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

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

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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

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

MURI coPIs

Al Hero
Michigan

Raj Nadakuditi
Michigan

Randy Moses
Ohio State

Emre Ertin
Ohio State

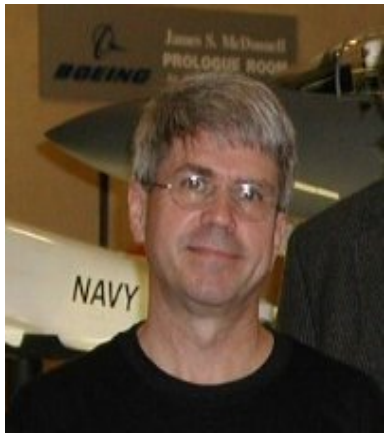
Jon How
MIT

John Fisher
MIT

Angela Yu
UCSD

Stefano Soatto
UCLA

Mike Jordan
UC Berkeley



Doug Cochran
Arizona State

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.

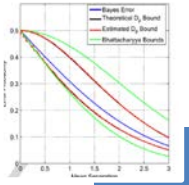
MURI application domains

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)

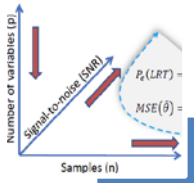
Domains of progress of MURI

Performance and Tradeoffs



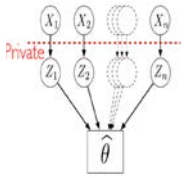
Performance

- **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

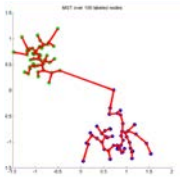
- **Scaling laws**
  - VoI/smpl/dimension
  - Phase transitions
  - Mixed asymptotics
  - Purely high dimensional regime
  - Task-dependent scaling
- **Models**
  - Elliptical, GLM
  - Latent GGM
  - Matrix normal
  - Low rank + sparse
  - Toeplitz+LR+sparse



Tradeoffs

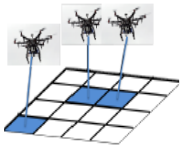
- **Constraints**
  - Energy
  - Communication
  - Computation
  - Privacy
- **Measures**
  - VoI/Sample/Joule
  - VoI/Sample/Hz
  - VoI/Sample/flop
  - VoI/Sample/bit

Proxies and Surrogates



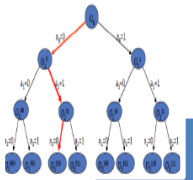
Information proxies

- **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

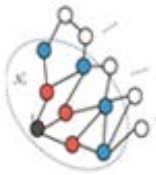


Sub-modular proxies

- **Surrogates**
  - Information gain
  - Weighted IG
  - Algebraic connectivity
- **Tasks**
  - Greedy scheduling
  - Plan-ahead sensing
  - Multiple models
  - Deep community detection

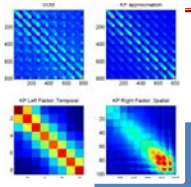
Composition and Separation

Composition and Separation



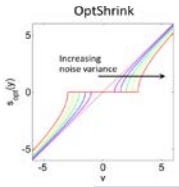
Inference over networks

- **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

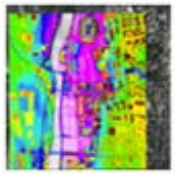
- **Method**
  - Kronecker PCA
  - Robust KPCA
  - Toeplitz KPCA
  - Dynamic Graph PCA
- **Application**
  - Meteorology
  - GMTI-SAR
  - Gait recognition
  - Biochronicity



Factor analysis

- **Method**
  - OptShrink
  - Robust OptShrink
  - Bayesian FA
  - Multimodal FA
- **Application**
  - Signal subspace recovery
  - SSR with outliers
  - Robust PCA
  - Social net analysis

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"
- **Jonathan P. How**, "VoI-oriented Inference and Planning for Mapping and Navigation"
- **Doug Cochran, "**Value of information sharing in networked systems**"**
- **Angela Yu**, "Exploration versus exploitation: human multi--armed 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"
3. Gene Whipps, Emre Ertin, Randy Moses, "Distributed change detection of a radioactive source"
4. Gene Whipps, Emre Ertin, Randy Moses, Decentralized iterative algorithm for ML estimation of a mixture of factor analyzers
5. H.W. Chung, B. Sadler, A. Hero, "When does entropy-driven search work?"
6. T. Xie, N. Nasrabadi and A.O. Hero, "Multi-sensor classification via consensus-based multi-view maximum entropy discrimination"
7. Brian E. Moore, Raj Rao Nadakuditi, and Jeffrey A. Fessler, "The accuracy of singular vectors of thresholded low-rank plus noise plus outlier matrices"
8. B. Mu, G. Newstadt, D. Wei, A.O. Hero, J.P. How, "Adaptive Search for Multi-class Targets with Heterogeneous Importance,""
9. G. Papachristoudis, J. W. Fisher III, "On the Complexity of Information Planning in Gaussian Models"
10. J. Straub, J. Chang, O. Freifeld, J. W. Fisher III, "A Dirichlet Process Mixture Model for Spherical Data"