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

Summary

MURI Annual Review Meeting

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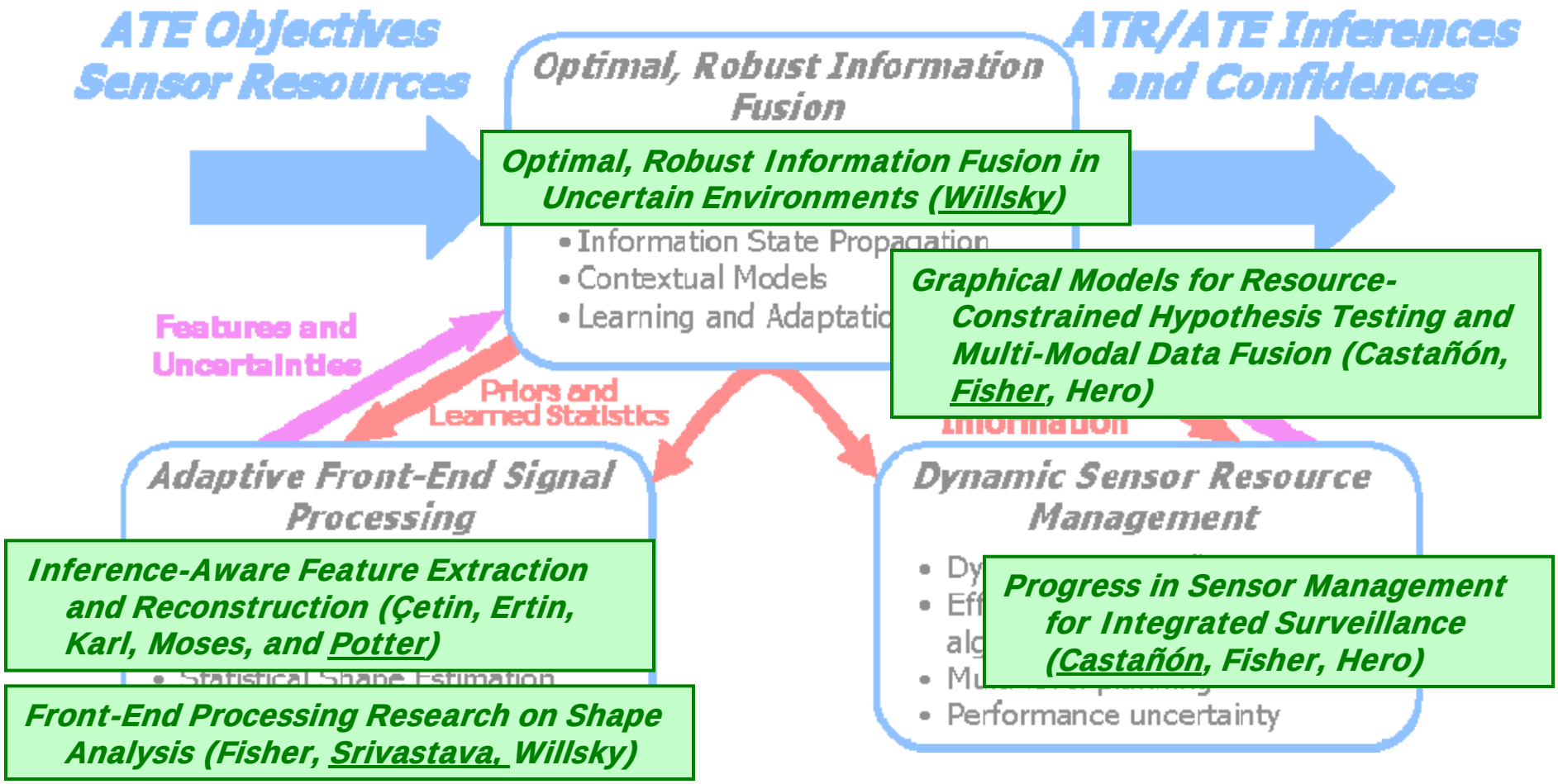
Today's Presentations



Key Accomplishments

- Scalable, flexible information fusion using graphical models
  - Multiscale structures
  - Graphical model structures for tracking
  - Learning structure for inference (e.g. behavior)
- Sensor signal processing approaches that support multi-modal, multi-sensor inference
  - Robust to sensor configuration and sparsity of data
  - Tools to support performance and performance prediction
  - Amenable to complex scenes
    - Scene/target motion; 3D structure; anisotropic behavior
- Scalable, information-based sensor management
  - Low-complexity algorithms with guaranteed performance
  - Information metrics for sensor management

Publications and Student Degrees

- 129 Publications
  - 2 book chapters
  - 45 Journal publications
  - 82 Conference proceedings papers
- Student Graduate Degrees
  - 7 Ph.D. graduates
    - Williams (MIT), Rangarajan (UMich), Joshi (FSU), Malioutov (MIT), Johnson (MIT), Bashan (UMich), Liang (BU)
  - 8 M.S. graduates
    - Austin (OSU), Som (OSU), Varhney (MIT), Chen (MIT), Choi (MIT), Chandrasekaran (MIT), Batu (Sabanci), Bangla (BU)

Research Leadership

- **Journal Special Issue**
  - Shape Analysis and Its Applications in Image Understanding, IEEE PAMI (Srivastava)
- **Themed Workshops**
  - Workshop on Challenges and Opportunities in Image Understanding, Jan 2007 (Srivastava)
  - Workshop on Signal and Information Processing, July 2008 (Hero)
- **Conference Special Sessions**
  - Sparse Reconstruction methods in Radar
    - SPIE Defense Symposium, April 2008 (Moses)
  - Signal Processing for Inference
    - IEEE 5th DSP Workshop, January 2009 (Moses)
  - Signal Processing and Learning for Sensor Signal Exploitation
    - 2008 Asilomar Conference on Signal, Systems, and Computers, Oct 2008 (Ertin)
- **Scientific Advisory Boards**
  - Castañón: Air Force SAB
  - Hero: ARL TAB
  - Willsky: DARPA POSSE;
  - Willsky: Chief Scientific Consultant to BAE-AIT
  - Hero: National Research Council
  - Moses: US/UK International Technology Alliance

Synergistic Interactions

- Graphical Models as a synergy catalyst
- Graphical Models and Manifold Learning
  - Outgrowth of Hero sabbatical at MIT
- Front-end Signal Processing
  - Coordinated, unified approach to address statistical fusion and performance assessment
  - Multiple modalities; multiple operating modes
  - Features and shape under one umbrella
- Information-based resource management
  - Information cost metrics and performance bounds
  - Physical scattering models (OSU) for SM (BU)
- Intra-team visits and student mentorship
  - Cetin to MIT/BU summers; Hero sabbatical at MIT; Moses multiple summer visits to MIT+BU
  - Student research co-advising and thesis committees

Transitions I

- Strong, Fruitful Connection to AFRL
  - Frequent faculty visits and student internships
  - Collaborative data collections
  - Research collaborations
  - Transitional research topics (e.g. via ATR Center)
- Technology transfer to industry via DoD programs
  - DARPA Visibuilding, ATIF, POSSE
  - AFRL Gotcha
  - SBIRs with AF, MDA
- Student internships
  - Several at AFRL; also GD-AIS, NG, BAE-AIT
- Non-DoD technology transitions
  - Medical imaging and shape inference
  - Seismic processing for oil exploration

Transitions II: Year 2 Examples

- Sparse aperture research transitioned to AFRL GREP program
- Srivastava statistical shape analysis transitioned to Northrup-Grumman via Innovation Alliance Award
- The Lagrangian Relaxation method has led directly to a module in BAE-AIT's ATIF (All-Source Track and ID Fusion) System
- Multi-target tracking approaches being transitioned to BAE-AIT
- MIMO radar network research at UMich transitioned to GD-AIS via Mike Davis
- MURI LADAR model identification and radar scheduling provided to Lincoln Laboratory

What's next – Signal Processing

- Multistatic processing
  - Complexity reduction
  - Incorporating anisotropy
  - Addressing calibration uncertainty/mocomp
- Nonlinear models
  - Exploit sparsity on low-dimensional manifolds
  - Close the gap between parametric and nonparametric approaches
- Performance prediction
  - Expand scope of pre-sensing impact metrics

What's next – Information Fusion

- More on learning behavioral models and multi-target tracking
- More on learning tractable models for fusion and discrimination
  - E.g., introducing hidden variables to capture hidden causes
- Inference over object interactions
  - Learning graphical dependency structures to infer interaction states.
  - How to do this efficiently
- Integrated learning of embedded graphical models
  - Joint clustering/classification and manifold learning
  - Distributed topological inference

What's next – Sensor Management

- Multi-task multi-platform guaranteed uncertainty sensor management (SM)
- Multistatic sensor management for tomographic target recognition
- Integration of improved information theoretic performance models into SM
- Multiplatform trajectory optimization for SM
- Distributed SM algorithms
- Performance bounds for layered ATE systems

Expected End States

- **New methods for building and using graphical models**
  - Scalable and tractable for large, militarily-relevant problems
  - Enable both fusion across levels and sensor resource management
  - Graphical Models for tracking and behavior extraction
  - Incorporate learning from experts and non-conventional information sources
- **Decision-directed front-end signal processing**
  - A unified understanding and structure for uncertainty characterization monitoring, incorporation of context and higher-level fusion information, and adaptation.
- **Robust sensor processing algorithms**
  - Combine robustness of nonparametric techniques with accuracy and tractability of parametric techniques for sensor signal processing
- **General theory for information-seeking resource management**
  - Heterogeneous sensors
  - Inference metrics and predictions drive sensing actions