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Speed Algorithm for Underwater Moving Objects Detection Based On Image Sequence

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Abstract : A real-time algorithm is presented to detect moving targets in underwater complex environment. The difference image is obtained by subtraction operation in frames of image sequence. An appropriate threshold is selected and the binary image of the difference image is obtained. Every part of the binary image is segmented into one single image by image segment algorithm. A definition of linear level is given based on the shape of objects formed by motion of targets in the difference image. The actual sizes of the original moving targets are inferred from linear level and area of the formed objects. The function of real-time detecting underwater moving targets is implemented using this algorithm. The algorithm has been used in underwater intelligent monitoring system in some large international games and meets the requirement of real-time. In practice, it is proved a fast and stable algorithm.

Key Words: Image Processing, Image Sequence, Linear Level, Underwater Moving Targets, Image Segmentation

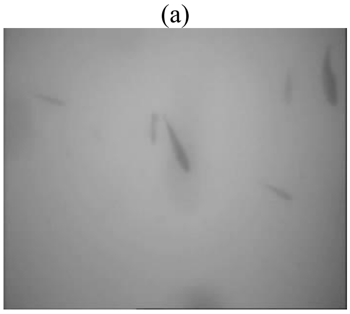
I. INTRODUCTION

How to detect speedily and effectively if the interested moving targets exist in the view field is a problem concerned by many researchers in the field of image processing and targets recognition in the underwater intelligent monitoring system. Underwater environment is very complicated. There are a mass of inorganic material and various organic substances which are different size, shape, and performance. We must extract the interesting targets from complex background. Researchers have proposed many methods, for example M estimation, character matching method and main motion estimation based on light flow. However, these methods have some shortcomings: complicated transform, large computation, ineffectively extracting moving targets from complex background. We analyze in detail characteristics of underwater images and select an appropriate threshold level to binarize the difference image of image sequence. Then we segment every part of the binary image into single object in one image by image segmentation algorithm. Finally we can realize speedy detection for moving targets by some characteristics which are convenient to detecting targets.

II. ANALYZING CHARACTERISTICS OF THE UNDERWATER IMAGES

Fig. 1 shows two continual frames of underwater scene sometime.

(a)



(b)

Figure 1. Two continual frames of images of underwater scene at sometime

We can see that the images are covered a layer of fog because of light noise introduced by scattering of complex composition of water. Scattering has declined image contrast greatly. Medium of objective space causes so great difference on image illumination between on-axial and extra-axial point that brightness of background is very different. In Fig. 1 left part of the image is brighter than right part since installment error of the underwater camera. Image background is so complicate that if we only process a single image and detect effectively moving targets from it the corresponding algorithm will be too complicate, large computation and bad real-time function. Image background is little different between two continual frames in image sequence. If we can wipe off resemble background to large extent, restrain noise and stand out targets the precision and efficiency to detect targets can meet the real-time requirement of monitoring system.

III. SPEEDY DETECTION ALGORITHM

We obtain the difference image by subtraction operation to the two frames of image sequence. An example of the difference image is shown in Fig. 2. Since contrast of two serial frames was too small, we use the two images at interval three frames for obvious effect.

Figure 2. Difference image of two frames

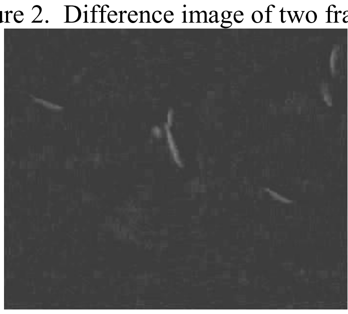


Figure 3. Difference image after adjusting contrast

Fig. 3 is the image after adjusting contrast of Fig. 2. Besides some targets are obvious, there are a lot of noise signals. Underwater images are different from images in air. Random float arouses some difference of background gray-scale level in the two frames. The histogram of the difference image is shown in Fig. 4. Since the gray-scale level concentrates on low part, Fig. 4 shows only an interval of 0 – 100.

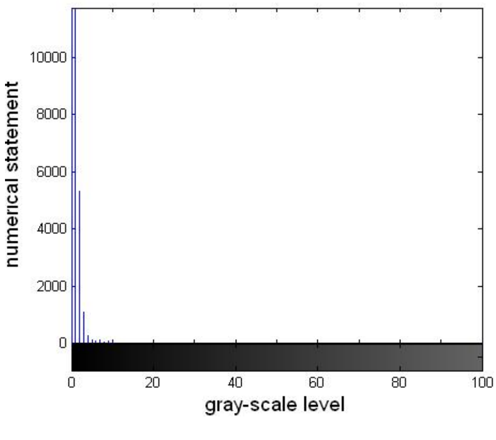


Figure 4. Histogram of the difference image

We calculate ratio R of gray-scale level sum of the difference image and that of the original image. Then we determine threshold R_T according to size of targets to be detected. We can consider that targets perhaps exist when $R > R_T$. Otherwise, no target exists and we can start to calculate a new difference image. According above stated, underwater background is complicated. If we judge targets only depending on the difference image we may misjudge. So we still carry out following calculation when we consider that targets perhaps exist.

To calculate mean μ and variance σ respectively:

$$\mu = 0.444$$

$$\sigma = 1.127$$

To use formula of threshold:

$$T = \mu + 3\sigma$$

To determine $T = 3.825$ as threshold of the difference image, we make the difference image into the binary image using the threshold T. Pixel gray-scale level G(i,j) is transformed into B(i,j):

$$B(i,j) = \begin{cases} 0 & G(i,j) < T \\ 1 & G(i,j) \geq T \end{cases}$$

The binary image is shown in Fig. 5. Most noise of background is filtered, and targets and a few stochastic noises are left.

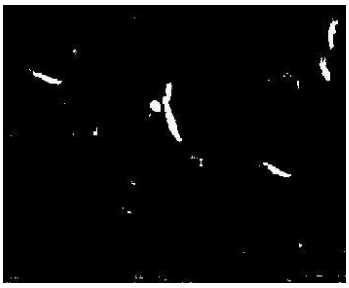
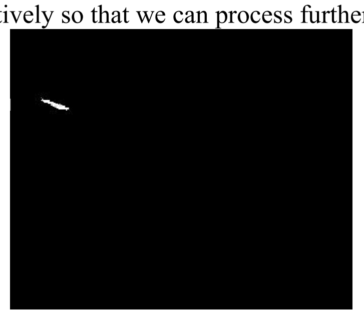
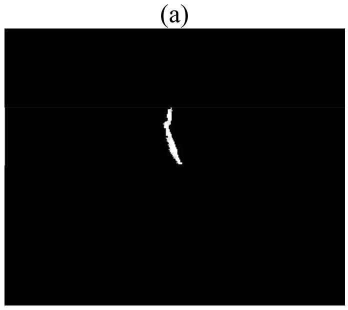


Figure 5. Binary image of the difference image

We use image segmentation algorithm based on region to segment the binary image. The task is to detect whether targets are exists or not, so we only keep down targets which have bigger area. Results of segmentation are shown in Fig.6. Three targets which have bigger area are put in a single image respectively so that we can process further them.



(a)



(b)

(c)

Figure 6. Images after segmentation

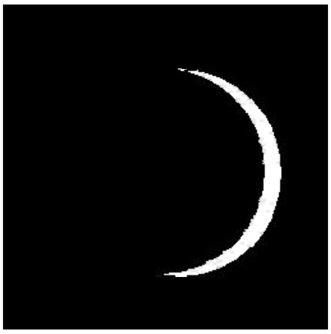
The target after segmentation is formed by motion of the underwater target. It reflects only a small part of the actual target. We can infer actual size of the original target according to the shape and size of the target in segmentation image. Therefore we can determine whether the target is interesting one or not.

We give a new definition of linear level: $L = A / P$

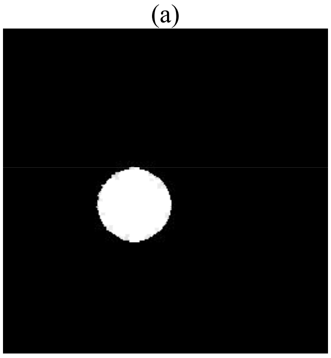
Here P is the perimeter of the target, and A is the area of the target. Their units are both pixel. L is linear level, no dimension.

Linear level is so defined because its value is minimum to the target which shape is linear, and the minimum is 1. More round the target, more big the value of linear level.

Linear level may be used to differentiate targets which their areas are close, but their shapes are different. Fig. 7 depicts two targets. The one is crescent and the other is round.



(a)



(b)

Figure 7. Two targets at equivalent areas and different shapes

TABLE I. Calculation Result Of Two Targets In Fig.7

Characteristics of targets	**Target in Fig. 7(a)**	**Target in Fig. 7(b)**
Area	2639	2744
Perimeter	464	166
Linear Level	5.688	16.530

Linear levels of two targets which are close areas are quite different in Tab. I. Smaller linear level of the target, bigger the actual target of the original image. Combining linear level and area, we can depict the shape of the target and infer the size range of the actual target in the original image.

We can calculate feature properties of a target, such as area, perimeter, linear level and ratio of length and width, and determine if it is a target interested. So we can fulfill our goal to detect speedy underwater moving targets.

IV. ANALYZING COMPLEXITY OF THE ALGORITHM

This algorithm is mainly used in underwater intelligent monitoring system. The demand of real-time of the system is critical, so the algorithm must be efficient and fast. We analyze complexity of the algorithm based on time consumed by every procedure of the algorithm.

The algorithm has been implemented in Microsoft Visual C++ 6.0 on the platform of Microsoft Windows 2000 Professional. Performances of the computer used are Celeron® CPU 3.06GHz, DDR400 512MB.

TABLE II. Time Statistics Of Every Procedure Of The Algorithm

Procedure	**Time(ms)**
Difference operation	1.23
Image thresholding	5.12
Image segmentation	15.68
Area and Perimeter	3.41
Length width ratio	1.19
Summary	26.63

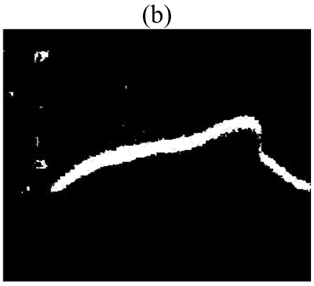
Frame rate of video signal is 25frame/s. Frame-to-frame time interval is 40ms. From Tab. II we can see that time consumption of the algorithm is 26.63ms and it can meet the requirement of real-time monitoring.

V. VERIFYING ALGORITHM AND CONCLUSION

The algorithm has been applied successfully in underwater monitoring system of some large scale international games. We test the system using a frogman. Fig. 8 shows two continual frames of image sequence and processing result. When the frogman moves a lot of bubbles which cause noise arise.

(a)

(b)



(c)

Figure 8. Two continual images and proceeded result of the frogman's palmiped

There is noise which is aroused by bubbles in the difference image after image thresholding. We can separate the target formed by the palmiped using image segmentation algorithm. Its area A, perimeter P and linear level L are respectively:
A=4971, P=798, L=A/P=6.23

We can infer that the original target is larger from big area and small linear level. We can give cue information and go on the following processing, such as feature extraction and pattern recognition.

Results show that we can detect underwater moving targets by this algorithm and realize monitoring function. The algorithm can eliminate interfere of floater or shoal in time. But bigger fish may be reported as a target. Thanks to discussing only targets detection, we should assure all targets are detected. Misreport can be corrected by the following algorithm of targets recognition. In addition, the image segmentation consumes a great deal of time. We should consider how to improve image segmentation algorithm and boost efficiency so that we have more time to use in the other function modules.

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