Research on Marine Radar Image Processing Method in Sea Ice Information Extraction Process

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Abstract. Firstly, the effectiveness of sea ice information extraction research with navigation radar is proposed. Different methods of image pre-processing are used for different sea ice information elements, and then the functions and characteristics of various processing methods are respectively summarized. The above processing methods, while taking advantage of the convenience of obtaining image data by shipborne navigation radar, can successfully process the radar image through MATLAB and provide a basis for the next extraction of sea ice information and further expansion of research on sea ice monitoring by marine radar.

1. Introduction

In some seasonal cold regions of the world, sea ice has brought great challenges to the safety of shipping vessels and offshore platforms. With the gradual opening of the Arctic waterway, the accurate, timely and effective grasp of sea ice information by shipping vessels is one of the most important factors for safe navigation in the Arctic. In China, the Bohai Sea and the northern Yellow Sea are the icy seas with the lowest latitudes in the northern hemisphere, and icing occurs to varying degrees every winter [1]. Therefore, real-time and accurate continuous monitoring of sea ice information is not only an important part of marine management, but also a significant way to ensure the safety of shipping transportation and marine development and production. When a vessel is sailing in an ice zone, it is necessary to fully understand the sea ice characteristic information or the sea area around the vessel to ensure the navigation safety.

In the current stage of shipping business and offshore engineering, the sea ice elements we mainly focus on are shown in Table 1 [2].

Table 1. Major sea ice information elements in focus.

| Observation elements | Unit       | Accuracy |
|----------------------|------------|----------|
| Sea ice density      | Share      | ±1       |
| Drifting direction   | (°)        | ±5       |
| Drifting speed       | m/s        | ±0.1     |
| Ice thickness        | cm         | ±1       |

At present, a variety of technical methods can provide a large amount of original image information for sea ice monitoring, such as satellite remote sensing, radar detection, and video shooting [3]. Compared with satellite remote sensing and aerial remote sensing, marine radar can be used for sea ice monitoring...
in the sea area near sailing vessels or offshore platforms due to its simple technical means and strong universality. Marine radar has the characteristics of continuous work under any weather conditions, and how to use appropriate methods to process radar images for different sea ice elements is the primary work of sea ice monitoring technology research by marine radar.

2. Acquisition and analysis of sea ice image

This article focuses on the research of image information processing technology based on the images measured by marine radars containing different sea ice information, such as sea ice density, sea ice thickness, and direction and speed of sea ice drift.

2.1. Sea ice density

Sea ice density is the main parameter describing sea ice, and it is defined as the ratio of the area covered by floating ice to the area existing floating ice \[2\]. Sea ice density is one of the main factors affecting the navigation safety of vessels. When the sea ice density is large, vessels may not even be able to sail at all. Many scholars have used satellite remote sensing and aerial remote sensing data to conduct massive experimental studies in polar regions and high latitudes, and have comprehensively analysed the information of each element of sea ice. This research is based on the radar sea ice image obtained from the observation of marine radar installed on offshore platform. And we binarize the image by differentiating the gray value of sea ice and sea water reflected on the image. As shown in Figure 1, sea ice is highlighted on the radar image, while seawater is gray.

![Fig. 1. Radar image with sea ice information.](image_url)

The Maximum inter-class variance method (Otsu algorithm) is an adaptive threshold determination method proposed by the Japanese scholar Otsu. The idea is to divide the image into two parts: the target and the background based on the gray characteristics of the image. The larger the interclass variance between the target and the background, the greater the difference between the two parts that make up the image. Therefore, the segmentation with the largest interclass variance means the smallest probability of misclassification\[^4-5\]. The Maximum inter-class variance method (Otsu algorithm) was used to select the threshold to determine the above images, and the processing effect is as shown in Figure 2. However, it should be noted that the obtained sea ice density data is relatively small after the image is processed by binarization. This is because the radar image will ignore some sea ice information with weak echo reflection signals when the data is collected.
Fig. 2. Processed with Otsu algorithm.

2.2. Sea ice thickness

Ice thickness is another major parameter describing sea ice, defined as the vertical distance from the ice surface to the bottom of the ice [2]. The thickness of sea ice is one of the main factors affecting the safety of vessels. When the thickness of sea ice is large, it not only affects the movement of the vessel, but even damages the vessel due to the broken ice. Compared with satellite sea ice images, radar sea ice images cannot calibrate sea ice of different thicknesses by colour information. Therefore, for radar images with a narrow range of brightness information, we use Histogram equalization to improve this disadvantage.

Histogram equalization is a method that automatically adjusts the contrast quality of the image by using gray scale transformation. The basic idea is to find the gray scale transformation function by using the gray level probability density function [6]. As a non-linear image enhancement algorithm, the equalized radar image histogram can better disperse the image brightness information into a wider interval and provide more details of pixel brightness changes. Perform histogram equalization on radar images processing, the results are shown in Figure 3. We can find that the brightness information of the sea ice image can be better distributed on the histogram. Using the method of equalizing the histogram of the sea ice radar image brightness information, we can classify the brightness information of the image according to features, set different levels, and then use linear mapping to make the brightness information represent different sea ice thicknesses.

Fig. 3. Processed with Histogram equalization.
2.3. Sea ice drifting direction and speed
The direction and speed of sea ice drift are affected by various factors in actual observation, such as hydrometeorology and other factors such as sea current and sea wind. The direction of sea ice rafting refers to the direction of floating ice drifting. The drifting speed is the distance that the floating ice moves per unit time \(^2,7\). When using radar to observe a specific sea ice, continuous observation can be performed by selecting the target, but the process mainly depends on manual operation, and the reproducibility of the results is poor. Therefore, in the radar images obtained by continuous observation, we can adopt the method of Feature matching algorithm to obtain the sea ice drifting direction and speed.

Feature matching algorithm has three main processes for feature matching: feature point extraction, feature point description, and feature point matching \[^8,9\]. In the process of finding the direction and speed of sea ice drift, we can take the sea ice image at time \(T\), \(I(X, Y)\) is the characteristic pixel coordinate of a certain sea ice in the picture. After a short interval \(\delta t\), the distance it moves horizontally is \(\delta x\), while the distance it moves vertically is \(\delta y\). Under the assumption that other conditions have not changed, the horizontal ice speed and vertical ice speed of the sea ice movement can be obtained which are as shown in formula (1) and formula (2):

\[
V_x = \frac{\delta x}{\delta t} \quad (1)
\]
\[
V_y = \frac{\delta y}{\delta t} \quad (2)
\]

And thence we can obtain the sea ice drift direction and speed through the speed vector synthesis. The speed of sea ice drift is as shown in formula (3):

\[
V = \sqrt{V_x^2 + V_y^2} \quad (3)
\]

Therefore, the direction \(\theta\) of sea ice drift of the position after \(\delta t\) with respect to the previous position is as shown in formula (4):

\[
\theta = \tan^{-1}\left(\frac{V_y}{V_x}\right) = \tan^{-1}\left(\frac{\delta y}{\delta x}\right) \quad (4)
\]

3. Conclusion
Marine radar not only plays an excellent role in navigation and collision avoidance during navigation, but also provides basic data for our research in marine hydrometeorology. In the process of extracting sea ice information based on radar images, each of the required sea ice information can be smoothly obtained through the above various methods. When extracting the sea ice density, we use a method of binarizing the radar image and using the Otsu algorithm to determine the threshold value. When extracting sea ice thickness, we use the Histogram equalized radar image brightness information to reflect the details and characteristics of sea ice thickness, and then map the sea ice thickness spectrum by dividing it into different levels. And when extracting the drift direction and speed of sea ice, by comparing two consecutive images, Feature matching algorithm is used to calculate the drift direction and speed of sea ice.

At the same time, we should note that due to the working principles and working conditions of marine radar equipment, the quality of the collected radar images is still insufficient, and the image processing methods need to be improved. Only under this circumstance can the role of marine radar in sea ice observation inevitably become more prominent.

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