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New Algorithms and Sparse Regularization for Synthetic Aperture Radar Imaging

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Final Report

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The PI led a collaborative effort to quantify the super-resolution potential of different computational methods for the direction-finding problem in sensing and surveillance. The difficulty of super-resolution is summarized in three quantities (the super-resolution factor, the signal-to-noise ratio, and the number of targets), and tight scalings between these quantities are presented to decide whether some methods can succeed -- or every method must fail -- at the target detection task. The analysis identifies the algorithms that perform well, and those that don't, even in the case of targets that shadow each other (nearby azimuths, different ranges).

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PI: Laurent Demanet
Department of Mathematics
Massachusetts Institute of Technology.

- Grant title: New Algorithms and Sparse Regularization for Synthetic Aperture Radar Imaging
- Grant number: FA9550-12-1-0328
- Period: June 2012 - June 2015
- Research results:

  The PI led a collaborative effort to quantify the super-resolution potential of different computational methods for the direction-finding problem in sensing and surveillance. The difficulty of super-resolution is summarized in three quantities (the super-resolutio factor, the signal-to-noise ratio, and the number of targets), and tight scalings between these quantities are presented to decide whether some methods can succeed – or every method must fail – at the target detection task. The analysis identifies the algorithms that perform well, and those that don't, even in the case of targets that shadow each other (nearby azimuths, different ranges).

  Our results (with postdoc Nam Nguyen) concern the old question of super-resolution from bandlimited measurements. In applications of interest to the Air Force, this question is also known as "direction finding" (from measurements of plane waves recorded on linear antenna arrays). A few different signal processing methods exist for this problem, and some of them currently play an essential role in the military's ability to find targets. What was not yet know about these methods, however, is their statistical behavior under noise. Nam Nguyen and I have recently obtained the proper statistical analysis of one such method, the so-called MUSIC algorithm (multiple signal classification). We have a publication that mathematically justifies the scaling of the phase transition observed numerically in noise vs. bandwidth vs. number of targets. These new scalings replace the typical Shannon-Nyquist rate from linear Fourier analysis in a nontrivial and new way.

  The practical outcome of this work concerns the operational decisions that have to be made as to whether there are electromagnetic emitters, how many, and where, from passive narrowband array data. Five important questions are:

  - what is the chance that the detection of some of the targets actually results from noise in the system (false positives)?

  - what is the chance that there exist some targets that weren't detected (false negatives)?

  - if a detected target is indeed a true target, is there uncertainty on its position?

  - could someone, a few years from now, come up with a better method than the one we have now?

  - do we have a way to tell when the noise so strong that we should give up, i.e., no one, no matter how sophisticated, could ever make sense of the data?

  The field that deals with those 5 questions is broadly called statistics. This grant's results go in that direction, and provide partial answers to all these questions. Mere familiarity with a device or a processing method, no matter how extensive, cannot provide such quantitative guarantees.

- Publications:

  L. Demanet, N. Nguyen, The recoverability limit for superresolution via sparsity, submitted, 2015

  L. Demanet, V. Jugnon, Convex recovery from interferometric measurements, submitted, 2015

  V. Jugnon, L. Demanet, Interferometric inversion: a robust approach to linear inverse problems , in Proc. SEG annual meeting, Houston, September 2013.

  N. Nguyen, L. Demanet, Sparse image super-resolution via superset selection and pruning, in Proc. IEEE CAMSAP 2013 conference, Saint Martin, December 2013.

  L. Demanet, D. Needell, N. Nguyen Super-resolution via superset selection and pruning, in Proc. SampTA conference, Bremen, July 2013.

- AFRL contacts: The PI is currently in contact with Jason Parker (AFRL/RYAP), Michael Levy (AFRL/RYAP), and Clark Taylor (AFRL/RYAT) for ongoing work on direction finding and geolocation. Two interns (Alex Gutierrez in 2013 and Sang Min Han in 2015) were selected for work at AFRL and MIT with the PI and Dr. Parker.

1.

1. Report Type

Final Report

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Demanet, Laurent

Program Manager
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Nachman, Arje

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Abstract

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Reporting Period

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Funding Summary by Cost Category (by FY, $K)

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Equipment/Facilities			
Supplies			
Total			

Report Document

Report Document - Text Analysis

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Appendix Documents

2. Thank You

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