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Discussion on a Method to Extract Scallop Using Line Convergence Index Filter from Granule-Sand Seabed Videos

Koichiro ENOMOTO
Niigata University, Japan
8050, Ikarashi-2, Niigata, Japan
e-mail enomoto@ie.niigata-u.ac.jp

Masashi TODA
Kumamoto University, Japan
2-39-1, Kurokami, Kumamoto, Japan
e-mail toda@cc.kumamoto-u.ac.jp

Yasuhiro KUWAHARA
Hokkaido Abashiri Fisheries
Experiment Station, Japan
1-1-1 Masuura, Abashiri,
Hokkaido, Japan

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 are located on gravel, sand, and granule-sand seabed. Seabed videos are necessary to visually estimate the number of scallops of a particular farm. However, there is no automatic technology for measuring resources quantities and so the current investigation technique is the manual measurement by experts. In granule-sand fields, 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 extract scallop areas using the line convergence index filter from videos of granule-sand seabed, explain the results, and evaluate the method's effectiveness.

1 Introduction

Recently, the investigation method has been developed to measure fishes using an underwater camera [1, 2, 3] or an underwater video camera [4]. The image analysis techniques can investigate the benthic fishery resources, but the acoustic survey cannot. However, these investigations do not use automatic measurements from the images and the videos but only taken images.

In the scallop culture industry in Abashiri, Japan, the fisheries are investigated by analyzing seabed images [1]. The results of investigations are used to estimate the catch size, time fish are caught, and future stocks. We showed a method to extract the scallop area from the seabed images in the fields of gravel [5] and sand [6]. Moreover, we proposed a method to classify the bottom sediments from the seabed images [7]. However, these methods cannot be adapted to images of granule-sand fields.

In this paper, we propose a method to extract the scallop areas using professional knowledge from images of granule-sand seabed, explain the results, and evaluate the method's effectiveness.

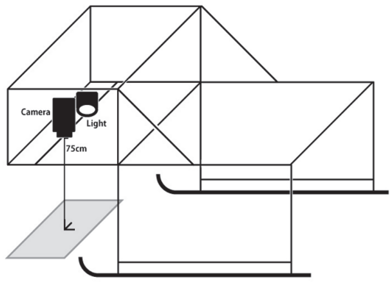


Figure 1. Simplified schematic of the shooting equipment for the seabed video.

2 Design Consideration

2.1 Seabed Video

The method of capturing seabed videos is based on professional knowledge and ecology. Figure 1 shows a simplified schematic of the photography environment for the seabed video. The shooting equipment is a metallic frame, a digital video camera, and lighting. The legs of the equipment are the sled-like structure. The shooting equipment glide over the seabed. Therefore, the distance between a video camera and the seabed is stabilized when shooting a seabed video.

Figure 2 shows a captured image of granule-sand seabed (1920×1024 pixels in 24-bit color) from a seabed video. This seabed video contains scallops, sand, granule, and shell debris. There is much more shell debris in granule-sand fields than in sand fields. The size of the scallops can be determined because if we have information about the target area, we can determine the age of the scallops.

2.2 Relation between Scallop and Bottom Sediments

The scallop lives in the fields of gravel, sand, and granule-sand. Sand and gravel are classified as the seabed and shore that consists of sediments ranging in size from 0.0625*mm* to 2*mm* for sand and 2*mm* to 64*mm* for gravel. Granule-sand is mixed the sand, granule gravel, and the shell debris. In the targeted areas, almost the shell debris is the dead scallops and white.

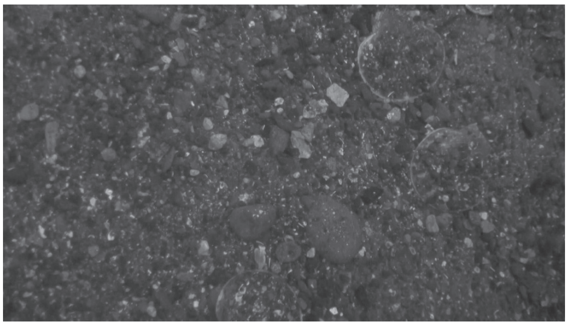
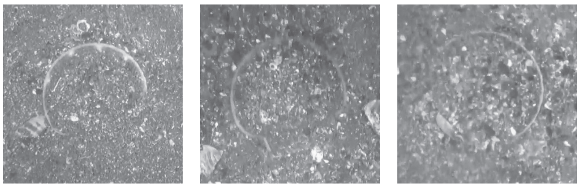


Figure 2. Sample image of the seabed video. In this image, there are two scallops on the right.



(a) (b) (c)

Figure 3. Sample images of the scallop area in granule-sand fields.

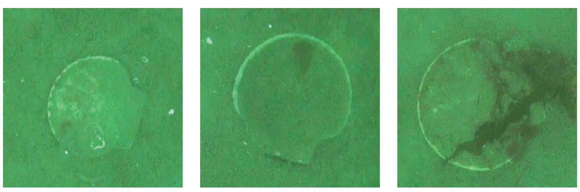
Figure 3 shows a scallop area of 450×450 pixels in granule-sand fields. In granule-sand fields (Fig. 3), the scallop areas that are buried in the white debris have special features such as white fan-shaped shelly rims. In gravel fields, the scallop features are fluted patterns, colored shells, and fan-like shapes [5].

Figure 4 shows a scallop area of 600×600 pixels in sand fields. In sand fields, the scallop areas have special features such as white fan-shaped shelly rims [6]. There is usually no sand on the shelly rim due to the scallops opening and closing their shells while aliving and breathing. For the same reason, the scallops do not overlap each other. These facts are based on knowledge of ecologists and fishermen.

2.3 Proposed Method

The scallop's shelly rim can be seen in all fields. In a method to extract the scallop area from the sand seabed images [6], it's defined as the sand region is contained a few of the shell debris(Fig. 3 and Fig. 4). Therefore, this method uses the high brightness pixels as the shelly rim. However, this method cannot be adapted to images of granule-sand fields, because there is a lot of the shelly debris.

We assumed an arc line of the shelly rim as a characteristic shape in granul-sand fields, but these are many



(a) (b) (c)

Figure 4. Sample images of the scallop area in sand fields.

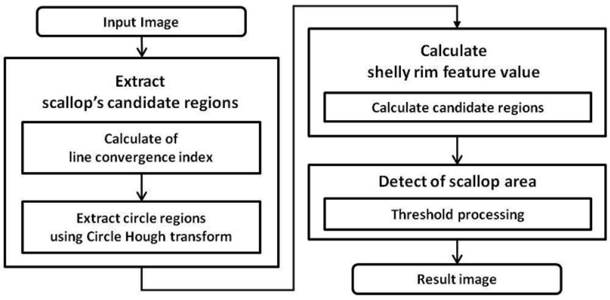


Figure 5. Proposed method.

shell debris. We proposed a method to extract the scallop areas using the line convergence index filter [8] in granule-sand fields. In this paper, we defined a method for sand fields [6] as the previous method, and conduct a comparative experiments. Figure 5 shows our proposed method to extract the scallop areas in granule-sand fields. First, the line convergence index is calculated from the seabed image(Sect. 3.1). Next, the candidate scallop area is extracted using the Circle Hough transform (Sect. 3.1.2). Finally, the scallop areas are extracted by threshold processing using shelly rim features (Sect. 3.2).

3 Modeling of Scallop Features

3.1 Extraction of Scallop's Candidate Region

In granule-sand fields, the scallop's shelly rim is sight because moving the scallop's shell(Fig. 3). Scallop's shelly rims are generally white, but there is a lot of the shelly debris with similar color. We define scallop's shelly rims as circular arc contained lines, and describe a method for extracting shelly rim areas using the line convergence index filter and Circle Hough transform.

3.1.1 Line Convergence Index Filter

We use the line convergence index filter [8] to extract a scallop's shelly rim. Therefore, in this section, we briefly explain the line convergence index filter. The line convergence index filter regards linear bright region as regions that contain gradient vectors that are perpendicular to a line like in Fig.6. Figure 7 shows the gradient vector aspect of the near point of vector convergence line. According to the line convergence line index filter definition, this line is called the "line convergence vector field". Because the convergence index filter focuses on only gradient orientation, it is free from absolute intensity and relative contrast variations.

It is necessary to calculate $C(x, y)$, whitch is the line convergence index at the point (x, y), to extract linear bright regions. We assume that the vector convergence line V_c passes (x, y), we define C_p which is evaluation value of the level of line convergence at P, which is near point of V_c as follows,

$$C_p = \begin{cases} \cos(\theta_p) & \text{if } |\vec{g_p}| \neq 0 \\ 0 & \text{if } |\vec{g_p}| = 0 \end{cases} \tag{1}$$

where $\vec{g_p}$ is gradient vector at P and θ_p is gradient orientation at P.

Let A_l, A_r is the area that spreads from the vector convergence line in both directions. We define C_{Al} and C_{Ar} as follows

$$C_{Al} = E\left[\cos(\theta_p)\right](P \in A_l) \quad (2)$$

$$C_{Ar} = E\left[\cos(\theta_p)\right](P \in A_r) \quad (3)$$

$C(x, y)$ calculated in accordance with following equation under the assumption that the vector index line passes (x, y), the angle of which is ψ.

$$C(x, y) = \max_{\varphi} \left[\frac{\max_{w_l} C_{Al} + \max_{w_r} C_{Ar}}{2} \right] \quad (4)$$

where w_l, w_r is the length from vector convergence line to edge of A_l,A_r. The range of $C(x, y)$ is 0.0–1.0. If (x,y) is on vector convergence line, $C(x, y)$ becomes the maximum value 1.0. If (x, y) is on liner bright region, $C(x, y)$ becomes more than 0.5.

The line convergence index filter targetes at ideal linear bright regions. However, because gradient vectors in real environments are disturbed by noise, the rule by which the line convergence index becomes the maximum value (1.0) on the vector convergence line may not apply to real images.

The simplest method of the extraction of the vein is that we calculate convergence index of the image which is the target of extraction and extract the pixels which convergence index is more than 0.5. However, the convergence index has tendency to become higher than 0.5 in the region which direction of gradient vector focus on a point.

In regard to this tendency, the proposed method erase the short linear bright region from the extraction target. Therefore, to make the correspondence of the size of region to the length of vein better, the proposed method calculate only convergence index of the pixels that are near the centerline with centerline detection method which was proposed by Yoshinaga, et al.[9].

Note that the number of regions does not change by this method. The method to calculate only convergence index of the pixels near the centerline uses function $C_{ct}(x, y)$ instead of $C_(x, y)$. $C_{ct}(x, y)$ is as follows:

$$C_{ct}(x, y) = \begin{cases} \max_{\varphi} \left[\frac{\max_{W_l} C_{Al} + \max_{W_r} C_{Ar}}{2} \right] & \text{if } |W_l - W_r| < T_w \\ 0 & \text{if } |W_l - W_r| \geq T_w \end{cases} \quad (5)$$

where T_w is constant parameter. T_w controls whether leave or remove a convergence index according to the length from centerline. In this paper, we set the T_w to 4 according to line width of the shelly rim.

3.1.2 Circle Hough Transform

The scallop's shell is shaped like a fan. We define the shape of the scallop shell as a circle and extract it using the Weighted Hough transform to detect circles, but the previous methods [6] define it as ellipse. This method is effective against noise and can be set at arbitrary sizes. Moreover, we can estimate the actual size of the scallop from its results.

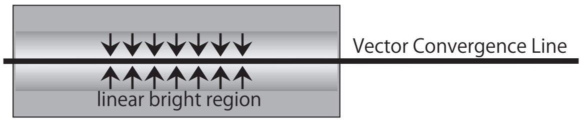


Figure 6. Line convergence vector field.

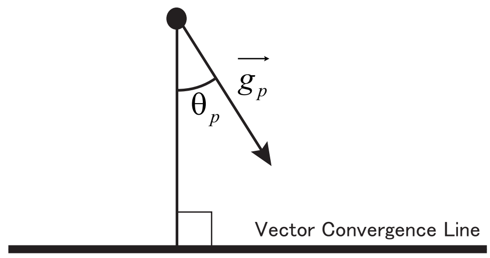


Figure 7. The near point of vector convergence line.

An ellipse is defined as $f(x, y, r)$ by three parameters (Fig. 8): the center point (x_0, y_0) and the radial r. These parameters are determined by voting in the Hough parameter space. The weighted value is defined as the line convergence index. This method is different from the Gradient Weighted Hough Transform(GWHT) [10], because it use the points of line. The extracted circles are the candidates for the scallop areas.

In this paper, we use only the line convergence index higher than 0.6, because there is a lot of the shelly debris. Additionally, since the scallop areas have a constant range of sizes, we can set the radius at $70 \leq r \leq 180$.

3.2 Definition of Scallop Area

This section describes how features of scallop areas are determined by the shelly rim and shape. Some sand fields contain granulees, fine sand, and sand. Therefore, the candidate pixels of a shelly rim vary in their distribution in some states.

In this paper, we use the shelly rim feature in the proposed method [6], and only the pixels of the line convergence index higher than 0.6 (binarize). Moreover, we do not use the shell feature, because the scal-

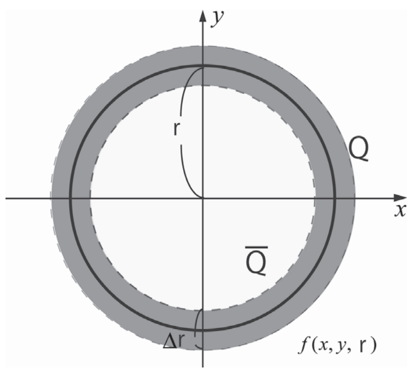


Figure 8. Circle and scallop area anatomy.

lop's shell is covered with the shell debris in granule-sand fields.

In the shelly rim feature, it is defined the boundary length of the circle l and the parameter D ($1 \leq D$). The length of an arc is expressed as $\frac{1}{D}l$. In the range of $\frac{1}{D}l$, the maximum number of feature points on a region Q is calculated, and denoted as Num_Q(Fig. 8). Here, the value of the shelly rim feature R_Q is defined as

$$R_Q = \frac{Num_Q}{\frac{1}{D}l}. \quad (6)$$

The scallop areas is defined when R_Q satisfy

$$Th_Q \leq R_Q \quad (7)$$

where Th_Q is the threshold for the shelly rim feature R_Q.

4 Experiment

4.1 Method

In this experiment, we used 45 captured seabed images containing 84 scallops. We conduct a comparative experiments with the proposed method and the previous method [6].

The evaluation methods are defined as follow. If a scallop area was extracted correctly in all extracted areas, we determined the results to be true-positive (TP). If the scallop area was not extracted, we determined the results to be false-negative (FN). Furthermore, if a non-scallop area was extracted incorrectly, we determined the results to be false-positive (FP). We use for the evaluation items of Recall, Precision, and F-measure.

4.2 Result

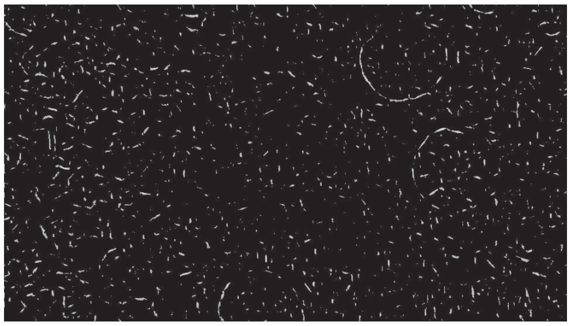
Samples the experimental results of the proposed method and the previous method are shown in Figs. 9–12. In Fig. 10 and 12, the feature points were extracted to many pixels of the shelly rim and the shell debris by the previous method. Although, in Fig. 9(a) and 11, the feature points were extracted only the pixels of line by the proposed method. In the result of the proposed method of Fig. 9(b), two scallops were extracted correctly, but the previous method were extracted a scallop and were not extracted the one in Fig. 10(b).

In Fig. 11, these images were recognized as the scallop area using the shelly rim feature (Sect. 3.2), but many candidate areas were extracted. In Fig. 11, these images were detected to the scallop area and other area. The proposed method is defined the feature point as line pixels for Hough transform, although in the previous method, the feature points was defined as a white pixel.

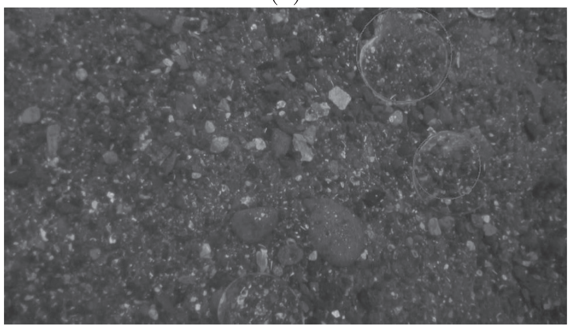
All experimental results are listed in Table 1. The experimental results showed that the Recall of the proposed method was 94.1%, while that of the previous method was 34.5%. The proposed method is a higher accuracy than the previous method.

4.3 Discussion

We developed a method to extract the scallop areas from granule-sand seabed images using the shape and



(a)



(b)

Figure 9. Sample of experimental results by proposed method. Object image is that in Fig. 2. (a) the image of the line convergence index (b) result image

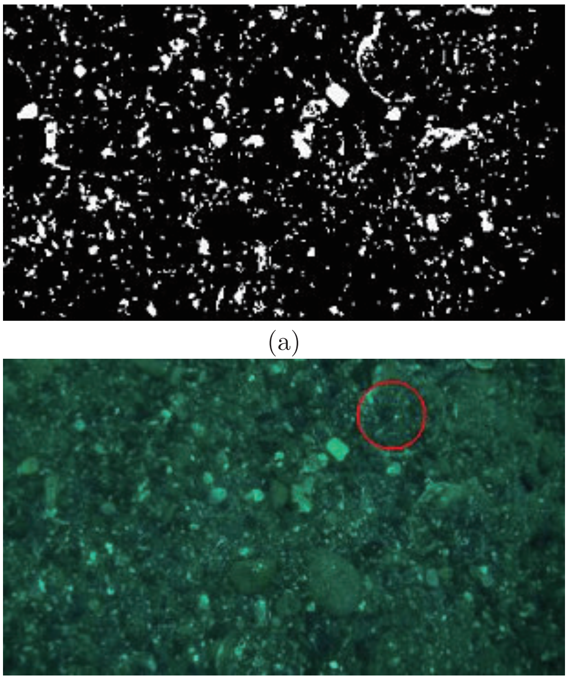
color of the shelly rim. The proposed method use the line convergence index filter and the Weighted Hough transform to detect circles, but the previous method was used the feature points as the candidate pixels of the shelly rim and the Hough transform.

If the feature points for the Hough transform are the line convergence index, they included the points of granule, sand, and debris. Therefore, the scallop areas cannot be extracted correctly using only the line segments of the scallop shape. The scallop area cannot be extracted correctly using only the shape feature in granule-sand fields. The proposed method could extract scallop areas because the candidates of the shelly rim were widely distributed.

There were also five false-negative cases, although

Table 1. Experimental results.

	Proposed Method	Previous Method
No. of scallops	84	
TP	79	29
FP	15	6
Recall	0.941	0.345
Precision	0.840	0.829
F-measure	0.888	0.487



(a)

(b)

Figure 10. Sample of experimental results by previous method. Object image is that in Fig. 2. (a) the image of the feature points for Hough transform (b) result image

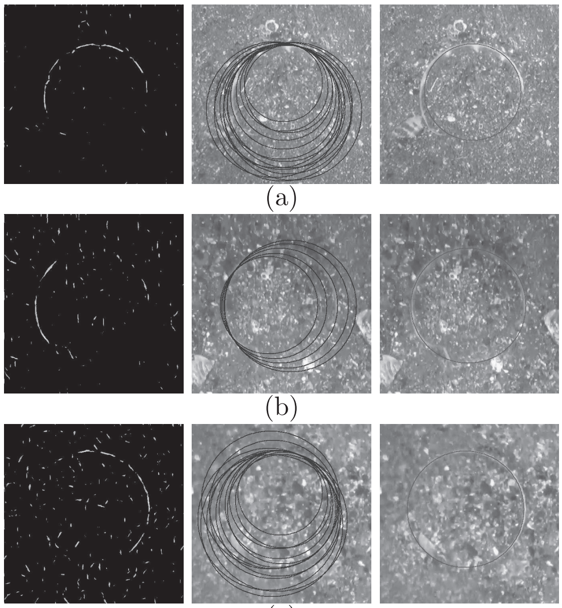
the extraction rate accuracy was high enough to measure the scallop. Some cases are extracted correctly the candidates for the scallop areas, but are not recognized as a scallop. It is need that the recognition method of the scallop is improved. Although, this method is accurate enough and comparable to the extraction method for sand seabed images [6].

Recall was 0.941 (Table 1) with the proposed method, but recall manual measurement is said to be 0.95. These results are sufficiently accurate.

5 Conclusion

This paper has presented a method to extract the state of scallop beds from granule-sand seabed images. In granule-sand seabed images, the scallop's shelly rim is not covered with sand (Sect.2.2). This method defined the features of the scallops by using the shape of the scallop's shelly rims. The proposed method is a higher accuracy than the previous method in the experiment by using the line convergence index filter. Additionally, the experimental results showed that our method is effective.

For future work, we will improve the recognition method of the scallop using the line convergence index, because this proposed method used only the feature of line segment or otherwise. In all fields of bottom sediment, there is usually no sand on the shelly rim. Therefore, we will also apply the proposed method to the fields of gravel and sand.



(a)

(b)

(c)

Figure 11. Experiment results of the scallop area by proposed method. Object images are that in Fig. 3. (Left) the image of the line convergence index; (center) the image of the candidate areas; (right) the result image.

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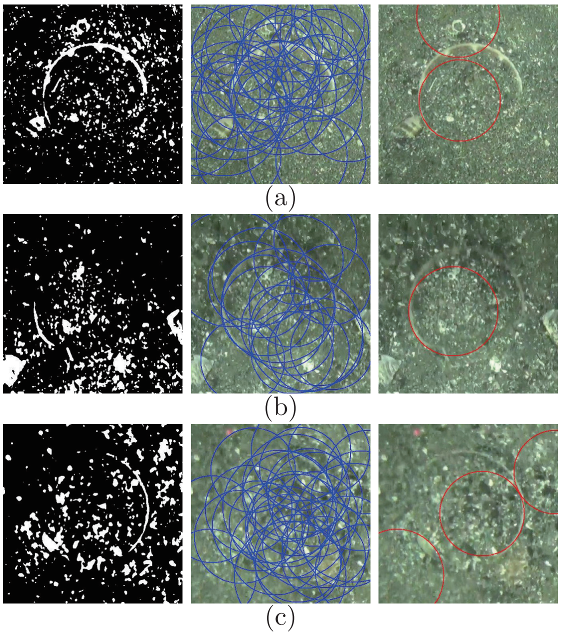

Figure 12. Experiment results of the scallop area by previous method. Object images are that in Fig. 3. (Left) the image of the feature point for Hough transform; (center) the image of the candidate areas; (right) the result image.

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