Integration of Collision And Violation Data for Optimal Spatio-Temporal Deployment of Traffic Enforcement

DANA STEIL, PhD
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Outline
• Objectives for Law Enforcement
• Hotspot/Target Area Identification
• Patrol Routing
  – Objectives
  – 4ES Model
    • Expression
    • Execution
    • Evaluation
    • Engagement
  – Case Studies
• Conclusion

Objectives for Law Enforcement
• Identify Hotspots & Target areas
• Recommend goal-driven, non-deterministic, complementary patrol routes given fixed resources
• Provide sound data for targeted enforcement grant applications and reporting
Hotspot/Target Area Identification

- Not all target areas are hotspots
- Two methods we use
  - Linear 2D target area identification
  - Grid based target area identification
- Routing on roadways
  - Vehicles mostly travel on roadways
  - Events or measures of activity near roadways
  - End goal is to assign weights to roadway segments

Linear 2D Hotspot Identification
Dimensions - Segments of roadway and time

Grid based target areas
Patrol Routing Objectives

- Create complementary patrol routes for officers that target hot road segments
- Allow for hotspot definition flexibility
- Allow for patrol strategy flexibility
- Be able to evaluate/compare patrol strategies
- Make patrol route recommendations accessible

VRPTW

(Vehicle Routing Problem with Time Windows)

Similar Problem?

- Similarities
  - Routing Vehicles
  - Time Windows
- Differences
  - Single optimal solution desired
  - Travel overhead
  - Not all targets have to be visited
  - Multiple visits to single target
  - Agents not dispatched from central depot
  - Interruptions

4ES Model
PatrolSim

EXECUTION & EVALUATION

Execution & Evaluation Infrastructure

Milepost Network

Execution & Evaluation Infrastructure

Agent Start Locations

By Node, Shift, Days, Mode

By County, Shift, Days, Agent Count

Data Nodes, Sims, Agent Count

Data Nodes, Sims, Agent Count

Mission

Mission

Mission
PatrolSim Execution

```java
while (simulation time remaining) {
  foreach (agent in agentList) {
    if (agent.isInArea and
        agent.status == agentStatusInArea and
        agent.nextAction == agentStatusInArea) {
      if (agent.belonging == agent.belonging) {
        select destination for agent
        step agent toward destination
      } else {
        generate events
        select available agents to respond to events
        log agent positions
        increment simulation time by 1 minute
      }
    }
  }
  calculate and report simulation metrics
}
```

Figure 1.1: PatrolSim Pseudocode
Evaluation Metrics

Average Response Time = \frac{\sum_{i=1}^{EventCount} \text{ResponseTime}(e_i)}{EventCount} \quad (3.2)

Network Coverage = \frac{\sum_{\text{Date}} \text{Date}}{\text{DaysInSimulation}} \quad (3.3)

Hotspot Coverage = \frac{\sum_{\text{Date}} \text{HotspotCoverage}(h)}{\text{DaysInSimulation}} \quad (3.4)

Hotspot Exposure = \frac{\sum_{\text{Date}} \text{HotspotExposure}(h)}{\text{DaysInSimulation}} \quad (3.5)
PatrolSim in ADVANCE

Turn Language

EXPRESSION
Turn System Architecture

Purpose: Express patrol routing algorithms.
Method: Target selection using a series of Set Reduction Functions (SRFs).
Specification of "stay" durations at targets.

<table>
<thead>
<tr>
<th>Reserved Word</th>
<th>Required</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>turn</td>
<td>No</td>
<td>NA</td>
</tr>
<tr>
<td>useTemplates</td>
<td>No</td>
<td>false</td>
</tr>
<tr>
<td>travelFunction</td>
<td>No</td>
<td>true</td>
</tr>
<tr>
<td>maxAgencyEvents</td>
<td>No</td>
<td>5</td>
</tr>
<tr>
<td>numIterations</td>
<td>No</td>
<td>10</td>
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<tr>
<td>eventResponseDuration</td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>allAreas</td>
<td>No</td>
<td>All areas in the road network</td>
</tr>
</tbody>
</table>

Table 4.3: TURN Reserved Words

Example Turn Program

```c
//example TURN Program
1     int main() {
2     int turn = 1;
3     int travelFunction = 1;
4     int maxAgencyEvents = 10;
5     int numIterations = 10;
6     int eventResponseDuration = 0;
7     int allAreas = 1;
8     int source = 1;
9     int destination = 2;
10    int turnDirection = 1;
11    int travelFunction = 1;
12    int maxAgencyEvents = 10;
13    int numIterations = 10;
14    int eventResponseDuration = 0;
15    int allAreas = 1;
16    int source = 1;
17    int destination = 2;
18    int turnDirection = 1;
19    int travelFunction = 1;
20    int maxAgencyEvents = 10;
21    int numIterations = 10;
22    int eventResponseDuration = 0;
23    int allAreas = 1;
24    int source = 1;
25    int destination = 2;
26    int turnDirection = 1;
27    return 0;
}
```
Dispatch Centers, Highway Patrol

CASE STUDIES

Dispatch Centers

• Purpose
• Center point selection for dispatch centers
  – Methods
    • County Roadway Center Point (CRCP)
    • Crash Hotspot - County Roadway Center Point (CH-CRCP)
    • Crash-Hotspot County Roadway Center Point Improved (CH-CRCP-I)
    • Crash-Hotspot County Roadway Center Point Improved by Time of Day
    • Crash Center Points (CCP)
Highway Patrol

- Greedy
  - Network Coverage
  - Hotspot Coverage
  - Hotspot Exposure
- Team Coverage
- Parameters
  - 2007 & 2008 evaluated separately
  - Agents (1st shift – 147, 2nd shift – 110, 3rd shift 67 on call)
  - Events – actual
  - Event Response Duration – 60 min
  - Hotspots - 2007 crash data

Greedy Network Coverage

```python
1 title=greedyNetworkCoverage
2 useTemplate=T11v;
3 agentResponseTime=5m;
4 eventResponseDuration=00; 
5 6 regionSet=AgentRegions(allVertices);
7 visitedSet=Visited(RegionSet);
8 closestSet=Closest(visitedSet);
```

Greedy Hotspot Coverage

```python
1 title=greedyHotspotCoverage
2 useTemplate=T11v;
3 agentResponseTime=5m;
4 eventResponseDuration=00; 
5 6 regionSet=AgentRegions(allVertices);
7 hotspotSet=HotSpots(regionSet);
8 visitedSet=Visited(hotspotSet);
9 closestSet=Closest(visitedSet);
```
Greedy Hotspot Exposure

```python
# title='greedyHotspotExposure'
# useTemplate='T1'
# agents=agents() if true
# eventResponse=0.5
# 0
# if len(regions) < len(agents)
# 0
# for region in regions:
# 0
# 0
```

Team Coverage

```python
# title='teamCoverage'
# useTemplate='T1'
# agents=agents() if true
# eventResponse=0.5
# 0
# if len(regions) < len(agents)
# 0
# for region in regions:
# 0
# 0
```

Highway Patrol Results

<table>
<thead>
<tr>
<th>Daily Patrol Metric Averages</th>
<th>Year</th>
<th>Network Coverage</th>
<th>Miles</th>
<th>Response Time</th>
<th>Hotspot Coverage</th>
<th>Hotspot Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greedy Hotspot Exposure 2017</td>
<td>2017</td>
<td>135,465.9</td>
<td>19.7</td>
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<td>6.71</td>
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Questions

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