

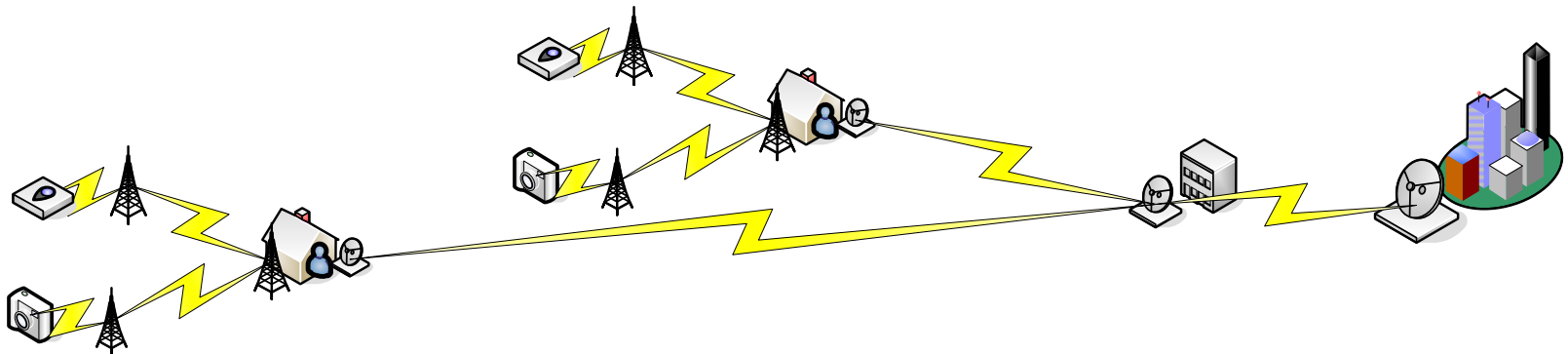


Enhanced Decision Support with Adaptive Data Fusion

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Precision Strike Technology Symposium
2008

- 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



- 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

- 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

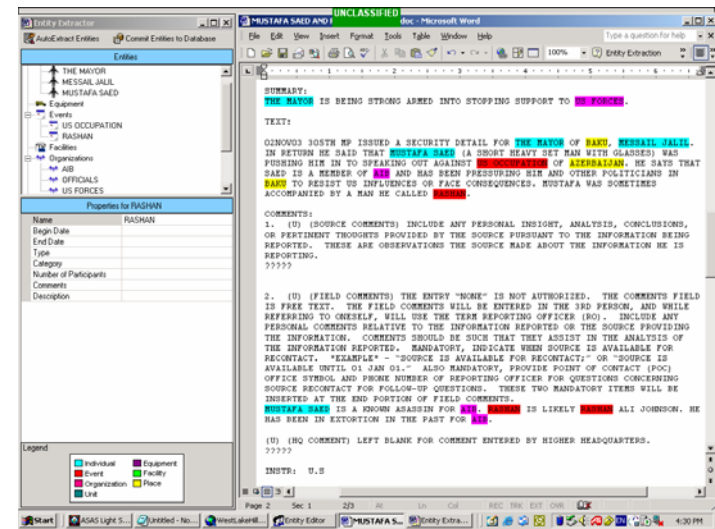
- Observe sensor reports - HUMINT sensors and SIGINT internals
- Use current archive of reports to generate patterns of interest (e.g. correlated with events of interest) by training the system with complete set of archived reports
- Select relevant sensor reports (features) to reduce delay from collection 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 internal 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.



Raw HUMINT reports



Sample Sensor Reports

-[CASE-1]->~

Report created by PalmerJ at AustinInfo using Netica 1.12
 Jun 28, 2007 at 14:10:36.

ActorThreat	FinTies	Ethnicity	Wkly_Contact	Hostiles	Religious_Focus	Criminal_Focus	Religion	Actor_Ge				
Hostile	Direct	Arab	30.6085	Religious	Some	Shia Male Sibling	Normal	46.6888	Yes	Ye		
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	20.8006	Zealot	Some	Shia Female	Sibling	Zealot	26.2274	No	No	
Hostile	Direct	Arab	21.0734	Zealot	Some	Shia Male	Sibling	Normal	43.9205	No	Ye	
Hostile	ShareAcc	Arab	30.6085	Zealot	Some	Sunni Male	Tribe	Zealot	23.9845	Yes	No	
Hostile	ShareAcc	Arab	34.46	Zealot	Some	Shia Female	Sibling	Normal	33.4881	No	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	14.228	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	21.6535	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	6.78893	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	

- Adaptive Resonance Theory (ART) is a neural network architecture developed by Stephen Grossberg and Gail Carpenter
 - Build output categories to classify inputs
 - Carpenter, G.A. and Grossberg, S., 1987, "A massively parallel architecture for a self-organizing neural pattern recognition machine", *Computer Vision, Graphics, and Image Processing*, 37:54-115
- 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
 - Carpenter, G.A., Grossberg, S., Reynolds, D.B., 1991, "ARTMAP: Supervised real-time learning and classification of nonstationary data by a self-organizing neural network", *Neural Networks*, 4:565-588

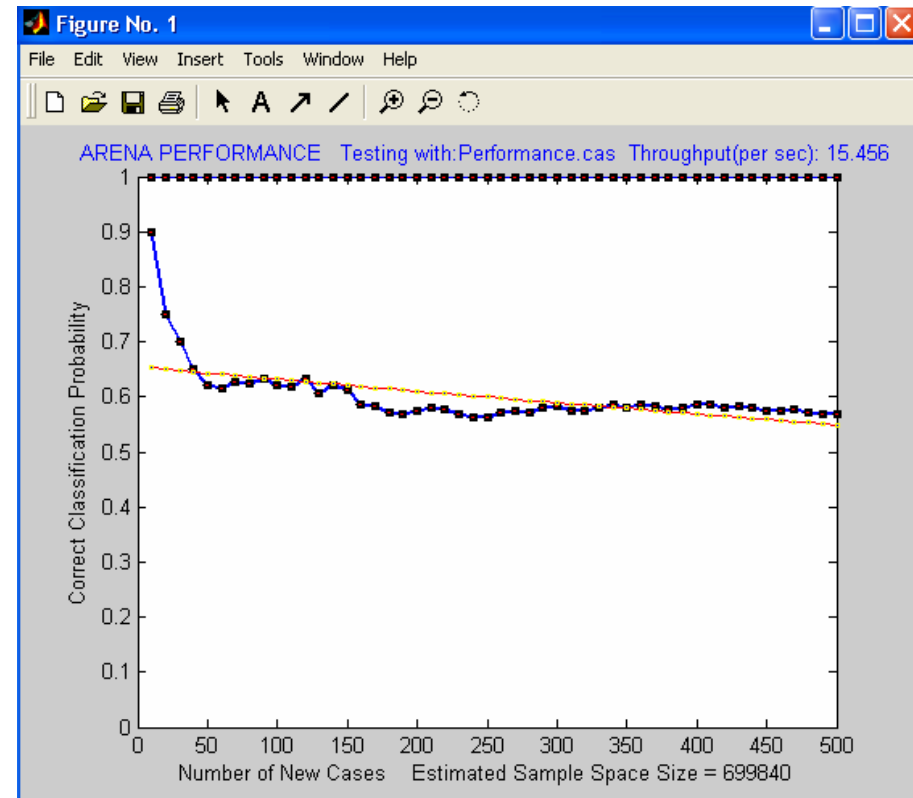
- Use current archive of reports to generate patterns of interest by training ARTMAP with complete set of archived reports
 - Input ART network gets sensor reports as input
 - Example: Financial Ties, Ethnicity, Religion, Gender, etc.
 - Event/Result ART network gets event or result reports as input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

- 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

- 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

- 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

- 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)



- 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

- 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

- 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

- 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

- Enhanced Decision Support with Adaptive Data Fusion
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