Enhanced Decision Support with Adaptive Data Fusion

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Goal

- Provide semi-automated assistance to decision maker for resource allocation issues
  - What data to send over scarce communications bandwidth
  - Where to focus limited number of analysts
  - Where to focus sensors
  - When to change focus

- Get the right people looking at the right data sooner
Approach

- Use all available (archived) sensor and event reports to train a filter to monitor sensor report stream
  - Results of training allow:
    - Reduce amount of real-time, high priority, data sent from sensor to processing node by selecting most relevant subset of data

- Monitor filter performance to determine when something has changed:
  - Sensor relevance/performance
  - Tactics of sensor targets
Motivation

● Too much raw data to send from collection nodes to processing nodes in real-time over limited bandwidth links

● Too much raw data to process in real-time from collection nodes at processing nodes

● We need to limit what we process and still produce relevant results

● We need to determine when we need to change what we use as input
Process

- Observe sensor reports - HUMINT sensors and SIGINT internals

- Use current archive of reports to generate patterns of interest (e.g. correlated with events of interest) by training the system with complete set of archived reports

- Select relevant sensor reports (features) to reduce delay from collection to finished processing - Soft Retasking™

- Train the system using selected sensor reports (features) to identify patterns of interest

- Use trained system to process selected sensor reports

- When system needs to add/learn a new pattern, restart process with training the system with complete set of archived reports
Sensor Reports

- Use attributes from HUMINT and SIGINT internals reports as sensor inputs

- Sources of attributes
  - Individual fields as applicable and available
  - Extracted entities and attributes from reports and transcripts
    - Other projects working on this aspect

- Use generated data for testing:
  - Three Bayesian Belief networks for (Actor, Action, Target) generate data.
    - Based on factors that are plausibly connected to end-state attribute of each.
    - Conditional probability tables that relate these factors to the (Actor, Action, Target) end state selection implicitly represent adversarial tactics and are, in fact unknown.
    - Change in values in tables represents change in tactics.
    - Goal is to recognize change and adjust processing to account for this change.
### Sample Sensor Reports

*Created by PalmerJ at AustinInfo using Netica 1.12*

| Actor | Threat | FinTies | Ethnicity | Wkly_Contact HOSTILES | Religious Focus | Criminal Focus | Religion | Actor_GO | Hostile | Direct | Arab | Religious | Some | Shia | Male | Sibling | Normal | 46.6886 | Yes | Yes |
|-------|--------|---------|-----------|------------------------|-----------------|----------------|----------|---------|---------|--------|-------|-------|--------|--------|--------|--------|--------|--------|---------|------|------|
| Neutral | None | Arab | 18.57 | Religious | None | Sunni | Female | None | Zealot | 30.0792 | Yes | No |
| Friendly | None | Kurd | 1.48767 | Zealot | Some | Shia | Female | None | Normal | 62.1113 | No | No |
| Neutral | None | Arab | 11.6549 | Religious | None | Sunni | Female | None | Zealot | 29.0059 | Yes | No |
| Hostile | None | Arab | 33.3205 | Zealot | Some | Shia | Male | Uncle | Zealot | 47.3395 | No | No |
| Neutral | None | Arab | 22.2961 | None | None | Sunni | Female | Village | Normal | 6.65112 | No | No |
| Hostile | ShareBank | Turkmen | 31.712 | Zealot | Some | Sunni | Male | Tribe | Zealot | 14.5116 | No | No |
| Friendly | None | Arab | 2.59035 | Religious | None | Christian | Male | None | Little | 11.0394 | No | No |
| Hostile | ShareAcc | Arab | 20.5006 | Zealot | Some | Shia | Female | Sibling | Zealot | 43.2045 | No | Yes |
| Hostile | Direct | Arab | 21.0734 | Zealot | Some | Shia | Male | Sibling | Normal | 33.4881 | No | No |
| Hostile | ShareAcc | Arab | 30.6085 | Zealot | Some | Sunni | Male | Tribe | Zealot | 23.9845 | Yes | No |
| Friendly | None | Arab | 0.00136909 | Religious | Habitual | Jewish | Male | None | Little | 19.9033 | No | No |
| Neutral | None | Arab | 0.251959 | Religious | Habitual | Shia | Male | None | Normal | 38.7663 | Yes | No |
| Neutral | None | Kurd | 17.9544 | Religious | None | Shia | Female | None | Zealot | 42.0997 | No | No |
| Neutral | None | Kurd | 17.2083 | None | None | Sunni | Female | Village | Normal | 8.61916 | Yes | No |
| Friendly | None | Arab | 2.73632 | Religious | None | Sunni | Male | Village | Normal | 14.225 | No | No |
| Friendly | None | Turkmen | 9.01729 | Religious | None | Shia | Female | None | Little | 14.4174 | No | No |
| Neutral | None | Kurd | 21.5407 | Religious | None | Shia | Male | None | Zealot | 21.5535 | Yes | No |
| Hostile | ShareAcc | Arab | 25.4288 | Religious | Some | Christian | Male | Uncle | Zealot | 47.3212 | Yes | Ye |
| Friendly | None | Kurd | 7.72351 | Religious | None | Sunni | Male | Tribe | Normal | 52.4941 | No | No |
| Friendly | ShareBank | Arab | 6.753893 | Religious | None | Shia | Male | Uncle | Little | 9.90032 | No | No |
| Hostile | ShareBank | Arab | 33.817 | Religious | Some | Shia | Male | Uncle | Zealot | 29.3863 | Yes | No |
| Friendly | None | Arab | 14.5183 | Religious | None | Hindu | Male | None | Little | 12.2821 | No | No |
Pattern Recognition - ARTMAP

- Adaptive Resonance Theory (ART) is a neural network architecture developed by Stephen Grossberg and Gail Carpenter
  - Build output categories to classify inputs

- ARTMAP learns to classify arbitrarily many, arbitrarily ordered vectors into recognition categories based on predictive success
  - Two ART networks
    - One for input observations
    - One for event/result observation
    - With network to link results of output and input networks
Find Patterns of Interest

- Use current archive of reports to generate patterns of interest by training ARTMAP with complete set of archived reports
  
  - Input ART network gets sensor reports as input
    - Example: Financial Ties, Ethnicity, Religion, Gender, etc.
  
  - Event/Result ART network gets event or result reports as input
    - Example: Actor-Threat
System Training

- ARTMAP supports on-line and off-line learning
  - Off-line takes advantage of statistical nature of selecting different training and validation sets from training data
    - Often trained until correctly classify all training data and weights stabilize
    - Can use “Don’t know” classification as indicator that need to retrain system with potentially new sensor report features
  - On-line allows system to start processing immediately, albeit with a potentially higher error rate
  - Combination possible
    - Start with off-line and update weights as new reports are available
    - Use category creation as indicator of need to retrain
Select Relevant Features

- **Soft Retasking™**
  - Select relevant sensor reports (features) to reduce delay from collection to finished processing
  - System indicates which features should receive bandwidth and process priority

- Selection process based on weights allocated to feature during training
  - Motivating example from Carpenter, Grossberg, Reynolds categorization of mushrooms into poisonous or non-poisonous
    - 22 observable features
    - Categorization system used only 17 of these features
Patterns Specific to Relevant Features

- In experimental test, trained ARTMAP using selected sensor reports (features) to identify patterns of interest.

- Original model using 5 features obtained error rate of 2% with 500 training samples.

- Computing statistical correlation of category weights with observed threat identified features that could be excluded.

- Reduced model using 3 features obtained error rate of 1.2% with 500 training samples.
Monitor Sensors and Performance

- Use trained system to process selected sensor reports
  - Potential reduction of communication and processing time to get reduced selection of sensor reports
  - Potential for increased accuracy due to reduction in noise

- Monitor classification error rate and number of input classification categories to determine when to retrain with potential new set of features (sensor reports)
New Patterns as Required

- When system needs to add/learn a new pattern, restart process with training ARTMAP with complete set of archived reports
  - Restart when system needs to add a new classification category
  - Not restart when system only adjusts using current classification categories

- Retraining with complete set of reports allows for identification of need for new features to allow identification of potentially new tactics
Other Applications

- Processing multiple types of SIGINT and event reports
  - Identify patterns in SIGINT data associated with events
    - Identify network activity patterns (social network analysis) associated with events of interest (IED activity)
      - Networks built from SIGINT externals
      - Events culled from HUMINT reports and SIGINT internals
    - Allow watch for new patterns/tactics while monitor current activity

- Multi/Hyper-spectral decoy identification
  - Each layer as sensor report feature
  - Each decoy/threat type as result
  - Allow adapt to and identify new decoy/threat types
Other Applications

- **Person identification**
  - Usage pattern (e.g. radio, radar) as sensor report
  - Person identification as result
  - Allow adapt to and identify new persons

- **Sensor fusion**
  - Sensor data and metadata, i.e. data about the sensor, as sensor report
  - Fused picture as result
  - Allow adapt to and identify changes in sensor performance
Summary

- **Goal:**
  - Get the right people looking at the right data sooner

- **Motivation:**
  - Too much raw data
  - Select what data is relevant
  - Mechanism to identify when “relevant” changes

- **Approach:**
  - Use filter to identify reduced feature set of interest
  - User reduced filter to monitor reduced sensor stream
  - Monitor filter performance to determine when to adjust feature set
Contact

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