Ice Detection and Tracking Based on Satellite and Radar Images

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Introduction

The increased marine activity in ice affected areas have made detection, tracking and management of ice more important than ever.

In this thesis, an algorithm for detection and tracking of targets have been made and tested on ice targets on the East Coast of Greenland. The algorithm have been adapted for satellite imagery, and to do so different image processing methods have been used.

To classify different targets, the target properties have been investigated in multi-polarized satellite imagery. In addition, data from the Automatic Identification System (AIS) used by ships all over the world have been combined with the satellite imagery to identify targets as vessels.

The detection and tracking algorithm

The detection and tracking of targets in this thesis is carried out using an algorithm divided into two significant parts: the identification of ice objects within an image, and the matching of objects from one image to the next.

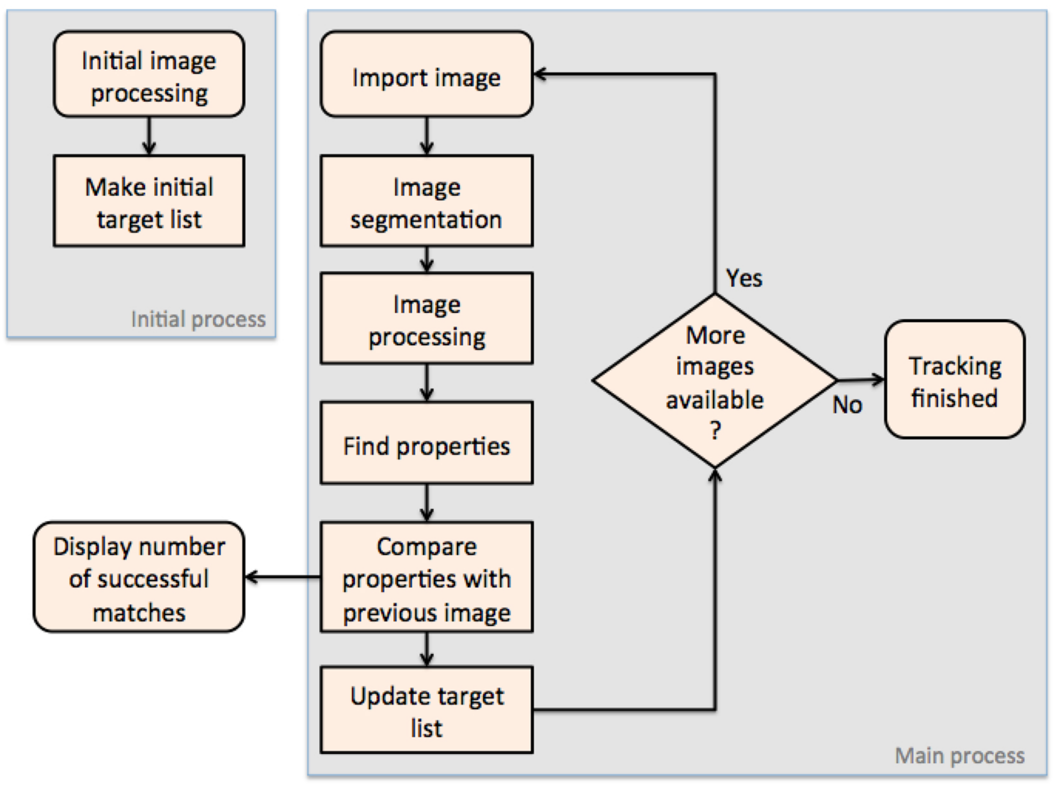

Figure 1: Flow chart of the detection and tracking process

For each target, some geometrical features are found, and these are compared with other targets to check for matches. To be able to extract the correct geometrical values, a proper image segmentation is crucial.

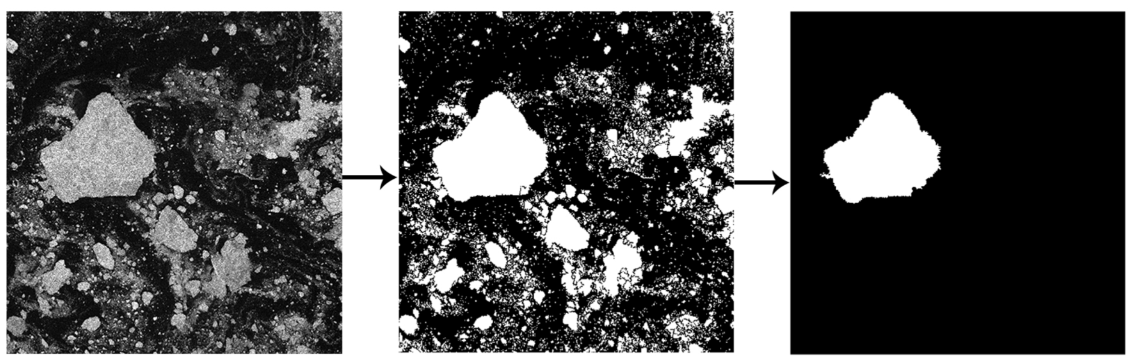

Figure 2: A target in different steps of the image segmentation process

If a target is surrounded by ice, deformations in the target shape will most likely occur. To allow this, but still maintain accurate matches in a sequence of images, a deviation for each geometrical feature is included when comparing the targets.

Identifying vessels by using AIS-data

To identify targets as vessels in the satellite imagery, data from the Automatic Identification System (AIS) was incorporated. The geographical location of each image was found from geolocation, and then used as a restriction while sorting through the AIS data-files.

In addition, to achieve the correct time synchronization between images and vessel data, the vessel positions were interpolated to match with the image timestamps.

By using the estimated positions of each vessel, the targets were manually identified in each of the images. These targets were used as truth data when analyzing target returns for vessels in multi-polarized imagery.

Conclusions

By using image processing, it has been possible to develop a target tracking algorithm suitable for objects in satellite imagery. By using a sequence of satellite images, it was possible to track a piece of ice over the course of 6 days and with a total distance traveled of over 50 km. The algorithm is robust to rotations and deformations, but is not invariant to large deformations. Thus, the algorithm will work best a targets maintaining a distinct shape throughout the tracking period.

In addition, it has been shown how multi-polarized imagery can be used to classify between vessel and ice targets. However, this classification feature is mainly indicative, and will have result in some misclassification.

Tracking on the East Coast of Greenland

A piece of ice have been tracked on the East Coast of Greenland in August 2013. This is to demonstrate how the tracking algorithm can be used to identify and track specific objects of interest. In a sequence of 15 satellite images, the target was detected in 7 images.

Table 1: Detection pairings of the ice floe in a sequence of images

Start date	End date	Distance traveled (km)	Average speed (m/s)
20-Aug-2013	21-Aug-2013	11.0985	0.1311
21-Aug-2013	22-Aug-2013	6.1451	0.0726
22-Aug-2013	23-Aug-2013	7.9975	0.0882
23-Aug-2013	24-Aug-2013	4.1974	0.0496
24-Aug-2013	25-Aug-2013	5.8279	0.0689
25-Aug-2013	26-Aug-2013	18.4961	0.1535

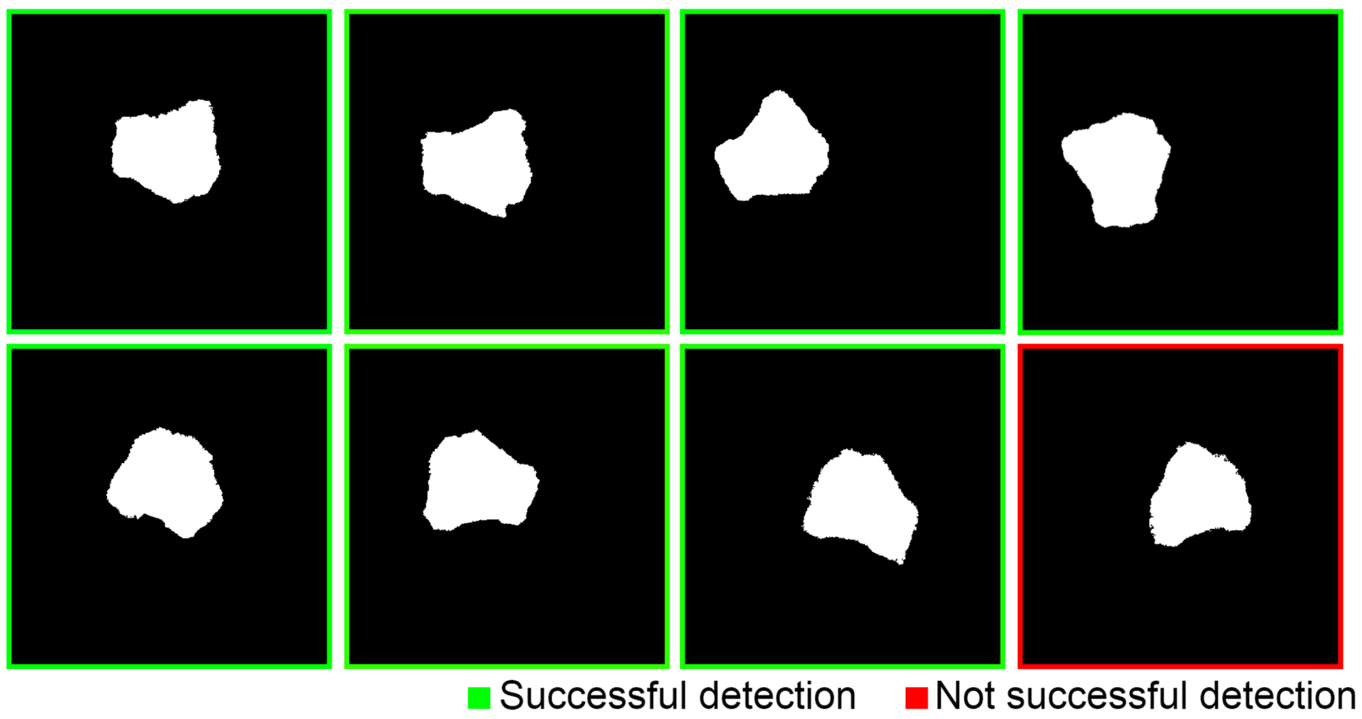

Figure 3: Segmented target in a sequence of images

The algorithm is robust to deformations and rotations of the shape, as is evident in Figure 3.

Manually, the target was also detected in an eighth image. However, the shape was too deformed to render a successful matching in the tracking process. Consequently, the algorithm will only track targets that remain a distinct shape, and the amount of deformation it allows is limited.

For an iceberg in open water the deformations will be minimal. Thus, this algorithm is more suitable for icebergs in open water than ice floes in pack ice where the floe shape is jeopardized by surrounding ice.

Classification of targets in multi-polarized imagery

Radars can be configured to transmit and receive horizontally or vertically polarized radiation. By emitting a mixture of polarizations and using receiving antennas with a specific polarization, several images can be collected from the same series of pulses.

Using dual-polarized imagery, different targets have been analyzed in the HH (horizontal transmit and horizontal receive) and HV (horizontal transmit and vertical receive) channels.
Figures 4-5 show the brightness return of an image of an ice floe surrounded by water. The highest peaks in the plots represent the ice returns. Clearly, ice targets have a lower brightness return in the HV channel compared to the HH channel.

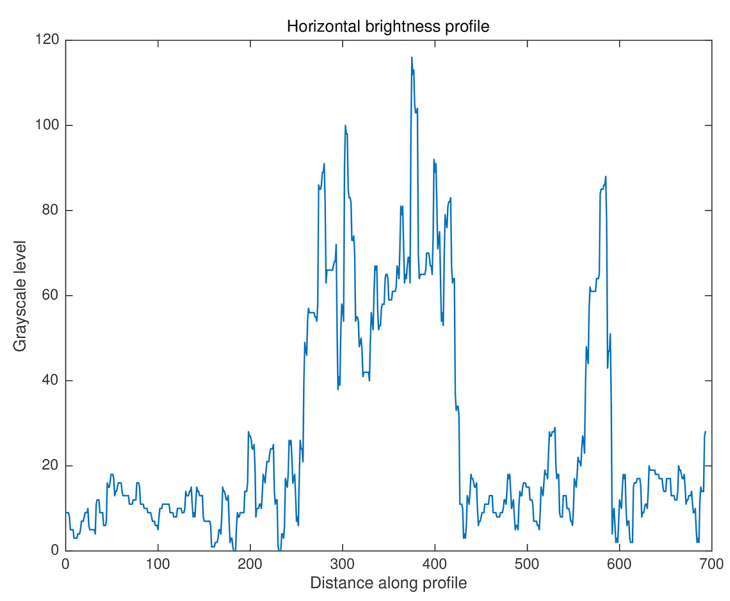

Figure 4: Horizontal brightness profile of image in HH

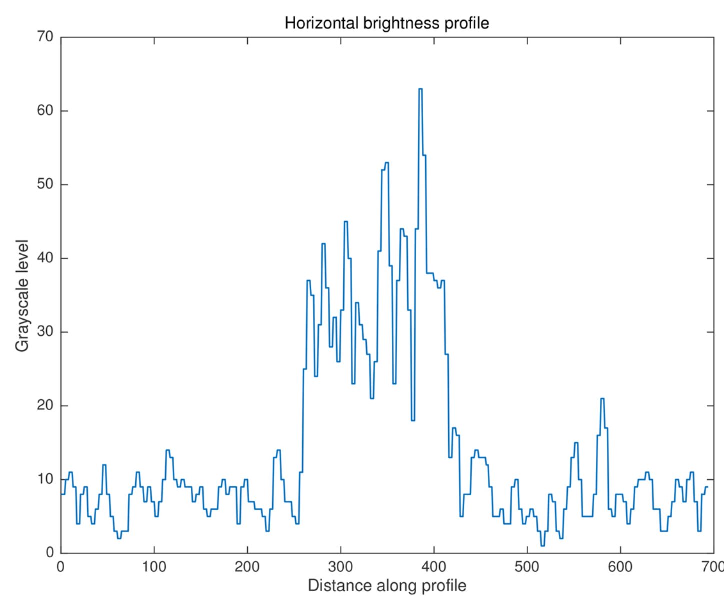

Figure 5: Horizontal brightness profile of image in HV

For vessel targets no such pattern was found by comparing the brightness return in each channel. Instead, for a random selection of ice and vessel targets the HV/HH area ratio was found (Figure 6). For vessel targets the HV/HH area ratios are scattered, however, its average HV/HH area ratio is close to 1. Thus, the conclusion is that there is a high correlation between HH and HV areas for vessel. For the ice targets, however, the correlation is low. The majority of the ice targets have twice as large HH area than HV area, which results in most of the them having a ratio under 0.4.
By using the criteria that all targets with a low ratio (in this case <0.4) are ice targets, it is possible to develop a classification feature in dual-polarized imagery. However, since the ratio for vessel targets fluctuates, the accuracy would be compromised by occasional vessel targets having a low ratio. In this scenario, the target discrimination feature would yield an accuracy of 82 %.

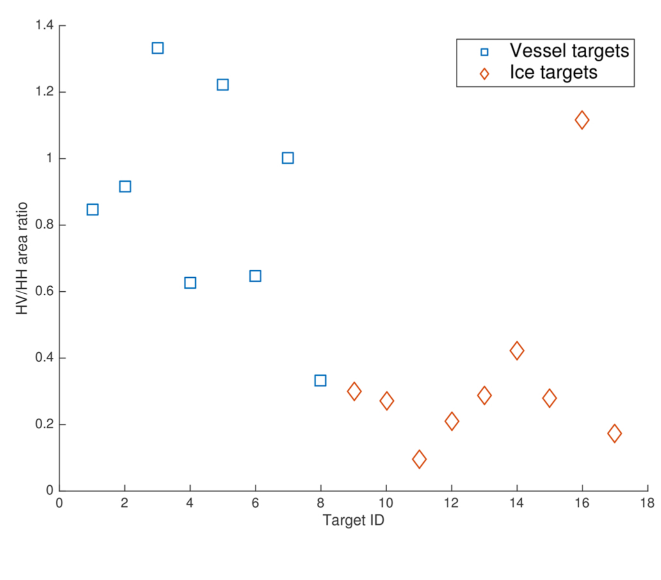

Figure 6: HV/HH area ratio for vessel and ice targets.