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Extraction Method of Scallop Areas Using Shelly Rim Features Considering Bottom Sediment of Sand

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Abstract

The results of fishery investigations are used to estimate the catch size, times fish are caught, and future stocks in the fish culture industry. In Tokoro, Japan, 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 the amount of scallops. However, there is no automatic technology to measure the quantities of resources, and so the current investigation technique is the manual measurement by experts. This paper describes our method to extract scallop areas from fine sand seabed images from the sand field. The photography environments have a high degree of noise including large differences in lighting. In the sand field, we can see only the shelly rim because the scallop is covered with sand and opens and closes its shell while it is alive and breathing. We propose a method to categorize the bottom sediment of the seabed image and extract the shelly rim areas under varying illumination, extract the scallop areas using the shelly rims by using professional knowledge in the sand field, presents the results, and evaluate the method's effectiveness.

1 Instructions

Recently, investigation methods have been developed to measure fishery resorces using an underwater camera [1]. The results of investigations are used to estimate the catch size, time fish are caught, and future stocks. Therefore, investigations must more accurately measure the numbers, sizes, and states of fisheries.

In the scallop culture industry in Abashiri, Japan, the fisheries are investigated by analyzing seabed images [1]. 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 $580m^2$ of the fishing area of $58.5km^2$ in 2007. It 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 wide ranging. Automatic systems must be developed to measure scallop more quickly and investigate fisheries more accurately.

Our work [2] showed a method to extract the scallop area from gravel seabed image. However, their method cannot be adapted sand field images for these scallops are covered with sand. In the fishing area, Tokoro, Hokkaido, the distribution of bottom sediments include the fields of the gravel, granule, fine sand, and sand [3]. In the sand fields, these investigations need the seabed images for this area to be more wider and more accurate, because the population density of scallop is low [3]. Automatic systems must be adapted to measure scallop in the sand fields.

In this paper, we describe a method to extract scallop areas using professional knowledge from the fine sand seabed images, present the results, and evaluate the method's effectiveness.

2 Design Consideration

Figure 1 shows a digital photograph of the sand seabed (1536×1024 pixels and in 24-bit color). Figure 2 shows scallop areas of 64×64 pixels in sand field. In sand fields like those in Fig. 2(a) and (b), the scallop areas have special features, such as the shelly rims being white and shaped like fans. There is no sand in the shelly rim, but the scallop shell is covered with sand. The scallop opens and closes its shell while it is alive and breathing. For the same reason, the scallop does not overlap with other scallops. This is based on the professional knowledge of ecologists and fisherman.

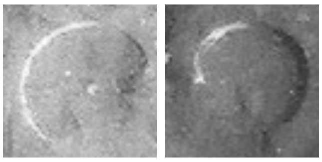
Figure 3 shows our proposed method to extract the scallop area in the fine sand field. First, in preparation, the seabed images were smoothed by Mean-Shift filtering, the frame area was removed, and the unrecognizable areas were removed. The candidate shelly rim pixels are extracted from the obtained image by dynamic threshold processing. Next, the candidate scallop area was extracted using the Hough transform. Finally, the scallop areas are extracted by threshold processing.

3 Preparation

3.1 Classification of Bottom Sediments

In the sand seabed images, the bottom sediments include the fields of fine sand and sand. We pro-

Figure 1. Sand seabed image.



(a) (b)

Figure 2. The images of scallop area (size:64×64). (a) and (b) are sand seabed images.

pose a method to classify the bottom sediments of the seabed image using the grey level co-occurrence matrix (GLCM). GLCM is used as a texture descriptor in the process of feature extraction [4].

The object area is selected the upper left of the middle of the frame (3.3) that have a margin 32×32 pixels, and its' size is 256 × 256 pixels. Here, displacement is denoted as $\delta = (r, \theta)$. In this paper, we set $\delta = (1, 0)$ and used the features as standard deviation and homogeneity.

Figure 4 shows a result of the 130 seabed images. We defined the fine sand filed as the feature values is upper of the border line and used only the fine sand seabed images.

3.2 Image Smoothing

In this study, the seabed images were smoothed by Mean-Shift filtering. Mean-Shift filtering is a smoothing method for the edge-preserving smoothing. Here, s and r denote the spatial and range components of a vector, respectively. The kernel bandwidths are denoted as (h_s, h_r). Here, in this paper, we set $(h_s, h_r) = (20, 15)$ and use the seabed images that were smoothed.

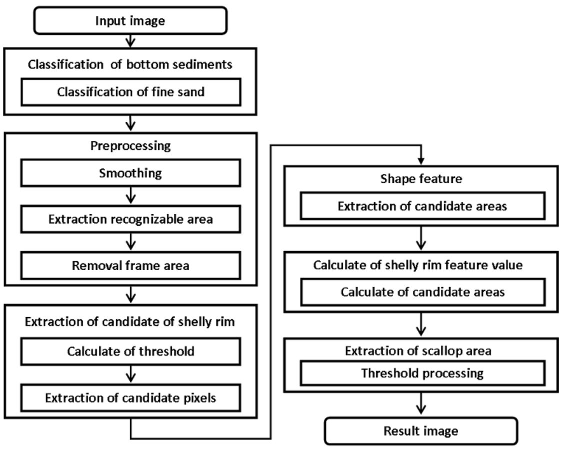


Figure 3. Proposed method.

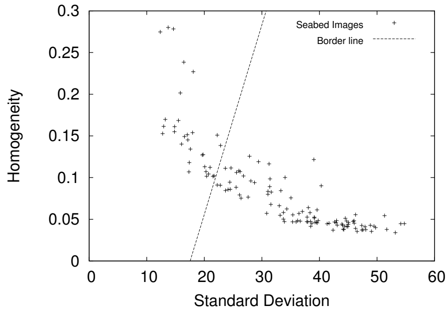


Figure 4. Result of the features and a border line.

3.3 Removal of Frame

The frame is removed by template matching. The templates are part of the top center and the middle of the frame. The match metrics of template matching are the sum of squared differences (SSD). The frame is removed by the coordinate of two templates that were obtained using template matching.

3.4 Recognizable Areas

The seabed image has great differences in illumination due to the photography environment. Because of this, it is difficult to recognize color and shape in the dark parts of these images when modeling the features of scallops. We propose a method that defines the recognizable areas and removes the unrecognizable areas.

The recognizable area is defined as follows. The image I of size (M, N) and localized region I_{local} of size (W, H) in Image I is denoted as $(I_{local} \subset I)$. Localized region I_{local} is defined as the recognizable area when the mean lightness L_μ of localized region I_{local} satisfies threshold $Th_L \leq L_\mu$. This process does a whole image I on moving bandwidth k of localized region I_{local}. In this paper, we set the localized region size $(W, H) = (64, 64)$, moving bandwidth $k = 16$, and threshold $Th_L = 75$. In this paper, we use the images of the recognizable area obtained in this way and analyze the extracted area.

4 Modeling of Features

4.1 Candidate of Shelly Rim

In the sand fields, there is no sand in the shelly rim, but the scallop shell is covered with sand because the scallop opens and closes its shell while it is alive and breathing (Fig. 2(a), (b)). In general, the scallop's shelly rim is white. We describe the method to extract the shelly rim areas using dynamic threshold.

Image I and localized region $I_{local'}$ of size (W', H') in Image I is denoted $(I_{local'} \subset I)$. Even if the localized region $I_{local'}$ is wide enough, the rate of the shelly rim pixels is low. This is because the localized region $I_{local'}$ has almost only sand areas (Fig. 2(a), (b)). In localized region $I_{local'}$, the shelly rim pixels have a high lightness, because the scallop of shelly rim is white.

The candidate pixels of shelly rim SR_c are defined as follows on the basis of these features. The histogram of lightness is obtained in localized region $I_{local'}$. When central coordinate of localized region $I_{local'}$ is (x'_0, y'_0), the threshold of a candidate shelly rim $Th_{SR}(x'_0, y'_0)$ is defined as

$$Th_{SR}(x'_0, y'_0) = L_{\mu'} + \lambda L_{\sigma'}, \quad (1)$$

where $L_{\mu'}$ is average lightness and $L_{\sigma'}$ is standard deviation. Also, λ is set by the rate of a candidate shelly rim is parameter p when this histogram is assumed to have normal distribution. Here, if threshold Th_{SR} is higher than $Th_{SR_{upper}}$, we define it as $Th_{SR} = Th_{SR_{upper}}$, because the lightness value is limited. This threshold $Th_{SR}(x'_0, y'_0)$ is the threshold of $I(x, y)$, when coordinates of image I correspond to (x'_0, y'_0) is (x, y). This process dose a whole image I on moving bandwidth k' of localized region $I_{local'}$. A whole image of threshold Th_{SR} is calculated by a linear interpolation method. A pixel of image $I(x, y)$ is defined as a candidate pixel of shelly rim SR_c, when $I(x, y)$ satisfies

$$Th_{SR}(x, y) \leq I(x, y). \quad (2)$$

In this paper, we set the localized region $I_{local'}$ size $(W, H) = (64, 64)$, moving bandwidth $k' = 16$, $Th_{SR_{upper}} = 245$, the rate of the shelly rim $p = 0.01$, and λ is given as 2.326.

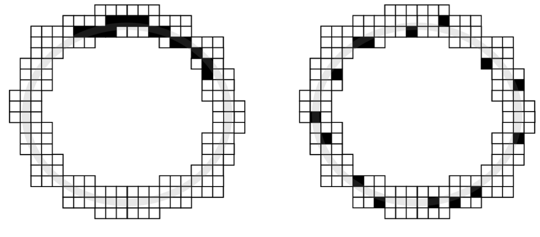
4.2 Shape of Scallop Shell

The scallop shell is shaped like a fan. 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. However, the feature points used are described in the following section. An ellipse is defined as $f(x, y, \alpha, \beta, \phi)$ by five parameters: the center point (x_0, y_0), two semi-axes (α and β), and an orientation ϕ. These parameters are determined by voting in the Hough parameter space. Here, a parameter of the orientation is set at $\phi = 0$, because there are the shape of a shelly rim is less than half an ellipse. Therefore, the Hough transform uses the four dimensional parameter space. The extracted ellipses are the candidates for scallop areas. Since the scallop areas have sizes in a constant range, two semi-axes are set at $22 \leq \alpha, \beta \leq 36$, and an ellipticity β/α is set at $0.85 \leq \beta/\alpha$.

4.3 Integrate Shelly Rim and Shape Features

The scallop shell is a fan-like shape, and the shelly rim is white. Therefore, the candidate for shelly rim pixels follows the scallop rim if these pixels are the scallop shelly rim. In this paper, the candidate pixels of a shelly rim are defined as the feature points for the Hough transform, but the feature points are usually the edge points.

In the parameters of the Hough transform, $\Delta\alpha$ and $\Delta\beta$ denote the resolutions of parameter space. The



(a) (b)

Figure 5. Distribution of the feature points on a extracted ellipse.

near-field of this ellipse F has the feature points that were voted. A region F is

$$f(x, y, \alpha - \frac{\Delta\alpha}{2}, \beta - \frac{\Delta\beta}{2}) \leq F \leq f(x, y, \alpha + \frac{\Delta\alpha}{2}, \beta + \frac{\Delta\beta}{2}). \quad (3)$$

A vote number in the parameter space is same the number of the feature points on near-field of the corresponding ellipse F. In this paper, we set $\Delta\alpha, \Delta\beta = 2$.

4.4 Definition of Scallop

This section describes how a feature of the scallop areas is given by the shelly rim and the shape.

There are some sand fields containing granule, fine sand, and sand. In scallop area, the inside a shelly rim is sand area. The candidate shelly rim points vary in their distribution in some states. Figure 5 shows the distribution of the candidate for shelly rim pixels on the extracted ellipse described. There is a high possibility that the scallop area is shown in Fig. 5(a), and the noise area in Fig. 5(b). Therefore, we defined the inside a shelly rim feature and the value of the shelly rim feature in relation to the distribution of the candidate pixels.

An area of the inside F denoted as F_i. The number of the feature points on F_i is calculated, and denoted as Num_i.

The boundary length of the ellipse l and the parameter $d (0 < d \leq 1)$ are defined. In the range of dl, the maximum number of the feature points on near-field of ellipse F is calculated, and denoted as Num_{SR}. Here, the value of the shelly rim feature R is defined as

$$R = \frac{Num_{SR}}{dl}. \quad (4)$$

We defined the scallop areas when Num_i and R satisfy

$$Th_R \leq R \cap Num_i \leq Th_i \quad (5)$$

where Th_i is the threshold for the inside a shelly rim feature and Th_R is the threshold for the shelly rim feature. Equation 5 is a condition for the scallop area. In this paper, we set $d = 0.25$ and $Th_i = 50$.

5 Experiment

5.1 Method

We used 25 seabed images that had 89 scallops in this experiment. There were 71 scallops that are clear

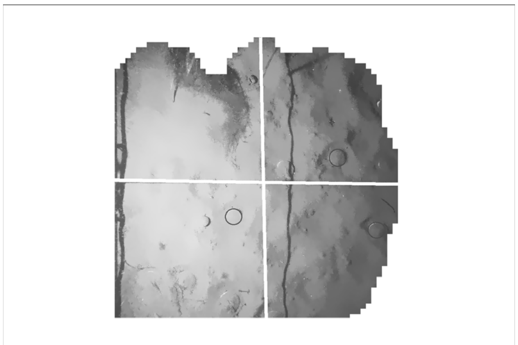
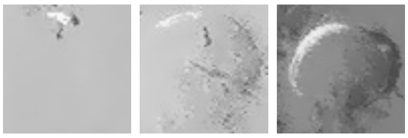
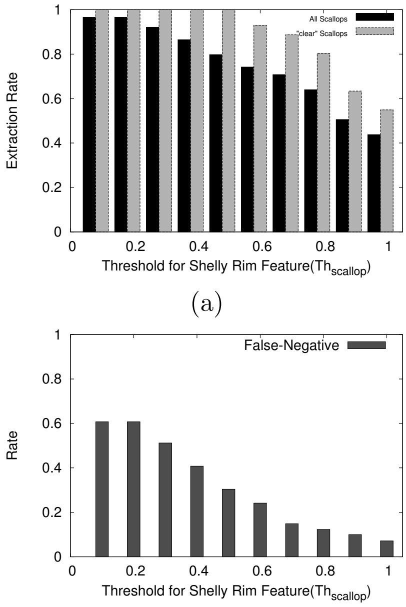


Figure 6. Result of threshold processing for the shelly rim feature. The threshold is $Th_R = 0.8$.



(a) (b) (c)

Figure 7. Results of shelly rim feature R. (a)–(c) are the scallop area images. (a) $R = 0.3$. (b) $R = 0.5$. (c) $R = 1.0$.



(a)

(b)

Figure 8. Experiment results. (a) is the result of extraction rate, and (b) is the result of false-negative. The clear scallop is "clear".

and have enough shelly rim area to be extracted in the 25 seabed images. Here, the clear scallop is defined as this have eight of the boundary length of the ellipse l, and referred to as "clear". In all extracted areas, if a scallop area was extracted correctly, we determined the results to be accurate in the extraction rate. If the scallop area was not extracted, we determined the results to be false-positive. Furthermore, if non-scallop area was extracted incorrectly, we determined the results to be false-negative.

5.2 Results

Figure 6 presents samples of experiment result. In Fig. 6, the scallop areas were extracted, but the scallop areas were not extracted when the scallop's shelly rim area was low. In Fig. 7(a)–(c), the value of the shelly rim feature adapted to the variance of the clear area of the shelly rim.

Figure 8 shows all results of the experiment when the threshold for the shelly rim feature was changed. While $Th_R = 0.1$–0.5, all "clear" scallop were extracted correctly. In $Th_R = 0.7$, the extraction rate accuracy of scallop areas was 70.8%, and the extraction rate accuracy of "clear" is 89.0%. In $Th_R = 1.0$, there were only three extracted false-negative areas.

5.3 Discussion

We developed a method to extract the scallop areas from the fine sand seabed images using their shape and the color of the shelly rim. The scallop areas cannot be extracted correctly using only the edges of the scallop shape. The proposed method defined the feature points as the candidates for shelly rim pixels and the shelly rim feature. The proposed method could extract the scallop areas, because the candidates for shelly rim were widely distributed.

It is said that the extraction rate of experts' manual measurement is 95%. The extraction rate of "clear" scallops is about 95% when $Th_R = 0.58$ (Fig. 8(a)) when the proposed method is used. These results are accurate enough.

6 Conclusion

This paper has presented a method to extract the scallop areas from fine sand seabed images. In few visual features, this method defined the features of scallops by using the color of the shelly rim and shapes, and models them on the basis of professional knowledge. Additionally, the experimental results gained by applying the proposed method to the seabed images show our method to be useful.

Future work, we will consider a method to extract the scallop areas from mixed sand and gravel fields and apply our technology to the videos for the fishery investigation.

References

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