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New Algorithms and Sparse Regularization for Synthetic Aperture Radar Imaging

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14. ABSTRACT
The PI and his collaborators proposed an algorithm to form a synthetic aperture radar (SAR) image in low algorithmic complexity. It is based on the so-called butterfly scheme. Control over the accuracy is provided. Speedups in the hundreds are reported on the Air Force's GOTCHA dataset. The PI and his collaborators also investigated the possibility of forming super-resolved images from bandlimited pulse-echo data with ideas of sparse optimization that bear a link to compressed sensing. The difficulty of super-resolution is summarized in a single number, a principal angle between subspaces, which also governs the algorithmic complexity of the minimization.

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Synthetic aperture radar, algorithms, optimization, super-resolution

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Final performance report for AFOSR program manager Arje Nachman

PI: Laurent Demanet
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- Grant title: New Algorithms and Sparse Regularization for Synthetic Aperture Radar Imaging
- Grant number: FA9550-11-1-0221
- Period: Sep 2011 - Sep 2012
- Research results: A first line of work concerns fast algorithms for synthetic aperture radar (SAR) imaging. The PI and his collaborators proposed an algorithm to form a SAR image from N data points in provable complexity $O(N \log N \log(1/\epsilon))$ without making the far-field approximation or imposing the beampattern approximation required by time-domain backprojection, with ϵ the desired pixelwise accuracy. It is based on the so-called butterfly scheme, which unlike the FFT works for vastly more general oscillatory integrals than the discrete Fourier transform. A complete error analysis is provided. The strength of the algorithm is in the control over the accuracy. The interpretability of the resulting image is demonstrated not to suffer from the change of algorithm. Speedups in the hundreds are reported on the Air Force's GOTCHA dataset.

  Another line of work concerns the possibility of forming super-resolved images from bandlimited pulse-echo data, with ideas of sparse optimization that bear a link to compressed sensing. The PI and his collaborator studied the range of applicability of a particular algorithm, known as the Douglas-Rachford iteration, for super-resolution. The difficulty of super-resolution is summarized in a single number, a principal angle between subspaces, which also governs the algorithmic complexity of the minimization. The results are supported by numerical validation.

- Publications:

  L. Demanet, M. Ferrara, N. Maxwell, J. Poulson, L. Ying, A butterfly algorithm for synthetic aperture radar imaging, SIAM J. Imaging Sci. 5-1 (2012) 203-243. Archived at `http://math.mit.edu/icg/papers/butterfly-radar.pdf`

  L. Demanet, X. Zhang, Eventual linear convergence of the Douglas Rachford iteration for basis pursuit, preprint. Archived at `http://math.mit.edu/icg/papers/DR.pdf`

- AFRL contacts: The work on fast algorithms for SAR was done in collaboration with Nicholas Maxwell, an intern with the PI at MIT and with Matthew Ferrara at AFRL/RYAT. The PI is currently in contact with Jason Parker at AFRL/RYAP for further work on the butterfly algorithm for SAR in the MIMO case (moving arrays of antennas), a situation of interest to the Air Force. Another topic under consideration for future collaboration with J. Parker is an alternative approach to autofocus for SAR using novel ideas of interferometric inversion. An intern (Alex Gutierrez) was selected from a pool of applicants for work at AFRL with the PI and J. Parker during the summer of 2013.