Critical Thinking, Operations Research and Structured Analytic Techniques for WiSAR

SARGIS8
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USGS National Center – Reston, VA

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A member of
Appalachian Search and Rescue Conference
Expanding the Search Area

- Subject not found with reflex tasks, need to consider how to expand the search area

- The Challenge!
  - Search is an emergency
    - Subject health and welfare
    - Resources are limited
    - Risk to responders
  - SAR is abstract (at least the Search part). In most types of emergency response we can see the problem directly.
  - Lots of unknowns and uncertainty
  - Get very little feedback (clues / subject) if we are pursuing the right path
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Application of Operational Research to SAR

- Goal of search management is to maximize the probability of success at the greatest rate possible (PSR).

- Need a systematic method to prioritize regions within the search area and evaluate progress.
  - Data driven process
  - Address some of the uncertainty through terrain analysis and historical/statistical data
  - Assigning a probability to a hypothesis (scenario) and adjusting the probability through testing (Bayesian Probability).
Utilizing GIS to Apply Statistical Models

“IPP Distance to Find” Statistical Model based on hundreds of cases with similar subject category and similar terrain.

Utilization of Topographical Position Index to quickly identify ridge tops and valley bottoms.

Stream/Trail Interface

Scripted tools to define intersections between hydrology and travel aides.
Utilizing GIS for Terrain Analysis

- Terrain and environment influences subject behavior and search tactics.

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- Ginseng Habitat
  \[ \text{Habitat} = 0.0589 \times \text{Slope} - 0.0012 \times \text{Elevation} + 0.0181 + \% \text{Deciduous Forest} - 0.0129 + \text{Avg Solar Insolation} - 1.2931 \]

- Cellular strength estimate (Free Space Path Loss model) to aid in search for missing subject with cellphone.

- Identify decision points and catching features

Probabilistic model of Ginseng habitat to aid in search for missing Ginseng Gather.
Chronology and Timeline

James Avalon - Dolly Sods - Oct 16, 2012

Oct 16 2012 11:45 AM
- Subject left trailhead with parents

Oct 16 2012 1:15 PM
- Parents lose visual at IPP

Oct 16 2012 4:15 PM
- Parents return to PLS

- Father searches around PLS

Oct 16 2012 7:15 PM
- Hat found near PLS

Oct 16 2012 9:15 PM
- K9 Alert near PLS

Oct 16 2012 1:15 PM - Oct 16 2012 2:45 PM
- Parents search to end of Bear's Nest Trail

Oct 16 2012 5:30 PM
- Mother calls 911

Oct 16 2012 6:10 PM
- WV State Police on-scene

Oct 16 2012 5:50 PM - Oct 16 2012 9:15 PM
- Fire Dept on-scene - search trail and PLS

Timeline Maker
www.timelinemaker.com

Open source option: Timeline
http://thetimelineproj.sourceforge.net
Chronology and the Search Map

How far ahead of the parents was the subject when they lost sight?

Did they lose sight because of the switchbacks in the trail?

Foot travel is faster in the section due to terrain?

Why didn’t parents see subject on trail where trail straightens out and terrain flattens?

Why was subject not waiting at the intersection?
Scenario Based - Structured Analytic Technique

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>H1</th>
<th>H2</th>
<th>H3</th>
<th>H4</th>
<th>H5</th>
<th>H6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evidence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subject’s last seen by parents on Bear’s Nest Trail</td>
<td>MASINT HIGH HIGH</td>
<td>CHH</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>CHH</td>
</tr>
<tr>
<td>Located John Dario baseball cap (not for subject) approximately 200 meters S of FLS and 300 meters E of trail</td>
<td>MASINT HIGH HIGH</td>
<td>IIHH</td>
<td>CCHH</td>
<td>CCHH</td>
<td>CHH</td>
<td>CHH</td>
</tr>
<tr>
<td>LPQ with relatives: Subject typically waits at intersections where ahead of the group</td>
<td>HUMINT MEDIUM MEDIUM</td>
<td>IMM</td>
<td>N</td>
<td>N</td>
<td>IMM</td>
<td>IMM</td>
</tr>
<tr>
<td>LE Investigation: No known instances of abuse or probable cause for foul play</td>
<td>HUMINT MEDIUM MEDIUM</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>IIMM</td>
</tr>
<tr>
<td>LPQ with relatives: Subject typically unable to furnish evidence of back</td>
<td>HUMINT MEDIUM MEDIUM</td>
<td>CCMH</td>
<td>CCMH</td>
<td>CCMH</td>
<td>CMM</td>
<td>CMM</td>
</tr>
<tr>
<td>Possible sighting: ~1.3km S of FLS and approx 300 m E of Bear’s Nest Trail</td>
<td>MASINT LOW LOW</td>
<td>ILL</td>
<td>CLL</td>
<td>CLL</td>
<td>CLL</td>
<td>CLL</td>
</tr>
<tr>
<td>Rock outcropping visible (aerial image confirmation) from trail near 76 682 836 731311</td>
<td>GEOINT HIGH MEDIUM</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>K9 alert: Inconclusive; Air scent K9 alert at 76 682 836 4313630</td>
<td>MASINT MEDIUM MEDIUM</td>
<td>IIMM</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Mobility model suggests closest trail intersection going South is 5 hours walk from FLS</td>
<td>GEOINT MEDIUM MEDIUM</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Trees along FS 70 and South Prong Trail visible from FLS</td>
<td>GEOINT HIGH MEDIUM</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Subject’s parents search along Bear’s Nest Trail to intersection of FS 70 was inconclusive</td>
<td>MASINT HIGH HIGH</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Credibility</th>
<th>Relevance</th>
<th>I</th>
<th>II</th>
<th>C</th>
<th>CC</th>
<th>N</th>
<th>NA</th>
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</thead>
<tbody>
<tr>
<td>HIGH</td>
<td>HIGH</td>
<td>-2</td>
<td>-4</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

-7.5     11.086  11.086  10.742  9.328  -1.914

Weighted inconsistency score: - Lower score less probability

**Least Unlikely** Scenario is the Most Likely

Probability of scenario is evidence-based (not consensus). Evidence is either Consistent (CC or C), Inconsistent (II or I), Neutral or Non-Applicable. Scenario that is the least unlikely is the most likely. **Is the Evidence diagnostic?**
Cumulative Probability - ROW

ROW = 21.13%

1. CC POA: 12.15
   BB POA: 17.41
   DD POA: 28.19
   AA POA: 21.13
   ROW = 21.13%

2. CC POA: 14.53
   BB POA: 20.83
   AA POA: 25.28
   DD POA: 14.1
   ROW = 25.28%

3. CC POA: 16.99
   BB POA: 24.35
   AA POA: 12.64
   DD POA: 16.48
   ROW = 29.56%

4. CC POA: 19.72
   BB POA: 12.18
   AA POA: 14.67
   DD POA: 21.48
   ROW = 38.53%

5. CC POA: 9.86
   BB POA: 13.68
   AA POA: 16.47
   DD POA: 16.48
   ROW = 50%

6. CC POA: 19.72
   BB POA: 12.18
   AA POA: 14.67
   DD POA: 21.48
   ROW = 50%
Summary

- There is considerable cognitive bias in situations with lots of uncertainty.
- Need a systematic, data-driven approach to prioritize regions within the search area and evaluate search progress.
- Geospatial application of Statistical / Historical data coupled with Terrain Analysis
- Scenario-Based Structured Analytic Techniques
  - Externalize information
  - Decompose the problem – how does the evidence influence the hypotheses?
- Bayesian Probability provides a method to evaluate progress
Questions?

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