Task 9: Studies of Technology Concepts of Employment.  
Jim Llinas

Objectives

- **Basis for Effectiveness/Operational Value Assessment** for most Information Fusion/AI technologies
- **Framework for:**
  - **Architectural Design:** fit of IF software to Operational Infrastructure—critical Interfaces, standards compliance, etc
    - Main driver for defining the **human role**
  - Understanding and addressing **Operational Reqmts** imputed onto IF design—eg nature of Actionable Intelligence, OpTempo (OOSM), Predictive Reqmts, HCI and Visualization, etc
  - **Technology Transition**, to 6.3 type Army programs

Technical Approach

- **Literature Review**
  - Various Army Docs and Open Source
  - Limited discussion with Army SME (e.g., Walsh)
- **Deeper technical analysis re Reasoning, Discovery, Learning, and Hypothesis Composition techniques**

Accomplishments

- Evolving but document-based understanding of BCT/IC and COIST COE
- Evolving architectural and functional framework for user support

Challenges

- Deeper, real-world understanding of COE’s
- **Practical designs and implementations of:**
  - Foraging function
  - Hypothesis Composition
  - Visualization
- Support to T&E design and plan
Main Scientific/Technical Accomplishments
Studies of Technology
Concepts of Employment

- Rationalization of Discovery/Learning-based Approach to User Support: Limited a Priori Deductive Knowledge

**Learning-Based**
- Unsupervised Pattern Discovery
- Supervised Concept Learning
- Statistical Relational Learning
- Query-Response-Based Learning
- PIR State Discovery

**SNA-Based**
- Frequent Subgraph Discovery
- Wide Variety of Centrality Metrics
- Community Detection
- Random Graphs

**Focus for Inferencing and COE Research**

- Graph-Matches
- SNA-Matches
- Abductive-Matches

- "Atomic" Events, Behaviors
- "Composite" Phenomenology

- Hypothesis Composition Service

- Complex Event Recognition
  - Markov Networks
  - Probabilistic Models
  - SVM+
  - Logic Pgmmg
  - Other

**NEED:** SME Complex Event Ontology
Nominal Users and Differences in Requirements

Brigade Combat Team Context

(3000-5000 Soldiers)

- Brigade Combat Team Commander
- LOE Desired Effects
- MOE's -- Measurable -- Tangible
- Intelligence
- Operations
- Lines of Effort
- Functional Area Officers -- Governance -- Essential Services -- etc
- ISR Synchronization Plan
- PIR Running Estimate

Company Operations Intelligence Support Team (COIST) Context

Outgoing patrols are briefed on the following

- **Current threat** assessment for the Area of Operations with regard to significant activities in the last 24 hours.
- Current IED threats and locations of concentrated IED attacks.
- Enemy activity expectations for the next 24 hours. *(Predictive Analysis)*
- Current HVI list with pictures if possible.
- Information requirements

“The only mission of the Intelligence Section is to answer the commander’s PIR “
Publications and Briefings


Technology Transition 1: Graph-Matching Discovery/Learning Tool Prototype

Figure 2: Prototype Analyst Workstation

CMIF
Graph-matching Algorithm (Web Applet)

Army Research Lab
6.2 Development
Aberdeen Proving Grounds
Objectives:

- Align observations with consideration for observational uncertainties
  - Assess observational biases/variances
- Possibility-Probability Xforms

DOD Program Benefit:

- Uncertainty alignment enables accurate uncertainty propagation through situation assessment process
Technology Transition 3: SYNCOIN Data Set

Description

• Counter-Insurgency (COIN) scenario in Bagdad and contains synthetic soft (human report) data, synthetic hard (physical sensor) data, and real hard data collected using human-in-the-loop vignettes collected at a special facility in central Pennsylvania.
  – 600 soft messages
  – Hard messages flexible if synthetic
  – Hard messages IAW taxonomy of events if based on real data

DOD Program Benefit:

• Truthed and operationally realistic research data set provides a flexible, adjustable data set for algorithm development that permits testing and evaluation

Provided to many organizations:

• ARL Tactical Fusion Branch
• ARO Network Science CTA
• AFRL/SNAA
• Army I2WD
• Spawar Systems Ctr
• Qinetic
• BAESystems
• Raytheon
• Stottler-Henke
• Aptima
• UCONN
• UMIami
Description

- To handle large quantities of entity observations, the Lagrangian heuristic for Graph Association is adapted for the multidimensional assignment problem and implemented in a map-reduce framework.

DOD Program Benefit:

- Transition to 6.3 Pre-DCGS-A transition environment for ablation testing for possible consideration for DCGS-A
- Possible use on Knowledge Discovery and Dissemination program at IARPA

Lagrangian Relaxation of $GA^N$

Dualize the triangle constraints, which enforce transitivity when handling more than 2 graphs:

$$
GA^L = \max_{(G_m, G_n) \in \binom{\mathcal{G}}{2}} \left( \sum_{v_i^m \in V_m} w_{v_i^m} x_{i} + \sum_{e_{ij}^m \in E_m} w_{e_{ij}^m} y_{e_{ij}^m} \right) + \sum_{(v_i^m, v_j^m, v_k^m) \in \mathcal{P} \setminus \mathcal{R}} \theta_{v_i^m v_j^m v_k^m} (x_{v_i^m v_j^m v_k^m} + 1 - x_{v_i^m v_j^m} - x_{v_i^m v_k^m}) + \sum_{(e_{ij}^m, e_{jk}^m, e_{km}^m) \in \mathcal{P}^{nm}} \theta_{e_{ij}^m e_{jk}^m e_{km}^m} (y_{e_{ij}^m e_{jk}^m e_{km}^m} + 1 - y_{e_{ij}^m e_{km}^m} - y_{e_{jk}^m e_{km}^m})
$$

subject to:

- $\sum_{v_i^m \in V_m} x_{i} \leq 1 \quad \forall v_i^m \in V_m, G_m \in \mathcal{G}, G_n \in \mathcal{G} \setminus G_m$
- $2y_{e_{ij}^m} \leq x_{i} + x_{j} + x_{i} + x_{j} \quad \forall y_{e_{ij}^m} \in E_m \times E_n, (G_m, G_n) \in \binom{\mathcal{G}}{2}
- y_{e_{ij}^m}, x_{i} \in \{0, 1\}$

Can solve using subgradient method. $(x_{jk} + 1 - x_{ij} - x_{jk})$ is the gradient at $x$.

Provided to:

- IARPA
- Army I2WD (A2SF Program)