Detecting Search and Rescue missions from AIS data

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MASTER
Multiple Aspect Trajectory Management and Analysis

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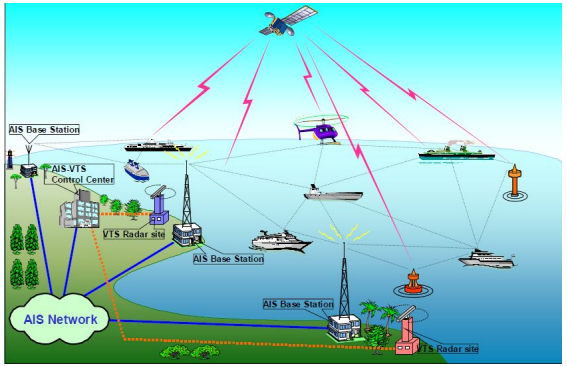
Definitions

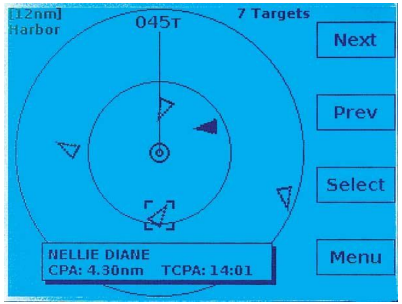
- AIS: Automatic Identification System
  - Static and dynamic vessel information, broadcasted (VHF) by vessels (using an AIS transponder) and electronically exchanged between AIS-receiving stations (onboard, ashore or satellite)
  - AIS information is public

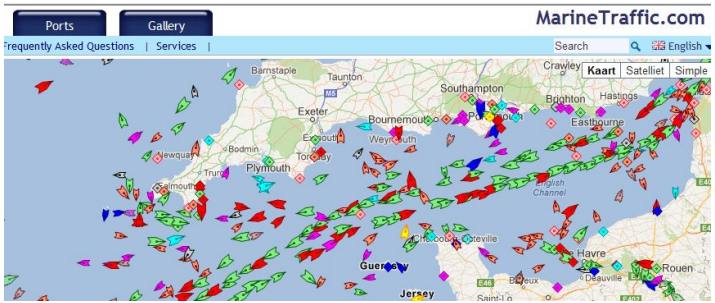


Static data (every 6 minutes)	Dynamic data (every 2-10 seconds)
Vessel: International Maritime Organization (IMO) number (vessel's lifetime ID), Name, Type (or cargo type), Dimensions, Location of the positioning system's antenna on board the vessel, Type of positioning system (GPS, DGPS, Loran-C) **Voyage**: Draught, Destination, ETA (estimated time of arrival)	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)

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

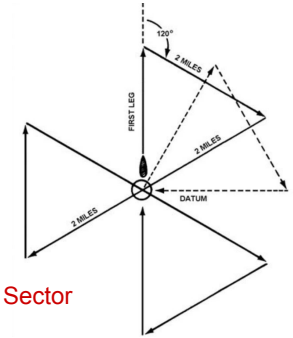
- SAR: Search and Rescue missions or ASR: Air-sea rescue missions
  - The combined use of aircraft and surface vessels, to search for and recover survivors of aircraft downed at sea as well as sailors and passengers of sea vessels in distress.
  - In the case of refugees, National Coastguards and NGOs 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/

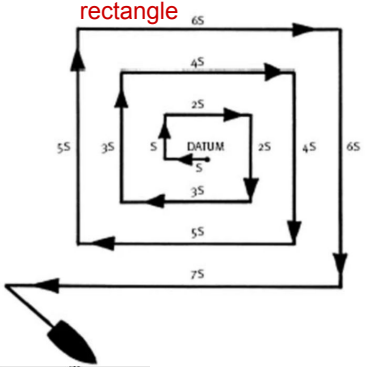
SAR maneuvers

Search

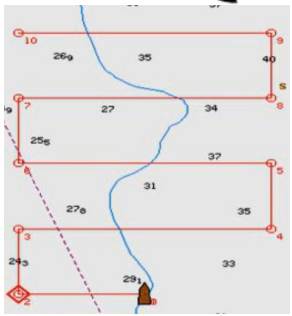


Sector

Expanding rectangle

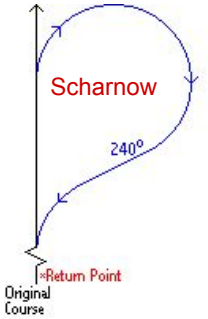


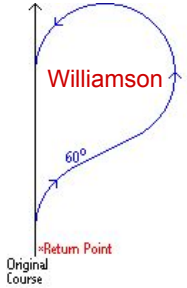
Parallel track

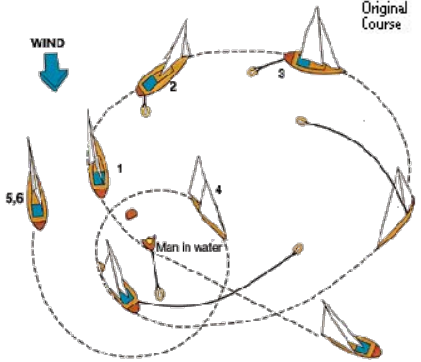


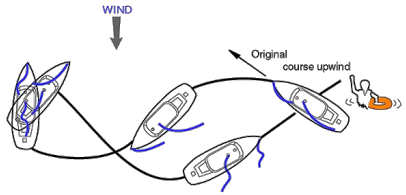
Rescue

Man overboard (MOB)





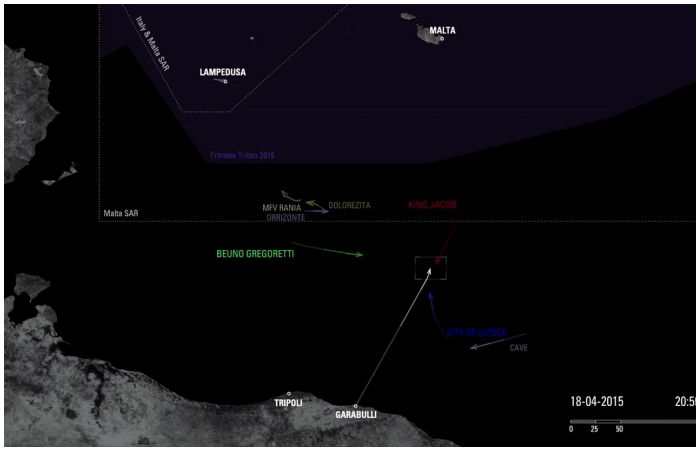




Quick-Turn

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…. ⟶



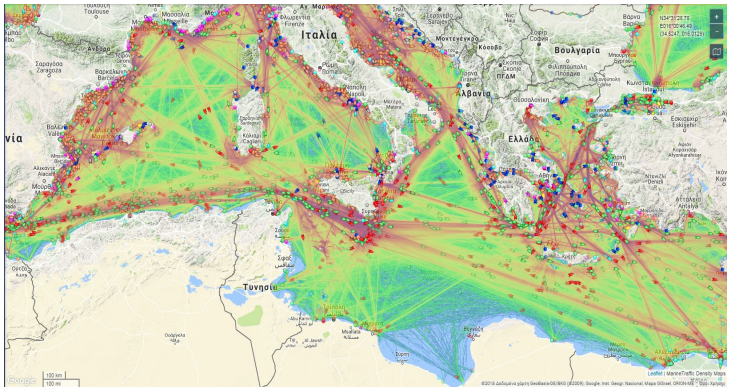
https://vimeo.com/219739614 @ 8:56

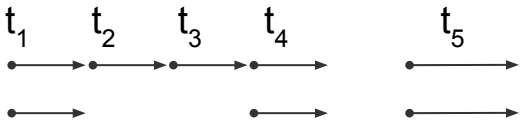
The challenges

- 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

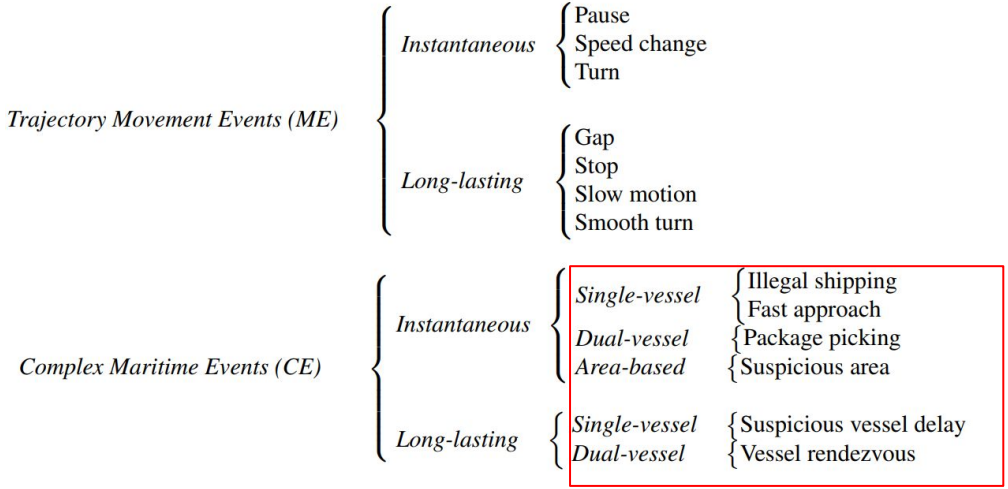
- Scalability
  - more than 3,000 vessels sail the Mediterranean sea per day
  - each vessel transmits data every few seconds
- Data filtering and noise reduction
  - only vessels' position, speed, heading, timestamp change during a trip
  - consecutive states are compared with speed & heading predictions. 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



SAR missions are
Multi-vessel & long-lasting

Patroumpas, K., Alevizos, E., Artikis, A., Vodas, M., Pelekis, N., & Theodoridis, Y. (2017). Online event recognition from moving vessel trajectories. *GeoInformatica*, *21*(2), 389-427.

Detect SAR maneuvers

- Proposed approach

For a single vessel

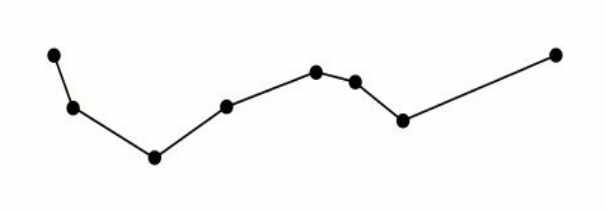
- Trajectory simplification
- Turn detection
- Maneuver detection and annotation

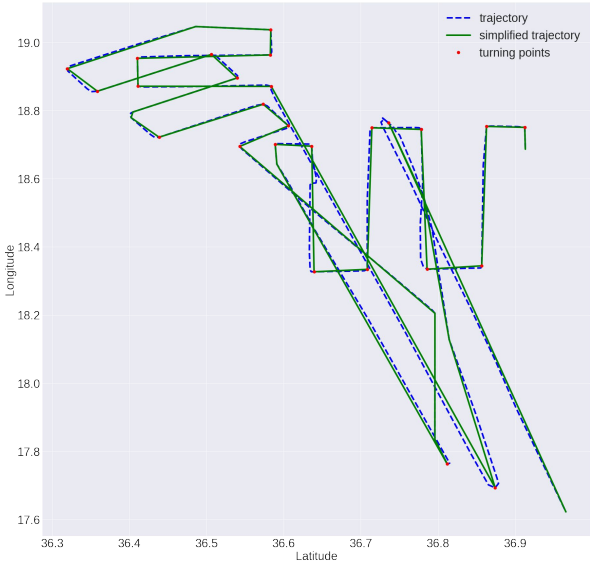
For multiple vessels

- Detection of multi-vessel maneuvers co-occurrence

Trajectory Simplification

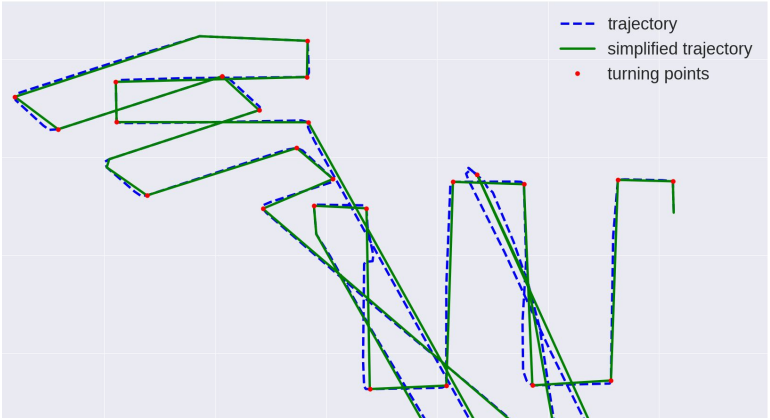
- Noise removal: Simplify trajectory information by removing records that do not provide much information about the vessel trajectory
- Ramer–Douglas–Peucker (RDP) algorithm: if max(dist$_{perpendicular}$ (p_i,ε)) <e then ignore all p_i





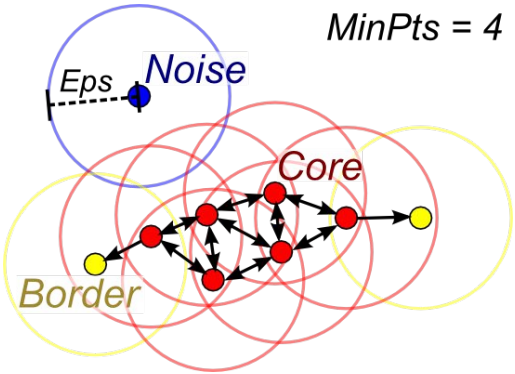
Turn detection

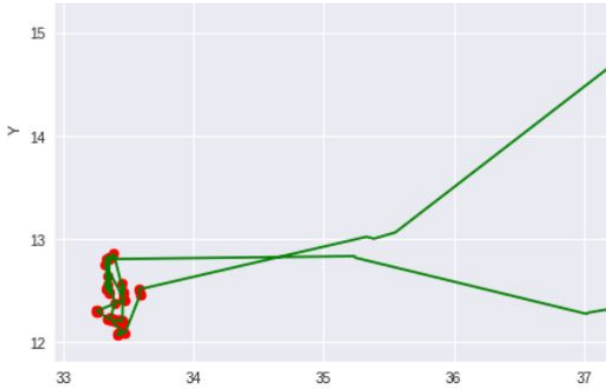
- Keep only the points where vessel's heading changes by more than 30 degrees (left or right)
- This happens near ports, dangerous areas or in case of emergency



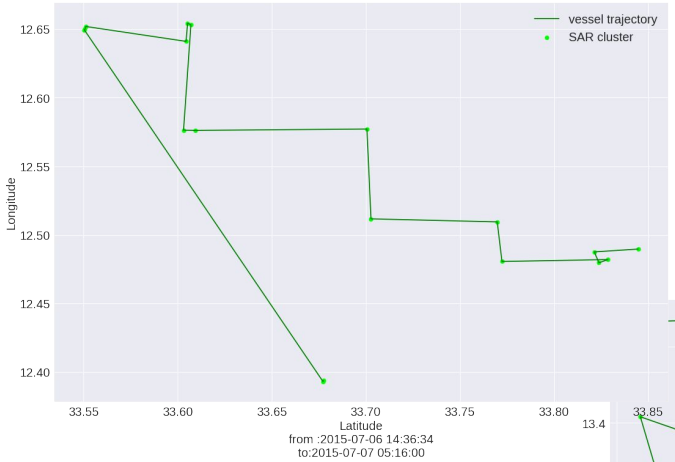
Maneuver detection

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

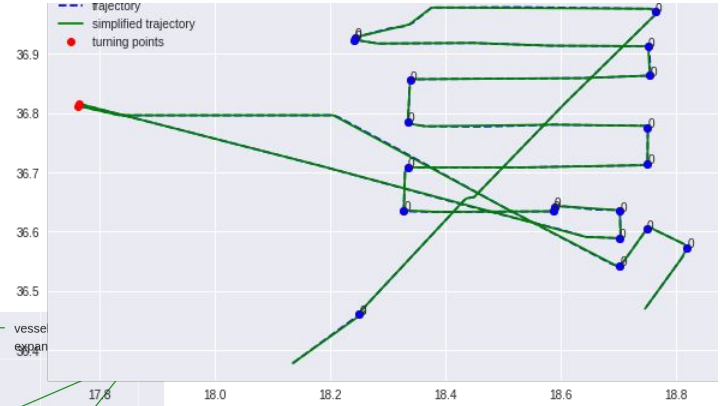


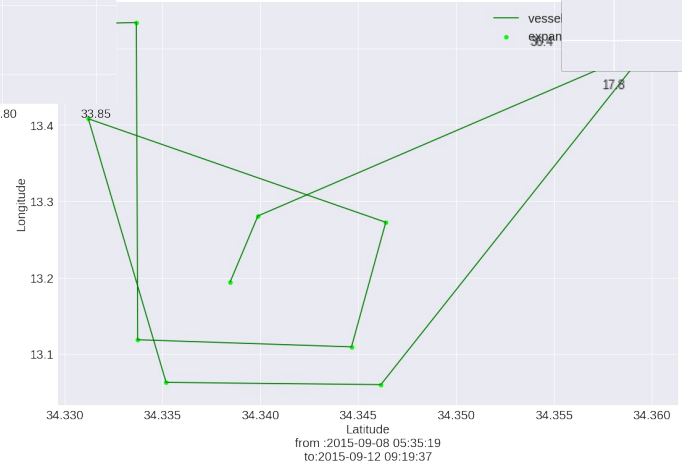


Maneuver annotation



Similarities among patterns





but:
Composite movements
Differences in scale
Differences in orientation

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

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

Clusters 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:

cluster	avgsp	difh	clustersize	totaldistance	stops
0	64.148257	75.428571	20.095238	76.468132	1.809524
1	12.952170	76.201258	60.440252	37.727155	32.679245
2	109.711685	33.000000	15.666667	50.164467	0.555556
3	32.408262	52.536585	25.715447	56.888629	8.788618

scanning vessel → 0
operating vessel → 1
sailing vessel → 2
operating vessel → 3

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

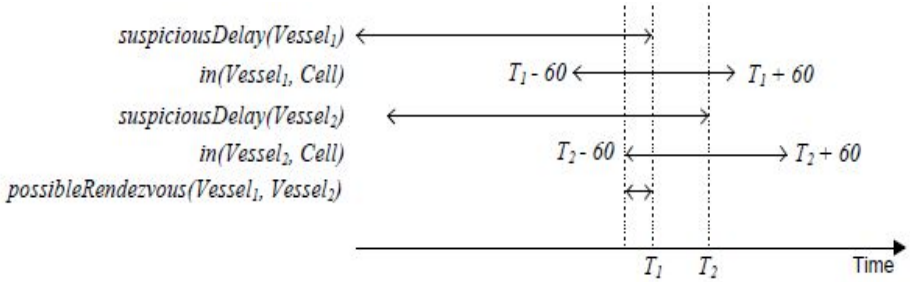
- Define the bounding box of a detected cluster
- Retrieve overlapping bounding boxes (in space) that also overlap in time
- Result:
  - 2015-09-02 06:50:07:::2015-09-02 18:20:07 PHOENIX & DIGNITY I
  - 2015-09-02 12:22:07:::2015-09-02 18:14:55 PHOENIX & BOURBON ARGOS

http://www.msf.org/en/article/mediterranean-migration-1658-people-rescued-busiest-day-ever-msf-search-and-rescue
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' Randezvous



- Vessel's fast approach to a pc

$$\begin{aligned}&\text{happensAt}(fastApproach(Vessel),\ T) \leftarrow\\ &\quad \text{happensAt}(speedChange(Vessel),\ T),\\ &\quad \text{holdsAt}(velocity(Vessel) = Speed,\ T),\\ &\quad Speed > 20\ knots,\\ &\quad \text{holdsAt}(coord(Vessel) = (Lon, Lat),\ T),\\ &\quad \text{not}\ nearPorts(Lon, Lat),\\ &\quad \text{holdsAt}(headingToVessels(Vessel) = \text{true},\ T)\end{aligned}$$

*(Patroumpas, et al 2017)

Links

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

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http://www.master-project-h2020.eu/

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Multiple Aspect Trajectory Management and Analysis

Thank you!

Questions?

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