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A TECHNIQUE OF CONTINUOUS ANALYSIS OF SEA ICE DISTRIBUTION USING VIDEO IMAGES TAKEN FROM A SHIP

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Abstract: A technique is described for patching video images of ice covered water. The sea ice was photographed by video camera from the ship. Continuous video images are obtained using geometric transformation and template matching. Both shape of the ice and compactness along the ship's route can be obtained continuously.

1. Introduction

Sea ice is one of the important factors affecting polar climate and the global atmospheric system (ALLISON, 1989; GORDON and TAYLOR, 1975; STURMAN and ANDERSON, 1985). Satellite data gave large scale information about ice conditions (COMISO and ZWALLY, 1982; ECKARDT *et al.*, 1992; STURMAN and ANDERSON, 1985; YAMANOUCHI *et al.*, 1991, 1992; ZWALLY *et al.*, 1983), and are useful for investigating large scale phenomena. On the other hand, observation of ice conditions from a ship gives more detailed information on ice processes and characteristics (ALLISON, 1989; JACKA *et al.*, 1987). It is important to examine what and what kind of phenomena influence sea ice distribution and structure. In order to compare satellite data with ground based observation data, it is necessary to patch the ground based data continuously; and both need to be analyzed quantitatively. MURAMOTO *et al.* (1992) proposed a method of geometric transformation of a binary image of sea ice; the method was extended to transformation of a gray level image by MURAMOTO *et al.* (1993). There is one other thing that is important for analyzing sea-ice images: large area analysis of sea using continuously photographed gray level images.

In this paper, a technique for measuring sea ice characteristics over a wide area using video images taken from a ship is proposed. Preliminary experiments to test the system have been carried out using video images photographed in ice-covered water in the Southern Ocean.

2. Recording System for Sea Ice

The sea ice was photographed by a video camera mounted on board the icebreaker SHIRASE as shown in Fig. 1. The camera was located at the upper

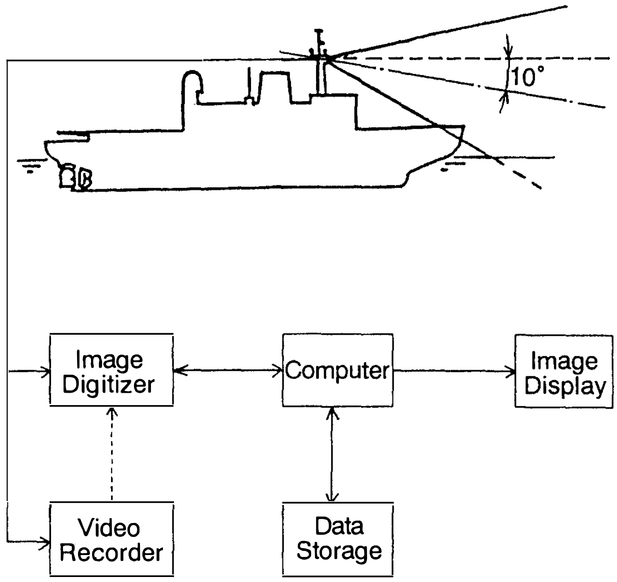

Fig. 1. System configuration for photographing sea ice and analyzing the image. The camera was located at the upper steering house at an angle of 10° downward from the horizon.

steering house pointing at an angle of 10-degrees downward from the horizon. The image was divided into 256×256 pixels using an image digitizer. At each pixel location, the image brightness was quantified into 256 gray levels.

3. Method of Image Analysis

In order to measure the sea ice characteristics over a wide area using video images, first, geometric transformation is performed to obtain an orthographic projection. Next, these transformed images are combined by template matching. Using these wide field images, sea ice characteristics are analyzed.

3.1. *Perspective transformation*

Figure 2 shows the spatial relation between the sea surface and perspective projection in the image plane. The *xy* plane is the camera image coordinate system, and (u,v) is the world coordinate system. Equations of perspective transformation are given by

$$u = (a_1x+a_2y+a_3)/(a_7x+\mathrm{a}_{8y}+1),$$
$$v = (a_4x+a_5y+a_6)/(a_7x+a_8y+1),$$

where the coefficients of perspective transformation are determined by known position such as hatch cover points (a–d) and sea surface positions (e–h) calculated from camera height and angle of depression of the camera (SCHOWENGERDT, 1983). By this transformation, a square region of sea with a side of 180 m is

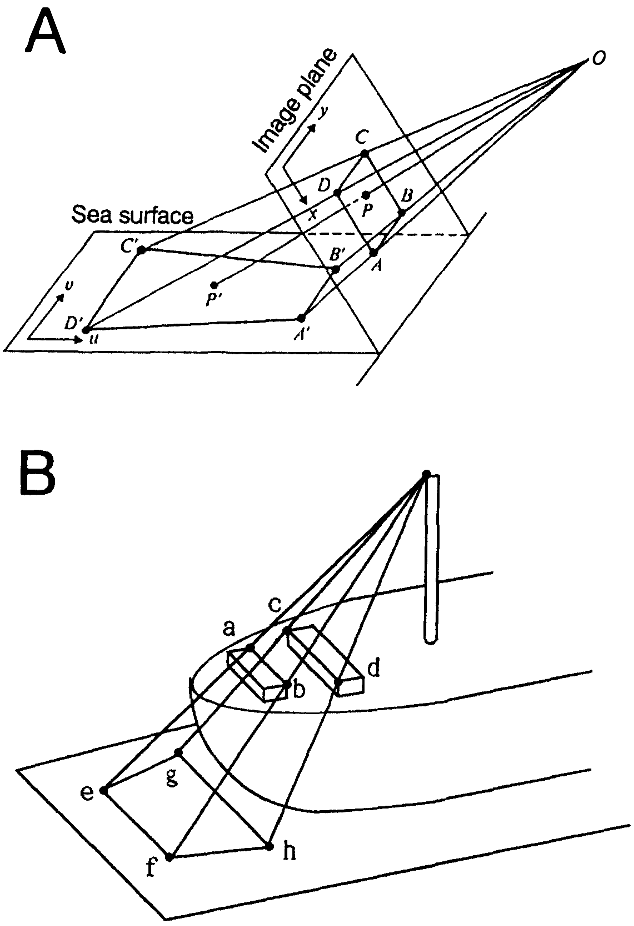

Fig. 2. A: Spatial relation between the sea surface and its perspective projection in the image plane. B: Using known points (a–h), initial coordinates A–D are transformed to A'–D'.

analyzed, and each sea ice image is transformed to an orthographic projection. In the geometric operation, the output pixels are mapped into the input image to establish their gray levels. If an output pixel falls between four input pixels, interpolation is necessary to determine the gray level of the output pixel. In this process, bilinear interpolation is used (MURAMOTO *et al.*, 1993).

3.2. Template matching

In order to measure the sea ice compactness and shape over a wide area, the orthographic projection images are joined by template matching (HALL, 1979). A template is chosen from the bottom of the transformed image where the pixel accuracy is highest and used to match a video image at time t with the next scene at time $(t+1)$. This method is illustrated in Fig. 3. A subimage of size 5×256 pixels within the orthographic projection image at time t is taken as the template shown in Fig. 3Ba. It is desired to determine the vertical location of the template within the image at time $(t+1)$ of size 25×256 pixels shown in Fig. 3Bb. In this way, the continuous image shown in Fig. 3Bc was obtained.

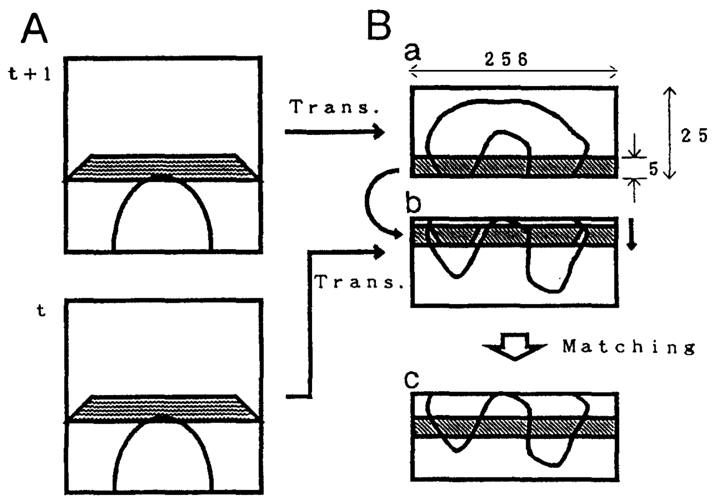

Fig. 3. Schema of template matching. A: Oblique projections at times t and (t+1). B: Orthographic projection transformed from the trapezoidal region shown in A by oblique projection. a: Template pattern. b: Search picture. c: Result of matching at offset location.

3.3. *Characteristics of sea ice*

Sea ice compactness is calculated from the ratio of ice to water for each row of matched images. Floe size distribution can be calculated along a line, such as the center line of the wide field image shown in Fig. 4. Although the floe size obtained by this method is only one-dimensional, it is useful to examine the general tendency of size distribution.

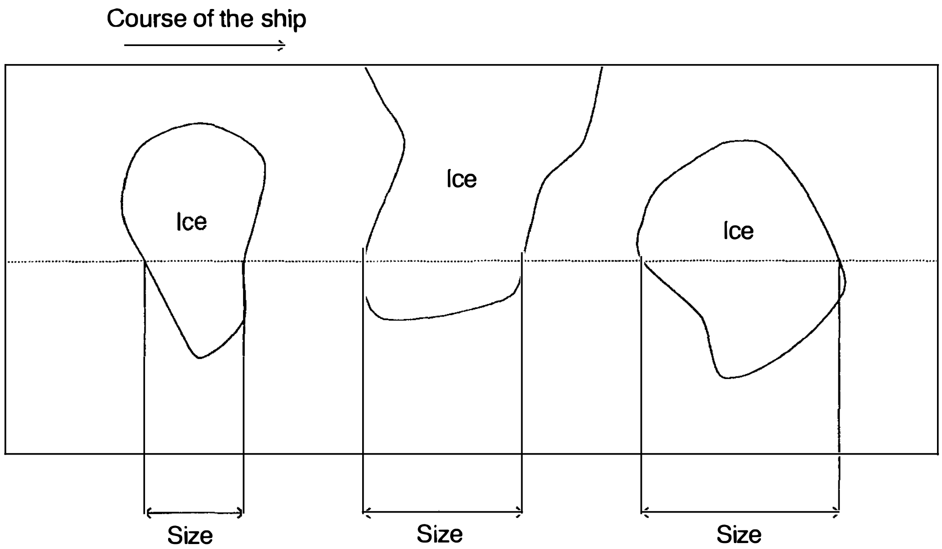

Fig. 4. Method of calculation of floe size distribution.

4. Results

Sea-ice images were recorded between Fremantle, Australia and Syowa Station in 1988 by T. Endoh, a member of the 30th Japanese Antarctic Research Expedition (JARE-30). The cruise track of the ship has been shown previously (Muramoto *et al.*, 1992).

Continuous analysis was performed at predetermined time intervals using images photographed during navigation. Figure 5 shows examples of sea ice images recorded on December 26 and 27, 1988. Figure 6 shows orthographic projections of the images of Fig. 5. Figure 7 shows changes of ice compactness estimated along the center line of images A, B and C of Fig. 6. Figure 8 shows the floe size distributions calculated for areas A, B and C of Fig. 6. In some

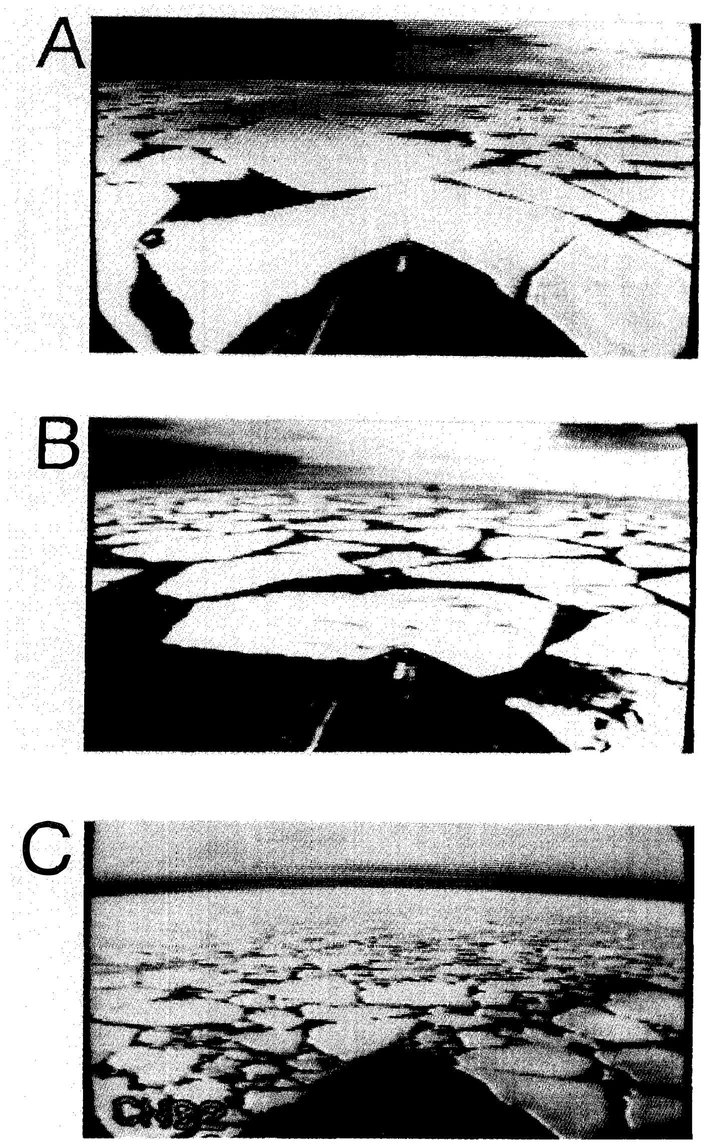

Fig. 5. Sea ice images from the video recorded images on December 26 and 27, 1988.

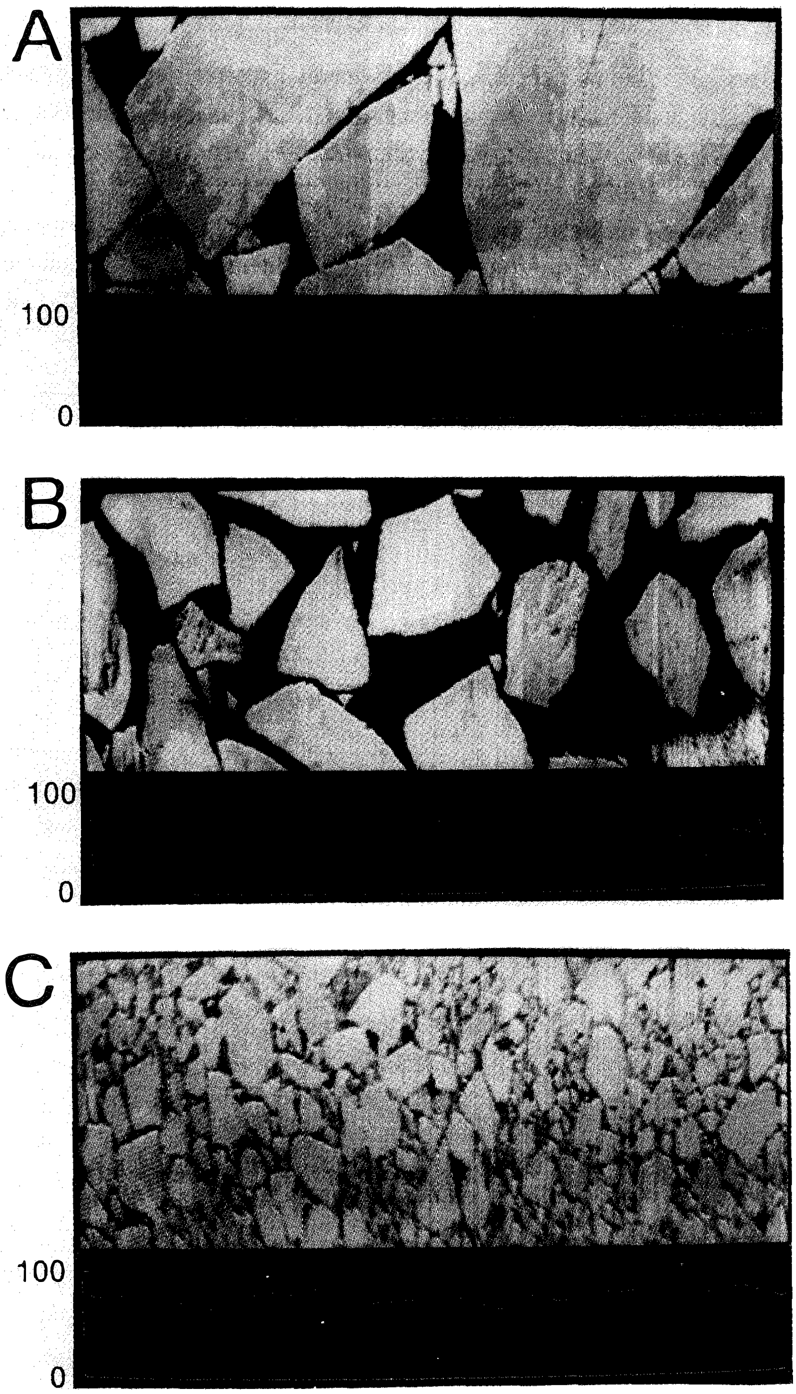

Fig. 6. *The trapezoid regions on ice-covered water of Fig. 5 were transformed continuously by orthographic projection. These images are rotated 90° against the image of Fig. 5 for convenience of display. The graphs below the images indicate changes of ice compactness.*

cases, the ice compactness had almost the same value but the floe size distributions were different. For example, the ice area is large but the number of floes is small in Fig. 8A, while the opposite is the case in Fig. 8C.

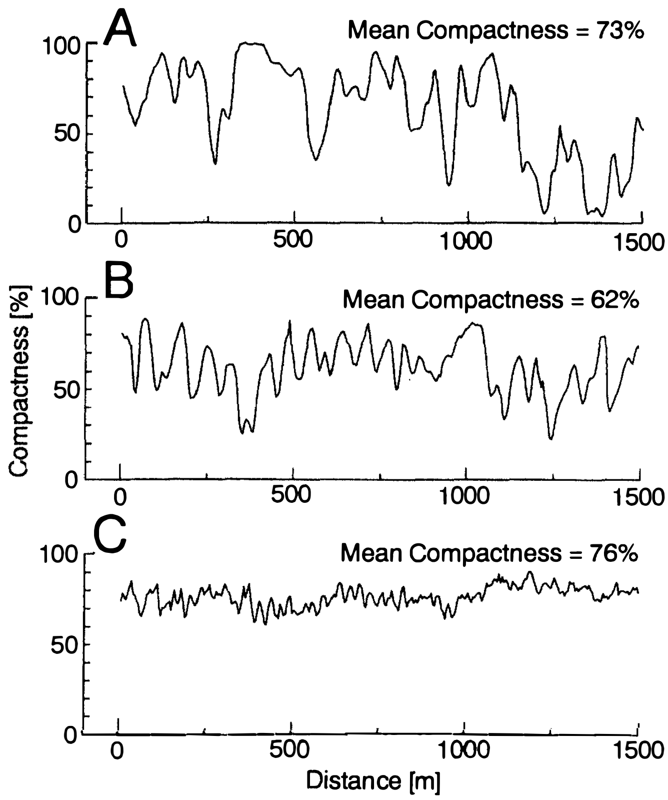

Fig. 7. Changes of ice compactness during 5 min in areas A, B and C of Fig. 5. Mean ice compactness during the 5 min intervals shown were 73% in A, 62% in B and 76% in C.

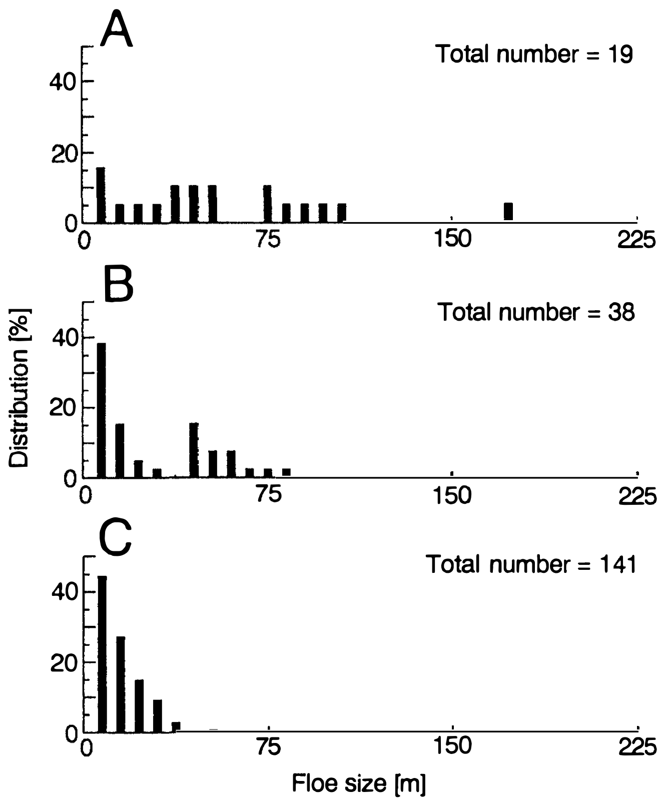

Fig. 8. Floe-size distributions for areas A, B and C of Fig. 6. Although the ice compactness had almost the same values in A and C, floe size distributions were different.

5. Conclusion

A system for analyzing wide field image data recorded during ship navigation has been proposed. The difference of the resolution between satellite and surface based data is very large. Therefore, many images recorded from the ground have to be patched together to compare them. Since it is now possible to obtain wide field quantitative data along ship route, we can analyze satellite information in detail.

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