Value-centered Information Theory for Adaptive Learning, Inference, Tracking, and Exploitation

[http://wiki.eecs.umich.edu/voimuri]

ARO W911NF-11-1-0391
Program manager: Liyi Dai

**Investigators:** Al Hero (PI), Raj Nadakuditi, John Fisher, Jon How, Alan Willsky, Randy Moses, Emre Ertin, Angela Yu, Michael Jordan, Stefano Soatto, Doug Cochran
4th Year VoI MURI Review: Agenda

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00 - 8:30</td>
<td>Get settled with coffee</td>
</tr>
<tr>
<td>8:30 - 8:35</td>
<td>Welcome, Liyi Dai</td>
</tr>
<tr>
<td>8:35 - 8:50</td>
<td>Project overview, Al Hero</td>
</tr>
<tr>
<td>8:50 - 10:20</td>
<td>Thrust area I: Information-driven Learning and Representation</td>
</tr>
<tr>
<td></td>
<td>PI Summaries, Michael Jordan, Stefano Soatto, Al Hero</td>
</tr>
<tr>
<td>10:20 - 10:30</td>
<td>Break</td>
</tr>
<tr>
<td>10:30 - 12:00</td>
<td>Thrust area II: Information Fusion</td>
</tr>
<tr>
<td></td>
<td>PI summaries, Raj Rao Nadakuditi, Emre Ertin, Jon How</td>
</tr>
<tr>
<td>12:00 - 2:00</td>
<td>Lunch and poster session</td>
</tr>
<tr>
<td>2:00 - 3:30</td>
<td>Thrust area III: Information Exploitation</td>
</tr>
<tr>
<td></td>
<td>PI summaries: John Fisher, Angela Yu, Doug Cochran</td>
</tr>
<tr>
<td>3:30 - 3:45</td>
<td>Wrap-up, Al Hero</td>
</tr>
<tr>
<td>3:45 - 4:30</td>
<td>Government discussion and de-briefing</td>
</tr>
<tr>
<td>4:30</td>
<td>Adjourn</td>
</tr>
</tbody>
</table>
MURI coPIs

Al Hero
Michigan

Raj Nadakuditi
Michigan

Randy Moses
Ohio State

Emre Ertin
Ohio State

Jon How
MIT

John Fisher
MIT

Angela Yu
UCSD

Stefano Soatto
UCLA

Mike Jordan
UC Berkeley

Doug Cochran
Arizona State

Year 4 review. MIT, Nov. 13 2015
Our MURI’s principal aim

• To derive a comprehensive set of principles for task-specific information extraction, distributed information fusion, and information exploitation that can be used to design the next generation of autonomous and adaptive sensing systems.

• **Specific objectives:**
  
  • Develop analytical frameworks for quantifying value of information.
  • Study fundamental tradeoffs for information collection and fusion
  • Develop info processing algorithms with performance guarantees
  • Validate theory and algorithms on sensing testbeds at MIT, OSU, UCSD and UCLA

• **Technical approach:** value-centered information theory, machine learning and control.
Developed principles are applied and validated in relevant applications

- **Application domains**
  - STAP, MTI, LIDAR, SAR, WAMI, video, acoustic, Seismic sensing and fusion (Ertin, Cochran, Fisher, Hero, Nadakuditi, Soatto, Zelnio, Nasrabadi)
  - Fusion in distributed sensor networks (Ertin, Hero, Moses, Sadler)
  - Mission-adaptive sensor planning (Cochran, Fisher, How, Hero)
  - Human collaboration and HMI modeling (Yu, Hero, Sadler)
  - Social media, crowdsourcing and text streams (Hero, Jordan, Nadakuditi, Kaplan)

- **Experiments undertaken**
  - Human experiments for model building and validation (Yu)
  - Wide area software radar data collect (Ertin, Fisher)
Domains of progress of MURI

- Applications
- Performance and Tradeoffs
- Proxies and Surrogates
- Composition and Separation
- Data Integration
- Experimental Validation
Performance and Tradeoffs

**Performance**
- **Bounds**
  - Fano, Assouad, LeCam, Chernoff
  - Cramer-Rao-Frechet
  - Talagrand, Rhee
  - Chen-Stein
  - Sub-modular greedy
  - HP-Bhattacharrya
- **Approximations**
  - Random matrices
  - Bag of bootstraps
  - Sparse l0 regression
  - MST-based HP/FIM

**Sample Complexity**
- **Scaling laws**
  - VoI/smpl/dimension
  - Phase transitions
  - Mixed asymptotics
  - Purely high dimensional regime
  - Task-dependent scaling
- **Models**
  - Elliptical, GLM
  - Latent GGM
  - Matrix normal
  - Low rank + sparse
  - Toeplitz+LR+sparse

**Tradeoffs**
- **Constraints**
  - Energy
  - Communication
  - Computation
  - Privacy
- **Measures**
  - VoI/Sample/Joule
  - VoI/Sample/Hz
  - VoI/Sample/flop
  - VoI/Sample/bit

**Year 4 review. MIT, Nov. 13 2015**
Proxies and Surrogates

Information proxies
- Surrogates
  - Intrinsic FIM
  - Information gain
  - Graph entropy
  - HP divergence
- Tasks
  - Sensor selection
  - Action selection
  - Viewpoint selection
  - Navigation
  - Feature selection

Simplified proxies
- Surrogates
  - Hybrid Pe x MSE
  - Mission-weighted hybrid Pe x MSE
  - Softmax
- Tasks
  - Wide area search
  - Multimodality multiobjective plan-ahead sensing
  - Exploration & Exploitation

Sub-modular proxies
- Surrogates
  - Information gain
  - Weighted IG
  - Algebraic connectivity
- Tasks
  - Greedy scheduling
  - Plan-ahead sensing
  - Multiple models
  - Deep community detection
Composition and Separation

Inference over networks

- Method
  - Latent GGM estim
  - Decentralized 20 questions
  - Minimax distributed inference
  - Deep learning nets
  - Gauge theory

- Application
  - MLE without MP
  - Collaborative target tracking
  - Estimation/identif.
  - Object recognition

Spatio-temporal PCA

- Method
  - Kronecker PCA
  - Robust KPCA
  - Toeplitz KPCA
  - Dynamic Graph PCA

- Application
  - Meteorology
  - GMTI-SAR
  - Gait recognition
  - Biochronicity

Factor analysis

- Method
  - OptShrink
  - Robust OptShrink
  - Bayesian FA
  - Multimodal FA

- Application
  - Signal subspace recovery
  - SSR with outliers
  - Robust PCA
  - Social net analysis

Year 4 review. MIT, Nov. 13 2015
Systems and models

Sensor Data
- Sensor
  - SAR-GMTI radar
  - STAP radar
  - LIDAR, WAMI
  - Acoustic/Seismic
  - Software defined HF radar
- Integration
  - Target model
  - Scattering model
  - Noise/clutter model
  - Covariance model
  - Graphical models

Human Data
- Data source
  - Social media
  - Twitter feeds
  - Email traces
  - Coauthorship
  - Speech signals
- Integration
  - Hashtags/Microtext
  - Unigram/bigram
  - Event streams
  - Geographic info
  - Cepstral features

Vision Data
- Source
  - Wide-area video
  - Multiview vision
  - Active vision
- Integration
  - Representations
  - Occlusion
  - Texture MRFs
  - Object recognition
  - DSP-SIFT features
  - Deep learning models
Co-PI presentation topics today

- **John Fisher**, “Information-adapted learning and inference”
- **Stefano Soatto**, “Minimal sufficiency and maximal invariance for deep learning”
- **Al Hero**, “VoI-driven learning over varying tasks and data-types”
- **Raj Rao Nadakuditi**, “Spectral fusion of low rank+sparse random matrices”
- **Emre Ertin**, “Fusion and inference in radar networks”
- **Doug Cochran**, “Value of information sharing in networked systems”
- **Angela Yu**, “Exploration versus exploitation: human multiarmed bandit behavior”
- **Michael Jordan**, “Minimax distributed estimation over networks”
Today’s posters

1. Nithin Sugavanam and Emre Ertin, “Waveform Design for Compressive MIMO Radar”
2. Diyan Teng and Emre Ertin, “Learning for Sequential Information Fusion”
8. B. Mu, G. Newstadt, D. Wei, A.O. Hero, J.P. How, "Adaptive Search for Multi-class Targets with Heterogeneous Importance,"