



## 2<sup>nd</sup> MURI Review 2013



# 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



# 2<sup>nd</sup> Year Vol MURI Review: Agenda

Time	Activity
8:00 – 8:30	Check in at ARL visitor office
8:30 - 8:35	Welcome, Liyi Dai
8:35 - 8:50	Project overview, Al Hero
8:50 - 10:15	Thrust area I: Learning and Representation Overview, Michael Jordan PI Summaries, Michael Jordan, Stefano Soatto, Al Hero, Angela Yu
10:15 - 10:30	Break
10:30 - 11:35	Thrust area II: Information Fusion Overview, John Fisher PI summaries, Raj Rao Nadakuditi, Emre Ertin, John Fisher
11:35 - 12:00	Collaborative highlights
12:00 - 12:15	DURIP testbed, Emre Ertin
12:15 - 2:15	Lunch and poster session
2:15 - 3:20	Thrust area III: Information Exploitation Overview, Doug Cochran PI summaries: Randy Moses, Jon How, Doug Cochran
3:20 - 3:30	Wrap-up, Al Hero
3:30 - 4:30	Government discussion and de-briefing
4:30	Adjourn



# MURI coPIs you will hear from today



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.

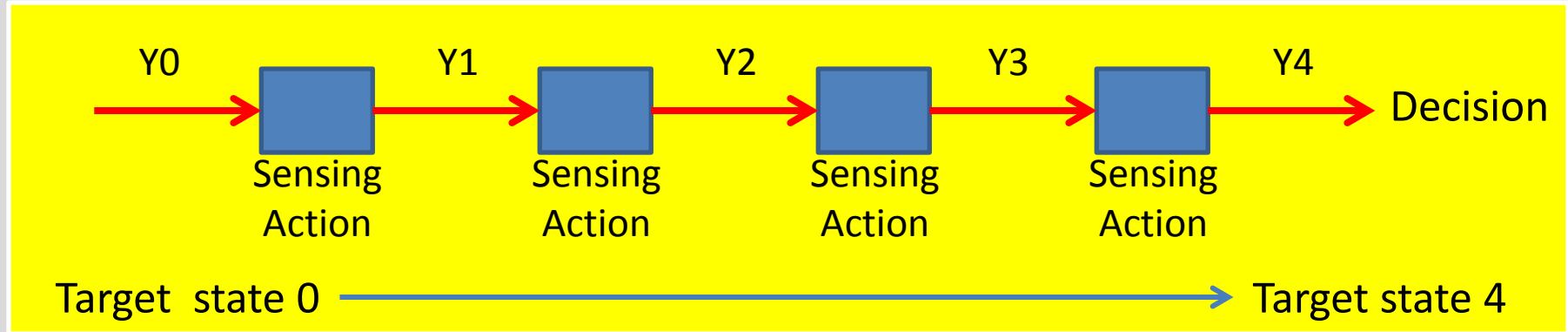
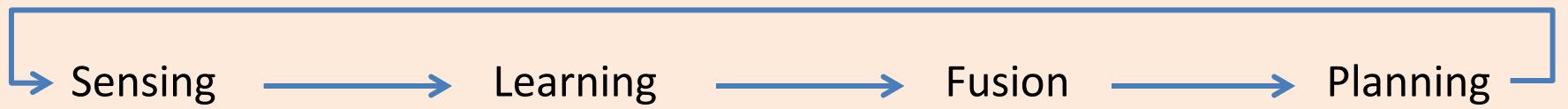




# Value-centered information theory



Adaptively measure variables  $Y_0, Y_1, \dots$  for decisionmaking



- Each sensing action acquires a sample (snapshot)  $Y_n$
- $Y_n$  contains information about target state, clutter, and sensor quality
- What is the intrinsic value of this information with respect to decision?

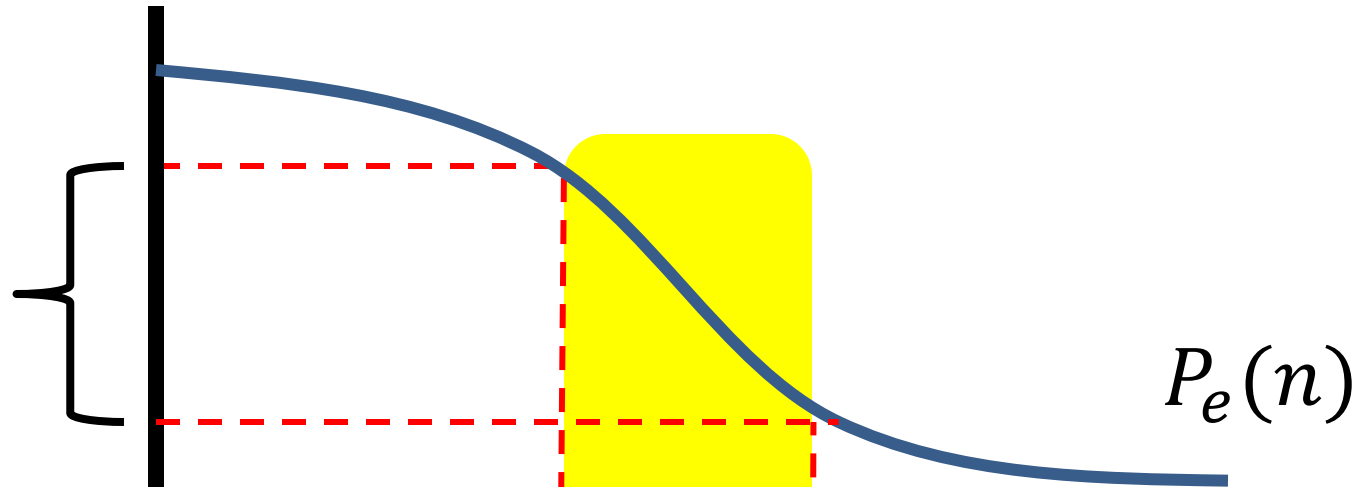




# Value of information accrued from a snapshot



Vol(B)  
for detection



Vol(B)  
for estimation

$n$   $n + 1$

Sensor A  
deployed

Sensor B  
deployed

Sensor A  
deployed

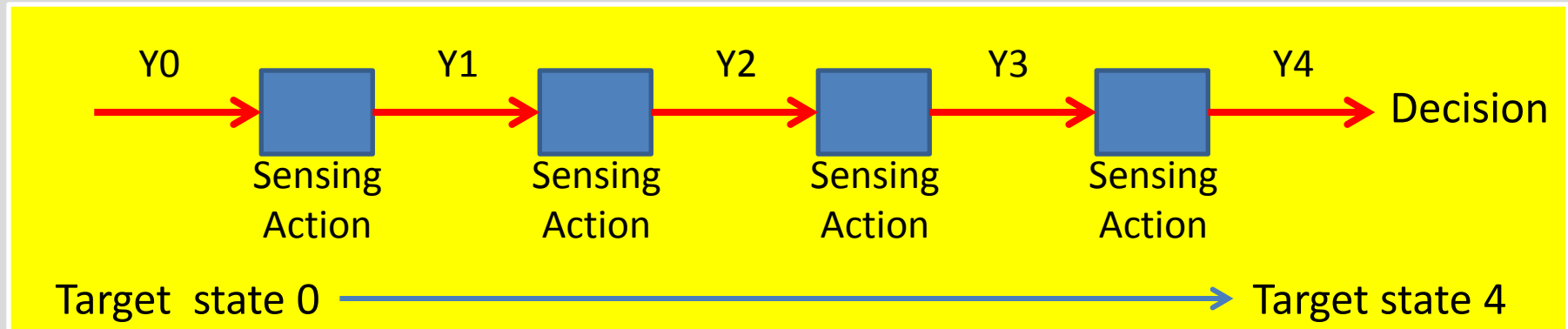
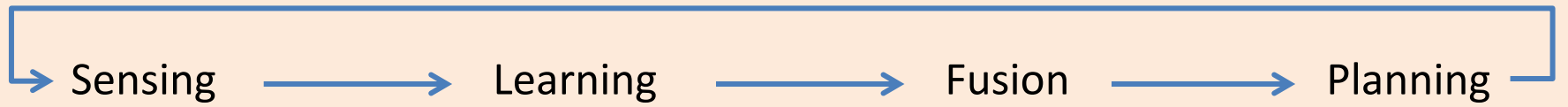
$MSE(n)$



# Value-centered information theory



Adaptively measure variables  $Y_0, Y_1, \dots$  for decisionmaking



**Our MURI has so far focused on the following:**

- Scalable information metrics that account for decision task
- Characterization of phase transitions, scaling laws, and bottlenecks
- Vol-driven fusion strategies for distributed data collection
- Applications to active vision, sensor nets, radar, human-in-the-loop





# Design space is high dimensional



## Information sources

- Collected sensor data
- Target/clutter signatures
- Contextual information
- Soft data

## Decision tasks

- Detect target
- Estimate target location
- Identify target class
- Assess threat level

## Processing constraints

- Time&Energy
- Computation&Memory
- Communication
- Human-in-the-loop







# Theory applicable to design space



## Information sources

Collected sensor data  
Target/clutter signature  
Contextual information  
Soft data

## Decision tasks

Detect target  
Estimate target location  
Identify target class  
Assess threat level

Information theory  
Decision theory

Machine learning  
Information fusion

Control theory  
Convex optimization

## Processing constraints

Time&Energy  
Computation&Memory  
Communication  
Human-in-the-loop





# Theory applicable to design space



## Central questions addressed by our MURI

- What is intrinsic value of information for a task?
- How do constraints affect value?
- What algorithms ensure max value?
- How to overcome computational bottlenecks?

## Our technical approach to address questions

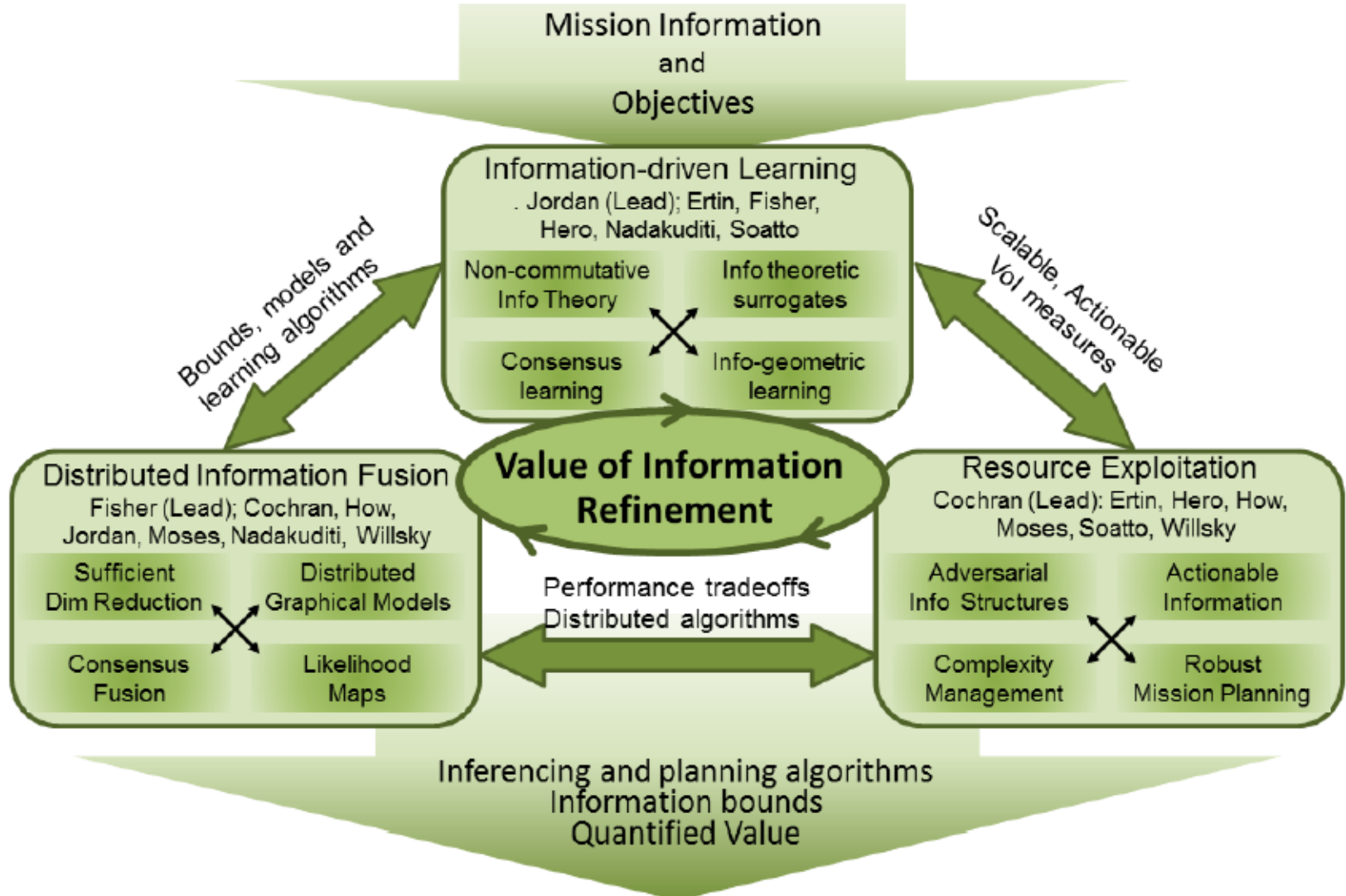
- Value-centered information theory
- Information-driven data fusion
- Information-aware controlled sensing/processing

Communication





# Research program: High level view





# Previous government comments



- **The government committee was pleased to see that the MURI team produces high quality, fundamental research results**  
We continue to maintain a rigorous foundational research focus
- **The poster session is an excellent idea, and should be an example for other MURI reviews**  
We have expanded the poster session this year.
- **The team has a good start with connecting research with Army laboratories.... The team is strongly encouraged to continue/expand the collaboration with ARL, AMRDEC, and other DoD laboratories**  
We have expanded our collaborations with DoD.





# Previous government comments



- **Collaborations among team members at different universities have been planned, and the team is encouraged to take actions as soon as possible to strengthen collaboration among team members**  
See today's session on collaborations and posters
- **Future research is encouraged to place more emphasis on multimodality sensors, particularly visual modality**  
We have expanded visual modality activities (video, LIDAR)
- **Experimental validation and verification is encouraged. Team responded with a pending DURIP proposal to ARO...It's desirable to have plans in place to validate and verify research results using carefully designed experiments, which is particularly important for modalities other than radar, such as visual imagers.**  
DURIP was funded. Other modalities will also be validated.





# Previous government comments



- **The committee noted that a wide range of research topics are being addressed, and encouraged the team to coordinate research efforts toward establishing a rigorous, foundational framework of value of information for distributed fusion.**

We have made efforts to coordinate research on establishing a foundational multi-faceted framework for Vol. These include several collaborations on foundational issues and organization of two special sessions on Vol at conferences this past year.





# Today's posters



1. *N. Asendorf* and R. R. Nadakuditi, "The Performance of Deterministic Matched Subspace Detectors: Informative Versus Useful Subspace Components" [Abstract](#)
2. *T. Broderick*, N. Boyd, A. Wibisono, A. Wilson, and M.I. Jordan, "Streaming Variational Bayes"
3. *L. Crider*, R. R. Nadakuditi, and D. Cochran, "Analyze-Fuse vs. Fuse-Analyze in Multiple-channel Emitter Detection" [Poster](#)
4. *Z. Meng*, *D. Wei*, *A. Wiesel*, and *A. Hero*, "Distributed learning of Gaussuab graphical models via marginal likelihoods" [Poster](#)
5. *B. Mu*, G. Newstadt, J. P. How, and A. Hero, "Heterogeneous Agent Target Assignment in an Unknown Environment" [Poster](#)
6. *B. Mu*, G. Chowdhary, J. P. How, "Vol Aware Active Task Assignment Hardware Experiment" [Poster](#)
7. *G. Papachristoudis* and J. W. Fisher, "Efficient Information Planning in Graphical Models"
8. *J. Straub* and J. W. Fisher, "Information gathering with mobile agents: sensor and model complexity tradeoffs"
9. *N. Sugavanam*, and E. Ertin, "Robust Filtering with Uncertainty in Initial State" [Poster](#)
10. *N. Sugavanam*, and E. Ertin, "Sensor Selection Problems in Adversarial Setting"





# Today's posters



11. *R. T. Suryaprakash* and *R. R. Nadakuditi*, "The Performance of MUSIC-Based DOA In White Noise With Missing Data" [Abstract](#)
12. *D. Teng*, and *E. Ertin*, "Optimal Quantization of Likelihood for Low Complexity Sequential Testing" [Poster](#)
13. *D. Teng*, and *E. Ertin*, "Learning Statistical Manifolds for Target Signatures" [Poster](#)
14. *T. Tsiligkaridis* and *A. Hero*, "Covariance Estimation In High Dimensions via Kronecker Product Expansions"
15. *T. Tsiligkaridis*, *B. Sadler*, and *A. Hero*, "Collaborative 20 Questions for Target Localization"
16. *G. T. Whipps*, *E. Ertin*, and *R. L. Moses* "Decentralized EM for a Mixture of Factor Analyzers"
17. *G. T. Whipps*, *E. Ertin*, and *R. L. Moses* "Distributed Detection with Collisions in a Single-hop Wireless Sensor Network"
18. *S. Zhang* and *A. J. Yu*, "Forgetful Bayes and Myopic Planning: Human Decision Making in a Bandit Setting"
19. *Y. Zeng*, *C. Wang*, *S. Soatto*, and *S.-T. Yau*, "*Nonlinearly Constrained MRFs: Exploring the Intrinsic Dimensions of Higher-Order Cliques*"

