Extraction Method of Scallop Area in Gravel Seabed Images for Fishery Investigation

Koichiro ENOMOTO†††, Student Member, Masashi TODA††, Member, and Yasuhiro KUWAHARA†††, Nonmember

SUMMARY The quantity and state of fishery resources must be known so that they can be sustained. The fish culture industry is also planning to investigate resources. The results of investigations are used to estimate the catch size, times fish are caught, and future stocks. We have developed a method for extracting scallop areas from gravel seabed images to assess fish resources and also developed an automatic system that measures their quantities, sizes, and states. Japanese scallop farms for fisheries are found on gravel and sand seabeds. The seabed images are used for fishery investigations, which are absolutely necessary to visually estimate, and help us avoid using the acoustic survey. However, there is no automatic technology to measure the quantities, sizes, and states of resources, and so the current investigation technique is the manual measurement by experts. There are varied problems in automating technique. The photography environments have a high degree of noise, including large differences in lighting. Gravel, sand, clay, and debris are also included in the images. In the gravel field, we can see scallop features, such as colors, striped patterns, and fan-like shapes. This paper describes the features of our image extracting method, presents the results, and evaluates its effectiveness.

key words: scallop, fishery resource investigation, automatic counting, image processing

1. Introduction

The quantity and state of fishery resources must be known so that they can be sustained. Each relevant organization conducts various fishery investigations and collects data required to estimate the state of resources [1]–[3]. The fish culture industry is also planning to investigate resources. The results of investigations are used to estimate the catch size, times fish are caught, and future stocks [4], [5]. Therefore, it is necessary for investigations to more accurately measure the numbers, sizes, locations, environments, and states of fisheries. It is also necessary to investigate non-invasively so that fishery resources are not affected.

Recently, the investigations are proposed the method to measure fishes using water video camera [2], [3]. These methods can not use the acoustic survey, because the acoustic feature is not known or these fishes are marine benthos. However, these investigations are not made using automatic measurements from a video camera. The scallop investigation has some problems.

In the scallop culture industry, Abashiri Japan, the fisheries are investigated by analyzing seabed images [5]. The scallop habitat is the gravel and sand seabeds [6]. The seabed images are used to investigate fisheries, because it is absolutely necessary to visually estimate and not have to use the acoustic survey. This method does not affect scallops because no fishing is involved. Seabed images are now obtainable from catamaran technology. However, there is no automatic technology to measure data from these images, and so the current investigation technique is the manual measurement by experts. Hokkaido Abashiri Fisheries Experiment Station took seabed images to investigate only 580 m² of the fishing area of 58.5 km² in 2007. This investigation took one month to measure all scallop. This investigation cannot cover a wider area as long as it measures scallop manually, because it takes a long time to measure scallop. Therefore, this investigation is neither efficient nor long ranging.

Automatic systems must be developed to measure scallop at higher speed and investigate fisheries highly accurately. There are varied problems in automating technique. The photography environments have a high degree of noise, including large differences in lighting. Gravel, sand, clay, and debris are also included in the images.

Our aim is to develop an automatic system to measure the quantities, sizes, and states of the scallop. In the gravel fields, the scallop is on gravel. There are times when the scallop is covered with sand. However, no live scallops are ever under stones. We can see the scallops’ features from this seabed images, such as colors, striped patterns, and fan-like shapes. In this paper, we describe a method to extract scallop areas from the gravel seabed images, and present its results, and evaluate its effectiveness.

The next section describes the seabed images and design considerations for extracting the scallop areas from the images. Because the images have noise with differences in lighting, we define the recognizable areas and remove the dark areas in Sect. 3. To extract the scallop areas, the scallop features, such as colors, striped patterns, and fan-like shapes are defined in Sect. 4. Section 5 shows the experimental method and results gained from applying our method to the seabed images and discuss the validity of our method.
2. Design Consideration

Figure 1 shows a digital photograph of the gravel seabed (1536 × 1024 pixels and in 24-bit color). This seabed image contains scallops, gravel, dead shells, and so on. The gravel is a variety of sizes, shapes, and colors. The seabed images have great differences in illumination, because they are taken for measurement and are not lit well enough. Therefore, there are areas of colors, textures, and shapes that are unrecognizable. In preparation, we define the recognizable areas and remove the unrecognizable areas, as explained in Sect. 3.

In this paper, the scallop areas refer to the images of scallops. The other areas also refer to the images of non-scallop. Figure 2 shows six scallop areas of 64 × 64 pixels. The scallop areas have special features, such as being sepia or sienna in color and shaped like fans with a striped pattern. Section 4 explains a modeling of these scallop features. Section 5 shows also the method for extracting the scallop areas.

3. Preparation

Figure 1 shows the seabed image has great differences in illumination due to the photography environment. Because of this, it is difficult to recognize color and form in the dark parts of these images when modeling the features of scallops. This section describes how the proposed method defines the recognizable areas and removes the unrecognizable areas.

3.1 Algorithm

Initially, localized regions are obtained by dividing the original image into smaller areas of 32 × 32 pixels. The mean lightness and standard deviation are calculated from all of these areas. The mean lightness show the index of the recognizable color. The standard deviation shows the index of the recognizable shape. These results are shown in Fig. 3.

We can see the distribution is concentrated at low values in Fig. 3. This is thought to be due to the influence of shadows around the images. Here, the unrecognizable area is defined as the mean lightness and standard deviation that are lower than the threshold, and removed the this area was removed by threshold processing. We set the threshold parameters to a mean of 100 and a standard deviation of 45.
The results for the extracted recognizable areas are shown in Fig. 4. The dark areas were removed from the seabed image. Moreover the extracted area has enough lighting. In this paper, we use the images of the recognizable area obtained in this way.

4. Modeling of Features

This section describes how we modeled the features of the scallop areas.

4.1 Color Information

The scallop areas can be colored sepia or sienna. To clarify the color of the scallops, we extracted 10,000 sample points from the seabed image of the recognizable area, and converted each R, G, and B element into hue, lightness, and saturation (HLS) color space. We selected only the scallop surface so as not to select the sand pixels. These were obtained as a histogram, and compared with the seabed image. The hue results are presented in Fig. 5. From the results in Fig. 5, we can see that the hue of the scallop area is concentrated in the peak ranging from 100–175°. However, we could not find the lightness or saturation features.

Next we modeled the hue feature of the scallop areas. We used the six scallop area images from Fig. 2. We also used the six other area images are extracted from the areas of 64 × 64 pixels from the recognizable area, and show Fig. 6. Here, these scallop images are not covered with sand or stone. These images were analyzed for hue histogram, mean and standard deviation of scallop and compared with the images of other area. Table 1 shows the results. The hue mean of the scallops area is settled from about 130–170° in Table 1. Moreover, standard deviates of the scallops area are lower than the others area. Here, we can define the color feature as hue the mean of which is 125–175°. However, it is difficult to set the range of the standard deviation because if the scallop is covered with sand, the standard deviation is higher. Here, we do not set a range of standard deviation and if many candidate scallop areas is overlapped, we define the standard deviate as the lowest standard deviate.

<table>
<thead>
<tr>
<th>Fig. 4</th>
<th>Results of the recognizable areas.</th>
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<td>Fig. 5</td>
<td>Comparing scallops and seabed image by hue.</td>
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<td>Fig. 6</td>
<td>The images of the other area.</td>
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<tr>
<th>Table 1</th>
<th>Results of hue mean and standard deviate of scallops and others area. The object scallop images are Fig. 2. The object other images are Fig. 6.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scallops</td>
<td>(a)</td>
</tr>
<tr>
<td>Mean (°)</td>
<td>139.1</td>
</tr>
<tr>
<td>SD</td>
<td>14.6</td>
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(i) The scallops area

<table>
<thead>
<tr>
<th>Others</th>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
<th>(d)</th>
<th>(e)</th>
<th>(f)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (°)</td>
<td>208.4</td>
<td>230.9</td>
<td>174.8</td>
<td>175.4</td>
<td>180.5</td>
<td>176.5</td>
</tr>
<tr>
<td>SD</td>
<td>59.0</td>
<td>50.7</td>
<td>15.7</td>
<td>33.6</td>
<td>14.3</td>
<td>19.2</td>
</tr>
</tbody>
</table>

(ii) The others area
4.2 Striped Pattern

The surface of scallop shells has a pattern that is a striped pattern. This pattern is called a radial rib [6]. In this section, the features of this striped pattern are modeled by spatial frequency analysis.

4.2.1 Extraction of Striped Pattern

In image $f$, the edge gradient of coordinate $f(x,y)$ is

$$\nabla f(x,y) = \left( \frac{\partial}{\partial x} f(x,y), \frac{\partial}{\partial y} f(x,y) \right)^T. \quad (1)$$

Then the edge strength $|f(x,y)|$ and direction $\theta$ are

$$|f(x,y)| = \sqrt{\left( \frac{\partial}{\partial x} f(x,y) \right)^2 + \left( \frac{\partial}{\partial y} f(x,y) \right)^2}, \quad (2)$$

$$\theta = \arctan \left( \frac{\partial f(x,y)}{\partial y} / \frac{\partial f(x,y)}{\partial x} \right). \quad (3)$$

Here, we used the Sobel edge operator. The results from treating edges are presented in Fig. 7. The striped patterns were extracted from the edge direction in Fig. 7 (c), but the edge detection was not influenced by the edge strength in Fig. 7 (b). In this case, the edge direction shows the striped patterns better, because these patterns have weak edges. Therefore, we used the edge direction to extract these patterns.

4.2.2 Analysis and Modeling

We describe the model of striped patterns.

The number of pixels is $M \times N$, the two-dimensional image is $f(m,n)$, and the two-dimensional Fourier transform is

$$F(u,v) = \frac{1}{MN} \sum_{n=0}^{N-1} \sum_{m=0}^{M-1} f(m,n) W_1^{mn} W_2^{nv}, \quad (4)$$

where $W_1$ and $W_2$ are

$$W_1 = e^{-j \frac{\pi x}{M}}, \quad W_2 = e^{-j \frac{\pi y}{N}}.$$

Here, the image made by using Fourier transform is called a power spectrum picture (PSP). When the power spectrum distribution of $P(\theta, r)$ is normalized, $P(r)$ is defined as

$$P(r) = 2 \sum_{\theta=0}^{\pi} P(\theta, r). \quad (5)$$

$P(r)$ expresses the sum of the power spectrum around the concentric area around the original point in power spectrum space.

We compared the scallop areas and the other areas by using the following processing. We crop these areas of $32 \times 32$ pixels, and the edge directions were detected from the images. These images were obtained as $P(r)$ by Fourier transform. The results from comparing the spatial frequency spectra are presented in Figs. 8 and 9, and $P(r)$ is presented in Fig. 10.

As shown in Fig. 10, the $P(r)$ of the scallop area is concentrated in the range of $7$–9 Hz. This result shows a striped pattern.

Therefore, we modeled this as follows. In the edge direction image, the local area of $32 \times 32$ is defined as $L(x,y)$. The $P_L(r)$ is the $r$ element of space frequency in the power spectrum. When the sum of the specific range of $P(r)$ is defined as $A$,

$$A = \sum_{r=k_{min}}^{k_{max}} P_L(r), \quad (6)$$

where $k_{min}$ and $k_{max}$ satisfy $0 \leq k_{min} \leq r \leq k_{max} \leq 16$. In this

![Fig. 7](image)

**Fig. 7** Results of edge treatment using Sobel operator. Object image is (a), edge strength image is (b), and edge direction image is (c). Pixels show the degree of edge direction in (c).

![Fig. 8](image)

**Fig. 8** Results in scallop area from using frequency analysis. Object image is (a), and PSP is (b).

![Fig. 9](image)

**Fig. 9** Results in the other area from using frequency analysis. Object image is (a), and PSP is (b).
paper, we have set \( k_{\text{min}} = 7, k_{\text{max}} = 9 \). If \( A \) is more than the threshold \( T_A \), then we assume it to be a candidate area for the scallop area.

4.3 Shape of Scallop Shell

The scallop shell is shaped like a fan. This shape of the shell rim is defined as an ellipse, and detected as an ellipse with a Hough transform.

4.3.1 Preparation

The shape of the scallop shell determines how clearly its edge is detected. We can extract only strong edges. In the object images, the edge strength calculated by the Sobel edge operator. The edge of the scallop shell is detected when the edge strength that is larger than the threshold, and this edge is obtained by threshold processing. Here, we set up the threshold parameters of the edge strength as 180. The obtained image is processed to obtain the line image by thinning. The results are shown in Fig. 11.

4.3.2 Detection of Shape

We define the shape of the scallop shell as an ellipse, and extract it using the Hough transform to detect ellipses. This method is effective against noise and can be set at arbitrary sizes. An ellipse is defined by five parameters (Fig. 12): the center point \((x_0, y_0)\), two semi-axes \((\alpha, \beta)\), and an orientation \(\phi\). These parameters are determined by voting in the Hough parameter space. The shape of the scallop shell will be detected from an edge image by using Hough transform. Here, since the scallop areas have sizes in a constant range, two semi-axes are set at \(26 \leq \alpha, \beta \leq 34\).

5. Experiment

5.1 Method

We tried to extract the scallop areas by using two processes. In process 1, the candidate scallop areas were extracted only using only shape features. Some candidate areas were obtained in this process. In process 2, a scallop area was selected from the candidate areas using the color feature or striped pattern. We defined the area of ellipses that was detected in a striped pattern of process 2 as \(S_e\), and this area contained a striped pattern of \(S_p\). We made the ratio of these areas equal \(R = S_p / S_e\). The scallop area was defined as being \(R\) more than threshold \(T_R\). We set up the threshold parameters of \(T_R\) as 0.18. In process 2, when some areas were selected, we defined the scallop area as the standard deviation of the color in the lowest area or the value of the striped pattern in the largest area.

In this experiment, we extracted the areas of \(128 \times 128\) pixels from the images of recognizable area and used these images. These extracted images do not include unrecognizable area. Here, the image with the scallop area is referred to a scallop image, and the image without this...
is referred to a other image. These scallop images include scallops covered with sand. If a scallop image was extracted correctly and a non-scallop area is not extracted, we determined the results to be accurate by the extraction rate. Furthermore, if a scallop image was not extracted and therefore the scallop area or non-scallop area image was extracted incorrectly, we determined the results to be wrong. We used 28 scallop images and 104 non-scallop images in this experiment. There were 29 scallops in the 28 scallop images. There are 19 scallops that are clear, and 10 scallops covered with sand or gravel. Here, the clear scallop is referred to as “normal”, and the scallop covered with something is referred to as “covered”.

5.2 Results

The sample of experiment results are presented in Fig. 13 and Fig. 14. In Fig. 13, the scallop area was extracted by combining its features but not with only its shape. In Fig. 14 (c) the incorrect area was not extracted, but in Fig. 14 (b), the non-scallop area was extracted incorrectly as only the shape was used. Figure 15 shows the experiment result samples and Table 2 shows all the results of the experiment. The extraction rate accuracy of scallop images is 86%, and the extraction rate accuracy of “normal” is 95%.

5.3 Discussion

We developed a method for extracting scallop areas from gravel seabed images using their shape, color, and striped pattern features. The scallop areas cannot be extracted correctly using only the scallop shape. In process 1, the candidate scallop areas were extracted using only their shapes. This is because large amounts of stones, sand, and gravel.

In process 2, a scallop area was extracted using its color and striped pattern. These results demonstrate that this method using these features is effective.

There were also errors, although the extraction rate accuracy of normal is enough to measure. The samples of errors are presented Fig. 16. In Fig. 16 (a), the problem was that the color and striped pattern could not be obtained because the scallop area is covered with sand. In Fig. 16 (b), this area likes scallop color feature.

It is said that the extraction rate of experts’ manual measurement is 95%. About 58% percent of total are the clear scallop covered with nothing in object gravel seabed area. The extraction rate of the clear scallops is 95% by the proposed method. This result is enough. But, the extrac-

<table>
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<th>Table 2</th>
<th>Experiment results. Clear scallop is “normal”, and scallop covered with something is “covered”.</th>
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<tr>
<td></td>
<td>Scallop images</td>
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<tr>
<td></td>
<td>normal</td>
</tr>
<tr>
<td>Num of scallop</td>
<td>19</td>
</tr>
<tr>
<td>True</td>
<td>18 (95%)</td>
</tr>
<tr>
<td>Error</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Total true</td>
<td>25 (86%)</td>
</tr>
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Fig. 13 Actual process: (a) Original image. (b) Detection of ellipse. (c) Selection of scallop area in detected ellipse.

Fig. 14 Actual process: (a) Original image. (b) Detection of ellipse. (c) Selection of scallop area in detected ellipse.

Fig. 16 Examples of error: (a) This image was extracted incorrectly. Two Scallops are covered with sand. (b) This image was extracted incorrectly.
tion rate accuracy of the scallop covered with something is 70%. This problem was that the color and striped pattern could not be obtained because the scallop area is covered with sand. We need to consider a method for extracting of scallop covered with sand.

6. Conclusion

This paper has presented a method of extracting scallop areas from gravel field seabed images. This method defines the features of scallops by integrating color, striped patterns, and shapes, and models them. The method extracts scallop areas using these modeled features. Additionally, the experimental results gained by applying the proposed method to the sample seabed images show the usefulness of our method, and the scallop areas are not extracted not only by using the shape.

Future work will be concentrated on automatic determining threshold to use the scallop features, implementing the precision extraction, and the photographic environments because the seabed images are taken for manual measurement. Moreover, we will consider a method for extracting scallop areas from sand seabed images, where the features used for extraction from gravel cannot be used.

References


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