Inverse Synthetic Aperture Radar based Classification of Sea Vessels

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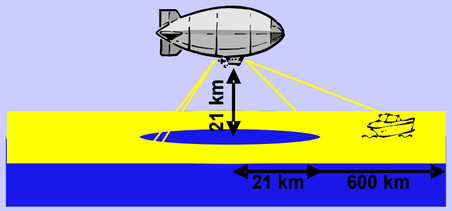
Abstract

The proposed Persistent Maritime Area Surveillance System for the South African Economic Exclusion Zone, referred to as Awarenet, requires the classification of sea vessels in order to provide situational awareness relating to activities of interest such as illegal fishing, pollution and military threats. The system is envisaged to operate in varying environmental conditions from a high altitude airship to cover ground ranges of 21-600km.



Inverse Synthetic Aperture Radar (ISAR) has been identified as a promising technique that can provide rich discriminative information of sea vessels for classification purposes [1]. ISAR involves the 2-D radar imaging of moving targets. The aim of this research is to investigate ISAR based classification techniques for the classification of sea vessels.

Research question and Key Objectives

What is the optimal radar transmit waveform, signal processing algorithm and classification algorithm for ISAR-based classification of sea vessels based on the vessel properties (physical dimensions, 3D translation and rotation motion), environmental properties (sea state, multipath) while taking into account complex radar backscatter (multi-bounce, walking scatterers)?

1. Characterise the effect of 3D rotation motion, multipath and complex radar backscatter on the resulting ISAR image.

2. Evaluate and compare the performance of signal processing algorithms for ISAR imaging.

3. Extract key discriminative features of the vessel from the ISAR image and evaluate various classification algorithms.

Sea Vessels of Interest

Various sizes of sea vessels:

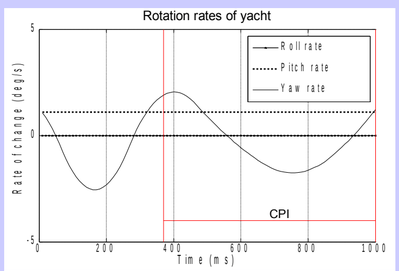
SAS Protea: survey ship

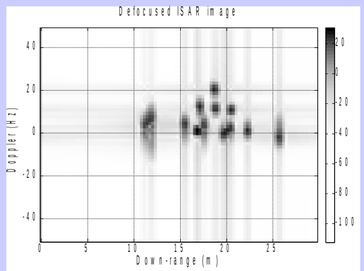
Sailing yacht

Commercial Fishing Trawler

Effect of 3D rotation motion on ISAR image

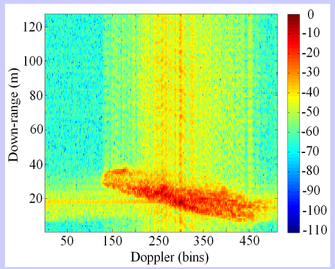
Variable roll, pitch and yaw motion continuously changes the image projection plane of the ISAR image over the Coherent Processing Interval (CPI) [2]. Simulated ISAR images based on real Inertial Navigation System (INS) measurements of a yacht at sea show that when the amplitude of the yaw rate is the same order of magnitude as the pitch rate, the resulting side-view ISAR image is defocused due to the significant change in direction of the Doppler generating axis of rotation over the CPI.



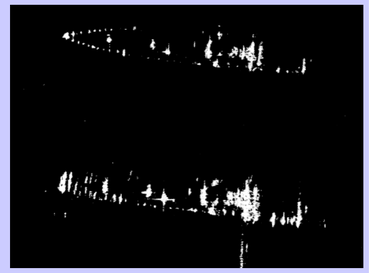


Preliminary ISAR results

Unfocused ISAR image of the Protea corresponds to a similar results in the literature.



Unfocused top-view ISAR image of the SAS Protea



Focused and unfocused ISAR images of a large sea vessel from [3]

Future work

Current and Future research topics include:

1) Choosing time intervals suited for ISAR imaging that take into account a vessel's time-varying axis of rotation and rotation rate over the CPI
2) Validating chosen time intervals on real radar data for various sea vessels
3) Estimating the time-varying axis of rotation and the rotation rate over the CPI from simulated radar data

References

[1] Musman, D. Kerr, C. Bachmann,(1996), "Automatic recognition of ISAR ship images", IEEE Transactions on Antennas and Propagation, Vol. 32, No. 4, pp. 1392-1404.
[2] M.Y Abdul Gaffar, W.Nel, "Investigating the Effect of a Target's Time Varying Doppler Generating Axis of Rotation on ISAR Image Distortion" accepted for publication in IET Radar Conference 2007, Scotland, October 2007.
[3] Wehner, D.R. (1995), High-Resolution Radar, second edition, Norwood, MA, Artech House.

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