

Measurement of Pack Ice Area and Concentration using Image Processing Package

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ABSTRACT

Due to the increasing possibility of passing the Arctic route, considerable works on the icebreaking vessels have been continuously published. The model ship test on the pack ice model in the ice tank is actively carried out as a way to investigate the performance of icebreaking vessels. The concentration as well as the individual area of pack ice are important since they directly affect the performance. However, it is not easy to obtain those properties because not only the pack ice has uneven shape but also it keeps floating around in the ice tank. In this paper, an algorithm to identify the concentration of pack ice is introduced. From a digital image of pack ice obtained in the ice tank, the goal is to measure the area of pack ice using an image processing technique. Instead of the general global thresholding that yields numerical errors in this problem, a local thresholding technique, coupled with image subdivision based on the quadtree structure, is developed. The individual area of each ice patch is calculated using the edge extraction and the watershed technique.

KEY WORDS: Pack ice; Concentration; Local thresholding; Individual area distribution; Segmentation.

INTRODUCTION

Recently, the frozen area of the Arctic has been decreasing and the duration of below freezing temperatures has been shortening. As a result, there is a growing need for basic research on icebreakers passing through the Arctic route. As a type of basic research, icebreaker model tests have been actively conducted by using integrated pack ice. In this experiment, the concentration and area distributions of each of the pack ice formations are the significant factors necessary to evaluate the performance of icebreakers. Pack ice is floating ice in a widely-bound state. Because pack ice floats freely in an ice tank, it has limited accessibility, and owing to its non-uniform shape, it is difficult to directly measure its concentration and area distribution. Therefore, we mainly use remote sensing to extract information on this object by using a sensor from a long distance (Rees, 2005). Among many methods, there is a method of analyzing the images of where pack ice is distributed, which yields lower initial investment requirements and operating costs than other methods. The images of a pack ice distribution were often analyzed via commercial software, which facilitated and simplified

the measuring process (Cho, et al., 2013). Although it is suitable for general objects, the commercial software not only requires users to constantly engage with the software, but it has the drawbacks of not providing accurate results for specific measurements such as pack ice concentration measurement. Furthermore, this software is particularly not applicable when the pack ice is under irregular illumination.

An algorithm optimized for pack ice concentration measurement has been actively studied. As an example, a study analyzing an image of a large area of pack ice after manual subdivision of the image via preprocessing has been reported (Zhang, et al., 2015). An enhancement for a non-uniform light and color region using thresholding following manual subdivision was recently introduced by Byun, et al. (2016). Subsequently, an automatic subdivision algorithm using quadtree and a local thresholding result, which automatically solved the problem of light or color non-uniformity, were presented (Lee, et al., 2017).

In this paper, we describe the automatic subdivision algorithm using quadtree. The generated binary image is then applied to the watershed object segmentation algorithm to extract the separable pack ice formations and to calculate the pack ice distribution. We add a local maximum finder algorithm to the watershed object segmentation algorithm to search among pack ice of various sizes and to clearly distinguish proximity objects by applying morphology erosion. This algorithm is applied to the model pack ice image of an ice tank, and an example of deriving pack ice concentration and the area distribution result is demonstrated. Open-source digital image processing technology is used for image analysis (Itseez, 2014).

QUADTREE-BASED DEVELOPMENT SUBDIVISION ALGORITHM

Global thresholding using only one threshold per image can be used for ideal pack ice image analysis. Most images are, however, never perfect owing to irregularities in light or color, which may lead to inadequate image analysis results. This problem can be improved by using a local thresholding method of image thresholding followed by subdivision.

The method of image subdivision and frequency are determined via an automatic subdivision algorithm using quadtree. Fig. 1 shows the overall flow diagram of the development algorithm.

First, images are input into quadtree process for histogram analysis and subsequently classified into four groups (#1). If it is classified as a complete one-peak, the binary image is extracted via the one-peak thresholding algorithm and reflected in the accumulated binary image (#2). Alternatively, if it is classified as a complete two-peak, the binary image is extracted and reflected via the two-peak thresholding algorithm (#3).

An image classified as an incomplete one-peak is subjected to a quadtree subdivision process if it satisfies the minimum pixel number requirement for analysis (#4). Hence, four sub-images are generated and subsequently re-input for histogram analysis (#5). Additionally, for the image classified as two incomplete peaks, if the number of images is larger than the minimum number of pixels, the quadtree data is extracted and re-input (#6). At this point, after excluding the inaccurate image, a binary image of accurate image is extracted and reflected via a two-peak thresholding algorithm (#7).

Since the developed algorithm follows the recursive flow via peak analysis of the histogram, there is a high probability that the obtained peak is inaccurate. This inaccuracy is induced because the information needed to generate the peak is insufficient in images in which the number of pixels is below a certain value. Therefore, it is necessary to set the minimum pixel reference. In this study, it is set to the result of analyzing a large number of images with

errors. Additionally, images with pixels below this number are excluded from the analysis.

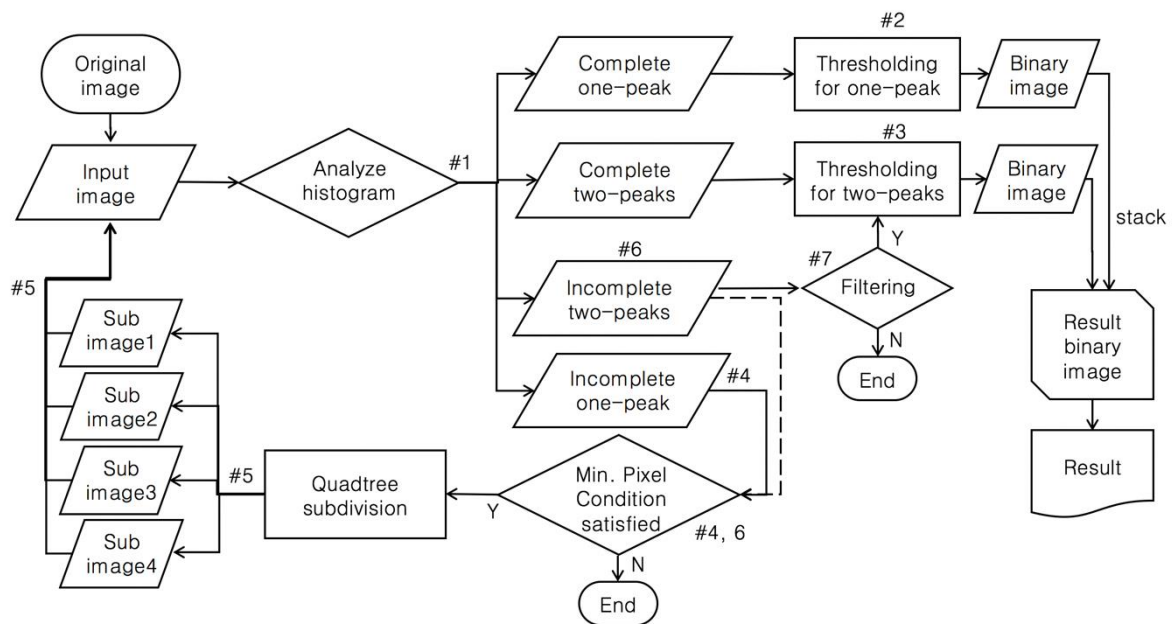


Figure 1. The overall flow diagram of the development algorithm

DETERMINING INDIVIDUAL AREA DISTRIBUTIONS USING WATERSHED OBJECT SEGMENTATION

Fig. 2 illustrates the watershed algorithm for object segmentation. The binary image is extracted via thresholding of the original input image. The edge and seed outline images are derived from the binary image via the edge detection and the seed outline extraction. The marker image merging these images and the original image are input as initial values of the watershed algorithm. Lastly the individual object segmentation images are derived.

This study utilizes a quadtree-based local thresholding development algorithm (#8), which minimizes the effects of color difference and light non-uniformity on the pack ice image. This enables the derivation of an optimized binary image that can distinguish between the pack ice and water. For the edge detection (#9), the Laplacian edge detection technique is utilized. This technique utilizes two-dimensional image differentials and is suitable for extracting pack ice edges with bidirectional distributions. Fig. 4 demonstrates the difference between the edges extracted in the first derivative and the second derivative of the original image. In the first derivative, only one directional edge is extracted, while in the second derivative both directional edges are extracted.

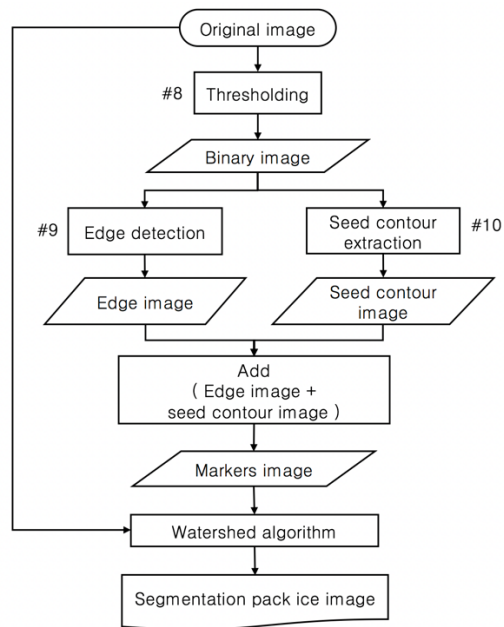


Figure 2. Watershed segmentation algorithm

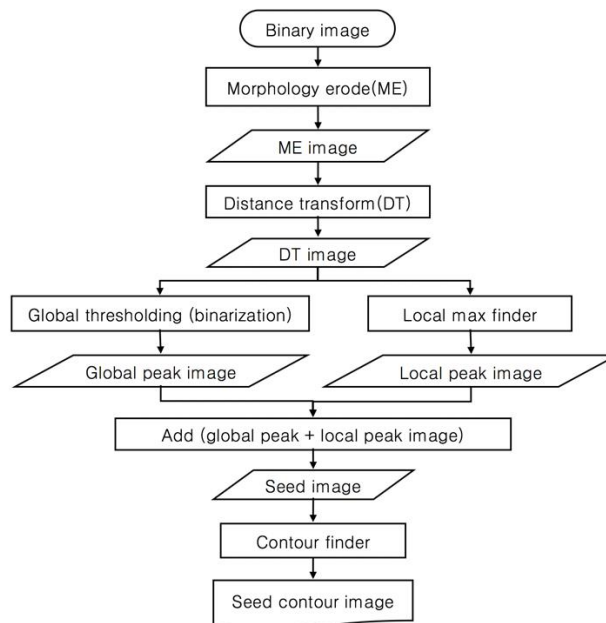


Figure 3. Seed contour extraction algorithm

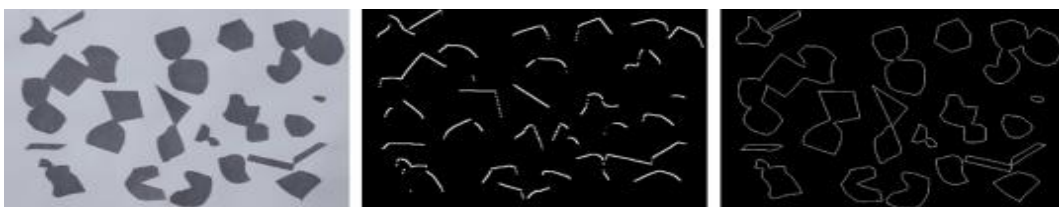


Figure 4. First (mid) and second derivative (right) edge of the original image (left)

Fig. 3 shows the seed contour extraction algorithm (#10). In this study, we applied morphology erosion, which reduces the white area representing the pack ice in the binary

image, to enable clear distinguishability of the closely distributed pack ice. This method is applied to the distance transform. Fig. 5 depicts the before and after application of morphology erosion, where the proximity pack ice is distinctly separated after application. Fig. 6 shows the image obtained after applying the distance transform to the original image of Fig. 4.



Figure 5. Binary image (left) and morphology erode image (right)

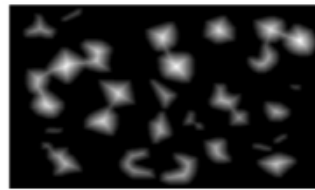


Figure 6. Example of distance transform

In general, global thresholding is used to extract only the global peaks located a sufficient distance from the outside. This method is only suitable for objects of a certain size. Since the size distribution of pack ice varies substantially, this study additionally incorporates a local maximum finder so that objects can be recognized regardless of size. Fig. 7 compares the segmentation between the global thresholding and the local thresholding, showing the segmentation of the original, via local thresholding, and global thresholding, respectively. Regarding distinguishability in global thresholding, small objects are not recognized. Conversely, local thresholding accurately recognizes small objects.

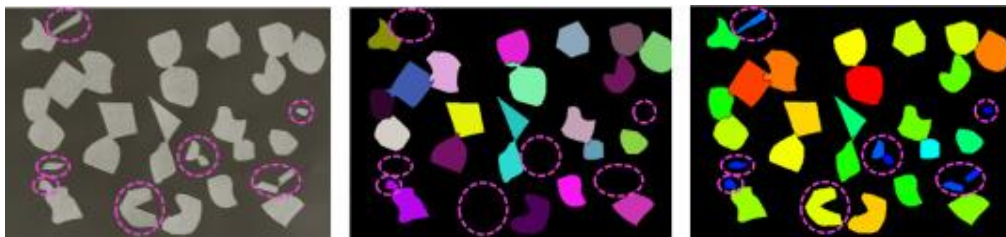


Figure 7. Images of original (left), segmentation with global (mid), and local thresholding (right)

Lastly, the local peak region is extracted and merged with the global peak to define the seed image. The seed outline image is thus extracted via the contour finder (Suzuki, 1985).

EXAMPLE

To verify the results of the local thresholding algorithm via quadtree, we compared the results to the global thresholding results. Fig. 8 shows the original and global thresholding results, in addition to the results obtained after applying the developed algorithm. The global thresholding results show that the lighting intensity of the right portion is not sufficient to

detect pack ice. The developed algorithm, however, is observed to adequately handle this problem. Fig. 9 shows the area distributions of each of the actual pack ice formations. This figure provides the original image with color labeling and a number chart according by size.

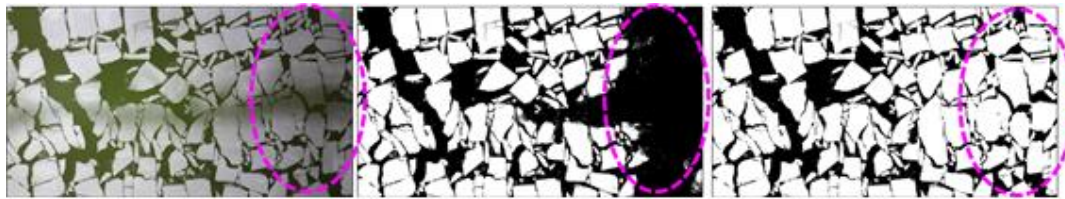


Figure 8. Original image (left), result of global thresholding (mid) and result of developed algorithm (right)

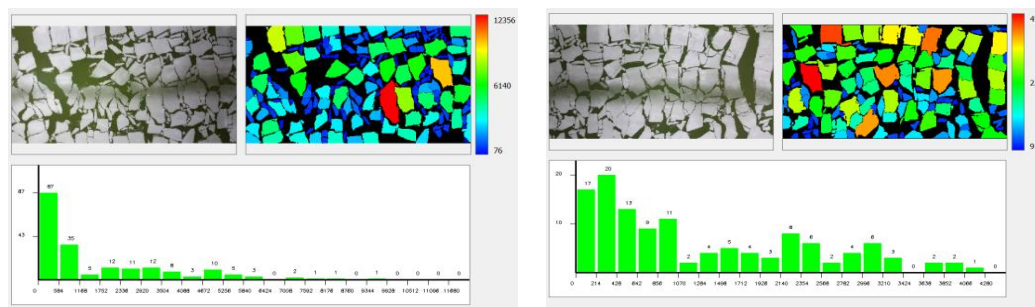


Figure 9. Example of individual pack ice extraction and area distribution chart

CONCLUSIONS

A localized thresholding algorithm using quadtree was developed to measure the pack ice concentration by distinguishing between pack ice and water. Additionally, the watershed object segmentation algorithm was modified to include pack ice extraction, yielding individual area distribution of pack ice.

Problems that may arise due to light non-uniformity or color difference are solved via local thresholding. The local thresholding method entails automatic extraction of small quadtree images and subsequent definition of each image into four categories according to the histogram results. It is confirmed that the development algorithm yields accurate binary results over the entire image independent of light irregularity or color difference.

The watershed algorithm is used to improve the sensitivity caused by the initial value inputs for pack ice extraction. For watershed-applied initial values, the edge was extracted via a Laplacian edge extraction technique that may be suitable for pack ice edge extraction of non-uniform shapes. Morphology erosion was applied to obtain clear distinction between the closely pack ice formations. We also added a local maximum finder to enable recognition of all sizes of pack ice.

Further research is needed to effectively apply an orthometric correction algorithm that is able to compensate for angle changes in angular images.

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REFERENCES

- Byun, S.H., Nam, J.-H., Woo, J., & Lee, S.-J., 2016. An algorithm for analysis of pack ice concentration using image processing technique. *The 31st International Symposium on Okhotsk Sea & Sea Ice*, Mombetsu, Hokkaido, Japan, 21-24 February 2016, pp.17-20.
- Cho, S.R., Jeong, S.Y. & Lee, S.S., 2013. Development of effective model test in pack ice conditions of square-type ice model basin. *Ocean Engineering*, 67, pp.35-44.
- Itseez, 2014. *OpenCV 2.4.11.0 documentation*. Sphinx: United States.
- Lee, J.H., Byun, S.H., Nam, J.-H. & Cho, S.R., 2017. An algorithm for measurement of pack ice concentration using localized binarization of quadtree-subdivided image. *Journal of the Society of Naval Architects of Korea*, 54(1), pp.49-56. (in Korean)
- Rees, W.G., 2005. *Remote Sensing of Snow and Ice*.
- Suzuki, S. & Abe, K., 1985. Topological Structural Analysis of Digitized Binary Images by Border Following. *Computer Vision Graphics and Image Processing*, 30(1), pp 32-46.
- Zhang, Q., Skjetne, R., Metrikin, I. & Løset, S., 2015. Image processing for ice floe analyses in broken-ice model testing. *Cold Regions Science and Technology*, 111, pp.27-38.