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Recognition by Using Image Processing for Different Size Distribution Schemes

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ABSTRACT

An unmanned aerial vehicle was used as a mobile sensor platform to collect sea-ice features, and several image processing algorithms have been applied to samples of sea-ice images to extract useful information about sea ice. The sea-ice statistics given by the floe size distribution, being an important parameter for climate and wave- and structure-ice analysis, is challenging to calculate due to difficulties in ice floe identification, particularly the separation of seemingly connected ice floes. In this paper, the gradient vector flow snake algorithm is applied to solve this problem. To evolve the GVF snake algorithm automatically, an initialization based on the distance transform is proposed to detect individual ice floes, and the morphological cleaning is afterward applied to smoothen the shape of each identified ice floe. Based on the identification result, the image is separated into four different layers: ice floes, brash pieces, slush, and water. This makes it further possible to present a color map of the ice floes and brash pieces based on sizes, and the corresponding ice floe size distribution histogram. The proposed algorithm yields an acceptable identification results.

KEYWORDS: *GVF snake algorithm, image processing algorithm, distribution histogram.*

I. Introduction

The floe size distribution is a basic parameter of sea ice that affects the behavior of sea-ice extent, both dynamically and thermodynamically. Particularly for relatively small ice floes, it is critical to the estimation of melting rate. Hence, estimating floe size distributions contributes to the understanding of the behavior of the sea-ice extent on a global scale.For example, by identifying large floes that escape the icebreakers operating upstream of a protected structure. The size and shape of managed floes can be identified by the image processing system, compared with limit values, and further processed by the risk management system.

It provides an early warning of an ice compaction event, which can be dangerous if the ice-structure interaction mode changes from a slurry flow type to a pressured ice type. Automatic identification of individual floe edges is a key tool for extracting information of floe size distribution from aerial images. In an actual ice-covered environment, ice floes typically touch each other, and the junctions may be difficult to identify in digital images. This issue challenges the boundary detection of individual ice floes and significantly affects ice floe size analysis.

To separate seemingly connected floes into individual ones, a gradient vector flow (GVF) snake algorithm is applied in this research. However, to start the algorithm, a proper initial contour is required for the GVF snake to evolve correctly. Therefore, a manual initialization is typically needed, particularly in crowded floe segmentation.

A remote sensing mission to determine ice conditions was performed by the Northern Research Institute (NORUT) at 78∘55 N 11∘56 E, from May 6 to 8, 2011. An unmanned aerial vehicle (UAV) was used as a mobile sensor platform because of its flexibility in coverage and in spatial and temporal resolution, which are three important sensor-platform attributes. The use of cameras as sensors on a UAV was explored to measure ice statistics and properties. The objective of the mission was to gather information about the ice conditions in the Arctic. The further goal was to develop tools based on the processed ice data that can be applied for decision support in Arctic offshore operations. A CryoWing UAV was used for the mission. This UAV was designed for cryospheric measurements and environmental monitoring, and its technical specification is found in Table1. The basic instrumentation of the CryoWing is an onboard computer that controls the different payload instruments, stores data to a solid-state disk, and relays data to the ground.

Figure 1. Cyro Wing UAV

The onboard payload system has a GPS receiver and a three-axis orientation sensor that is independent of the avionics system. The sensor device used in this analysis is a digital visual camera with specifications. The UAV flew in the inner part of Kongsfjorden to collect high-resolution images of sea ice. Several image-processing algorithms have then been applied to these images to extract useful information of the sea ice, such as ice concentration, ice floe boundaries, and ice types. Automatic identification of individual floe edges is a key tool for extracting information of floe size distribution from aerial images.

1.1 Problem Statement:

Sea-Ice, which is defined as any form of ice that forms as a result of seawater freezing covers approximately 7% of the total area of the world's oceans. It is turbulent because of wind, wave, and temperature fluctuations. Various types of sea ice can be found in ice-covered regions. Ice floe, which is the flat pieces of sea ice, can range from meters to kilometers in size. The floe size distribution is a basic parameter of sea ice that affects the behavior of sea-ice extent, both dynamically and thermodynamically. Particularly for relatively small ice floes, it is critical to the estimation of melting rate. Hence, estimating floe size distributions contributes to the understanding of the behavior of the sea-ice extent on a global scale

1.2 Existing System:

A. Ice Floe Identification in Satellite Images using Mathematical Morphology and Clustering about Principal Curves

The method involves several new statistical techniques:

1) A way of estimating closed principal curves that reduces both bias and variance and is robust to outliers. Here, outliers take the form of melt ponds on the surface of ice floes.
2) The erosion-propagation (EP) algorithm provides initial estimates of floe outlines. This combines the existing idea of erosion front mathematical morphology with that of local propagation of information about floe boundaries.
3) A method for clustering about principal curves. Existing clustering algorithms separate data into groups, each of which is clustered about some central point; Committee on Applied and Theoretical .Here we generalize this to allow each group to be clustered about a different principal curve. This opens the possibility that cluster analysis, may be useful more generally for fast feature extraction in images.
4) This method is implemented in an object-oriented programming environment for which it is well suited, and seems computationally efficient. Effective SAR Image Segmentation and Sea-Ice Floe Distribution Analysis via Kernel Graph Cuts based Feature Extraction and Fusion:

The main aim of this study is to create novel techniques to automatically segment and extract the sea ice floes from the SAR images of the area in the Arctic region being monitored. To achieve this it is important to fulfill the following smaller objectives

1. To develop an optimal segmentation technique for accurately segmenting individual ice floes from the background as well as from each other.
2. To refine the methods developed in 1 so they are efficient and inexpensive to compute.
3. To remove/reduce the speckle noise present in almost every SAR image using appropriate filters. That is, using filters which retain the original image characteristics as well as removing reducing the presence of speckle noise.
4. To make the techniques developed completely automatic and dynamic so that they can process any SAR image to segment the ice floes.

In an actual ice-covered environment, ice floes typically touch each other, and the junctions may be difficult to identify in digital images. This issue challenges the boundary detection of individual ice floes and significantly affects ice floe size analysis. Several researchers have tried to mitigate this issue. The authors separated closely distributed ice floes by setting a threshold higher than the ice-water segmentation threshold and separated the connected ice floes manually when the threshold did not work well. The authors applied and compared derivative and morphology boundary detection algorithms in both model ice and sea-ice images. However, nonclosed boundaries are often produced by traditional derivative boundary detection, while some boundary information is often lost by morphology boundary detection. To separate connected sea-ice floes into individual floes, the watershed transform (widely used in connected object segmentation) was adopted.

Due to an ineluctable over segmentation problem of the watershed-based method, the authors manually removed these over segmented lines, while those in automatically removed the over segmented lines whose endpoints were both convex. However, over- and under segmentation still affected the ice floe detection results.

1.2.2 Algorithms:

Different approaches may be employed to use the watershed principle for image segmentation.

- Local minima of the gradient of the image may be chosen as markers, in this case an over-segmentation is produced and a second step involves region merging.
- Marker based watershed transformation make use of specific marker positions which have been either explicitly defined by the user or determined automatically with morphological operators or other ways.

Meyer's Flooding Algorithm:

One of the most common watershed algorithms was introduced by F. Meyer in the early 90's.The algorithm works on a gray scale image. During the successive flooding of the grey value relief, watersheds with adjacent catchment basins are constructed. This flooding process is performed on the gradient image, i.e. the basins should emerge along the edges. Normally this will lead to an over-segmentation of the image, especially for noisy image material, e.g. medical CT data. Either the image must be pre-processed or the regions must be merged on the basis of a similarity criterion afterwards.

1. A set of markers, pixels where the flooding shall start, are chosen. Each is given a different label.
2. The neighboring pixels of each marked area are inserted into a priority queue with a priority level corresponding to the gradient magnitude of the pixel.
3. The pixel with the lowest priority level is extracted from the priority queue. If the neighbors of the extracted pixel that have already been labeled all have the same label, then the pixel is labeled with their label. All non-marked neighbors that are not yet in the priority queue are put into the priority queue.
4. Redo step 3 until the priority queue is empty.

The non-labeled pixels are the watershed lines.

1.2.3 Watershed Cuts:

Watersheds as optimal spanning forest have been introduced by Jean Cousty et al. They establish the consistency of these watersheds: they can be equivalently defined by their "catchment basins" (through a steepest descent property) or by the "dividing lines" separating these catchment basins (through the drop of water principle). Then they prove, through an equivalence theorem, their optimality in terms of minimum spanning forests. Afterward, they introduce a linear-time algorithm to compute them. It is worthwhile to note that similar properties are not verified in other frameworks and the proposed algorithm is the most efficient existing algorithm, both in theory and practice.

Fig 1.2.3 An image with two markers, and a minimum Spanning Forest computed on the gradient of the image.

The authors introduced a mathematical morphology together with principal curve clustering to identify ice floes and their boundaries in an almost fully automated manner. Their method operated on the binary images and focused on the morphological characteristics of ice floes rather than on the real boundaries. It was limited by crowded ice floe images, in which the ice floes in the mass were connected to each other, and no "hole" or concave regions could be found after binarization. Those methods are not applicable in our research because of these limitations.

1.3 Proposed Solution:

A. Image Processing for Identification of Sea-Ice Floes and Floe Size Distribution:

The steps in proposed method are

1. Ice Pixel Extraction.
2. Ice Edge Detection.
3. Ice Shape Enhancement.
4. Ice Type Classification and Floe Size Distribution.

To separate seemingly connected floes into individual ones, a gradient vector flow (GVF) snake algorithm is applied in this research. However, to start the algorithm, a proper initial contour is required for the GVF snake to evolve correctly. Therefore, a manual initialization is typically needed, particularly in crowded floe segmentation. To solve this problem, an automatic contour initialization is proposed to avoid manual interaction and reduce the time required to run the algorithm. Once individual ice floes have been identified, the floe boundaries are obtained, and the floe size distribution can be calculated from the resulting data.

1.4 Organization of Project Reportice Pixel Detection:

The Otsu thresholding (Otsu, 1975), which is used to perform histogram shape-based image thresholding automatically, is one of the most common threshold segmentation algorithms. This algorithm assumes that the histogram (the distribution of gray-values) is bimodal and that the illumination is uniform. It then divides the histogram into two classes (i.e., the pixels are identified as either foreground or background) and finds the threshold value that minimizes the within-class variance.

Another ice pixel detection method is k-means clustering, which is a statistical data analysis technique that minimizes the within-cluster sum of distance to partition a set of data into groups. By using this method, the image is divided into three or more clusters. The cluster with the lowest average intensity value is considered to be water, while the other clusters are considered ice .The k-means method is a good way for a quick review of data, especially if the objects are classified into many clusters.

1.4.1 Floe Boundary Detection:

Automatic identification of individual floe boundaries is a key tool for extracting information of floe size distribution from sea-ice images. In an actual ice-covered environment, ice floes typically touch each other, and the junctions may be difficult to identify in digital images. This issue challenges the boundary detection of individual ice floes, and it significantly affects ice floe size analysis. Several methods, such as derivative boundary detection morphology-based method watershed based algorithms have been applied to identify the floe boundaries. Gradient Vector Flow (GVF) Snake algorithm has a good detection capability of weak boundaries.

1.4.2 Floe Shape Enhancement:

After boundary detection, some segmented floes may contain holes or smaller ice floes inside. This means that the ice floe cannot be completely identified, and the shape of the segmented ice floe is rough. To smoothen the shape of the ice floe, morphological cleaning is used after ice floe identification

Step 1: Arrange all the segmented ice floes from small to large.

Step 2: Perform the morphological cleaning to the arranged ice floes in sequence. This process will ensure the completeness of the ice floe and that smaller ice floes contained in larger floes are removed.

II. Simulation Results

Fig 2.1 Input image.

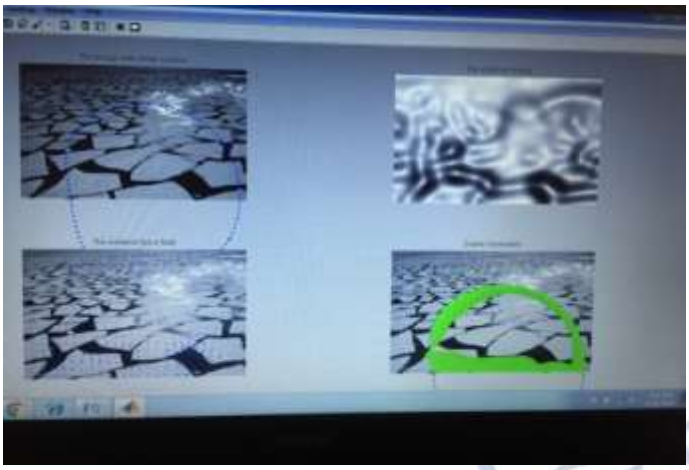

Fig 2.2 (a) Image with initial contour. (b) The external energy image. (c) The external force field image. (d) Snake moment image.

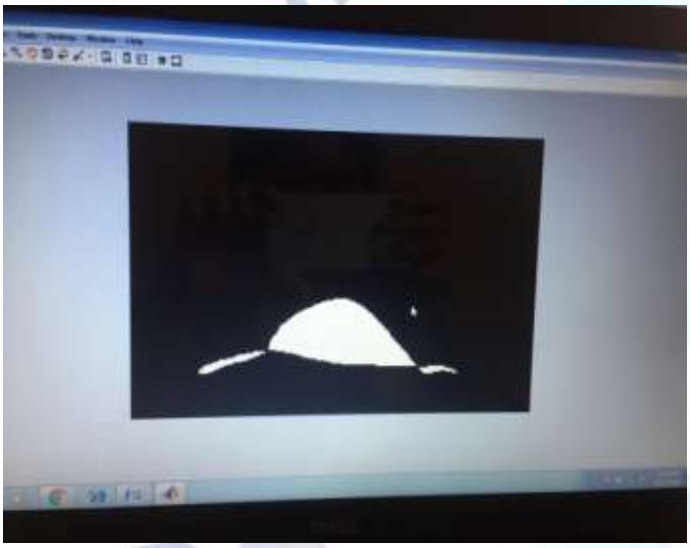

Fig 2.3 Gradient vector flow resultant image.

Fig 2.4 Segmented Image

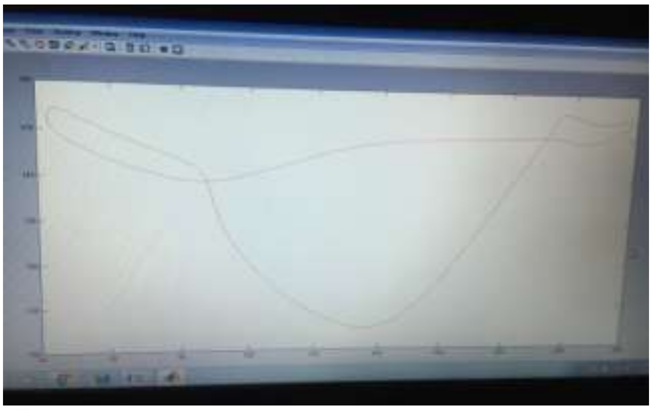

Fig 2.5 Floe size distribution image.

III. Results and Discussions

The remotely sensed images of sea ice were acquired in the NORUT mission to Ny-Ålesund. The aerial sea-ice images, collected by the UAV, usually cover a large area, and the illumination of the images is often nonuniform. In addition to this, the perspective distortion may also exist in the image data because of the shooting angle of the camera. Perspective distortion usually exists when an aerial vehicle orbits the observation field. Both of these two issues will affect the final ice floe identification and size distribution results.

3.1 Local Processing:

The image is first divided into smaller overlapping regions, such that each region can be analyzed locally. The ice edge detection algorithm is performed on each region to obtain a sub segmentation image. Then, we remove the overlapping part and superimpose the sub segmentation images into their locations (by stitching the sub segmentation images), resulting in an overall segmentation image.

Fig 3.1.1 Sea ice.

Processing the local sub-images of the overall sea-ice image is recommended to obtain an accurate segmentation result (but at the expense of more processing time and manual intervention). Some ice information can be lost when globally extracting “light ice” and “dark ice” from a sea-ice image, when nonuniform illumination or shadow problems exist in the sea-ice image. Moreover, a sea-ice image typically contains multiple ice floes that crowd together, as shown, where parts of floe boundaries become weaker than others.

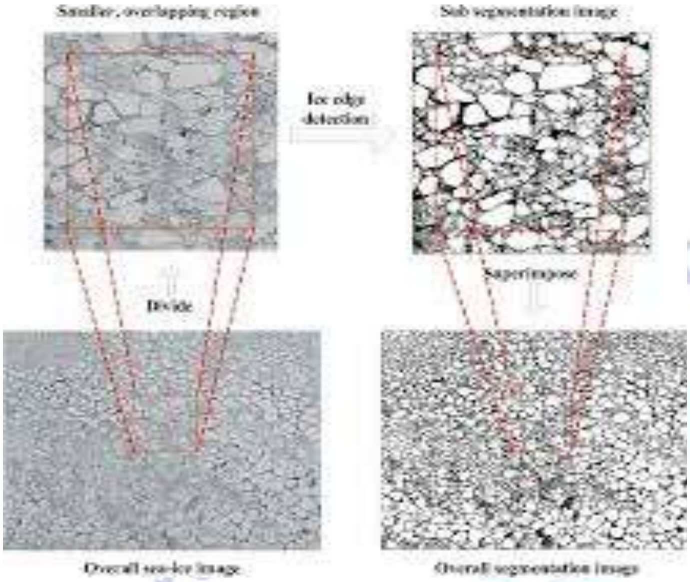

Fig 3.1.2 Local segmentation procedure. The white pixels are "light" ice pixels, and the gray pixels are "dark" ice pixels.

When using the same GVF parameter, which controls the capture range of the GVF, the external forces near weak connections are weaker than those near strong boundaries. If the GVF capture range is too strong, the capture range of the strong boundaries will dominate the entire external force field, while the external force near the weak connections will be too weak to pull the snake toward the desired boundaries.

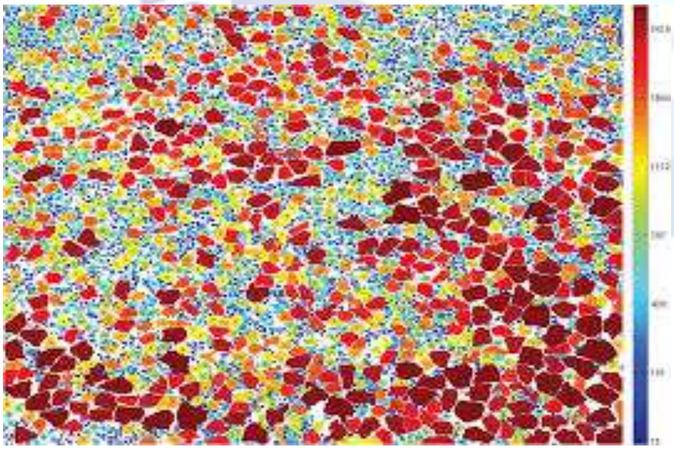

Fig 3.1.3 Ice floe and brash size distribution without orthorectification.

Usually, weak connections tend to be more difficult to detect when increasing the GVF capture range, which results in under-segmentation. If the capture range is decreased, however, the noise is enhanced and leads to over segmentation. Therefore, the GVF capture range under the same GVF parameter cannot represent an overall sea-ice image. To identify all of the boundaries, it should be adjusted according to each sub image.

3.2 Geometric Calibration:

When the perspective distortion exists in the image data, the final identification result, as illustrated, is not adequate for the calculation of size distribution statistics. The ice floes in the far range of the image will seem smaller than those in the near range. This distortion will therefore induce errors in further analyses. The image can be orthorectified when the values of the shooting angle and the field of view of the camera are known, thus needing a sensor to measure the camera's shooting angle. However, the actual parameters of the camera were not measured in this mission. Hence, to give an example to illustrate the overall algorithm, we have estimated the shooting angle to be approximately 20◦ and the field of view to be 46◦ (using to the statistical similarities between the size distributions of near and far range of the image). Using this, we can orthorectify the overall segmentation image.

For a no ridged and no shielded image, the geometric calibration should be performed on the segmented sea-ice image (after Algorithm 1) before ice shape enhancement (Algorithm 2). Otherwise, the small ice floes located at the far end of the image could be still considered to be brash ice. Furthermore, to reduce the visual distortion caused by the fractional zoom calculation, the image will be enlarged, and the total number of pixels will increase after orthorectification. The points between the pixels in the orthorectification coordinates that are mapped from the image coordinates must be interpolated. Each pixel holds quantized values that represent the color or gray level of the image at a particular point. Image interpolation therefore plays an important role in filling the values in those interpolated pixels by using known data to estimate values at unknown points.

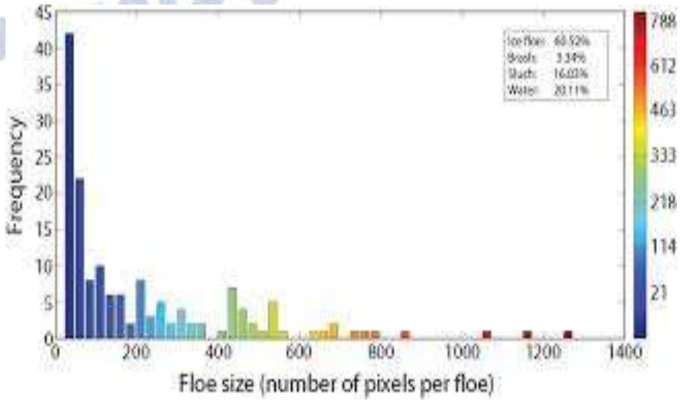

Fig 3.2.1 Ice floe distribution histogram.

The calibrated image, however, may be blurred because the values of the interpolated pixels are not the real values captured from the objects; as the number of interpolated pixels increases, the objects in the calibrated image become more blurry. The ice floe boundaries may become weaker or even be lost. The floe boundaries will become more difficult to detect. If the geometric calibration is performed before the ice floe identification, the proposed algorithm may fail to detect the ice floes in the far range of the image because of their blurred boundaries.

3.2 Results and Discussions:

After orthorectification, we enhance the shapes of all the ice pieces (Algorithm 2), and finally, we obtain the ice floe and brash ice size distribution, as shown. Brash ice is dark blue, smaller floes are light blue, and larger floes are red. Brash positions are not shown, whereas the floe positions are denoted using a black dot.

A total of 2511 ice floes and 2624 brash ice are identified. The coverage percentages are 65.98% ice floe, 5.03% brash ice, 17.52% slush, and 11.47% water. Instead of the actual size of ice floe and brash (since we do not have the height above sea level for the camera), the ice floe (brash) size is calculated by the number of pixels in the identified floe (brash). The relative ice floe distribution histogram is derived.

IV. Conclusion and Future Scope

We are identifying the non ridged ice floe in the marginal ice zone, and the managed ice resulting from offshore operations in sea ice, we proposed an algorithm to identify the individual ice floes in a sea-ice image using the GVF snake algorithm. To evolve the GVF snake automatically, “light ice” and “dark ice” were first obtained using the thresholding and k-means algorithms. The initial contours of both “light ice” and “dark ice” with proper locations and radii were then derived based on the local maxima from the distance transform. After ice edge detection, morphological cleaning was used to enhance floe shapes. The implementation on the sea-ice images, which contained multiple ice floes crowded together, is shown to give acceptable segmentation results.

Instead of using unmanned aerial vehicle as a mobile sensor for capturing the images of the ice floes in future, there is scope for developing unattended sensors, micro UAVs, robot sentry and autonomous underwater vehicles.

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