Context / Introduction

Vessel detection and route characterization is of interest for various services ranging from fishing monitoring, border control and traffic monitoring. Applying wake detection allows retrieving not only the route of a vessel but also its speed by using its shift from its turbulent wake as an indication of its radial speed. The ship wake detection is usually applied as a post-processing to the vessel detection itself and is a mean to estimate the route of the vessel together with its speed by measuring the Doppler shift between the turbulent and the vessel itself. Various wake detection techniques are proposed usually based on Radon transform (1,2,3).

We previously defined and developed a detection of wake signature in the Hough transform domain. The Hough transform aims to accumulate evidences of presence of the object of interest. The Hough transform for the detection of linear features is very similar to the Radon transform. In fact, both the Radon transform, and the Hough transform correspond to the same transformation.

Vessel Wake

The wake structure behind a moving vessel fall into four categories [4]:

1. Kelvin wake directly behind the vessel (D in the figure)
2. Narrow-W wakes visible through Bragg scattering from waves generated by hydrodynamic processes along the ship hull (B in the figure)
3. Turbulent wakes directly behind the vessel (D in the figure)
4. Internal wave wakes generated under conditions of shallow stratification (not illustrated in figure)

Vessel Wake on SAR Imagery

Under favorable weather conditions, vessel wakes can be observed on SAR imagery. The wind must be fast enough in order to allow sea backscattering that will be modulated by the wake, but slow enough in order to avoid blurring of the pattern.

In addition, all the categories of wakes may not be observed:

- The transverse wave is only observable on high resolution imagery.
- Only one arm of the Kelvin “V” wake may be observed depending on acquisition geometry.

Wake Detection using Basic Radon or Hough Transform

Wake detection can be achieved by detecting linear patterns in the vicinity of bright patterns corresponding to the echoes of vessels [1,2,3]. The Radon Transform is the eloboe integration of a two dimensional function (have an image) along a direction P. The method is here illustrated on a SAR image captured at a set of curves crossing in the Hough/Radon domain at a specific location characterizing entirely the original line. This transforms thus allows to accumulate in the transform domain evidences of linear patterns in the original image domain.

Using Doppler Shift to Refine the Detection

Considering that the wake is always behind the vessel and that radial speed induces a Doppler shift of the vessel echo, a vessel wake cannot be observed in all locations in the vicinity of a vessel of interest. Most specifically:

- The wake cannot be observed in quadrant above the vessel
- The wake cannot be observed for zero or small Doppler shifts (no wake if the vessel is not moving)

The method is here illustrated on a Sentinel-1A SAR Image of two vessels (one of the two vessels illustrated)

References


Methodology

The proposed methodology is then to use those considerations on Doppler shift in order to restrict the search of a potential wake based on statistical distribution of speeds for the location of interest and the category of vessel based on its size.

Statistical Distribution of Speeds

We computed histograms of vessel speeds at global scale from AIS messages (more than 2.7 million messages) and for vessels of different sizes. The histograms can then be regularized in order to weight the Hough transform in the right direction. This implies removing the large number of very low speeds likely corresponding to anchored vessels and not likely to be observed with wakes.

Results

With such a transformation, each point on the image is associated to a curve in the Hough/Radon domain. With this a priori information on vessel speed can be extracted from AIS data base. We demonstrated histograms of vessel speed at global scale. However local analysis could be done as well. For instance, within traffic lanes between two traffic separation schemes, vessels does not have the same behavior (speed and route) as in the middle of ocean or near the coast.

Conclusion

The proposed methodology allows to detect wakes in the vicinity of detected vessel taking into account a priori information on location of the wake with respect to the sensing geometry and on typical speed of vessel at sea.

Using this a priori information allows a more robust detection of wakes in difficult conditions (weak wake signatures, multiple vessels and wakes in the same areas, etc) and avoid misassociations between vessel echo and wake signature.

The a priori information on vessel speed can be extracted from AIS data base. We demonstrated histograms of vessel speed at global scale. However local analysis could be done as well. For instance, within traffic lanes between two traffic separation schemes, vessels does not have the same behavior (speed and route) as in the middle of ocean or near the coast.

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