Integrated Fusion, Performance Prediction, and Sensor Management for Automatic Target Exploitation

Overview

MURI Annual Review Meeting

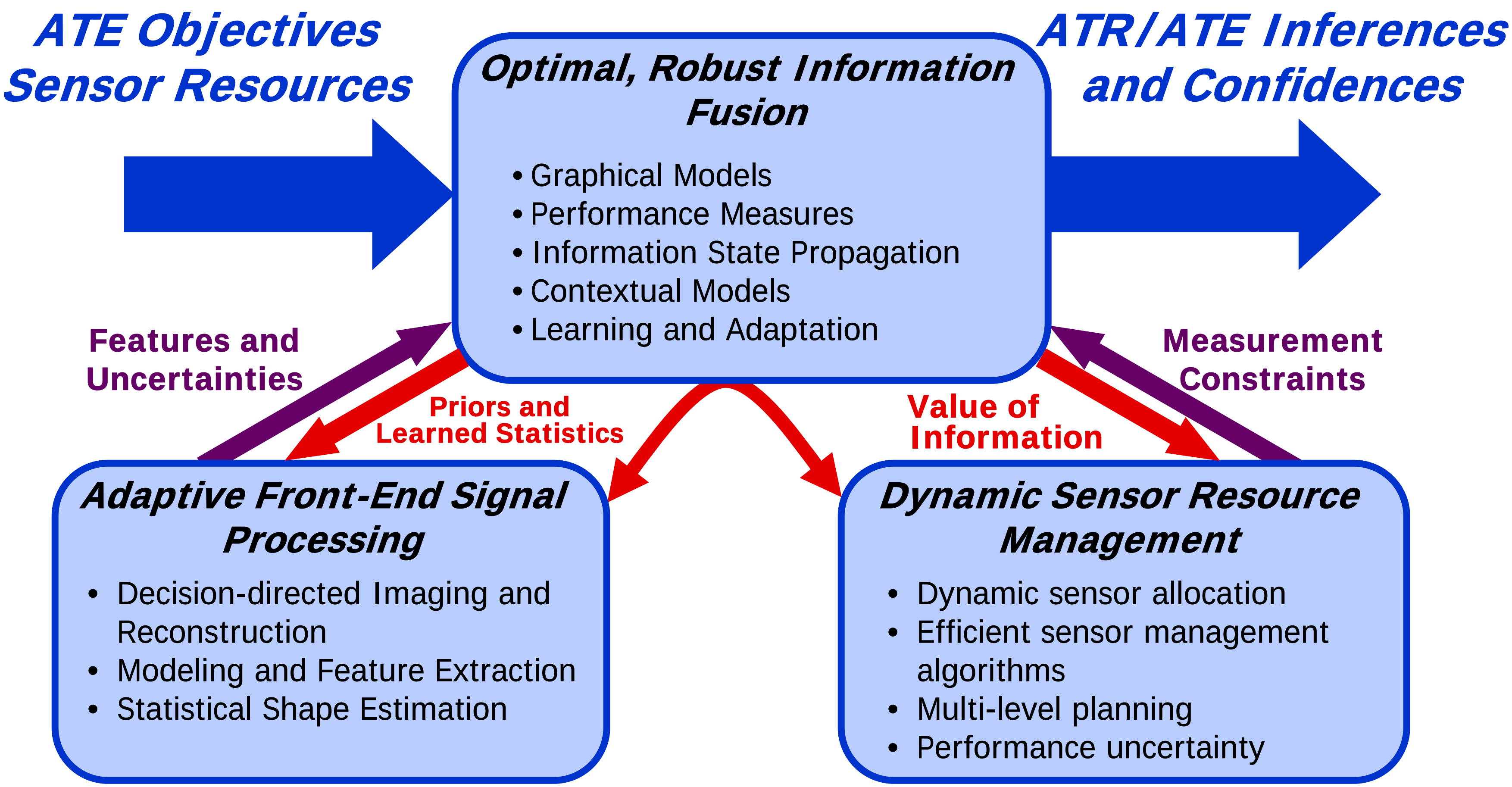
Randy Moses

November 3, 2008

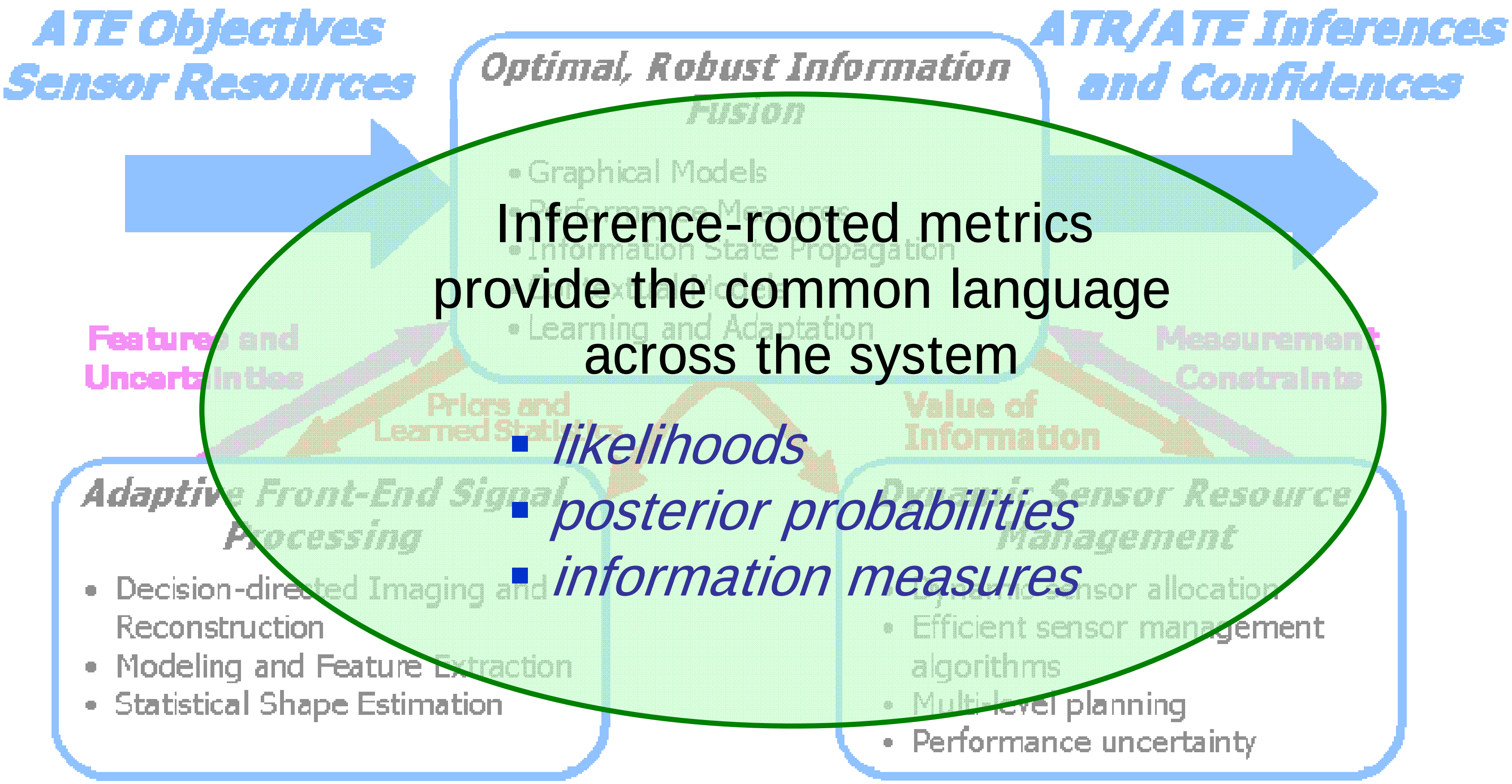
Research Goal

- *Develop an integrated systems theory that jointly treats information fusion, control, and adaptation for automatic target exploitation (ATE).*
  - Multiple, dynamic sensors
  - Multiple sensing modes
  - Resource-constrained environments

Research Framework



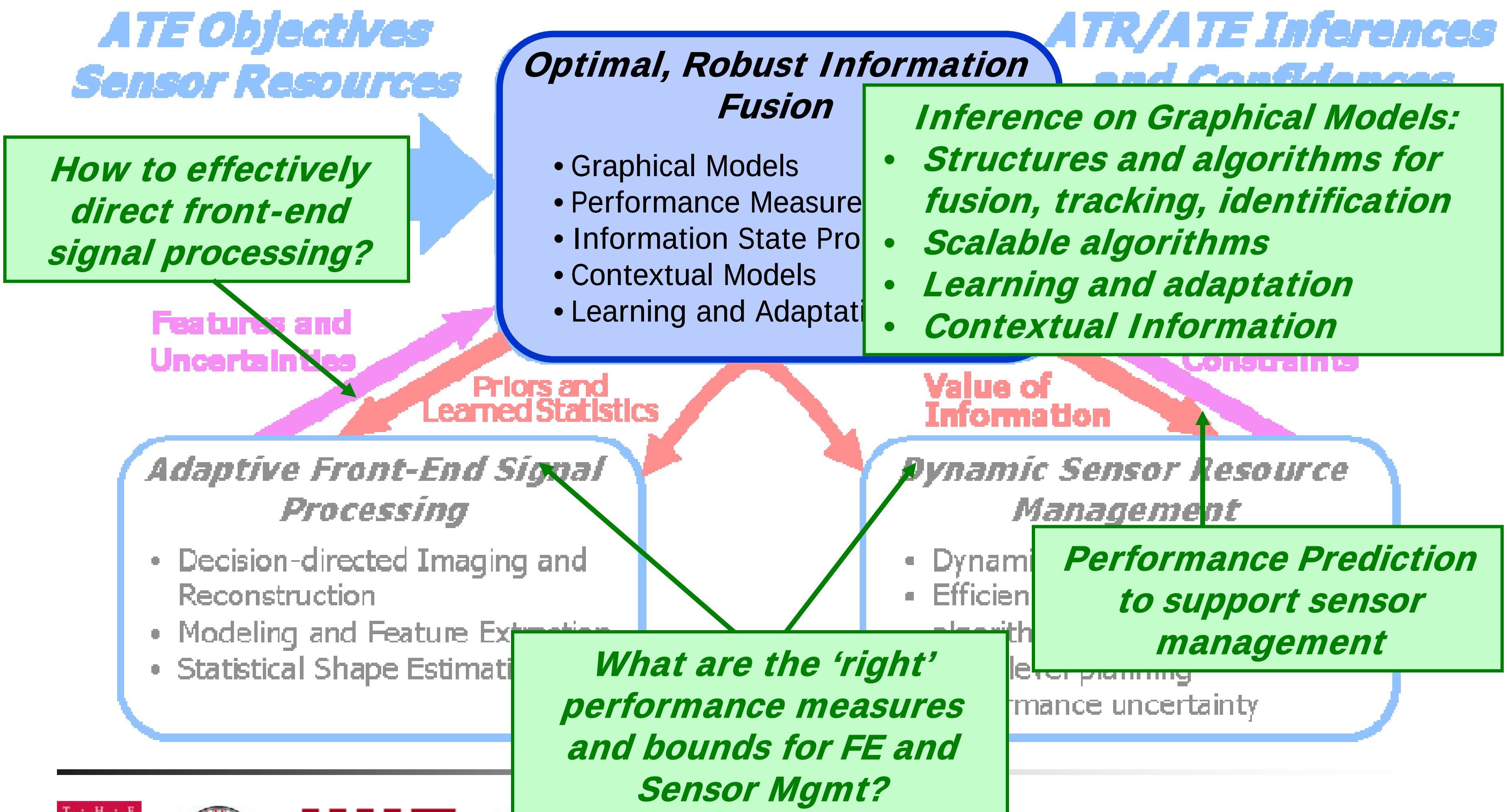
Research Framework



Inference-rooted metrics provide the common language across the system

- *likelihoods*
- *posterior probabilities*
- *information measures*

Information Fusion: Key Research Questions



Signal Processing: Key Research Questions

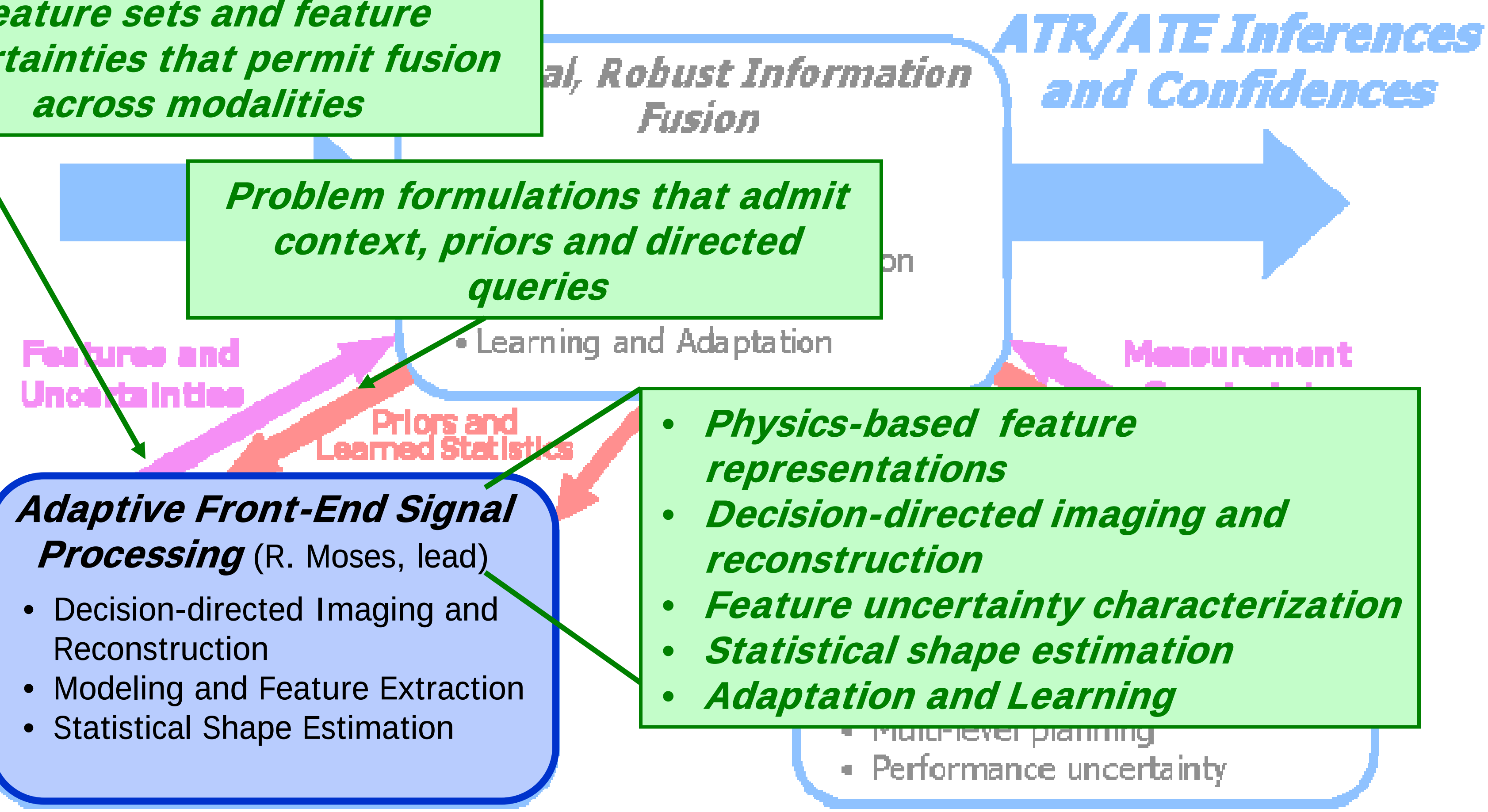
Feature sets and feature uncertainties that permit fusion across modalities

Problem formulations that admit context, priors and directed queries

Adaptive Front-End Signal Processing (R. Moses, lead)

- Decision-directed Imaging and Reconstruction
- Modeling and Feature Extraction
- Statistical Shape Estimation

- ***Physics-based feature representations***
- ***Decision-directed imaging and reconstruction***
- ***Feature uncertainty characterization***
- ***Statistical shape estimation***
- ***Adaptation and Learning***



Sensor Management: Key Research Questions

ATE Objectives
Sensor Resources

Optimal, Robust Inf
Fusion

- Graphical Models
- Performance Measure
- Information State Propagation
- Contextual Models
- Learning and Adaptation

- ***Integrate ATE performance based on graphical models***
- ***Manage evolution of "information state" in support of ATE missions***

Measurement Constraints

Value of Information

- ***Active sensor control that incorporate ATE performance metrics***
- ***Multi-modal, heterogeneous platforms***
- ***Scalable real-time algorithms for theater-level missions***
- ***Robust to inaccurate performance models***

- Modeling and Feature Extraction
- Statistical Shape Estimation

Dynamic Sensor Resource Management (D. Castañón, lead)

- Dynamic sensor allocation
- Efficient sensor management algorithms
- Multi-level planning
- Performance uncertainty

MURI Payoff

Goal: Develop an integrated theory for ATE systems that combines information fusion, platform control, signal processing, and adaptation.

Research Outcomes:

- *An integrated theoretical framework for dynamic information exploitation systems.*
- *Theoretical foundations for adaptivity and learning in complex inference systems.*
- *New algorithms and performance metrics for coupled signal processing, fusion, and platform control.*

Payoff:

- *Systematic design tools for end-to-end design of multi-modal, multi-platform ATE systems.*
- *Active platform control to meet ATE objectives.*
- *System-level ATE performance assessment methods.*
- *Adaptive, dynamic ATE systems.*

MURI Team

UNIVERSITY TEAM:

- Ohio State University (lead)
  - Randy Moses (PI)
  - Lee Potter
  - Emre Ertin
- Massachusetts Institute of Technology
  - Alan Willsky
  - John Fisher
  - Mujdat Çetin (also Sabanici U.)
- Boston University
  - David Castañón
  - Clem Karl
- University of Michigan
  - Al Hero
- Florida State University
  - Anuj Srivastava

AFOSR: David Luginbuhl → Doug Cochran

AFRL POC: Greg Arnold

Year 1 Meeting Feedback

- Strongly positive on team expertise and interactions.
- Strongly supportive of research plan
- Maintain emphasis on fundamental research.
  - Assumptions that maintain relevance.
- Maintain research continuity and relevance
  - Complementary research problem statements, compatibility across the team.
  - Scalability
  - Performance Prediction

Year 2 Advances

- Regularized Tomography for Sparse reconstruction
  - Sparse apertures – monostatic and multistatic
  - Sparse 'objects' (targets or scenes)
  - Anisotropy characterization
  - 3D Reconstruction for wide angle and circular SAR
  - Decision-directed reconstruction
  - Lots of cross-pollination
- Shape Statistics for Curves and Surfaces
  - Shape Analysis
    - Shape distribution; not just point estimates
  - Bayesian classification from shapes
  - Bayesian shape estimation from EO/IR images

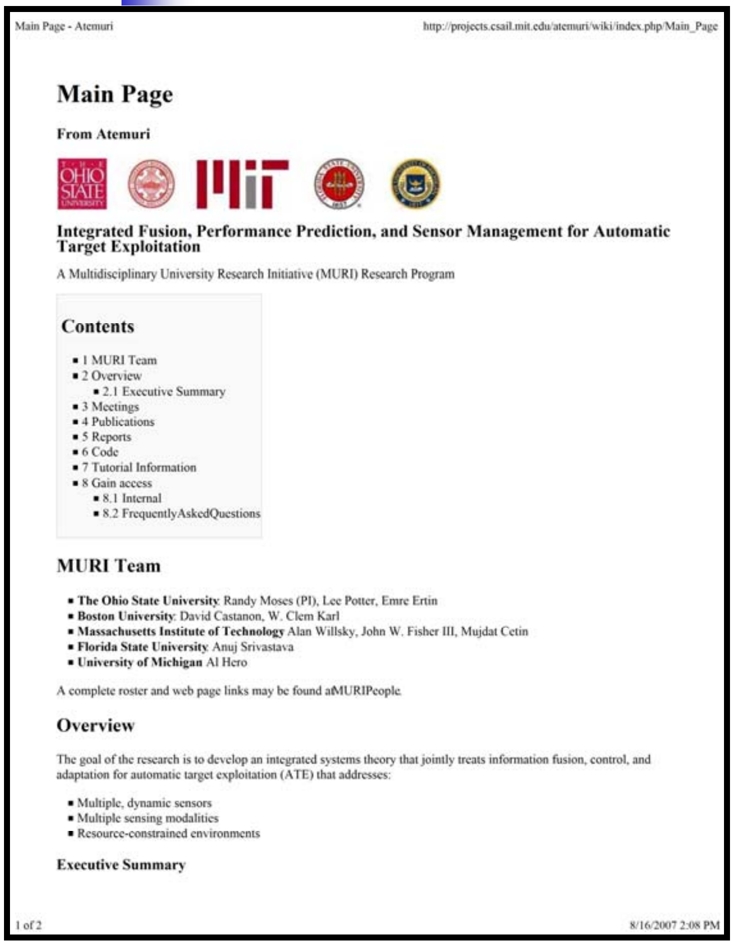
Year 2 Advances II

- Sensor Management
  - Multiplatform information-theoretic dynamic sensor management using integer optimization
  - Adaptive dynamic sensor management algorithms and performance bounds for radar search, detection and classification
  - Multi-Radar resource management with guaranteed uncertainty metrics
- Scalable Inference
  - Lagrangian relaxation and multiresolution methods for tractable inference in graphical models
  - New graphical model-based algorithms for multi-target, multi-sensor tracking
  - Learning Graphical Model structures directly for discrimination
  - GM-based distributed PCA and hyperspectral image discrimination
  - Graphical models to extract dynamic behavior modes

MURI Students

- 11 graduate students and 1.5 postdocs supported by the MURI.
- 14 graduate students and 1 postdoc working on the MURI team with outside support (e.g. fellowships) or partial funding.
- 7 PhD and 8 MS degrees awarded

ATE MURI Web Page


Main Page - Atemuri http://projects.csail.mit.edu/atemuri/wiki/index.php/Main_Page

Main Page

From Atemuri

Integrated Fusion, Performance Prediction, and Sensor Management for Automatic Target Exploitation

A Multidisciplinary University Research Initiative (MURI) Research Program

Contents

MURI Team

- **The Ohio State University**: Randy Moses (PI), Lee Potter, Emre Ertin
- **Boston University**: David Castanon, W. Clem Karl
- **Massachusetts Institute of Technology** Alan Willsky, John W. Fisher III, Mujdat Cetin
- **Florida State University**: Anuj Srivastava
- **University of Michigan** Al Hero

A complete roster and web page links may be found atMURIPeople.

Overview

The goal of the research is to develop an integrated systems theory that jointly treats information fusion, control, and adaptation for automatic target exploitation (ATE) that addresses:

- Multiple, dynamic sensors
- Multiple sensing modalities
- Resource-constrained environments

Executive Summary

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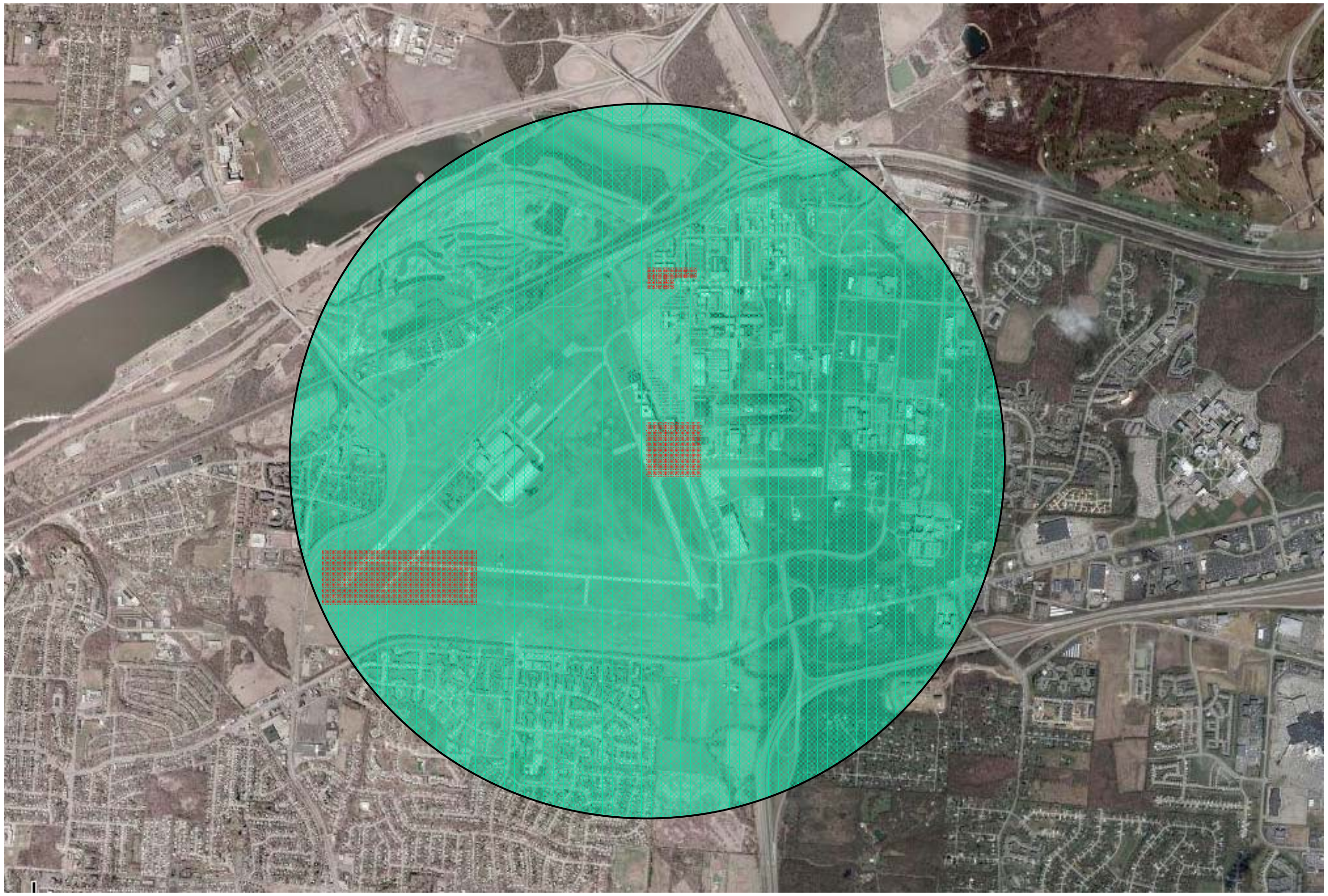
- People
- Publications
- On-line research collaboration space
- Resources

Synergy Examples: Joint Data Collections

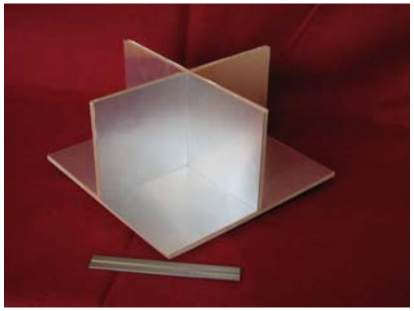
- October 2007: Layered Sensing over OSU Campus
  - AFRL: 3 airborne imaging sensors
  - AFRL and OSU: rooftop sensors
  - OSU: acoustic, seismic, microsensor radar ground sensors
- November 2007: Follow-up layered sensing collection
  - Rooftop and Ground sensors
  - Richer set of people tracking scenarios
- August 2008: AFRL Radar/EO sensing
  - Our MURI provided
    - test targets, stationary and moving vehicles, “sweat equity”
    - INS measurements of moving targets; Location ground truthing
    - Acoustic and Seismic ground sensing
    - Moving vehicle test plans
  - Data to benefit multiple university programs
    - MURI, AFOSR DCT program, ATR Center research

Gotcha Collection, August 2008



Test Reflectors

- Urban propagation measurements
  - Top hats
    - Isotropic even bounce return
    - 11.1 dBsm (48 inch base; 16x12.5 cylinder)
  - Quad corners
    - Quasi-isotropic odd bounce return
    - 10.0 dBsm (5 inch squares)
  - Bruderhedral at 45 degrees
    - Wide beam cross-polarization return
    - 5 dBsm
    - Loan from SET Corp



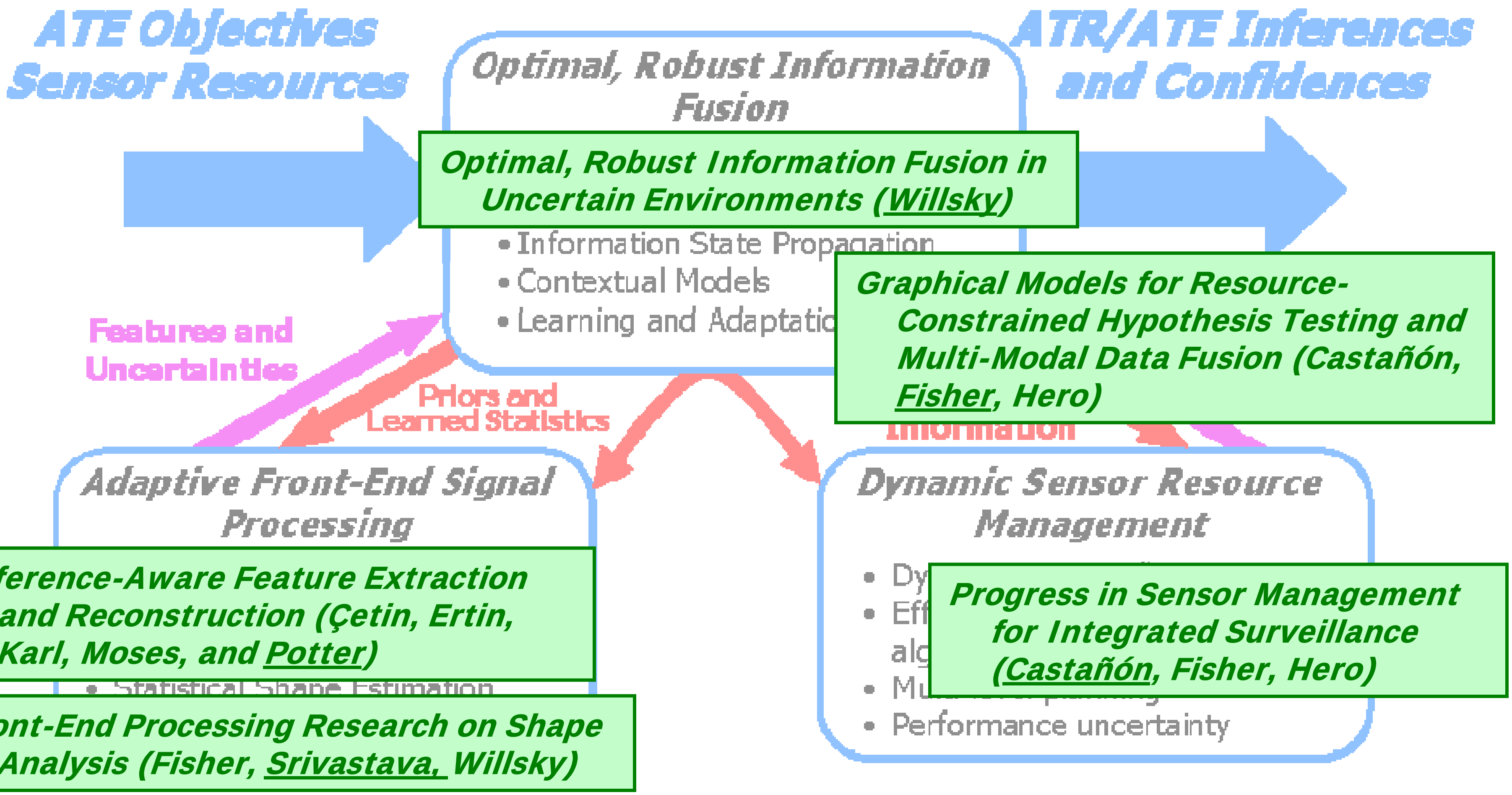
Phase Alignment Reflectors

- 14 Quad-corners
  - 37.2 dBsm

MURI: Integrated Fusion, Performance Prediction, and Sensor Management for Automatic Target Exploitation

Civilian Vehicles

Today's Presentations



- ***Optimal, Robust Information Fusion in Uncertain Environments (<u>Willsky</u>)***
- ***Graphical Models for Resource-Constrained Hypothesis Testing and Multi-Modal Data Fusion (Castañón, <u>Fisher</u>, Hero)***
- ***Inference-Aware Feature Extraction and Reconstruction (Çetin, Ertin, Karl, Moses, and <u>Potter</u>)***
- ***Progress in Sensor Management for Integrated Surveillance (<u>Castañón</u>, Fisher, Hero)***
- ***Front-End Processing Research on Shape Analysis (Fisher, <u>Srivastava,</u> Willsky)***

Agenda

8:30 - 9:00	Intro and Overview (Moses)
9:00 – 9:40	Optimal, Robust Information Fusion in Uncertain Environments (Willsky)
9:40 - 10:25	Inference-Aware Feature Extraction and Reconstruction (Potter)
10:25 - 10:45	Break
10:45 - 11:15	Shape Analysis Research (Srivastava)
11:15 - 11:55	Graphical Models for Resource-Constrained Hypothesis Testing and Multi-Modal Data Fusion (Fisher)
11:55 - 12:50	Lunch - ***Blackwell Ballroom***
12:50 - 1:30	Progress in Sensor Management for Integrated Surveillance (Castañón)
1:30 - 2:00	Summary (Moses)
2:00 - 2:30	Government caucus
~2:30	Feedback and Discussion