. One is the improvement of edge detection method; a filtering method based on region saturation control was designed to filter out the edge feature of underwater interference. Another is a method of pipeline detection based on linear feature clustering, including the Hough transform and K-means clustering algorithm, which is used to deal with the binary image of pipeline when the pipeline detection failure appears. As a result, the detection accuracy of underwater pipeline detection proposed method is higher than that of traditional pipeline detection algorithm.

Keywords—pipeline detection; image processing; hough transform; k-means clustering

I. INTRODUCTION

The accident rate of underwater pipelines can be dramatically reduced by periodic inspection. Obviously, using the AUV to complete the pipeline external detection can significantly reduce cost and save time, and can also make the large-scale underwater pipeline tracking detection possible. So the way of underwater pipeline detection using AUV is therefore the most effective, economic, convenient and efficient way. Adopting AUV to recognize the detection and tracking of underwater pipeline is mainly equipped with detection equipment such as underwater camera, forward looking sonar for pipeline image acquisition etc. The underwater images are real-time processed by using computer, and the position information of the pipeline is computed by computer until the detection and tracking of the pipeline finally recognized. The underwater optical imaging equipped system for pipeline detection can analyze the state of the bare pipe to determine the extent of corrosion of the pipeline. Be quite different from the land, underwater optical imaging environment, including serious noise pollution, shadows, and biofouling disruptors, which has great influence on the pipeline recognition, pipeline detection method design [1-2].

Chen C proposed an underwater cable detection method based on Hough transform to obtain the deviation angle and the forecast of regional cable. However, the method can be easily affected by the environment and the cable surface deformation, and is only suitable for linear type cable [3]. University of Balearic Islands has recognized the recognition under different

angle, the image processing is shown as FIGURE I. The researchers used two-dimensional minimal-spanning tree method of image segmentation, and the Sobel operator was used to extract the image edge. The Kalman filter was used to determine the interest region of image, and the amount of computation was reduced. The detection accuracy can be maintained no less than 90% [4].

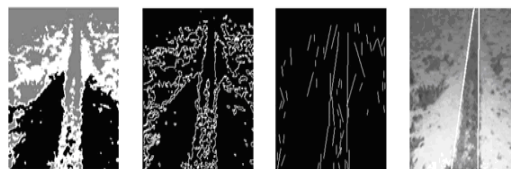


FIGURE I. THE PIPELINE IMAGE PROCESSING

II. METHOD

A. Underwater Pipeline Detection Process

As is shown in FIGURE II, there are five steps in the optical detection of underwater pipeline. Firstly, the images are collected by AUV equipped with the underwater camera. Secondly, image preprocessing of original image data filtering, enhancement, binarization processing, the goal of the pipeline from the image; the third step is to extract the pipeline feature in the image after segmentation, and the edge detection is generally performed using Hough transform. The fourth step is feature matching. The last step is to locate the pipeline. The pipeline position in the image can be obtained by coordinate transformation according to the relative position between the pipe and AUV. This paper mainly studies on the method of feature extraction and line matching.

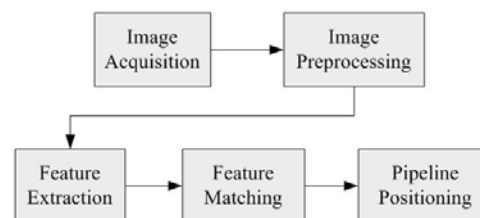


FIGURE II. FLOWCHART OF UNDERWATER PIPELINE DETECTION

B. Underwater Image Preprocessing Algorithm

The underwater pipeline image with strong noise, low

contrast is difficult for image pipeline characteristics extraction. So it is necessary to select a suitable image preprocessing method. Paper [5] detailed about the preprocessing method mentioned in this paper. In this paper, a median filter, a method including the image gray level and the neighborhood gray iterative optimal threshold segmentation and morphological processing was adopted for the image preprocessing, and the binary image of underwater pipeline was obtained. The underwater pipeline original image and preprocessed results are shown in Figure III and IV.

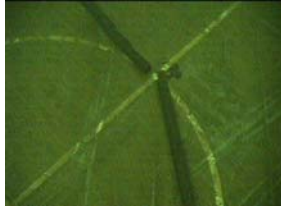


FIGURE III. ORIGINAL PIPELINE IMAGE



FIGURE IV. IMAGE PREPROCESSING RESULT

C. Edge Feature Filtering Method Based on Regional Saturation Control

The Canny operator edge detection method can be adopted to extract the edge features of pipeline, and the principle is described in detail in article [6] which are not explored in detail here. In the process of underwater pipeline image edge detection, edge pixels which belong to disruptors around pipeline can also be detected, therefore the wrong edges may lead to wrong Hough transform results, and result in error pipeline detection. In this paper, a method of edge feature extraction based on the region saturation control was proposed. The edge pixels of pipeline are arranged as a single line in FIGURE V. The edge pixels arrangement of disruptor is scattered and disordered. A closed curve definition of each pixel window surrounded is shown in FIGURE V:

$$Sat = \frac{S_e}{S_w} \quad (1)$$

$$\begin{cases} Sat \leq \delta \longrightarrow \text{pipeline} \\ Sat \geq \delta \longrightarrow \text{disruptor} \end{cases} \quad (2)$$

Sat here can be viewed as a saturation of the filter window, S_e is the area occupied by edge pixels, S_w is the area of window, δ is the threshold of saturation. The saturation of pipeline is smaller than disruptor, by setting the saturation threshold to distinguish if the edge pixel belongs to the pipeline or not. One

image can be divided into several windows with the same size; the calculation results that which window saturation exceeding the threshold will be filtered as the edge pixel of disruptor.

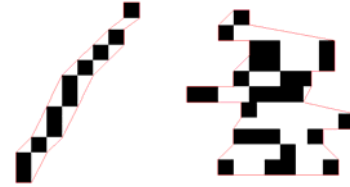


FIGURE V. EDGE PIXELS DISTRIBUTION OF PIPELINE AND DISRUPTOR

D. Pipeline Detection Method Based on Linear Feature Clustering

Due to the biofouling, corrosion and shadow of pipelines, the detected edge using the traditional pipeline detection algorithm based on linear feature extraction, is a series of points along the pipeline on both sides of the pipeline edge. Edge detection of pipeline loss linear feature information is easily leading to the wrong detection result. As a result, the edge points of the two pipes of elbows cannot be distinguished in the voting progress of Hough transform, which leads to the incensement rate of the elbows detection error.

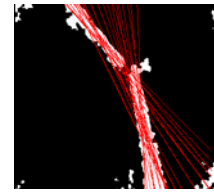


FIGURE VI. DETECTION LINES OF PIPELINE

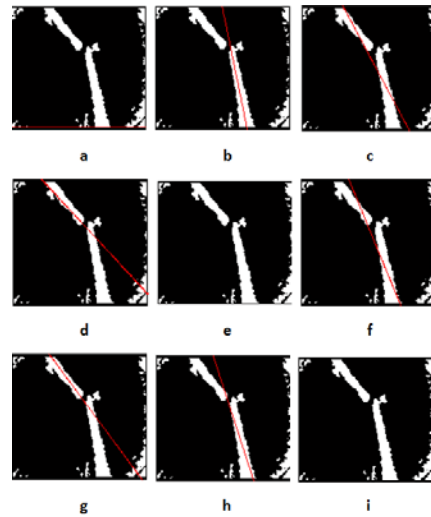


FIGURE VII. CLUSTERING RESULTS WITH DIFFERENT CATEGORIES

As is shown in FIGURE VI, using the pipeline detection method based on linear feature clustering directly using Hough transform, all lines extracted whose vote points are higher than the threshold these lines means the linear characteristics of pipeline. Then the K-means clustering method was applied to recognize linear feature similar clustering. Clustering data is

each line's coordinates in parameter space corresponding of Hough transform. The number of clustering is 9, the number of lines in FIGURE VII(e) and VII(i) is 0, and the final clustering results are divided into 7 categories. Linear features belonging to different pipeline will be clustered into different categories, select the group which has the most line as the result of pipeline detection, the mean of clustering lines is the axis position of the pipeline. As is shown in FIGURE VII(b) and VII(g), red lines stand for the position of pipeline. This method proposed can avoid the interference caused by the inaccurate result of edge detection, and reduce the interaction between multiple channels. It has a prior effect especially in elbows detection where traditional pipeline detection method prone to error.

E. Improved Pipeline Detection Method

The specific process of improved underwater pipeline detection method is as follows:

(1) Step of obtaining underwater pipeline images. The size of the original image is 600×490. Because the image of the edge position is weak, the center area of image is taken including 340×320 pixels.

(2) Step of the original image preprocessing. The image preprocessing includes the transformation of gray scale, median filtering, iterative optimal threshold segmentation, morphological processing, the binary image of underwater pipeline will be obtained after image preprocessing.

(3) Step of Canny operator edge detection. This step is used to obtain the edge of pipeline, and then edge feature filtering method based on the saturation control is adopted to filter the edge of disruptor. According to the results of debugging, the optimal filter window size is 10×10, saturation threshold is 20.

(4) Step of Hough transform. The Hough transform is used to extract the line characteristics of the pipeline, and then the top 6 voting lines was viewed as the candidate edges of the pipelines.

(5) Step of feature matching. According to the detected line matching, whether the angle and distance of line couples match relative position relation of pipeline edges is determined. If the matching is successful, the position of pipeline is determined. A method of pipeline detection based on line feature clustering is adopted as a re-detection.

The limiting condition can be summarized as follow:

- The straight line matching angle range can be from -5 degrees to 5 degrees;
- The distance between the straight lines can be less than 60 pixels;
- The last frame of the image angle of the change cannot be more than 15 degrees.

III. EXPERIMENT AND ANALYSIS

In order to verify the effectiveness of the underwater pipeline detection algorithm, an experiment of underwater pipeline detection using image processing sequences proposed

in an experimental tank was carried out. In this paper, the improved underwater pipeline detection method and the traditional underwater pipeline detection method were both compared under the same environment. The hardware environment includes the main frequency 2.5GHz, 16G memory computer; the software platform adopted win7 operating system, and matlab 2012.

FIGURE VIII to XIII shows the results in each processing steps of 4 images (a, b, c, d). FIGURE VIII(a) shows the situation of the pipeline entering the scope of the camera, the improved algorithm and the traditional algorithm can both successfully detected the first pipeline, and the second pipeline is too short to be detected. In FIGURE VIII(c), Hough transform results without using edge feature filtering failed in detecting the left edge of second pipeline, however using the edge filter both sides of these two pipelines can be detected. In FIGURE VIII (b), the first detection failed in detecting the left edge of the second pipes. Pipeline detection method based on linear feature clustering successfully obtained the position of the two pipelines. FIGURE VIII (d) is a straight pipeline test, both improved and traditional pipeline detection method successfully captured the position of the single pipe, but there is a deviation line in the result of Hough transform without edge feature filtering.

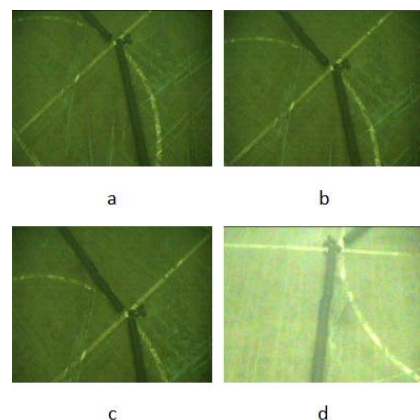


FIGURE VIII. ORIGINAL IMAGE

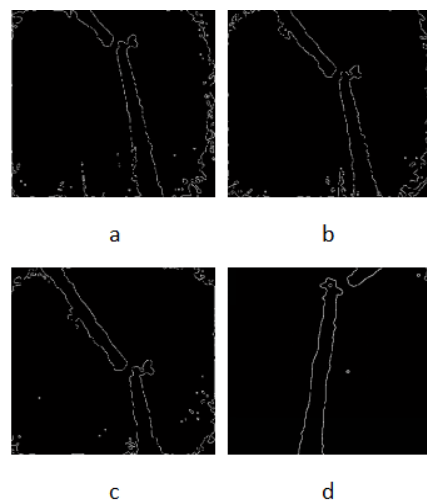


FIGURE IX. RESULTS OF EDGE DETECTION

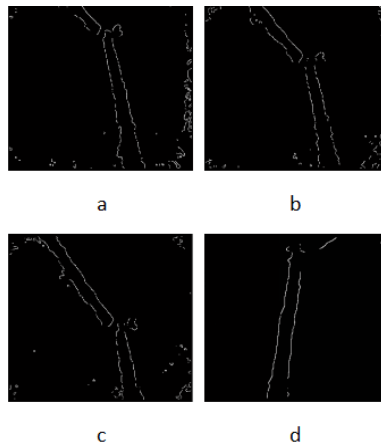


FIGURE X. RESULTS OF EDGE FEATURE FILTERING

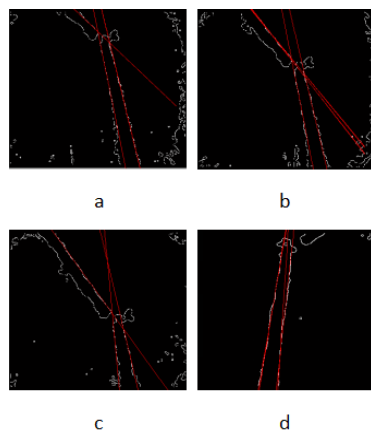


FIGURE XI. HOUGH TRANSFORM WITHOUT EDGE FEATURE FILTERING

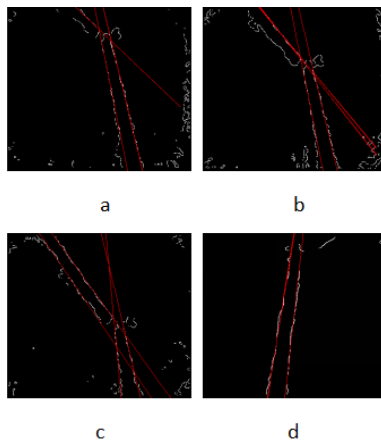


FIGURE XII. HOUGH TRANSFORM WITH EDGE FEATURE FILTERING

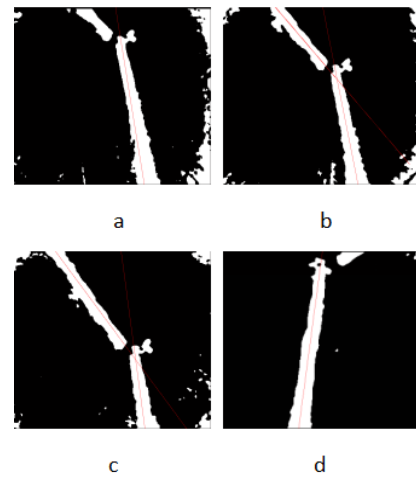


FIGURE XIII. RESULTS OF LINEAR FEATURE CLUSTERING DETECTION

IV. CONCLUSIONS

In this paper, according to the blurred characteristics of underwater optical image and the high failure rate of traditional underwater pipeline detection, an improved algorithm for underwater elbows detection was proposed. The edge feature filtering method based on region saturation control was adopted to filter out image edges interference. The pipeline detection method based on linear feature clustering was also involved for the re-detection for effectively reducing the detection failure in elbows and improving the accuracy of underwater pipeline detection. The results show that the improved algorithm is superior to the traditional algorithm in the underwater elbows detection.

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