Maritime safety and security: Tools and trends

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Spheres of Interest

• Maritime Security: defending the coasts
• Maritime Safety: responding to accidents
• Environmental Protection: responding to spills
• Coastal Zone Risk Management
Maritime Risk Model

**RISK FACTORS**
- Type and Level of Activity
- Environmental Conditions
- Operator/Passenger Training
- Regulations / Navigation and Safety Equipment

**OUTCOME MEASURES**
- Likelihood of Occurrence of Marine Incident
- Severity of Incident

**OVERALL RISK**

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### Activity Types

<table>
<thead>
<tr>
<th>Activity Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial shipping</td>
</tr>
<tr>
<td>Commercial fishing</td>
</tr>
<tr>
<td>Commercial recreational</td>
</tr>
<tr>
<td>Aquaculture</td>
</tr>
<tr>
<td>Ferries</td>
</tr>
<tr>
<td>Cruise ships</td>
</tr>
<tr>
<td>Private recreational</td>
</tr>
</tbody>
</table>
Traffic Modelling Processes

• Maximize use of information:
  – source: location, date, time
  – intermediate points: way points, fishing efforts
  – final destination: location, date, time
  – frequency

• Extrapolate using more general information
  – feasible range: distance, time
  – feasible location; eg. fishing grounds; tourist sites
  – typical locations: cluster analysis
## Data quality

<table>
<thead>
<tr>
<th>Class</th>
<th>Available Information</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Continuous time-stamped position data; vessel info</td>
<td>Canadian West Coast shipping transits; AIS</td>
</tr>
<tr>
<td>B</td>
<td>Specific origin &amp; destination, and intermediate waypoints; travel dates; vessel info</td>
<td>Canadian East Coast shipping transits</td>
</tr>
<tr>
<td>C</td>
<td>Specific origin &amp; destination; travel dates; vessel info</td>
<td>Ferries; Cruise ships</td>
</tr>
<tr>
<td>D</td>
<td>Specific origin; general destination; travel dates; vessel info</td>
<td>Commercial fishing by NAFO zones</td>
</tr>
<tr>
<td>E</td>
<td>Specific origin; general destination; frequency of trips; vessel info</td>
<td>Lobster fishing; ecotours</td>
</tr>
<tr>
<td>F</td>
<td>General origin; general destination; frequency of trips; classes of vessels</td>
<td>Recreational boating</td>
</tr>
</tbody>
</table>
Direct Connection Results
Land avoidance path
East Coast Merchant Shipping
Merchant Shipping Incidents vs traffic

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Data proliferation

• Sources
  – Transmission from ship
  – Airborne surveillance
  – Satellite surveillance
  – Coastal sensors

• Challenges
  – Amount of data
  – Reconciling different sources
  – Detecting unusual events
  – Storing info for multiple purposes
Research issues

• Limitations of each type of sensor
• Data fusion challenges
• Establishing baseline “typical” traffic patterns (Recognized Maritime Picture – RMP)
• Detecting and categorizing anomalous behaviour
• Process new information sources to maximize use Coastal Safety: AIS, LRIT, HITS
Research issues (cont’d)

• Small Boat Detection
• Resource Location models (SAR)
• Risk Modelling
  – Prioritize threats/hazards
  – Identify hot spots
  – Allocate resources optimally to achieve the best overall risk reduction
  – Can be used for prevention and/or response
Example 1

Abnormal ship trajectories
Traffic Monitoring System

- Vessel movement report (Radar/AIS)
  - Traffic Monitoring System
    - Trajectory Update
      - Trajectory Update
    - Data preparation
      - Keep only the "normal" trajectories
        - Anomalous Data
          - Prepared Data
            - Route Formation
              - Major Routes
    - Alarm?
      - Anomaly Detection
Route-Trajectory Updating

Route Central Axis
Weight: 2
End Normal Line
Start Normal Line
Trajectory Central Axis
Extended Nodes (Start)
Extended Nodes (End)
Resampled New Route
Route Envelope

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West Coast shipping: typical route identification
Two individual atypical trajectories

- Traj: 5-380
- Traj: 2-516

Locations: Nanaimo, Vancouver, Victoria
Example 2

Discriminating recreational boat types
Characterizing Recreational Boating Patterns based on GPS Trajectory Points

(a) Trajectory 1                (b) Trajectory 2               (c) Trajectory 3               (d) Trajectory 4
Boat classification by movement

Patterns of Different Recreational boat Types
Patterns of Different Recreational Boat Types at different Locations

Discrimination

Classification

Mean Speed
Max Speed
Max \( \frac{1}{20} \) Speed
Total Travelled Distance
Farthest Distance to Shore
Aspect Ratio
Complexity
Mean Turning Angle
Pattern analysis

• Aspect Ratio: Width of Bounding Box/Length of Bounding box
• Coverage Index: Perimeter of Bounding box/Total Distance
P(Motorboat) = 0.899
P(Sailboat)  = 0.101
Classification Results from Coastal Data

**Stepwise Computational Classification**

\[
\begin{align*}
\text{Canoe} & = - 6.878 + 3.066MS + 0.125MTA + 0.0002739DFS \\
\text{Kayak} & = - 5.624 + 3.183MS + 0.104MTA + 0.0002293DFS \\
\text{Motorboat} & = -27.071 + 9.611MS + 0.192MTA + 0.0002997DFS \\
\text{Sailboat} & = -13.720 + 5.293MS + 0.178MTA + 0.001683DFS
\end{align*}
\]

<table>
<thead>
<tr>
<th>TYPE</th>
<th>canoe</th>
<th>kayak</th>
<th>motorboat</th>
<th>sailboat</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>canoe</td>
<td>94.1</td>
<td>5.9</td>
<td>0.0</td>
<td>0.0</td>
<td>100.0</td>
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<tr>
<td>kayak</td>
<td>33.3</td>
<td>61.9</td>
<td>0.0</td>
<td>4.8</td>
<td>100.0</td>
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<tr>
<td>motorboat</td>
<td>20.0</td>
<td>0.0</td>
<td>80.0</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>sailboat</td>
<td>4.3</td>
<td>2.1</td>
<td>2.1</td>
<td>91.5</td>
<td>100.0</td>
</tr>
</tbody>
</table>

* 84.2% of original grouped cases correctly classified
Example 3

SAR Coverage
Station Location Decision

Site Characteristics

Response Characteristics

Calculations

Views

Multiple Attributes

Go/No Go

C1 C2 C3 C4 C5 C6

Average Response

Response Distribution

Load Balance

Coverage Balance
Response Time Improvements

From Chance Harbour

At 20 knots

Time Savings
1 Hour
2 Hours
3 Hours

From Saint John

At 20 knots

Time Savings
1 Hour
2 Hours
3 Hours

Saint John vs. Chance Harbour
Effect of moving lifeboats
Example 4

Fishing incident characterization
Fishing Incidents Density
Fishing Incident Rate Distribution
Example 5
How are the incident rates related to weather conditions?

Results
2 of these 6 factors are related to incident severity
Wave Height (m)
Ice Concentration (%)
Air Temperature (°C)
Amount of Precipitation (mm/day)
Sea Surface Temperature (°C)
Fog Existence Indicator
Sensitivity Analysis of Logistic Regression Model

Prob. of High Severity ($\theta$)

Wave Height (m)

Ice Concentration (%)

- 0.7-0.8
- 0.6-0.7
- 0.5-0.6
- 0.4-0.5
- 0.3-0.4
- 0.2-0.3
- 0.1-0.2
- 0-0.1

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MARIN – Current activities

• Maritime Traffic Pattern Analysis for Coastal Protection
• Boating Safety for Anglers & Hunters: a Survey of Perceptions and Practices
• Oil in Canadian Waters: Assessing Oil Pollution, Commercial Shipping and Ecological Impacts on Canada’s Three Coasts
• Sensor Interaction for Small Ship Tracking and Awareness in Harbour – A study of the value of using sensors together
MARIN – Current activities (cont’d)

• PIRACY (Policy Development and Interdisciplinary Research for Actions on Coastal Communities, Youth and Seafarers)
• Multi-Criteria Decision Making Framework and Risk model for Carbon Capture & Storage (CCS)
• A Multi-Disciplinary Approach to Risk Governance: Best Practices, Workshops and Online Training
• Factors affecting seaplane crash survival
• Traffic modelling for risk-based hydrographic survey prioritization