Single Channel Complex SAR Images Ship Speed and Current Motion Retrieval

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Abstract—The paper presents a novel method to estimate the speed of a moving ship and the range velocity component of the current sea surface. The estimate of the ship speed is obtained by multilooking techniques [1]. The generation of a sequence of images from one single complex SAR image corresponds to an image time series with reduced resolution. This allows evaluating the velocity components in range and azimuth of the target by applying change detection techniques of the time series. The estimation of the displacement vector of a moving target in consecutive images of the sequence allows the estimation of the azimuth velocity component. The range velocity component is estimated by the variation of the signal amplitude in time. The results are applied on TerraSAR-X StripMap and High-Resolution SpotLight data and validated by Automatic Identification System (AIS). Furthermore the method is applied in order to estimate the range component of the current speed. The measurements are compared to model results of Federal Maritime and Hydrographic Agency of Germany (BSH) and Federal Waterways Engineering and Research Institute (BAW).

I. INTRODUCTION

The availability of remote sensing data and in particular of SAR data, which are not affected by daylight and weather condition makes the monitoring of coastal area and open sea interesting in order to retrieve information about see state, ship detection, etc. Moreover SAR data have further potential, which is to extract information about moving targets. The speed of a moving object can be retrieved from one single-channel complex image exploiting the spectral properties of the coherent SAR imaging system. This potential has multiple applications: control of harbor areas and maritime traffic, security issue, etc. Furthermore the retrieved information might be integrated to Automatic Identification System (AIS) and Long Range Identification and Tracking (LRIT) information. The method is described in detail in [2]. In this paper we focus the attention on the fact that the method can be applied in order to retrieve the range component of the current speed. The technique exploits the effect of target motion on the SAR filter and allows to estimated the range and azimuth speed components of the target. The estimate does not depend on the context, but only on the target pixels. On the other hand one of the effect of the across track target motion is that the target is imaged in another position and not in its real location. The real location of the ship is indicated by the wake which can be taken as reference. In case of the see surface is moving the distance between the ship and the wake is given by the summation of the motions of the ship and of the current. Under the previous hypotheses the range component of the current speed can be indirectly inferred through the difference between the two estimates of the ship speed range component.

II. APPLICATION TO SHIP AND SEA SURFACE SPEED RETRIEVAL

The method has been applied to the cargo vessel Eurus Paris (length=148m, beam=24m, draught=6.8m). The ship is visible in a TerraSAR-X StripMap image acquired over the Street of Florida on 9th of June 2008 at 23:13:33 UTC. The image has a resolution of about ∼3.3m in azimuth and range, the polarization is HH. The speed of the ship, computed as the sum of the parallel and radial velocity components, is 12.2 knots. The AIS information with a lag of about two and half minutes (9th of June 2008, 23:11:57 UTC) reports a speed of 11.3 knots.

A. Analysis of Spotlight acquired over the Mouth of the Elbe River

After the application on StripMap data and the validation with AIS information, the method has been applied to an area of high commercial and maritime interest: the mouth of the Elbe River, shown in Figure 5. The area has the important harbor of Cuxhaven and it is characterized by strong currents. A numerical model of the current, shown in Figure 3, has been developed by the German Federal Waterways Engineering and Research Institute (BAW) and lower scale measurements of the current speed are provided by the Federal Maritime and Hydrographic Agency of Germany (BSH), shown in Figure 4. The TerraSAR-X High Resolution SpotLight scene of the harbor was acquired on 12th of December 2007, 05:50:36 UTC. It has a resolution of ∼1.1m azimuth and range. Unfortunately no AIS information is available for the selected ship, shown in Figure 1.

Before applying the method the phase of the data has to be previously corrected according to [3].

A. Analysis of Spotlight acquired over the Mouth of the Elbe River

The estimated velocity components give a speed of 5.3 knots which is reasonable because the ship is in a speed restricted zone of the Elbe estuary.

The range velocity component of the current speed is
estimated by the difference of the range velocity component of the ship estimated by the multilook method and the range velocity component of the ship estimated by the ship-wake distance.

The range velocity component of the sea surface speed, projected to the current direction considering an angle $\alpha \sim 28^\circ$ shown in Figure 2, is $v_{r} \sim 1.6$ m/s.

The estimate has been compared with the estimation in frequency domain based on the Doppler centroid estimation, which gives a speed of $v_{r} \sim 1.8$ m/s. Furthermore, because of the presence of a buoy in the image, shown in Figure 2 it is possible to calculate the speed range component of the current by estimating the distance between the buoy and its wake. The last gives a speed of $v_{r} \sim 1.32$ m/s. The results are resumed in Table I. The results are comparable to the available measurements of the current speed in the area of the Elbe river delta shown in Figures 3 and 4.

The BAW numerical model, available at http://www.baw.de/vip/en/departments/department_k/projects/elbe/intro-en.html and shown in Figure 3, gives a current speed of around 1.3 m/s for a standard tide situation.

The BSH provides the measurements at a lower resolution, available at http://www.bsh.de/aktdat/modell/stroemungen/db3/db3.htm) and shown in Figure 4. The area of interest is marked by a red box, where the standard current speed at natural tide situation is about 1.3 m/s.

### III. Conclusions

The paper presents an extension of the method proposed by [1] to maritime application using SpotLight data. The retrieval of the speed on StripMap data and SpotLight data is accurate, however the estimates depend on the observations. When possible, the AIS information has been used to validate the results. The results are promising for future inclusion in operational services.

The proposed method allows to estimated the current speed having only the information about the selected target. The
estimate is consistent with the other estimation methods but the accuracy of the estimation is a critical point, because of the slow velocity of the sea surface. The method is innovative and accurate, but the problem of identifying the principal axis of the wake remains [4].

REFERENCES


