WAMI for Multi-Source MOVINT Analytics

Q4 2013
Signal Innovations Group, Inc.

- Small business founded in May 2004
- Most technical staff M.S. or Ph.D.
- Innovative solutions to make better decisions with complex data

Research and Innovation

- Automatic Target Recognition (radar, sonar, imagery)
- Multi-source activity analysis: motion imagery, radar, comms
- Social network analysis, TTP, threat detection

ISR Products (DoD, DHS, Commercial)

- Video tracking (real-time on platform & post mission)
- ISR analytic products: TASS, Scout, Scorpion

VIDEO-CENTRIC ANALYTICS CAPABILITIES TO ENHANCE THE EFFICIENCY, EFFECTIVENESS, AND OUTCOMES OF INTELLIGENCE AND TACTICAL OPERATIONS
WAMI and FMV: Too Much Data!
Solution: Automated Tracking Enables Structured Analytics

Full Field-of-View Tracking enables relevant FMV activity to be analyzed and filtered for analyst review. SOLVES A CRITICAL BIG DATA PROBLEM.

Analyst Cueing and Threat Assessment

Too Much Data for Analyst to Interpret!!!
Mission Video/Imagery

- Full Field of View
- Tracks and Events

Platform/Sensor Telemetry

- Imagery Indexed in Cloud

Raw Imagery

- COMPACT 4U COTS CLUSTER

STANAG 4676 Metadata

Tracks in Cloud

Map Visualization

- Basic Queries and Cues
  - Transit time statistics
  - Activity detection in watchbox

- Complex Learning and Data Mining
  - Normalcy models, anomaly detection
  - Network modeling, threat analysis

Information Integration

- Multi-INT analytics
- SIGINT, GMTI, HUMINT, etc.

LARGE SCALE EXTRACTION AND STORAGE OF WAMI AND FMV TRACKS

NETWORK CONNECTIONS FROM TRACKS
Full Field-of-View WAMI Tracks
Network Discovery from WAMI Tracks
TASS Video Tracking Framework

Non-Parametric Models for Pixel Intensity, Object Shape, and Object Motion...

\[
p(A^t, \mu^t | I^t) = \\
\alpha \cdot p(I_t | A_t, \mu_t, C_{bg}^{t-1}, C_{fg}^{t-1}) \cdot p(A_t | \mu_t, S^{t-1}) \cdot p(\mu_t | T^{t-1}) \cdot p(C_{bg}^{t-1}, C_{fg}^{t-1}, S^{t-1}, T^{t-1} | I^{t-1})
\]

\(I^t\) : Image at time \(t\)  \(A^t\) : Object labels for each pixel  \(\mu^t\) : Object positions
\(C_{bg}, C_{fg}\) : Background/Foreground pixel intensity statistics  \(S\) : Object shape statistics  \(T\) : Object motion statistics

Combined via Rigorous Bayesian Probability...

Efficiently Implemented with Cutting-Edge, Data-Driven Inference
- Automated real-time tracking of dynamic movers in full-motion HD video
- Process multiple FMV streams - directly from the sensor or encoded video streams
- Send geo-referenced track metadata directly to tactical users on the ground
- Uncover activities, behaviors, and connections through forensic analysis
- Automatically control the sensor to follow and maintain the FOV on target

**SIG Scout**

**Realtime Airborne FMV Tracking**

- **Size**: ≤ 1.7”H x 17.09”W x 18”D
- **Weight**: ≤ 25 lbs
- **Power**: AVG./PEAK DC POWER = 250W/300W
- **Environ.**: Designed for MIL-STD 810G
- **Shock**: Designed for MIL-STD 901D
- **Vibration**: Designed for MIL-STD 167-1

**Features**

- **Automated real-time tracking of dynamic movers**
- **Process multiple FMV streams**
- **Send geo-referenced track metadata**
- **Uncover activities, behaviors, and connections**
- **Automatically control the sensor**

**Applications**

- **Warfighter on the Ground Needs REALTIME Situational Awareness**
- **Warfighter makes query for local activity**
- **FMV tracks are sent for display on thin-client**
**SIG Scout CONOPS**

**Real-time Airborne FMV Tracking**

**Scout: On-Board, Real-Time, Tracks**

Collection of FMV for Tactical Support

Image Archive

SIG Scout: Generates Full Field of View Tracks in Near Real-Time

Tracks broadcast via STANAG 4676 or Cursor on Target (COT) metadata stream

**Tactical Operations Center**

Track/Activity DB

Operators Supporting Warfighters

Request for Intelligence, Push Intelligence to Warfighter Device

Tracks and Activity Archived in Web-Enabled Database

Simple Queries and Cues from 4676 Stream:
1. Near real-time display of activity in AOI
2. Cues to activity associated with designated site
3. Cues to violations of security perimeter

Warfighter with Mobile Device (Android, iOS)

Intelligence Received and Displayed on Mobile Devices
Multi-Source Example: WAMI + SIGINT

TRACKING IN VIDEO
- Tracking targets in video provides high update rate, relatively accurate geolocation
- Video tracks inherently contain no information regarding specific object ID

SIGINTERRUPTS INTELLIGENCE (SIGINT)
- SIGINT intercepts provide highly accurate information regarding specific object ID
- Update rates typically slow, geolocation estimates typically spatially ambiguous

INTEGRATION OF VIDEO AND SIGINT
- Integration of video tracks and SIGINT enables association of specific ID with video tracks
- TASS tracking framework enables probabilistic association with video tracks
- Enables observations of track origin, destination, events, interactions, before/after SIGINT

Intercept 1: Uniform associations
Intercept 2: Small no. potential associations
Intercept 3: Associations more certain
Intercept 4: Association begin to peak
Intercept 5: Correct target uniquely identified
UNATTENDED GROUND SENSORS (UGS)

- UGS provide specific information regarding existence of radiological threat material
- Radius of detection relatively small, limited numbers of UGS can be placed discretely
- Detection ambiguity in urban/suburban environments

INTEGRATION OF WAMI TRACKS AND UGS

- Integration of WAMI tracks and raw radiological UGS measurements enables association of radiological threats with WAMI tracks
- Enables improved radiological threat detection/localization relative to conventional UGS

Fused WAMI-UGS ROC Curve: Nsensors = 3, Known Payload = 1e+006, RangeMin = 5 m

- 1 m/s (auc = 1.000)
- 5 m/s (auc = 0.976)
- 10 m/s (auc = 0.907)
- 20 m/s (auc = 0.802)
Multi-Source Analysis: MOVINT-Based Correlation

Tracker/Track Correlation / Track Management (STANAG 4676)

- S/GMTI
- FMV VMTI
- MASINT
- Biometrics
- COMINT
- Other
- ESM ELINT
- Link16
- BFT

Detection Processing

4607
4609
4716
4715
Text?
XXXX
4658/4633
5516
5527

“Detection Space”
“Tracking Space”
Multi-Platform Track & MOVINT Integration

FUSION OBJECTIVE

- Many possibilities, including track/attribute handoff across platforms, fused single tracks, ...
- Our initial objective: infer probabilistic track-to-track associations within and across sensor platforms
  - Enables a variety of critical downstream analytics (e.g., network inference) as well as alternative track fusion objectives
  - Avoid hard decisions (harsh penalties for wrong choices): rather, propagate link uncertainty to downstream analytics for improved robustness to inherent ambiguities

TRACK INTEGRATION APPROACH

- Infer posterior association PDFs using track-to-track likelihoods and track birth/termination characteristics as priors
- Efficient inference using message passing in a factor graph framework

RESEARCH QUESTIONS

- What are the performance impacts associated with real-world sources of uncertainty?
  - Geo-registration, time misalignment, perspective changes
- What are the sensing requirements (allowable coverage gaps, etc.) required to attain sufficient performance?

Problem: what is the probability associated with each track-to-track link*?

* tracks may also be disconnected at either end
Online Fusion Process: High-Level Description

**IDENTIFICATION OF PLAUSIBLE ASSOCIATIONS**
- Maximum-allowable time gap determines buffer window
- Spatial gating via prediction uncertainty vs. time

**LIKELIHOOD COMPUTATION**
- Kinematic and feature-based similarity
- Contextually-informed termination and birth likelihoods

**TEMPORAL CLUSTERING**
- Limits joint inference only to co-dependent groups of ‘input’ and ‘output’ tracks, supports online processing of clusters as soon as they are viable
- Clusters are ‘complete’ when their most-recent output time is older than the oldest input track in the buffer (can be significantly longer than the buffer window time)

**JOINT INFEERENCE OF LINK PROBABILITIES**
- Represents the collection of input and output tracks in a complete cluster as a graphical model
- Performs sum-product algorithm on the graph to obtain marginals from the joint posterior PDF

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**Joint Track-to-Track Association**
- Buffer tracks as they end
- As buffer period ends, identify plausible associations among newly-started tracks
- Compute plausible-link and termination likelihoods
- Update clusters, identify clusters that are complete
- Perform joint inference on completed clusters
- Update link probabilities in the central repository
Multi-Source Social Network Analysis

FULL FIELD OF VIEW TRACKING
• Accurately track all movers in scene
• Point of origin and destination for large percentage of movers

NETWORK DISCOVERY FROM TRACK METADATA
• Connect buildings to buildings
• Enabled by full field of view, long-term tracking
• Propagate threat from known red activities or intel

DISCOVERY OF NODE ROLES
• Infer building category/role from observed activity
• Identify anomalous building activity given alleged role/category
Multi-Source Activity Understanding

**PATTERNS OF LIFE FOR INDIVIDUAL VEHICLE MOVEMENT**
- Model how vehicles typically navigate through the area of interest
- Identify individual anomalous tracks

**PATTERNS OF LIFE FOR TRAFFIC FLOW**
- Typical traffic flow and how it changes with time and day
- Identify anomalous traffic patterns

**INFORMATION-THEORETIC CUEING FOR GUIDING DATA COLLECTION**
- Identify node links or attributes that would minimize uncertainty in threat assignment
Predicting Node Role with Topic Modeling

MODEL PATTERNS OF ACTIVITY TYPICAL FOR SPECIFIC NODE ROLES
• Enables prediction of node role from observed activities
• Detect anomalous activity given alleged role of node

RELATIONAL TOPIC MODEL (RTM) TO MODEL PATTERNS OF ACTIVITY ASSOCIATED WITH BUILDINGS/LOCATIONS
• Accurate starts/stops enable prediction of building role (e.g. home)
• Long-term tracking enables reduction in false alarms for same Pd
• Comms activity further reduces false alarms

EX: ACTIVITY FEATURES AGGREGATED OVER HOURS OF THE DAY
• Starts and stops (MOVINT) indicative of arrivals and departures
• Phone call and internet access (COMINT) indicative of comms activity – can connect specific actor to a building

<table>
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<th>Activities</th>
<th>Pd @ 0.01 Pfa</th>
<th>Pfa @ 0.99 Pd</th>
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<tr>
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<td>0.87</td>
<td>0.04</td>
</tr>
<tr>
<td>Origin/Destination</td>
<td>0.93</td>
<td>0.02</td>
</tr>
<tr>
<td>Origin/Destination + Comms</td>
<td>0.95</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Cross-validation, 2% of data withheld for testing on reach round