Generating a Vessel Route Model from AIS Data Using the Fréchet Distance

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Knowledge for Tomorrow

Idea

Idea

- Goal: model common routes

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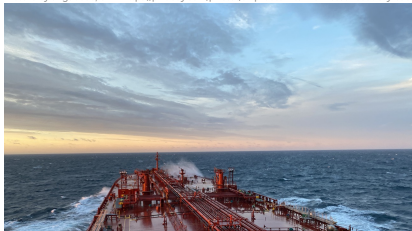- Traffic at sea is hard to describe

Picture by angad305, URL: https://pixabay.com/photos/ship-ocean-tanker-vessel-boat-sky-5957068/

Idea

- Goal: model common routes
- Traffic at sea is hard to describe
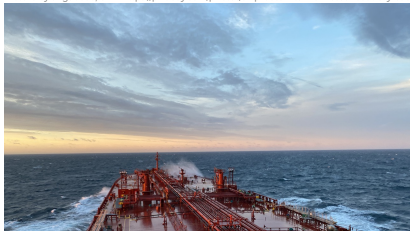- Automatic Identification System (AIS)

Picture by angad305, URL: https://pixabay.com/photos/ship-ocean-tanker-vessel-boat-sky-5957068/

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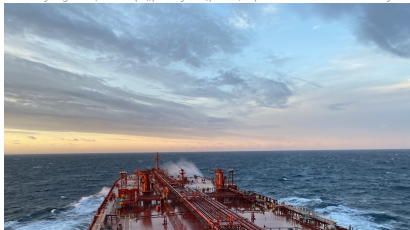
Idea

- Transform AIS reports to trajectories
- Cluster into common routes
- Final model uses cluster representatives

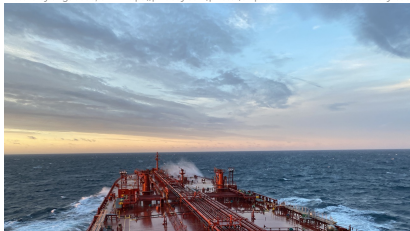Picture by angad305, URL: https://pixabay.com/photos/ship-ocean-tanker-vessel-boat-sky-5957068/

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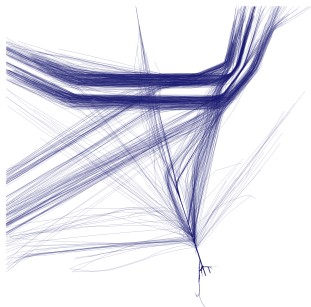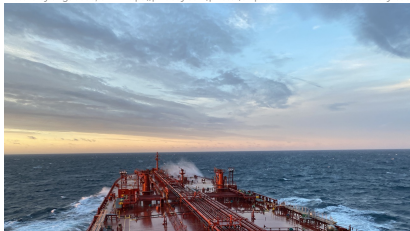
Idea

- Transform AIS reports to trajectories
- Cluster into common routes
- Final model uses cluster representatives
- Define model coverage

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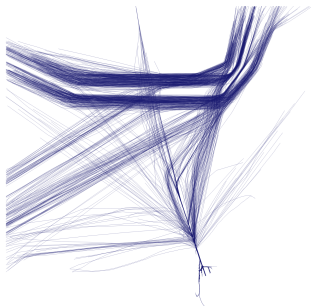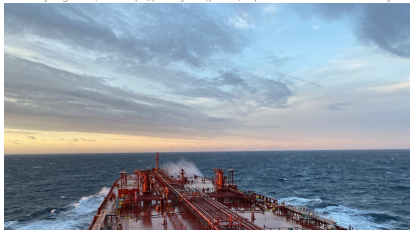
Outline

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Route

Definition (Route)

A route is the path a ship travels via waypoints to its planned destination.

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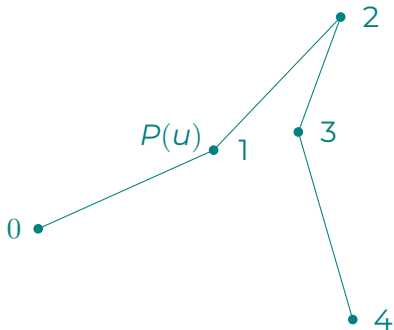
Polygonal Curve

Fréchet Distance δ_F
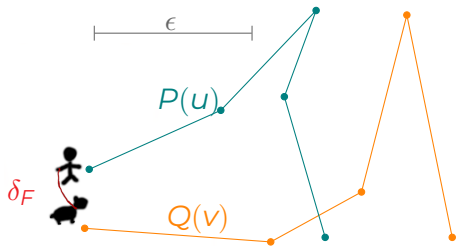
Fréchet Distance δ_F
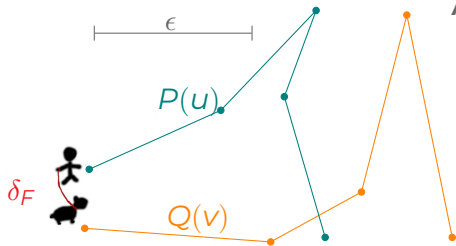
Advantages of δ_F

- Metric distance
- Factors in direction
- Works with irregular sampling & different length
- Sensitive to outliers

Fréchet Distance δ_F

Definition (Decision Problem)

Given: polygonal curves P and Q and some $\epsilon \geq 0$.
Decide, whether $\delta_F(P, Q) \leq \epsilon$.

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Outline

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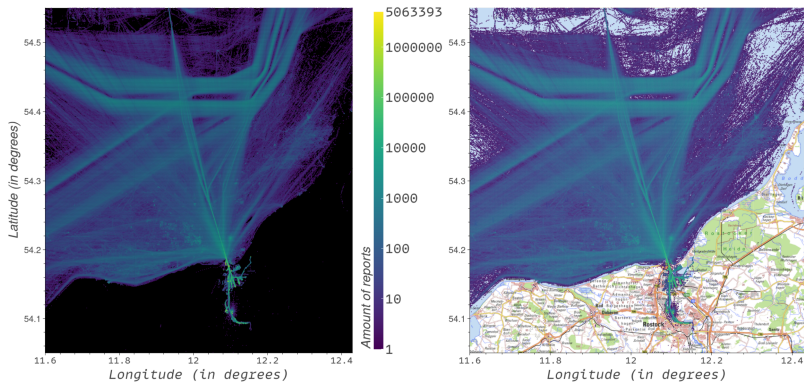
The AIS Data

Figure: A density plot of the received reports with and without a map background.

Outline

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Trajectory Generation

Temporal Segmentation

- $\Delta_{t_{moving}}$: Maximum time between 2 reports
- 10 seconds < $\Delta_{t_{moving}}$ < ?
- Free variable $\Delta_{t_{moving}} \rightarrow$ 180 seconds

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- Remove updates too close
- $\Delta_{p_{minzone}} := 10$ meters
- Remove outliers

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Anchor points
- Assumption: Ships stay idle
- $\Delta_{t_{anchoring}} := 30$ minutes

Trajectory Generation: Examples
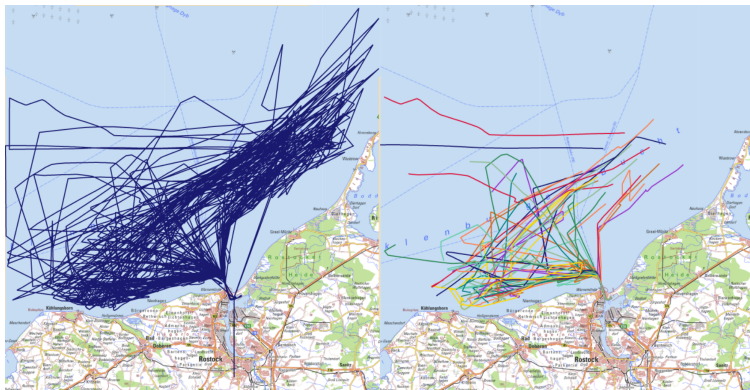
Figure: A one-year trajectory and the segmentation results.

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Trajectory Clustering

Idea

- Find groups of similar trajectories
- P, Q similar, if $\delta_F(P, Q) \leq \epsilon$
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- Groupsize $\leq \tau \rightarrow$ Representative (leader curve) of group added to model
- Free travel frequency variable τ

Outline

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Test Setup

Model
Training

- 2018 Jan.–Dec. Dataset
- Different Values for ϵ, τ

Test Setup

| Model Training | • 2018 Jan.–Dec. Dataset |
| | • Different Values for ϵ, τ |

Model Parameters	• ϵ	▸ 500m, 1000m, 1500m
		▸ Clustering Fréchet distance similarity threshold in meters (m)
	• τ	▸ 0,1,2,10
		▸ Minimum amount of support trajectories for model trajectory

Test Setup

Definition (Model Coverage)

A trajectory is covered by a model, if it has a Fréchet distance below ϵ_M to at least one model trajectory, where ϵ_M is the distance threshold used to generate the model M.

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- **Self Coverage** | Percentage of training trajectories covered by the model.

- **Test Coverage** | Percentage of test trajectories covered by the model.

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Results

		T	τ			
			0	1	2	10
	500	100	100	48.4	39.4	19.8
ϵ (m)	1000	100	100	84.4	80.2	62.2
	1500	100	100	92.7	90.3	81

(a) Self coverage (%)

T	τ			
	0	1	2	10
40.4	35.9	22.6	18	6.3
85.1	79.8	74	70.3	53.9
91.7	90.3	87.3	85.3	78.3

(b) Test coverage (%)

		T	τ			
			0	1	2	10
	500	301	196	32	16	2
ϵ (m)	1000	301	90	32	23	6.3
	1500	301	51	21	16	6.1

(a) Model size (MB)

T	τ			
	0	1	2	10
27.1	14.3	5.5	4.1	1.7
45	12.7	9.3	8.5	5.4
50	12.2	10.7	9.7	8.1

(b) Test comparison time (s)

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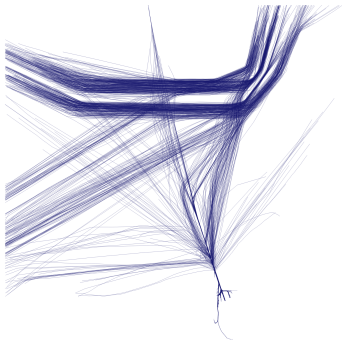| T	τ			
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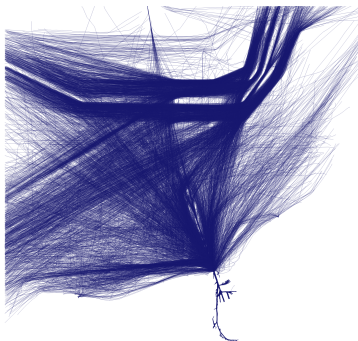
(a) $\tau = 0$ (b) $\tau = 10$

Figure: The final model trajectories at $\epsilon = 1500$ meters.

Summary

- Series of algorithms to automatically generate a trajectory movement model from AIS position reports
- Fréchet distance as trajectory similarity metric

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- Tests under various model settings
- Best result: 90% traffic coverage, 84% space reduction, 75% comparison time reduction

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Summary

- Series of algorithms to automatically generate a trajectory movement model from AIS position reports
- Fréchet distance as trajectory similarity metric
- Tests under various model settings
- Best result: 90% traffic coverage, 84% space reduction, 75% comparison time reduction
- Discovered importance of frequently travelled routes

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