Detecting
Search and Rescue missions
from AIS data

Iraklis Varlamis, Konstantinos Tserpes, Christos Sardianos
Department of Informatics and Telematics
Harokopio University of Athens, Greece

This work has been developed in the frame of the MASTER project, which has received funding from the European Union’s Horizon 2020 research and innovation programme under Marie-Skłodowska Curie grant agreement No 777695.
Definitions

- **AIS: Automatic Identification System**
  - Static and dynamic vessel information, broadcasted (VHF) by vessels (using an AIS transponder) and electronically exchanged between AIS-receiving stations (onboard, ashore or satellite)
  - AIS information is public

<table>
<thead>
<tr>
<th>Static data (every 6 minutes)</th>
<th>Dynamic data (every 2-10 seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vessel:</strong> International Maritime Organization (IMO) number (vessel’s lifetime ID), Name, Type (or cargo type), Dimensions, Location of the positioning system’s antenna on board the vessel, Type of positioning system (GPS, DGPS, Loran-C)</td>
<td>Maritime Mobile Service Identity (MMSI) number (vessel’s communication ID), Vessel’s Navigational Status, Rate of Turn (degrees per minute), Speed over Ground, Position Coordinates, Course over Ground, Heading, Bearing at own position, timestamp (in UTC seconds)</td>
</tr>
<tr>
<td><strong>Voyage:</strong> Draught, Destination, ETA (estimated time of arrival)</td>
<td></td>
</tr>
</tbody>
</table>
How AIS data can be used

- Increase safety by making vessel position widely known.
- Avoid collisions using AIS data from nearby vessels. A receiver must be installed in the vessel.
- Visualize the position of every vessel in an area. A network of AIS-receiving stations must be installed and operated.
Definitions

- SAR: Search and Rescue missions or ASR: Air-sea rescue missions
  - The combined use of aircraft and surface vessels, to search for and recover survivors of aircraft downed at sea as well as sailors and passengers of sea vessels in distress.
  - In the case of refugees, National Coastguards and NGOs are actively engaged on SAR missions (e.g. Italy’s ‘Mare Nostrum’ until 2015, MSF in southern Italy, Refugee Rescue in the Aegean Sea)

http://searchandrescue.msf.org/
http://www.refugeerescue.co.uk/
SAR maneuvers

Search

- Sector
- Parallel track

Expanding rectangle

Rescue

- Man overboard (MOB)
- Scharnow
- Williamson
- Quick-Turn

DESWEB/ICDE 2018
Varlamis, Tserpes, Sardianos: Detecting SAR missions from AIS data
What happens in an emergency

- A vessel’s radar or the coastguard radar detects the event and transmit a signal to nearby vessels.
- One ship is on command of the mission and the nearby ships head towards the event and perform SAR maneuvers one after the other.
- There is a long story on when the ‘nearby’ vessels have been engaged on the SAR mission and where they were before the mission. So…. →

https://vimeo.com/219739614 @ 8:56
The challenges

- Is it possible to
  - automate the surveillance of a marine region using AIS data and
  - understand when a SAR mission takes place only from AIS data?

- Break down
  - monitor all vessels in the region
  - detect when vessels perform SAR maneuvers
  - combine information from multiple vessels at time period
Monitor vessels in a region

- **Scalability**
  - more than 3,000 vessels sail the Mediterranean sea per day
  - each vessel transmits data every few seconds

- **Data filtering and noise reduction**
  - only vessels’ position, speed, heading, timestamp change during a trip
  - consecutive states are compared with speed & heading predictions. The last position is kept when there is no big difference. Result: seconds → minutes

- **Incrementality**
  - Data streams require incremental algorithms
Event detection on Vessel Trajectories

- Complex Event Processing (CEP) for vessels

- **Trajectory Movement Events (ME)**
  - **Instantaneous**
    - Pause
    - Speed change
    - Turn
  - **Long-lasting**
    - Gap
    - Stop
    - Slow motion
    - Smooth turn

- **Complex Maritime Events (CE)**
  - **Instantaneous**
    - Single-vessel
    - Dual-vessel
    - Area-based
  - **Long-lasting**
    - Single-vessel
    - Dual-vessel
    - Illegal shipping
    - Fast approach
    - Package picking
    - Suspicious area
    - Suspicious vessel delay
    - Vessel rendezvous


SAR missions are Multi-vessel & long-lasting
Detect SAR maneuvers

- Proposed approach

For a single vessel
  - Trajectory simplification
  - Turn detection
  - Maneuver detection and annotation

For multiple vessels
  - Detection of multi-vessel maneuvers co-occurrence
Trajectory Simplification

- Noise removal: Simplify trajectory information by removing records that do not provide much information about the vessel trajectory.
- Ramer–Douglas–Peucker (RDP) algorithm: if $\max(\text{dist}_{\text{perpendicular}}(p_i, \epsilon)) < \epsilon$ then ignore all $p_i$.
Turn detection

- Keep only the points where vessel’s heading changes by more than 30 degrees (left or right)
- This happens near ports, dangerous areas or in case of emergency
Maneuver detection

- Density based clustering of turning points
  - Using incremental DB-Scan to process turning points of a trajectory while they are detected
  - \( \text{Eps}=40, \text{MinPts}=8 \): 8 or more turns within a range of 40 Km
 Maneuver annotation

but:
Composite movements
Differences in scale
Differences in orientation

Similarities among patterns
Detecting potential SAR missions

- **Machine learning approach**
  - Classify clusters as SAR related maneuvers or not
  - Detect the features that characterise SAR trajectories

- **Information retrieval approach**
  - Spatio-temporal retrieval of clusters
  - Find maneuver clusters from 3 or more vessels in the same wider area during a specific time window (i.e. vessels operating in the same area within a few hours)
Empirical evaluation

- **Dataset:**
  - AIS data for 25 vessels for a 3 months period (Jul-Sept, 2015)
  - 5 supply vessels hired by NGO’s and used in SAR missions on that period and
  - 20 randomly chosen vessels operating in the same area the same period

- **Features**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ship_id</td>
<td>Unique identifier for each vessel</td>
</tr>
<tr>
<td>latitude, longitude</td>
<td>Geographic location in digital degrees</td>
</tr>
<tr>
<td>sog</td>
<td>Speed over ground in knots</td>
</tr>
<tr>
<td>cog</td>
<td>Course over ground in degrees with 0 corresponding to north</td>
</tr>
<tr>
<td>heading</td>
<td>Ship’s heading in degrees with 0 corresponding to north</td>
</tr>
<tr>
<td>ship_type</td>
<td>Ship’s type like: Yacht, Supply Vessel etc</td>
</tr>
<tr>
<td>timestamp</td>
<td>Full UTC timestamp</td>
</tr>
<tr>
<td>Departure_timestamp</td>
<td>Ship’s departure datetime</td>
</tr>
<tr>
<td>Departure_port_id</td>
<td>Ship’s departure port id</td>
</tr>
<tr>
<td>Departure_port_name</td>
<td>Ship’s departure port name</td>
</tr>
<tr>
<td>Departure_port_type</td>
<td></td>
</tr>
<tr>
<td>Departure_country_code</td>
<td>The country code for ship’s starting point</td>
</tr>
<tr>
<td>Arrival_timestamp</td>
<td>Ship’s departure datetime</td>
</tr>
<tr>
<td>Arrival_port_id</td>
<td>Ship’s arrival port id</td>
</tr>
<tr>
<td>Arrival_port_name</td>
<td>Ship’s arrival port name</td>
</tr>
<tr>
<td>Arrival_port_type</td>
<td></td>
</tr>
<tr>
<td>Arrival_country_code</td>
<td>The country code for ship’s arrival point</td>
</tr>
</tbody>
</table>
Clustering of turning points

- We applied trajectory simplification, turning points detection and clustering of turning points.
  - Result → 333 clusters each described with 21 features: e.g. average speed, duration (from first until last turn), cluster size, total distance covered, stops, cluster radius (avg, max).
- Clusters have been detected for almost all vessels but cluster features differ significantly.
- Clusters of clusters:

<table>
<thead>
<tr>
<th>_cluster</th>
<th>avgsp</th>
<th>difh</th>
<th>clustersize</th>
<th>totaldistance</th>
<th>stops</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>64.148257</td>
<td>75.428571</td>
<td>20.095238</td>
<td>76.468132</td>
<td>1.809524</td>
</tr>
<tr>
<td>1</td>
<td>12.952170</td>
<td>76.201258</td>
<td>60.440252</td>
<td>37.727155</td>
<td>32.679245</td>
</tr>
<tr>
<td>2</td>
<td>109.711685</td>
<td>33.000000</td>
<td>15.666667</td>
<td>50.164467</td>
<td>0.555556</td>
</tr>
<tr>
<td>3</td>
<td>32.408262</td>
<td>52.536585</td>
<td>25.715447</td>
<td>56.888629</td>
<td>8.788618</td>
</tr>
</tbody>
</table>
Classification of vessel trajectories

- Using
  - the same features
  - a decision tree classifier, and
  - a 5-fold cross validation split

- We get a 0.83 accuracy on predicting whether the cluster is from a vessel from the 5 vessels hired for SAR missions (52/333 clusters)

- A Random Forest classifier achieved 0.89 accuracy (+/- 0.06)
Retrieval of SAR events

- Define the bounding box of a detected cluster
- Retrieve overlapping bounding boxes (in space) that also overlap in time
- Result:

02/09/2015: “...Beginning at 7am, when the Bourbon Argos rescued 353 people from a wooden boat in the international waters north of Zuwara, the day continued with the Dignity I rescuing three inflatable boats with a total of 323 people onboard. Then the Bourbon Argos rescued another wooden boat bringing a further 650 people on board, and finally the MY Phoenix rescued 332 Eritreans from a wooden boat in the early afternoon...”
What is next?

SAR related complex events*

- Vessels’ Rendezvous
- Vessel’s fast approach to a point

*(Patroumpas, et al 2017)
Links

https://www.dit.hua.gr/~varlamis

https://www.dit.hua.gr/

http://www.master-project-h2020.eu/
Thank you!

Questions?

Iraklis Varlamis
varlamis@hua.gr
MASTER consortium

- CNR, Pisa, Italy
- UNIVE - University of Venice, Venice, Italy
- HUA - Harokopio University, Athens, Greece
- UPRC - University of Piraeus Research Center, Piraeus, Greece
- University of Versailles Saint Quentin - UVSQ, Versailles, France
- Thira Municipality, Santorini, Greece
- DAL - Dalhousie University, Halifax, Canada
- UFC - Federal University of Ceara, Fortaleza, Brazil
- PUC - Pontifícia Universidade Católica, Rio de Janeiro, Brazil
- UFSC - Federal University of Santa Catarina, Florianópolis, Brazil