Data-to-Decisions
S&T Priority Initiative

Dr. Carey Schwartz
PSC Lead
Office of Naval Research

NDIA Disruptive Technologies Conference
November 8-9, 2011
Washington, DC
1. REPORT DATE  
08 NOV 2011

2. REPORT TYPE

3. DATES COVERED
00-00-2011 to 00-00-2011

4. TITLE AND SUBTITLE
Data-to-Decisions S&T Priority Initiative

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Office of Naval Research, 875 North Randolph Street, Arlington, VA, 2217

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR’S ACRONYM(S)

11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Presented at the NDIA Disruptive Technologies Conference, November 8-9, 2011, Washington, DC

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:
   a. REPORT unclassified
   b. ABSTRACT unclassified
   c. THIS PAGE unclassified

17. LIMITATION OF ABSTRACT
   Same as Report (SAR)

18. NUMBER OF PAGES 16

19a. NAME OF RESPONSIBLE PERSON

Standard Form 298 (Rev. 8-98)  
Prescribed by ANSI Std Z39-18
National security decision systems span all QDR missions with a focus on finding threats in a specified data volume with limited manpower within a specified time window.
Data-to-Decisions Systems

Issues - Personnel

Predator Sensor

Increasing Resolution and Coverage

Analysts

Number of Highly Skilled and Trained Analysts Remains Constant or Decreases

Analysts

National security decision systems span all QDR missions with a focus on finding threats in a specified data volume with limited manpower within a specified time window.
D2D Technology Assessment

- Moderately Mature
- Driven by IT Industry

- Immature
- Driven by Defense

- Moderately Mature
- Driven by IT Industry

Data Management Layer

Analytics Layer

User Interface Layer

Current assessment is that unstructured data analytics is the most challenging and critical component of D2D

ASD D2D program intends to provide representative data of various types that have associated ground truth to support development and evaluation of algorithms and systems in a SOA to be made available
Challenge Problem and Framework for Analysis

Illustrative Challenge Problem
Detect, Track, and Infer Intent of Objects in an Urban Environment with All Source Data

Architectural Layers

Operational Issues

• Shear number of detections, tracklets, track associations overwhelm the limited number of analysts
• Integration of tracks from disparate modalities is manually intensive and time consuming
• Developing long duration tracks to support social network analysis including patterns of life
• Representation of unstructured data that is incomplete, imprecise, uncertain, and contradictory to support analysis, storage and retrieval
• Understanding the observed data in the context of multiple hypotheses that are consistent to develop indications and warnings, reduce the number of hypotheses, and to develop new hypotheses

Meeting mission timelines and operating with large sources of unstructured data requires that the analyst in the loop is more effective.
Highest Payoff Capabilities and Associated Metrics

• **Data Management**
  – Representations: Efficient representation of structured and unstructured data supporting format normalization, mission-aware computation and 100 x compression without loss of fidelity in applications

• **MOVINT Analysis**
  – Automated tools that support 100x improvement in the number of tracks that an analyst manages
    • Probability of correct association of tracklets and tracks > 0.98
    • Time to achieve track association by automation less than current SOA

• **IMINT Analysis**
  – Automated tools that support 100x improvement in the number of objects, activities, and events that an analyst can manage
    • Probability of correct classification of objects, activities, and events > 0.98
    • Time to develop objects, activities, and events less than current SOA

• **Text Analysis**
  – Automated tools that improve by 100 the rate at which information is extracted from documents in any language with
    • High Probability of correct extraction

• **User Interface**
  – Automated tools align the information models of all participants in the distributed man machine enterprise that are 98% accurate
Data Management Layer

- **Problem Statement:** Increasing data volumes and modalities have diminished our ability to communicate, store, retrieve and process sources within mission-critical timelines

- **3-to-5 year timeframe objective**
  - Computational infrastructure to support capturing, processing, marking, retrieval, and management of millions of information objects per second over discovery mission data requirements (PB/TB, long latency)
  - Network architecture with embedded information management on existing networks to support both real-time (MB/GB, low latency) and assisted (GB/TB, medium latency) mission data requirements

- **7-to-10 year timeframe objective**
  - Mission-aware information lifecycle management to age data from (typically) short-term concrete data storage to longer-term symbolic associative representation and retrieval based upon perceived utility and cost
  - Self-balancing merged storage and processing architecture to support analytics with minimal data movement
  - Synchronized anticipatory sensor control and compute/storage resource allocation to support rapid ingest and real-time exploitation
Data Management Roadmap

<table>
<thead>
<tr>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
<th>FY15</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
<th>FY19</th>
<th>FY20</th>
<th>FY21</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Data Representation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Format normalization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Storage lifecycle mgmt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Data Access</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Indexing &amp; retrieval</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Manipulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Ease of use</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Data/Knowledge Search</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- User/Task-Tailored Methods</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Knowledge Discovery Focused</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Scalable Computation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Architectures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Multi-structured computation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Distributed processing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Autonomous Networks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Mapping Info to Missions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Prediction models</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Resource optimization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Type/Time-based Pruning of PB data stores</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Age-based retrieval latency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mission-based retrieval latency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Distributed Product synthesis from distributed stores</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Interactive resource-aware content tailoring</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Automated context-driven search</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Medium Latency: 10s Interactive Users ~10 GFLOPS/Request</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Low Latency: 10s Interactive Users ~10 GFLOPS/Request</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Medium Latency: 1000s Interactive Users ~100 GFLOPS/Request</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Medium Latency: 10s Interactive Users ~10 GFLOPS/Request</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tasking-order to Info prediction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Predicting Resource Shortfalls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mission-aware Capacity Allocation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Analytic Layer

- **Problem Statement:** Existing automation tools do not aid users in finding today’s complex and adaptable threats within mission timelines

- **3-to-5 year timeframe objective**
  - Robust classification to accurately detect, geo-register, classify, and identify surface objects despite difficult environments, configurations and emplacements
  - Robust automation tools to identify relationships, patterns of life and activities of objects on the ground
  - Robust tools to capture, store and retrieve HUMINT-based information to identify and leverage popular support against insurgents
  - Domain-specific tools to capture, search, mine and exploit explicit information on insurgent networks from unstructured textual data sources

- **7-to-10 year timeframe objective**
  - Robust automation tools to identify relationships, patterns of life and activities of dismounts
  - Robust tools to search, mine and exploit open-source data to identify all aspects of insurgent networks
MOVINT Roadmap

• **Context Aware Tracking**
  - Real-time Context Mapping
  - Track Performance Model

• **Multi-Source Tracking**
  - Track Fusion
  - Track through Gaps
  - Move-Stop-Move

• **Performance Based**
  - Data Warehouse
  - Automatic Parameter Tuning

• **Advanced Tracking**
  - Feature-Aided Tracking
  - Graph Theoretic Approaches

• **Behavior Modeling**
  - Patterns of Life
  - Activity Recognition

• **Data Collections**
• **Demonstrations**
• **Milestones**
IMINT Roadmap

- **Multi-Source Detection**
  - Precision geo-registration
  - Multi-INT change detection
  - Scalable compression

- **Geometric Features**
  - 3D reconstruction
  - Rapid target insertion
  - Geometric clustering

- **Advanced Learning**
  - Large corpus training
  - Model-based learning
  - On-the-fly adaptation

- **Performance Models**
  - Sensor/Algorithm trade-off
  - Confidence reporting algorithm
  - Predictive performance estimation

- **Accurate Geo-location**
  - Dynamic adaptive sensor models
  - Disparate geometry and phenomenology

<table>
<thead>
<tr>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
<th>FY15</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
<th>FY19</th>
<th>FY20</th>
<th>FY21</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td>5X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FA Reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25X</td>
<td></td>
<td></td>
<td>50X</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Diamonds indicate the expected increase in the number of objects:
- 5X increase in # Objects
- 25X # Objects
- 50X # Objects
- 100X # Objects

**Distribution Statement A:** Approved for public release; distribution is unlimited.
Textual Data Roadmap

<table>
<thead>
<tr>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
<th>FY15</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
<th>FY19</th>
<th>FY20</th>
<th>FY21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone known, F95</td>
<td>Zone known/new, F75 (FUSE?)</td>
<td>Zone web-scale, known, new/variant doc types, F90 (TBD Program)</td>
<td>Cross-Lingual OCR, 90% (TBD)</td>
<td>Cross-Lingual ASR, 95% (TBD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Data Preparation**
  - Zoning (Source-specific)
  - OCR
  - ASR
- **Efficient Text Mining**
  - Efficient Text Mining
  - Doc/Corpus Categorization
- **Entity/Event Consolidation**
  - Entity Coreference, Consolidation
  - Event Coreference, Consolidation
- **Sentiment Extraction**
  - Explicit
  - Latent
- **Portability (Genre/Domain/L)**
  - Port Entities (E) to new G/D/L
  - Port E, Relations, Events “”

Abbreviations:
- E = Entity
- EV = Event
- L = Language
- ML = Multilingual
- R = Relation

160 docs/day (Exceed) 192 docs/day (TBD) 320 docs/day (TBD)
User Interaction Layer

- **Problem Statement:** Existing interface tools do not detect and proactively respond to the users information needs, given massive amounts of data collected from sensor and open-source assets.

- **3-to-5 year timeframe objective**
  - Reactive intelligent interfaces
    - Acquisition of massive data, including continuous learning and inference
    - Automatic identification of potential (human) collaborators
    - User-specified interface reconfiguration
  - Adaptable displays that automatically draw human attention to problem areas
  - Workflow tools that guide analysts in complex problems

- **7-to-10 year timeframe objective**
  - Proactive intelligent interfaces and inference engines that:
    - Generate and update rich models of their users current tasks, beliefs and intentions.
    - Socially-guided machine learning to support level 2+ fusion
    - Proactively identify task-relevant data based on current estimates of users beliefs, and intentions and to offer suggestions based on these estimates.
    - Communicate with users in the most natural way possible (language, when appropriate)
  - Workflow tools that capture and teach analysts’ best practices
User Interaction Roadmap

<table>
<thead>
<tr>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
<th>FY15</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
<th>FY19</th>
<th>FY20</th>
<th>FY21</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Knowledge Mgmt Tools</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Mission Level Knowledge Tagging</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Normalization of Ontologies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Continuous Learning &amp; Inf.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Large Scale Cont. Learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Fast Inference in Large KB’s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Collaboration Tools</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Topic/Interest Models</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Collaboration Recommendation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>User-Specified Interfaces</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- User Supervision of ML Stub</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Learning Human Operator</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Socially Guided ML</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Active Transfer Learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Interactive ML</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rich User Models</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Socio-Cognitive Architectures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Natural Language Dialogue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Best-Of-Breed Strategy Learning</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Crowdsourcing BoB Strategies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Data pedigree & history ‘unpacking’ >90% accuracy
- Manual correlations >90% relevance
- Automated correlations from LSA >70% relevance
- Automated correlations from LSA >90% relevance
- Manually monitored & correlated >90%
- Automated push-pull of shared searches > 80% relevance
- Automated P/P > 95% relevance
- Automation in display >90% relevance, ML
- User-Specified Interfaces >90% relevance
- Collaboration mechanisms >90% relevance
- Manual correlations >90% relevance
- Automated correlations from LSA >70% relevance
- Automated correlations from LSA >90% relevance
- Visual representation of people & tasks > 70% accuracy
- > 90% accuracy
- Machine advisors > 90% accuracy
- Machine advisors > 98% accuracy
FY12 Planned BAA’s

- **Data to Decision Special Notice, Spring 2012**
  - POC: Dr. Carey Schwartz
- **ONR Long Range BAA BAA 12-01**
  - POC: Dr. Wen Masters
- **Research Interests of AFOSR BAA 2010-1**
  - POC: Dr. Hugh De Long
- **ARO Core BAA, W911NF-07-R-003-04**
  - POC: Dr. John Lavery
- **DARPA I2O Office Wide BAA, 11-34**
  - POC: Mr. Daniel Kaufman
- **ONR Computational Intelligence for Rapid Accurate Decision Making Special Notice, Spring 2012**
  - POC: Dr. Carey Schwartz
Summary

• Data representative of the problem domain with ground truth to be made available for development and testing of algorithms
• Specifications of a Service Oriented Architecture will be made available to abet government testing and evaluation
• Understand the relationship between the “picture” and decisions based upon the picture
  – Bottoms Up to identify performance controlling functions/modules
  – Top Down to manage quality of picture and manage resources
• Symbiotic Relationship between automation and humans
  – Human is cognitive within the architecture and not a servant to the architecture
  – Human mentors the architecture to improve performance
• Reduce timelines between receipt of data, what does it mean, and what should be done across decision support systems