COLLEGE OF ENGINEERING AND COMPUTER SCIENCE
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for the degree of Doctor of Philosophy (Ph.D.)

"Application of signal decomposition to improve time delay estimates for synthetic aperture sonar motion compensation"

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ABSTRACT OF DISSERTATION
Application of signal decomposition to improve time delay estimates for synthetic aperture sonar motion compensation

Synthetic Aperture Sonar (SAS) provides the best opportunity for side-looking sonar mounted on underwater platforms to achieve high-resolution images. However, SAS processing requires strict constraints on resolvable platform motion. The most common approach to resolve this motion is to use the Redundant Phase Center (RPC) technique. Here the ping interval is set, such that a portion of the sonar array overlaps as the sensor moves forward. The time delay between the pings received on these overlapping elements is estimated using cross-correlation. These time delays are then used to infer the ping-to-ping vehicle motion. Given the stochastic nature of the operational environment, some level of decorrelation between these two signals is likely. In this research, two iterative signal decomposition methods well suited for non-linear and non-stationary signals, are investigated for their potential to improve the Time Delay Estimation (TDE). The first of this type, the Empirical Mode Decomposition (EMD) was introduced by Huang in the seminal paper, 'The empirical mode decomposition and the Hilbert spectrum for nonlinear and non-stationary time series analysis' and is the foundation for the algorithms used in this research. This method decomposes a signal into a finite sequence of simple components termed Intrinsic Mode Functions (IMFs). The Iterative Filter (IF) approach, developed by Lin, Wang and Zhou, builds on the EMD framework. The sonar signals considered in this research are complex baseband signals. Both the IF and EMD algorithms were designed to decompose real signals. However, the IF variant, the *Multivariate Fast Iterative Filtering* (MFIF) Algorithm, developed by Cicone, and the EMD variant, the *Fast and Adaptive Multivariate Empirical Mode Decomposition* (FA-MVEMD) algorithm, developed by Thirumalaisamy and Ansell, preserve both the magnitude and phase in the decomposition and hence were chosen for this analysis. The TDE performances for simulated sonar signals, over a wide range of SNR are presented. The results indicate that decomposing the signals prior to the TDE can potentially improve the performance relative to the baseline estimation error. At a very low SNR, -15 dB, improvement was seen for both algorithms; 47 percent when using the MFIF and 15 percent when using the FA-MVEMD.

BIOGRAPHICAL SKETCH
Born in Detroit, Michigan
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CONCERNING PERIOD OF PREPARATION & QUALIFYING EXAMINATION

Time in Preparation: 2016-2021

Qualifying Examination Passed: Fall 2016

Published Papers:

J.Gazagnaire and P.P. Beaujean, “Multivariate Fast Iterative Filtering and Intrinsic Mode Functions for Time Delay Estimation Applied to Motion Estimation for Synthetic Aperture Sonar Imagery”, *IEEE Oceans 2021 Conference*, September 2021, (In Press).