Sensor Fusion Developments in CenSSIS

- **Multiple Levels of Sensor Fusion in Subsurface Sensing and Imaging**
  - Fusion of decisions based on inputs from multiple modality images
  - Fusion of formed images
  - Fusion of signals to improve subsurface imaging

- Gordon-CenSSIS has been active in each of these fronts
  - Medical and environmental decision fusion from multi-modal imagery
  - Registration and mosaicing applications from multiple imagery
  - New inversion techniques for enhanced image formation from multi-modal signals
Early Example: Mosaicing and Multi-Modal Fusion

- 3-D mosaics of underwater scenes (SeaBED) (acoustic + optical, local)
- Retinal mosaics (IR + Optical, local)
Joint Multi-Modal Inversion

- Enhanced resolution by joint inversion of multi-modal data through shared common boundaries
- Automatically determines region boundaries for accurate inversion
- Fusion of registration, inverse problems

Input MR

Joint MR

Joint Boundary

Calcium  Lumen

Calcium  Lumen

Calcium  Lumen

Calcium  Lumen

CT FBP recon.  Joint CT (soft tissue windowing)  CT/MR Composite

Fatty

Fatty

Fatty

Fatty
Fusion of X-Ray and Diffuse Optical Tomography

- Application: breast cancer detection through fusion of structural info (x-ray) and functional information (DOT)
- Enhance DOT resolution using x-ray or MRI structural information

**X-ray Tomosynthesis**

- 2 cm Invasive Carcinoma with DCIS
- DOT Image of hemoglobin concentration

**GE Tomosynthesis**

- Optical measurement done under mammographic compression

**Optical Imager**
Multisensor Fusion of X-ray Prior on Glandular Region to Increase Resolution

No prior spatial information

Prior information on glandular/adipose and statistical prior on tumor location
Regularization + Fusion + Multispectral Unmixing to obtain Chromophore Distributions

Ground Truth

No Structure Fusion

Structure Fusion

Combined structural / multispectral DOT inversion with mixture estimation
Multimodality Breast Imaging: X-Ray and EIT

Admittivity loci for 6 frequencies (5 Khz - 1 MHz)

ROI 1

Linearity is strong
Indicator of carcinoma: LCM Statistic
Joint PET/CT for Coronary Imaging

- PET imaging is severely blurred through coronary and respiratory motion
- Fusion with information from high-speed CT allows for motion correction (Poster)
  - 4D extension of fusion of CT structure, PET
  - Transition to NIH project

Reference Slice  Conventional PET  Cardiac Motion removed  Both motions Removed
Multifrequency THz Inversion

- Exploit object shared boundary structure across frequencies plus spectrum priors
- Joint multifrequency reconstruction approaches to increase resolution, SNR (Poster)
- Transition to DHS (ALERT)

Reconstruction Accuracy of different methods:

- 1.8THz
- 2.0THz
- 2.4THz
- 3.0THz
Summary

- Some of the key barriers in subsurface imaging were low resolution and diminished signal/noise ratio
- Multisensor fusion at the signal level helps overcome such barriers
  - Exploit high resolution modalities to enhance resolution in other modalities
  - Integrate signal strength over modalities to reduce clutter, enhance objects of interest
- Gordon-CenSSIS has developed and demonstrated novel multi-modal signal fusion algorithms for important applications
  - Inversion algorithms exploiting side information, shared structure fusion
- Research continues (ALERT, NIH, ...), motivated by new applications (see Posters)