MVA'94 IAPR Workshop on Machine Vision Applications Dec. 13-15, 1994, Kawasaki

A Study on Underwater Cable Automatic Recognition using Hough Transformation

Chao CHEN, Masayuki NAKAJIMA

Dep. Information Science, Tokyo Institute of Technology
2 – 12 – 1 Ookayama, Meguro-ku, Tokyo, 152 JAPAN
chin@ctrl.titech.ac.jp, nakajima@ctrl.titech.ac.jp

Abstract

In this paper, we make an attempt to predict the location of a cable in next frame according to some parameters in current frame. At first, the initial condition is that the approximate location of cable must be given. From Hough Transformation, a high accumulated degree point in Hough Space is gotten. Afterwards, by inverse Hough Transformation, using that point, the location is detected and then cable is pointed out from its original image.

Based on the actual working conditions and performance indices, as well as the location in current frame, the maximum range of degree within which the cable maybe occurred in next frame with high possibility is evaluated. Furthermore, a narrower range of location in next frame is confirmed according to the speed of robot. It is this narrow range that reduces the influence of the background on the detect object to the least. Therefore, the location of cable can be detected more accurately.

1 Introduction

Recently, in the international communication area, there are a lot of researches about Optical Cable Network which were laid under sea have been constructed. Since the troubles with the Optical Cable Network would bring a lot of influences to the communication business, the maintenance technology with these cables have also been developed.

In Japan, there are some kinds of AUVs (Automatic Underwater Vehicle) have been developed by the KDD (Kokusai Densin Denwa) Crop's AUV Group. One kind of AUV named 'MARCAS—2500' was designed for making repairs on the Optical Cable. But this kind of AUV is too expensive in running cost just for examination, maintenance management and so on. So that, a new type of AUV named 'AQUA EXPLORER 1000' have been developed.

This AUV is just designed for examination and maintenance with cable. It run along with cable and examining it. In fact, video tape is recorded by the video camera which is settled on the AUV. Using these video tapes, we can know cable's status, and know whether the cable is in dangerous.

Developing with examination about the Underwater Optical Cable Network, there are a lot of video tapes are taken by the AUV's video camera. A useful automatic algorithms which can recognize cable and find whether the cable is in dangerous is required. This paper shows a study on how to recognize an underwater cable effectively by means of time sequence of limited parameter using Hough Transformation.

2 Normalized Distribution

2.1 Recognition on Road

In the past, researches' subjects on Automatic Recognition System were limited on road. For example, a Advanced Car Driver System[1], a Car Automatic Tracking System[2], a Car's Number Plate Extraction System and etc. In these researches, researches' direction are how to detect a subject from a complexity background. It is also a very important that whether it is a real-time process.

2.2 Recognition on Underwater

In underwater image processing area, researches can be distinguished into two groups by the difference of deep. In shallow sea, most researches' themes are how to reduce the influences from the Sun. In accurately, there are a lot of troubles in measurement and recognitions, because the sunlight is very strong at this deep[3][4][5]. In ocean depths, the researches' theme are how to find and avoid an obstacle just like a mountain and stock using a sonar system[6][7].

2.3 Feature of Underwater Image

1. There are very small information in underwater image. In fact, there are a little useful patterns when

the light is moving with the AUV.

2. The contract of a underwater image is very bad. Fundamentally, light system is designed on AUV, and there are a lot of relationship with energy, traveling course etc, it becomes very difficult in edge detecting.

3. The appearance of Optical Cable would be changed since it was layed down for a long time under sea. A living thing would adhere to the cable, and the outside appearance would change. It becomes difficult to recognize cable using same recognition pattern.

3 The Based Conditions

3.1 AUV Data

In the following, some AUV technology data of *Aqua Explorer 1000* would be showed.

1. The AUV run on the height of 1 meter.

2. AUV's speed is below 1 m/sec.

3. Angle of depression is 30°.

4. Images would be taken at a speed of 3 frame/sec.

5. There is not't a current at that bottom of the sea.

Based on these technology data and working conditions, several very important data used in this algorithm can be acquired.

3.2 About Underwater Image

Digital image are digitalized from video tape. A 640 × 480 dots image would be used. In Figure 3.1, the AUV working environment is showed.

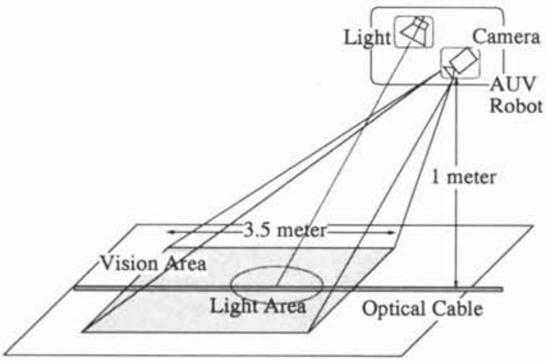


Fig. 3.1 AUV Working Environment

Using following function, the length $\hbar$ which is distance between two dots matched the actual sea bottom can be counted.

$$\hbar = \frac{3.5 \times 100}{480} = 0.73cm/dot \quad (1)$$

Next, the maximum numbers of dots δD which could be varietied between two frequency frames must be considered. Based on the AUV's speed is 1 m/sec and the A/D alternate speed is 3 frames/sec, this value δD is simply

$$\begin{aligned} \delta D &= \frac{1.0 \times 100}{0.73} \times \frac{1}{3} \\ &= 45.6dots \doteq 46dots \end{aligned} \quad (2)$$

From the above calculation, although the AUV's traveling course is perpendicular to the cable, the maximum dots δD which would be varietied, should be less than 46 dots. So that the maximum variable region with one point between two sequence frames would not be larger than a circle which radius is 46 dots. It is one of the base conditions in this estimation methods.

3.3 Accuracy of Hough Transformation

There are a lot of paper discussing about Hough Transformation. It is very clear that the accuracy of Hough Transformation is a very important theme. A high accuracy Hough Transformation can get a high level accurate upon cable's position, but it also bring many faults such as working memory, execution time and etc. On the opposite, a low accuracy would bring a big accidental error. In this paper, the accuracy is set as 1° in Hough Space.

4 Detect Algorithms[8]

4.1 Methods

As a simplify experimentation, the cable would be provided on the following conditions:

1. There is few sand covered on the cable.

2. The cable can be seen like a stick.

In previous processing, a histogram equalization a filter and a 9×9 Median histogram filter are used. A Laplacien-Gaussian filter was used in edge detection.

As the initial condition, the cable's approximate location must be given at first. Using Hough Transformation, a high accumulated degree point in Hough Space can be gotten. Afterwards, by inverse Hough Transformation, using that point, the cable's location is detected and then cable is pointed out from its original image. This point in Hough Space called an *angle of inclination* is a very important parameter which would be carried across the following frame.

In order to calculate the *angle of inclination*, the following AUV technology data are necessary.

At first, since AUV's maximum speed v_{max} is 1 m/sec, and minimum rotate radius R_{min} can be assumed less than 3 meters. Then the maximum variable angle $\delta\theta$ between two sequence frames can be calculated by the following function.

$$\begin{aligned}\delta\theta &= \frac{180}{2\times\pi}\times\frac{v_{max}}{R_{min}} \quad (3)\\ &= 28.65\times\frac{1}{3}\\ &= 9.55^\circ \doteq 10^\circ\end{aligned}$$

Using this maximum variable angle $\delta\theta$ and the previous *angle of inclination* θ_{front}, which is the cable's inclination angle in the previous frame, the current *angle of inclination* θ_{now} could be able estimated between the following maximum variability range.

$$\theta_{front} - 10^\circ \leq \theta_{now} \leq \theta_{front} + 10^\circ \quad (4)$$

It's a great problem that Hough Transformation cost a lot of time on calculation. Using this *angle of inclination*, the degree variability range would be limited, and the calculation time could be reduced in a drastic retrenchment.

Based on the actual working conditions and performance indices, as well as the location in current frame, the maximum range of degree within which the cable maybe occurred in next frame with high possibility is evaluated. This value of degree is used as a very important parameter in this research.

Still more, there is another parameter called *prediction area* is used in this research. It is designed for estimating the maximum appearance region. At first, the maximum variable number of dots δD should be recalled. This value should be added to the region where the cable is in the previous frame. In current frame, the cable must be in this estimated region, and this region would be applied as the target region.

4.2 Data Flow

Figure 4.1 shows this algorithm's flow-chart.

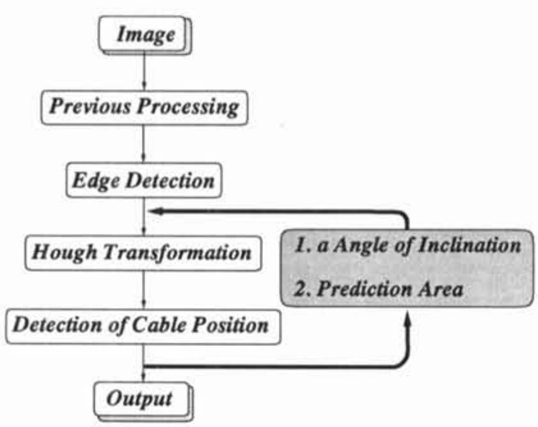


Fig. 4.1 Data Flow

In the previous processing, a histogram equalization and median filtering are used at first. A Laplacien-Gaussian filter is used in edge detection. Considering simplicity of a underwater image, a larger processing window are used in Laplacien-Gaussian filter.

The *angle of inclination* and *prediction area* are used as field-back values. The estimated variability extent can be calculated using *angle of inclination* in previous frame and the maximum variability range. The *prediction area* can be calculated using the AUV's technology data and AUV's position in the previous frame. Based on these two parameters, a time sequence of limited parameter recognition algorithm have been developed.

5 Result

In this experiment, a comparatively simplify scene was selected.

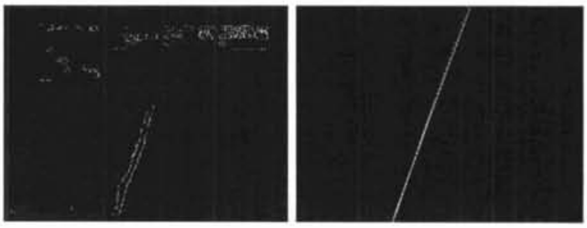
Fig.5.1 shows a adjusted contrast image, because the original image is too dark to see. It is very clear that the center of this image is concentrate bright, and the corner is very dark.

Fig.5.1 Original Image

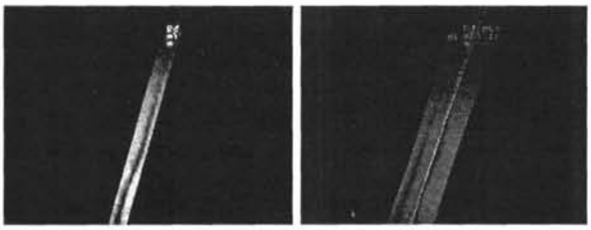
In Fig.5.2, a process flow chart would be showed.

Fig.5.2.(a) is a edge image. A standard Laplacien-Gaussian filter is used. In order to get more edge points, the processing window's size is set as 11×11. Minimum length of a segment is 10 dots.

Fig.5.2.(b) is result of inverse Hough Transformation. A high accumulation degree is gotten in Hough Space through Hough Transformation using the edge image, and a straight line is gotten.



(a) Edge Image (b) Hough Trans.



(c) Cable Position (d) Composed Image

Fig.5.2 Process Flow Chart

Fig.5.2.(c) shows the cable's location in previous frame. The cable region is cut from original image using Fig.5.2.(b)'s line.

Fig.5.2.(d) is a composed image for showing a simple and plain cable location between two sequence frames. The detected cable on the right is the previous image's cable, and the valid region is prediction area centered Hough's line.

Fig.5.3 shows the result of this scene. It is very clear that the cable is detected from the current image.

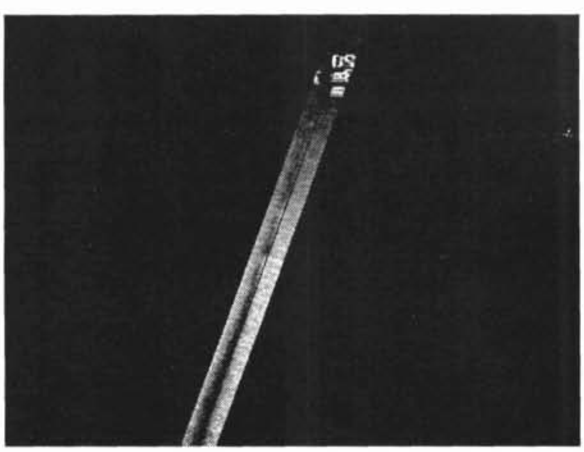


Fig.5.3 Detected Cable Image

6 Conclusion & Thanks

Developing with the international communication system construction, more researches study on underwater image processing system would be developed.

In this paper, a underwater cable recognition algorithm which used Hough Transformation have been developed. Still more, a new algorithm called **time-sequence limited parameter using Hough Transformation** were considered. It is clear that Hough Transformation is also a effective algorithm in pattern recognition using underwater image. As intelligent parameter that established in this research, *inclination angle* and *prediction area* are also very effective data.

Nevertheless, this algorithm is used that the cable is on straight. In actually, there are a lot of difficult cases about underwater cable. For example, sometimes cable's appearance are changed, and sometimes cable would be in a curve and so on. How to solve these cases is also a big theme have to do.

This research was developed also thanks to Dr. MATUMOTO and the KDD AUV Group.

Reference

1. M.Nakajima : "A Study of an Automatic Identification and Tracking of a proceeding Car", Vol.27, No.7, Information Processing Society of Japan 1986.

2. SAI, T.Agui : "Extraction of Passing Car and Its Number Plate using a Series of Image", D-II Vol.J73, No.3 pp.392-398, IEICE 1990.

3. J.S.JAFFE : "Computer Modeling and the Design of Optimal Underwater Imaging Systems", IEEE Journal of Oceanic Engineering, Vol.15, No.2, April 1990.

4. J.S.Chu, L.A.Lieberman, P.Downes: "Automatic Camera Control For AUVS : A Comparison of Image Assessment Methods", Autonomous Underwater Vehicle Technology, June 2 and 3, 1992.

5. S.Negahdaripour, Chih Hoo Yu, A.H.Shokrollahi : "Recovering Shape and Motion From Undersea Images", IEEE Journal of Oceanic Engineering, Vol.15, No..3, July 1990.

6. D.N.Oskard, Tsai-Hong Hong, and Clofford, A.Shaffer : "Real-Time Algorithms and Data Structures for Underwater Mapping", IEEE Transactions on System, MAN. and Cybernetics, Vol.20 No.6 November/December 1990.

7. David N.Oskard, Tsai-Hong Hong, C.A.Shaffer : "Real-Time Algorithms and Data Structures for Underwater Mapping", IEEE Transactions on System, MAN. and Cybernetics, Vol.20 No.6 November/December 1990.

8. C.Chen, M.Nakajima : 'A Study on Underwater Cable Automatic Recognition using Hough Transformation — Part 1', D-621, IEICE Spring Conference, 1994.