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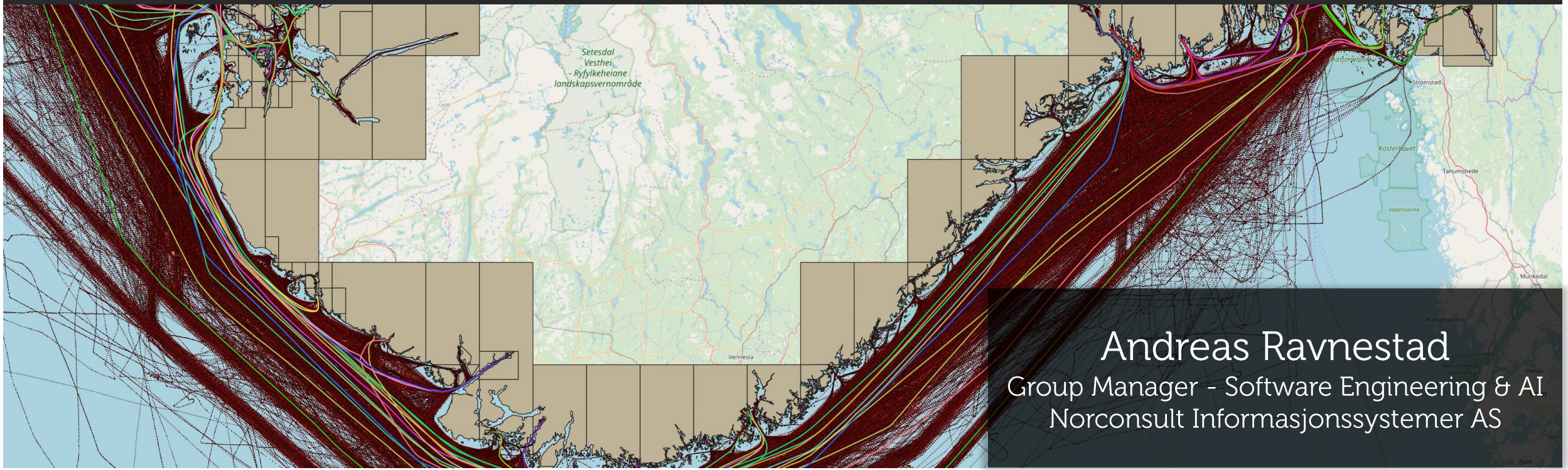
Machine Learning in marine traffic data

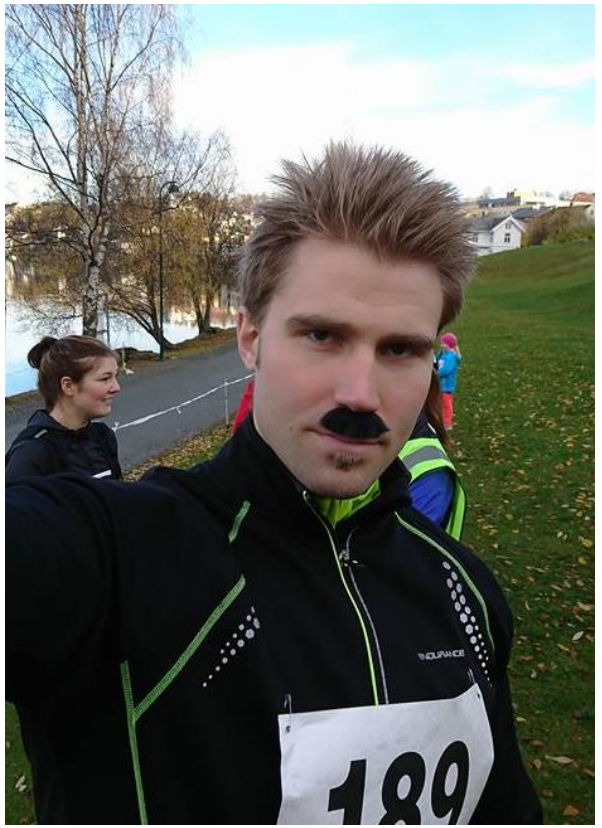
Possibilities for shipping and coastal engineering



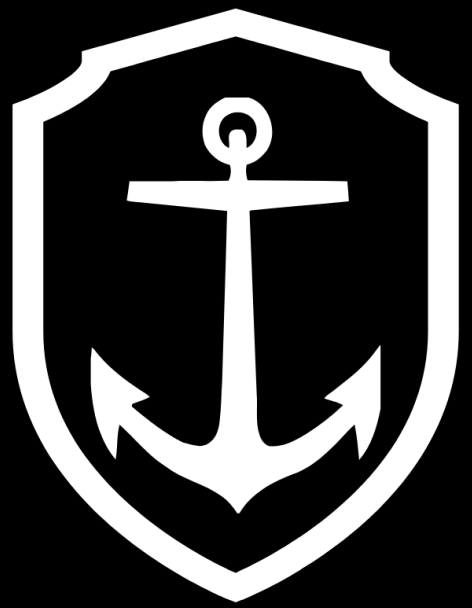
Andreas Ravnestad
Group Manager - Software Engineering & AI
Norconsult Informasjonssystemer AS

> whois andreas _

- **Age**: 36
- **Residency**: Fossegrenda, Trondheim
- **Employer**: Norconsult Informasjonssystemer AS
- **Title**: Group Manager, Software Engineering & AI
- **Education**: MSc. Computer Science, NTNU, 2008
- **Life Motto**: «*Education is important. But big biceps are importanter*»
- **Interests**: Ships not doing what they are supposed to (also other things)



Barteløpet 2017



MADART

MACHINE LEARNING ANOMALY DETECTION WITH AIS IN REAL TIME

Agenda

- Method
- Destination prediction
- Anomaly detection
- Grounding prediction
- ETA prediction
- Energy consumption prediction

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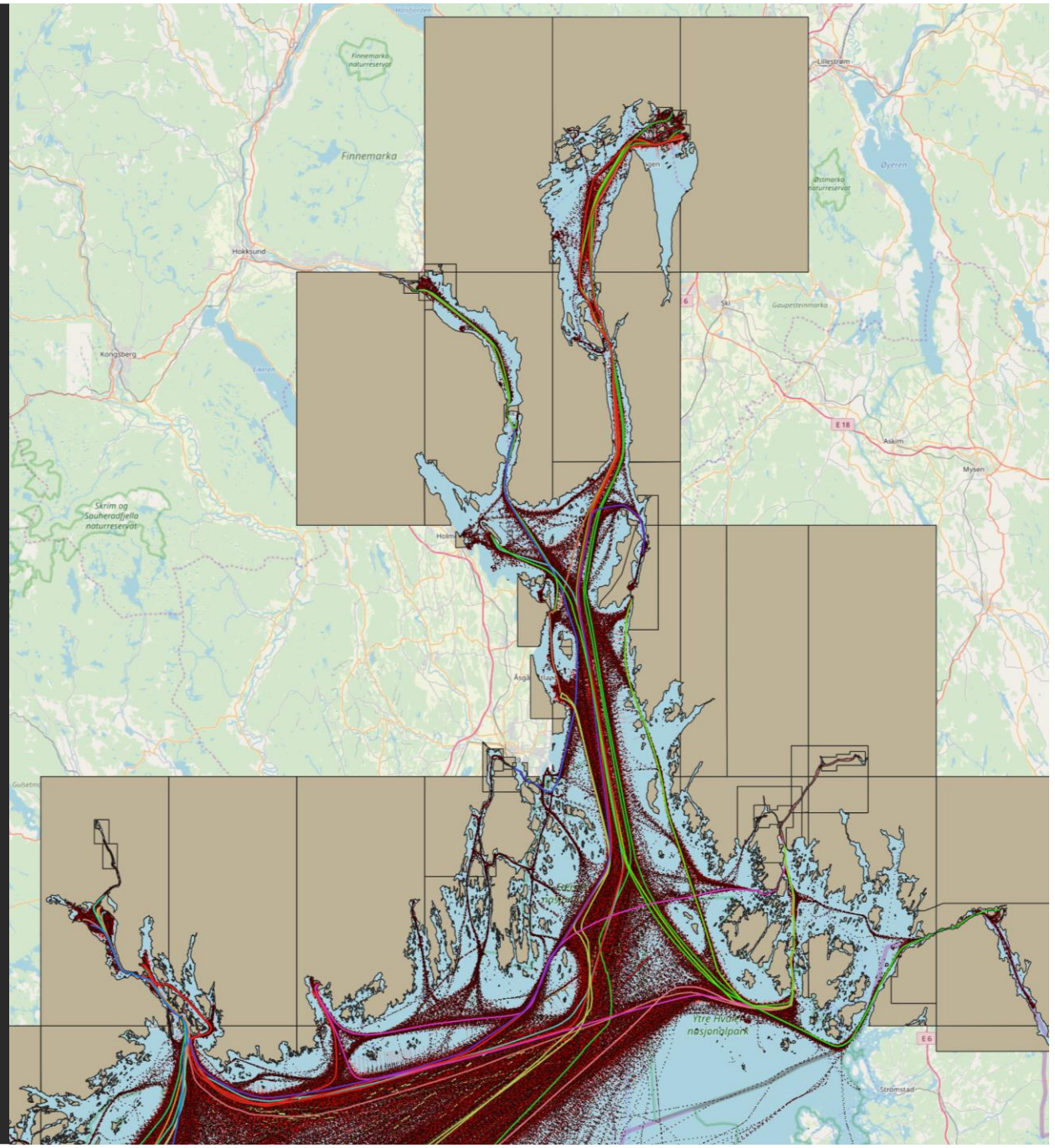
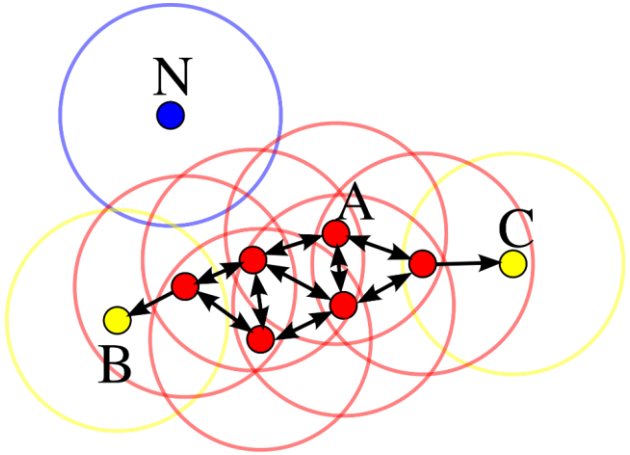
Method



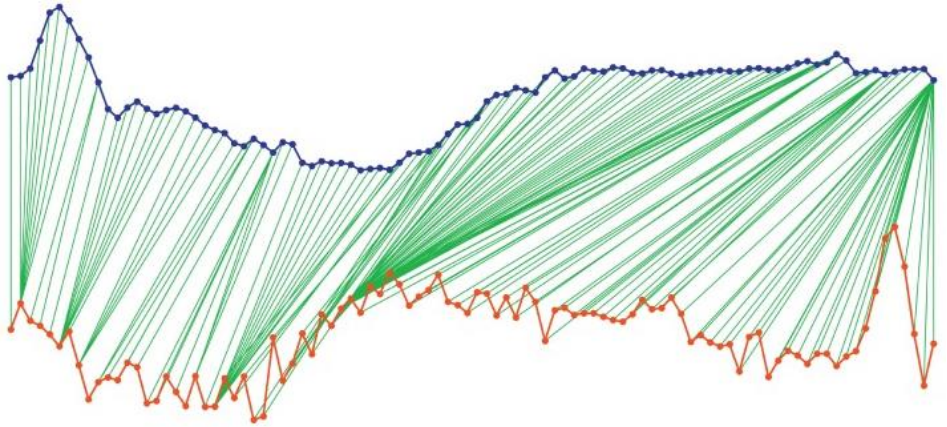
Algorithms

- HDBSCAN
  - Density-based Clustering Algorithm
  - Recognizes clusters in spatial data
  - Generates detailed statistics
  - Excels in detecting and removing noise



https://en.wikipedia.org/wiki/DBSCAN

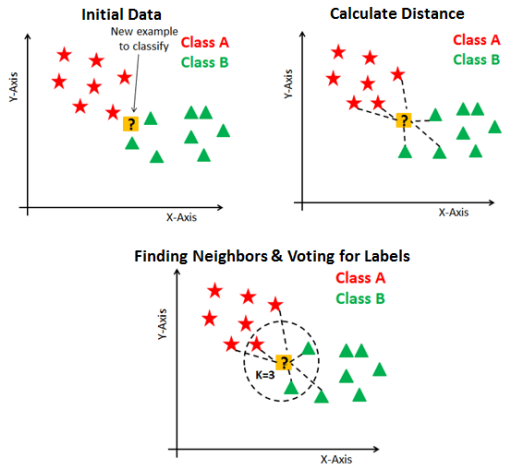
- Dynamic Time Warping (DTW)
  - Used for speech and hand signature recognition
  - Measures similarity between sequences of data
  - Detects and exploits temporal distortions
  - Excels in temporal shape matching



https://en.wikipedia.org/wiki/Dynamic_time_warping

Algorithms, continued

- k Nearest Neighbours (kNN)
  - Pattern recognition algorithm
  - Used for classification of voyages to routes
  - Uses DTW as distance metric



https://en.wikipedia.org/wiki/K-nearest_neighbors_algorithm

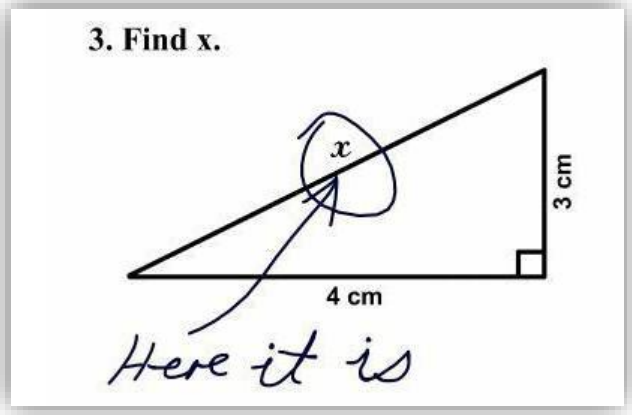
- CatBoost
  - Gradient boosting over decision trees
  - Used for ranking matching routes

The housecat Boost soon realized he had made a terrible decision that day

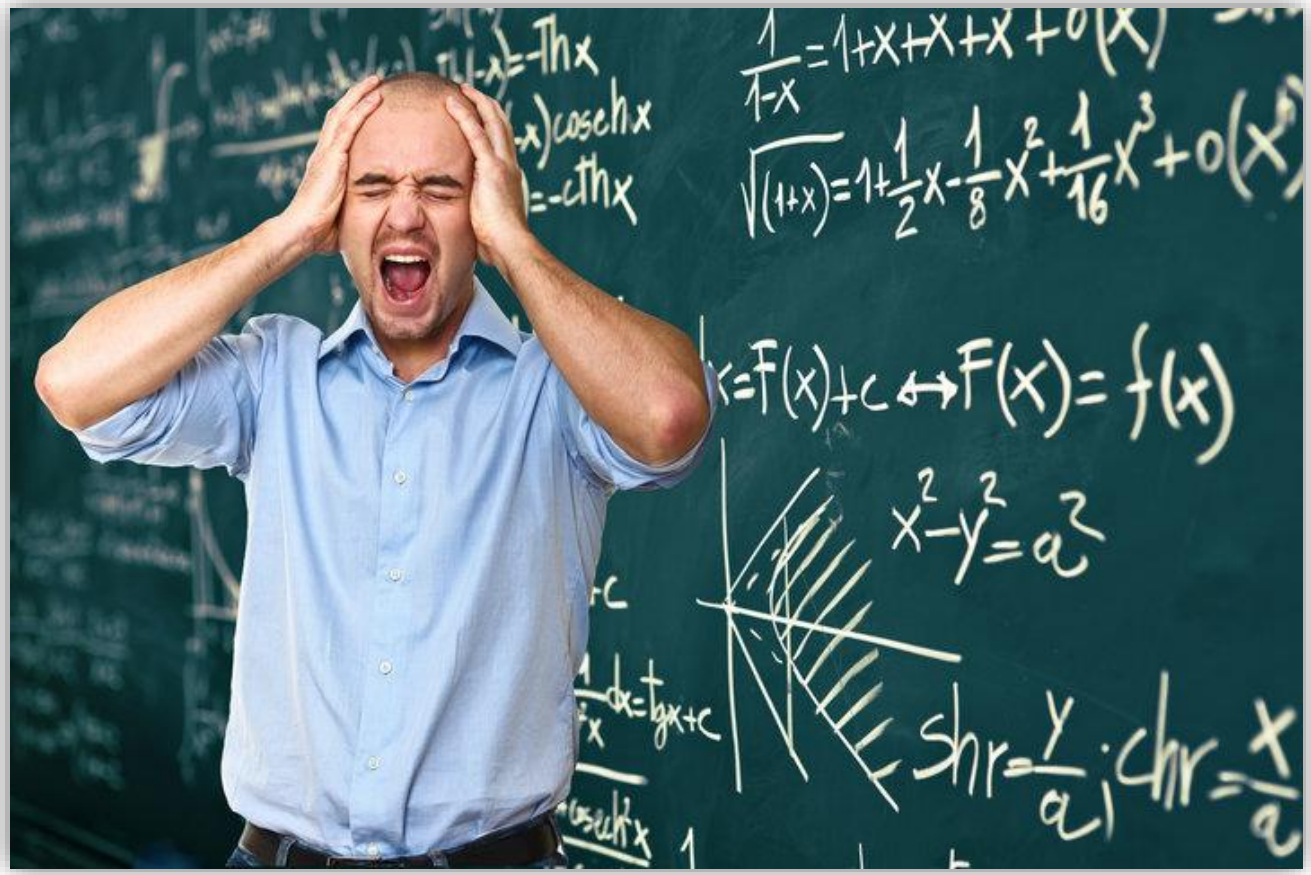
https://en.wikipedia.org/wiki/Gradient_boosting

Algorithms, continued

- Also, **maths**
  - Very hard
  - But we have to do lots of it
  - Used for mostly everything
  - We cannot escape it

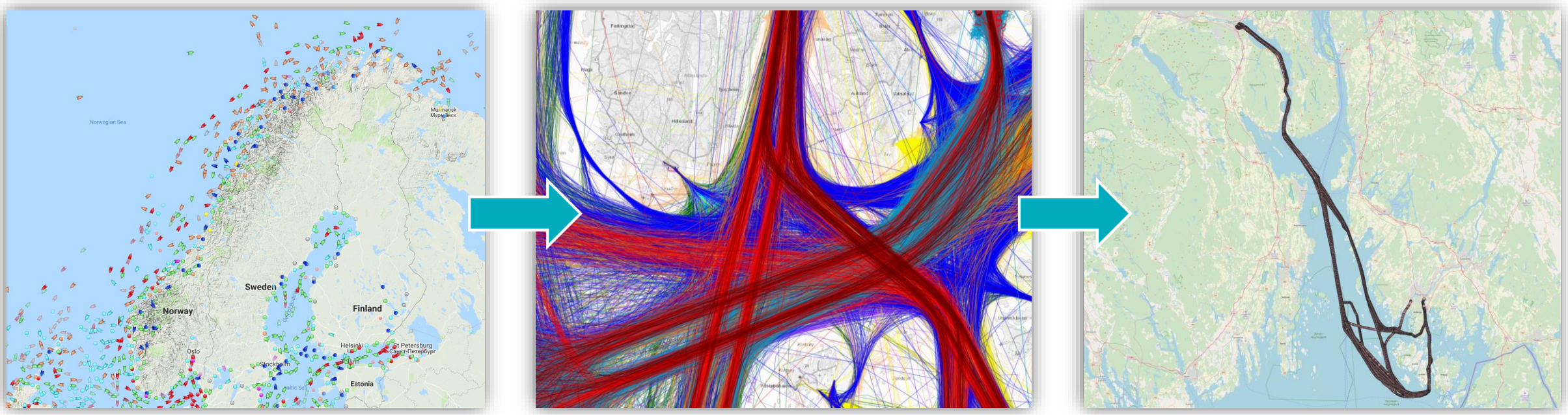


https://en.wikipedia.org/wiki/Mathematics

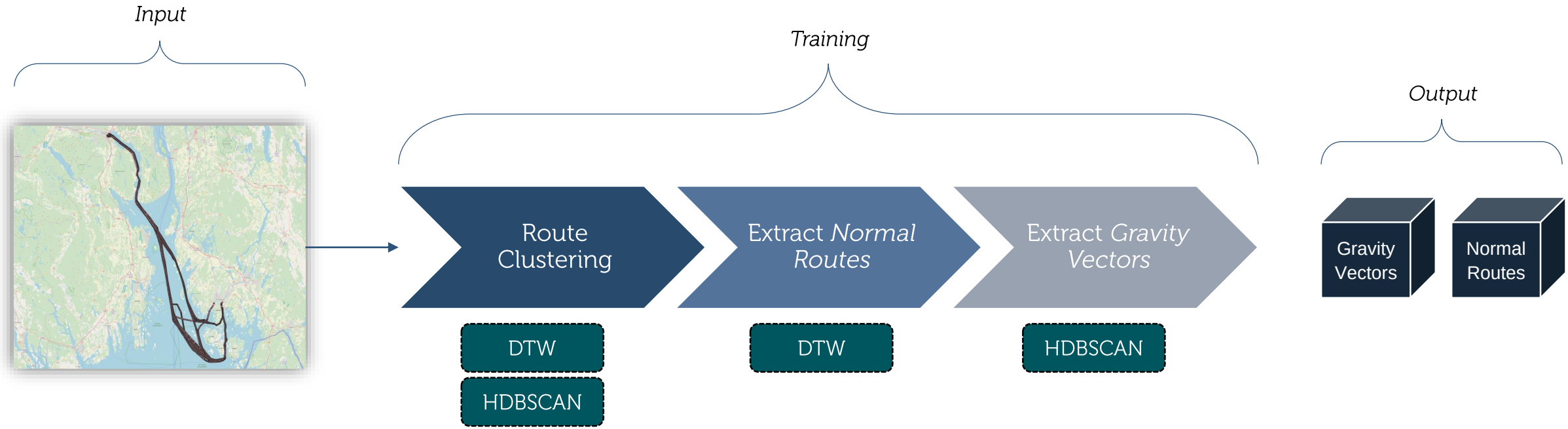


Input data

- 3 years of historical marine traffic data
- Approximately 3TB in size
- Cleaned, filtered, and separated into distinct voyages



Training process



What are *Normal Routes* and *Gravity Vectors*?

Normal Route

- Departure Port
- Arrival Port
- Linestring Geometry

Gravity Vector 01

Gravity Vector 02

Gravity Vector 03

Gravity Vector 04

...

Gravity Vector

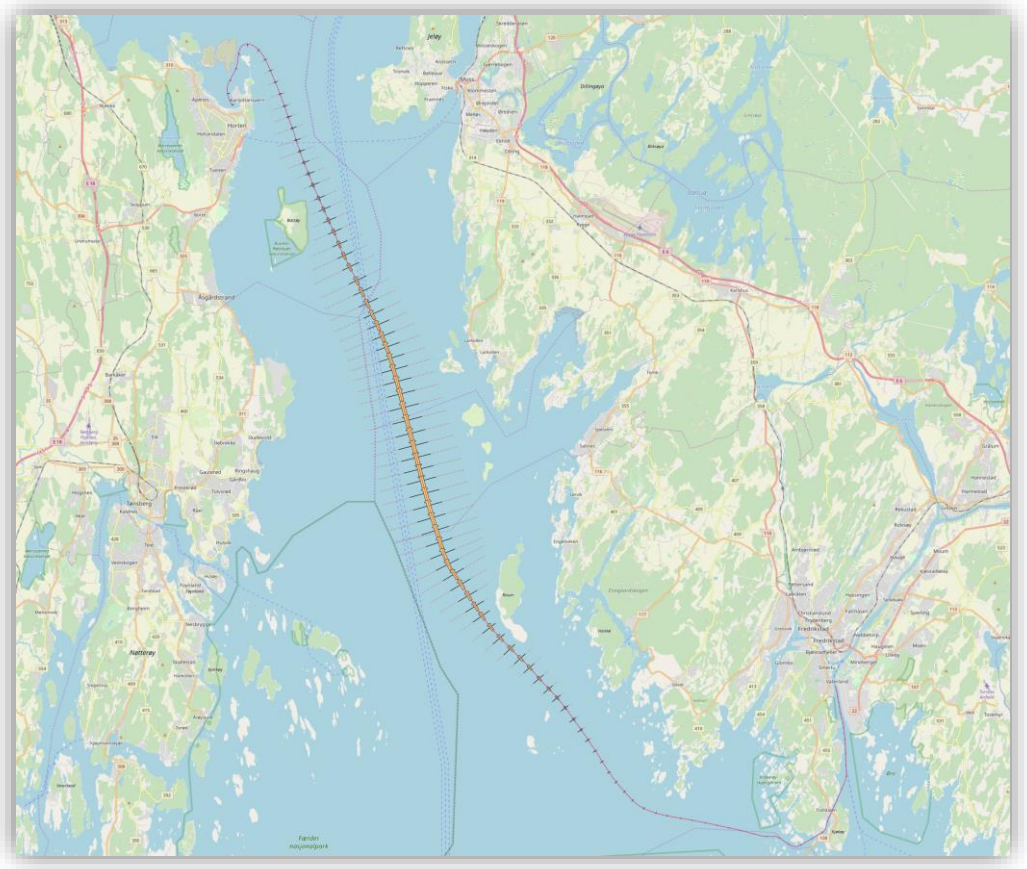
Position
- Average position (point geometry)
- Standard deviation port side
- Standard deviation starboard side
- Max. deviation port side
- Max. deviation starboard side

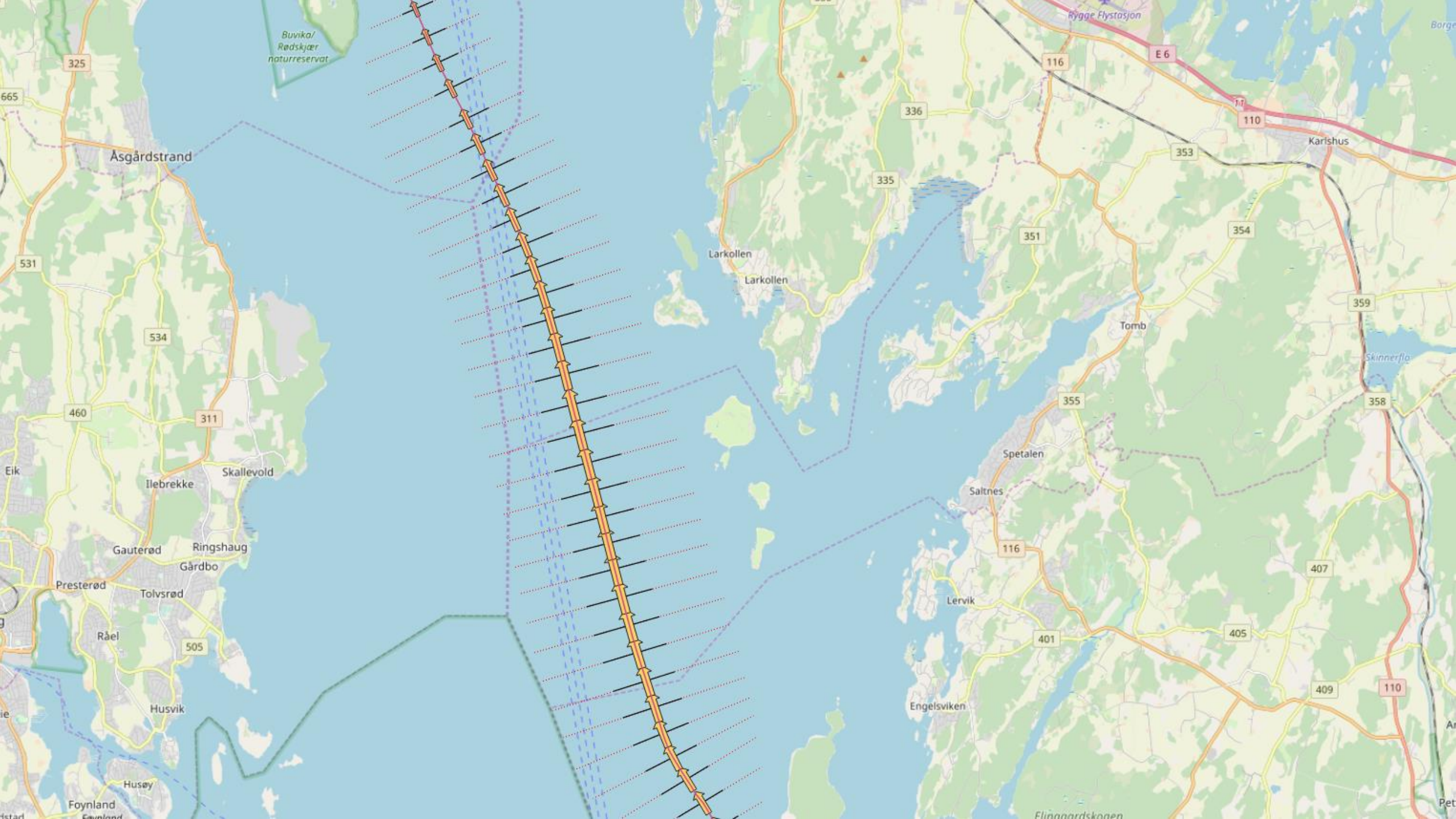
Speed
- Average speed
- Standard deviation
- Max. deviation

Course
- Average course
- Standard deviation
- Max. Deviation

Time to arrival
- Average ETA
- Standard deviation

Traffic density





Buvika/
Rødskjær
naturreservat
325
665
Åsgårdstrand
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460
311
Eik
Ilebrekke
Skallevold
Gauterød
Ringshaug
Gårdbo
Presterød
Tolvsrød
Råel
505
Husvik
Husøy
Foynland
Larkollen
Larkollen
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335
351
116
E 6
Rygge Flystasjon
110
Karlshus
353
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Tomb
Skinnerflo
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358
Spetalen
Saltnes
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Lervik
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110
Engelsviken

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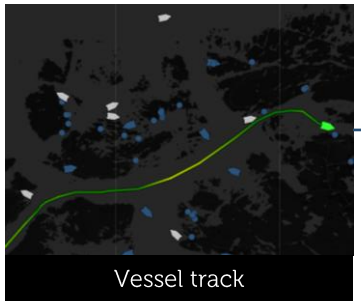
Destination Prediction

Destination Prediction Process



Identify candidate routes

Filter

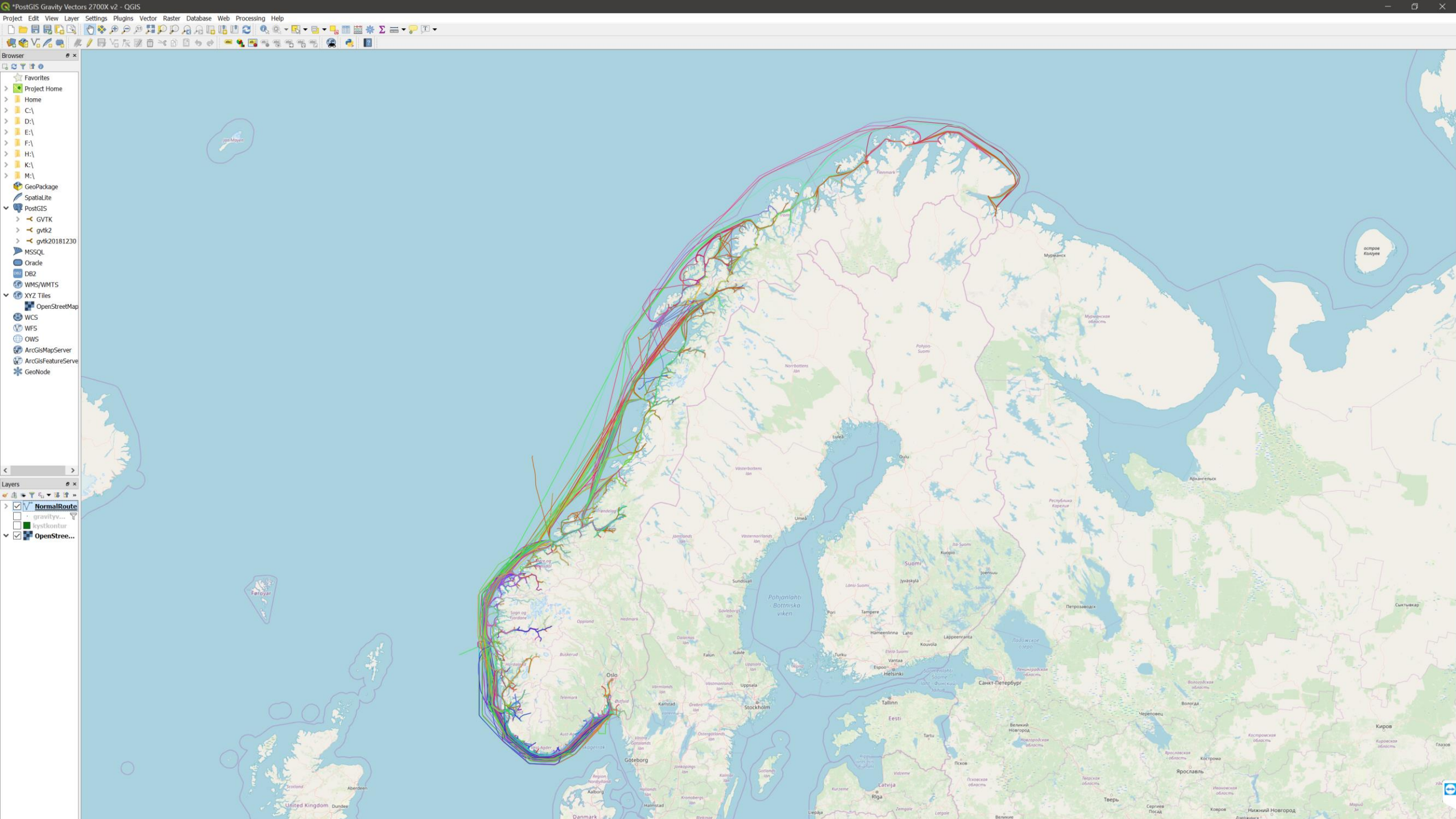
Rank

kNN

DTW

CatBoost

Matched Normal Routes


*PostGIS Gravity Vectors 2700X v2 - QGIS
Project Edit View Layer Settings Plugins Vector Raster Database Web Processing Help
Browser
Favorites
Project Home
Home
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GeoPackage
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PostGIS
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Oracle
DB2
WMS/WMTS
XYZ Tiles
OpenStreetMap
WCS
WFS
OWS
ArcGisMapServer
ArcGisFeatureServe
GeoNode
Layers
NormalRoute
gravityv...
kystkontur
OpenStree...
Oslo
Stockholm
Göteborg
Helsinki
Tallinn
Санкт-Петербург
Murmansk
Oulu
Umeå
Luleå
Tampere
Turku
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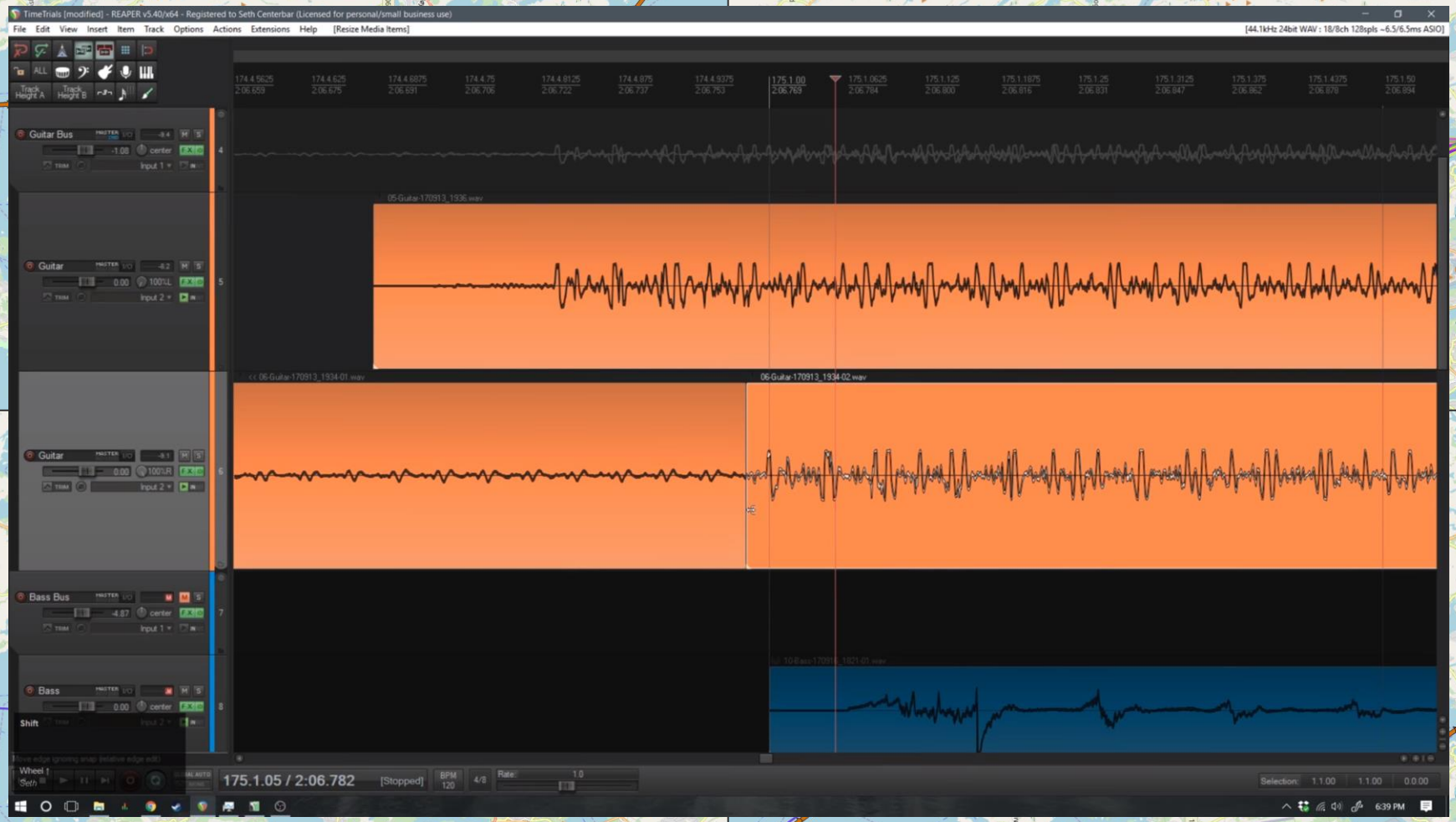
Bottniska viken
Suomi
Eesti
Latvija
Färöyar

kNN
DTW


TimeTrials [modified] - REAPER v5.40/x64 - Registered to Seth Centerbar (Licensed for personal/small business use)
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Guitar Bus
Guitar
Guitar
Bass Bus
Bass
05-Guitar-170913_1936.wav
06-Guitar-170913_1934-01.wav
06-Guitar-170913_1934-02.wav
10-Bass-170913_1821-01.wav
175.1.05 / 2:06.782
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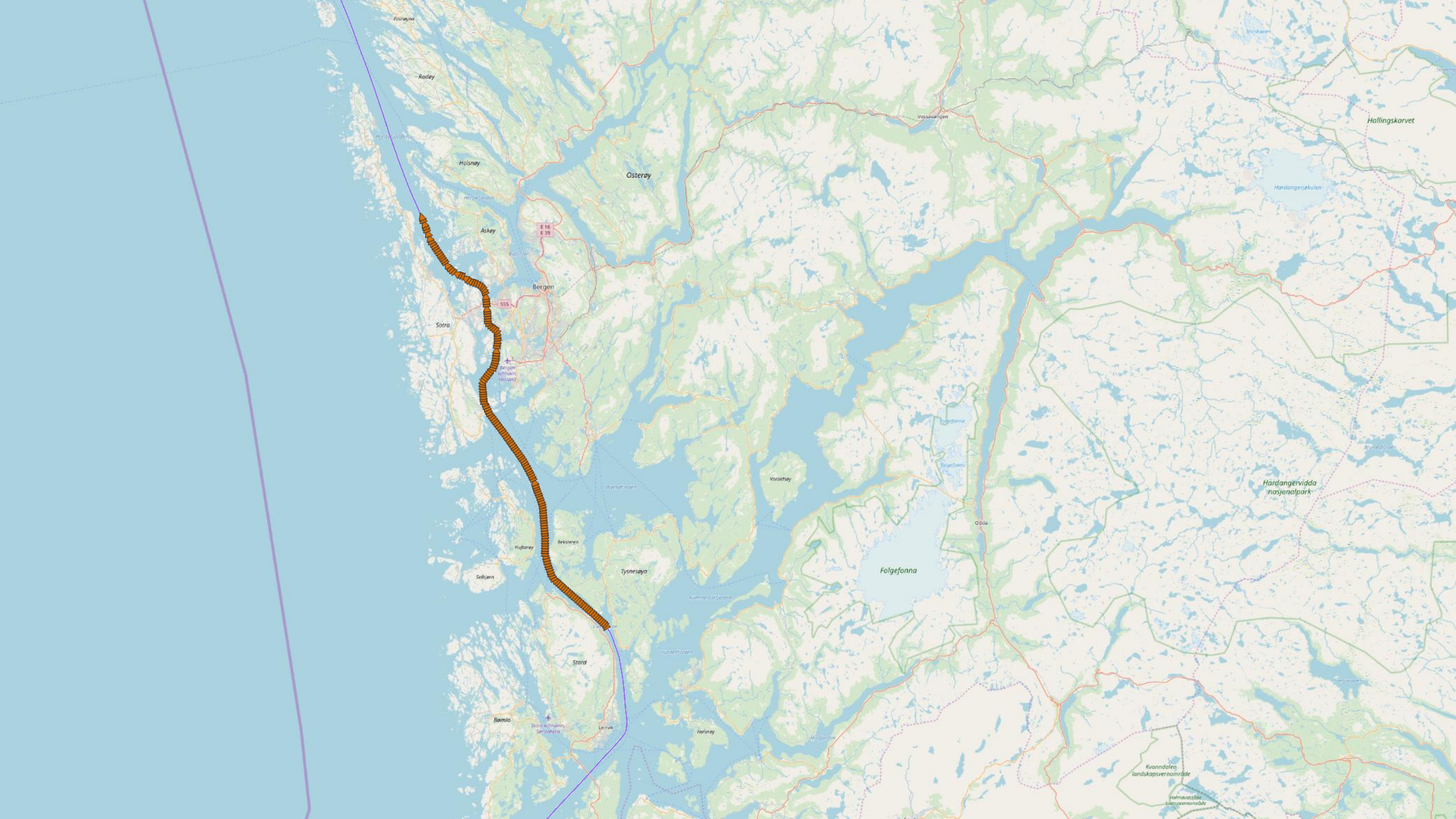
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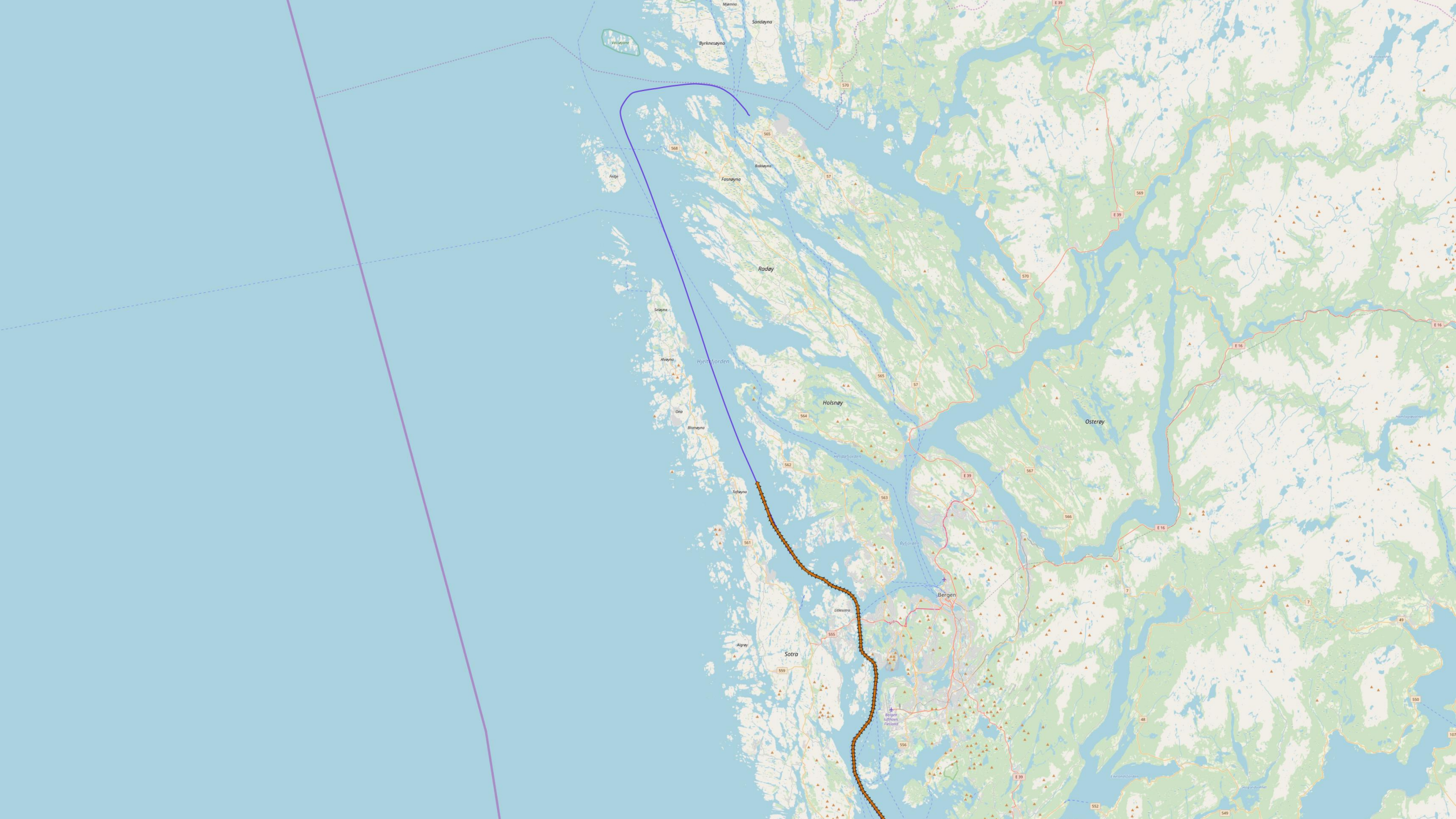
Holsnøy
Osterøy
Askøy
Bergen
Sotra
Vossavangen
Hallingskarvet
Hardangerjøkulen
Hardangervidda nasjonalpark
Folgefonna
Odda
Tysnesøya
Stord
Bømlo
Halsnøy
Kvanndalen landskapsvernområde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549

Home page - MADIertidigART

https://localhost:44383

FAR SUPERIOR

MMSI: 257911000
IMO: 9766877
Callsign: LATJ7
Speed: 11 knots
Course: 15.8°

Show track
Route forecast
Disable warnings

Zoom To

Streetmap Seamap Darkmap

Leaflet | © OpenStreetMap contributors © CARTO

Applications for destination prediction

Vessel movement prediction

Anomaly detection

Reporting automation (Kystverket)

Pilotage or PEC requirements

ETA prediction

Fuel consumption prediction

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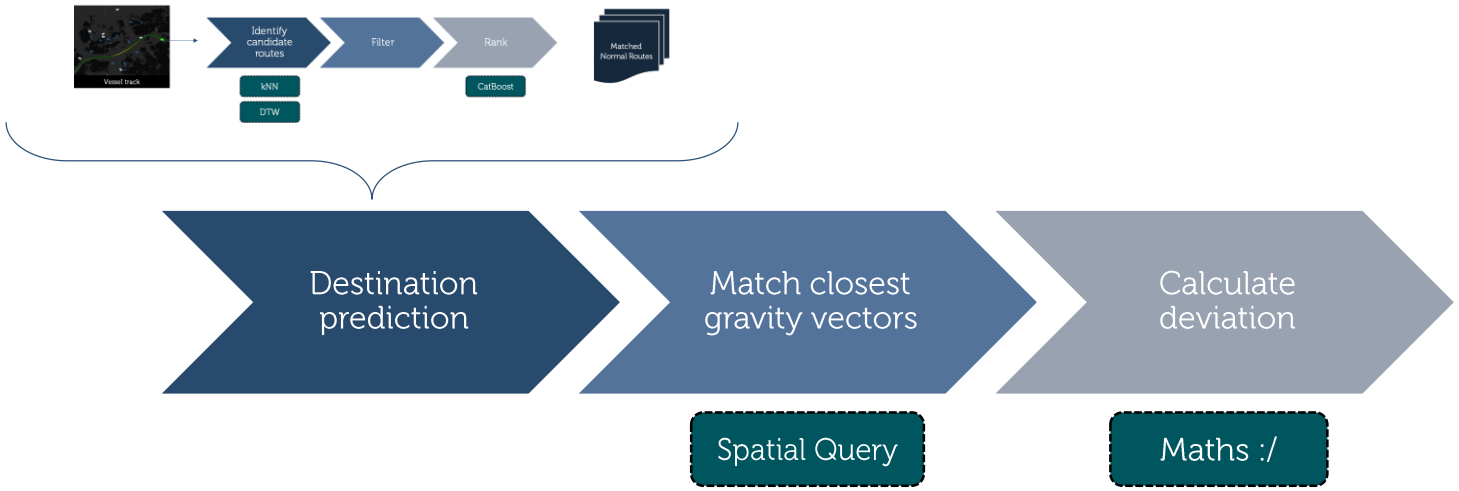
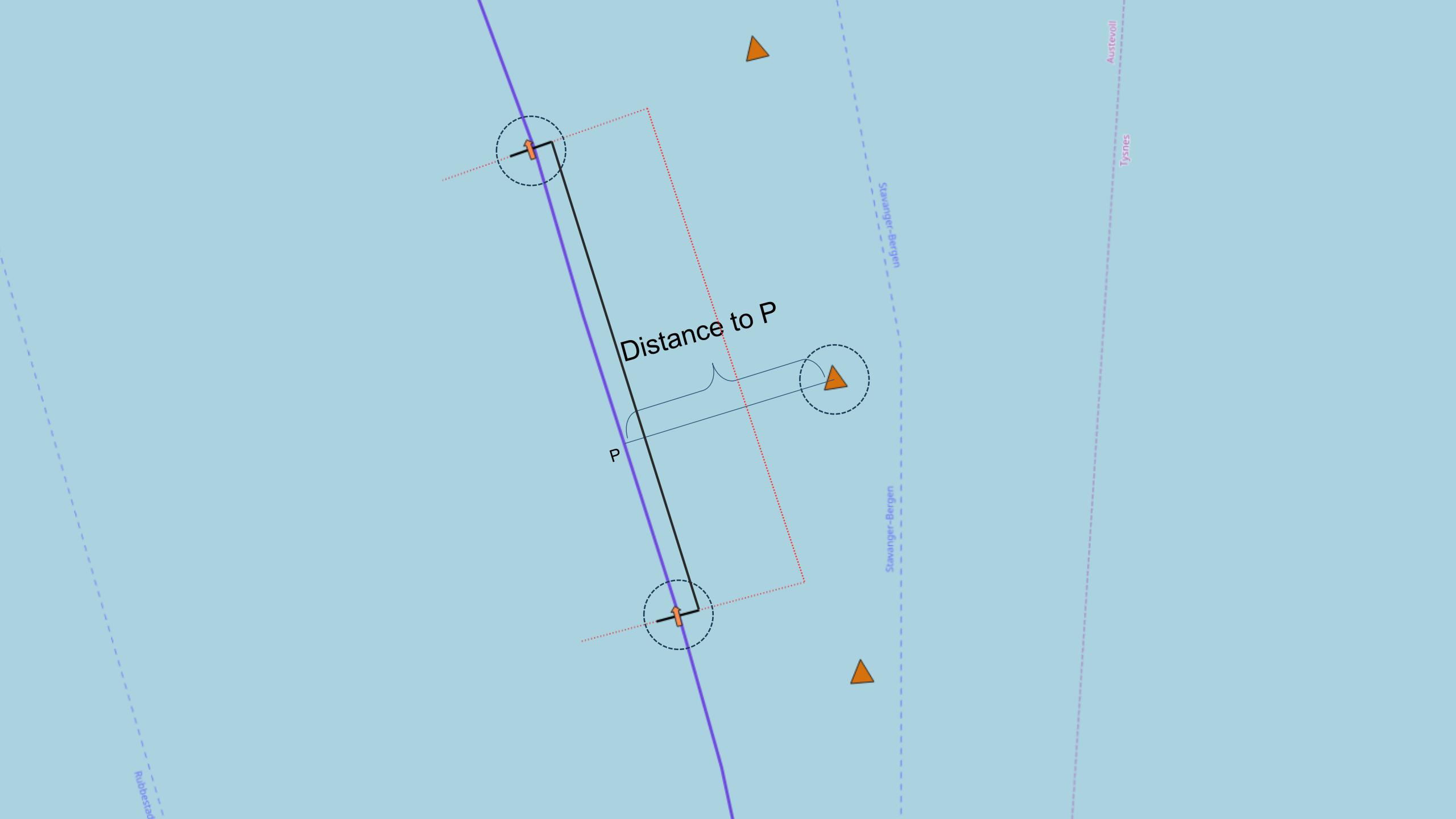
Anomaly Detection

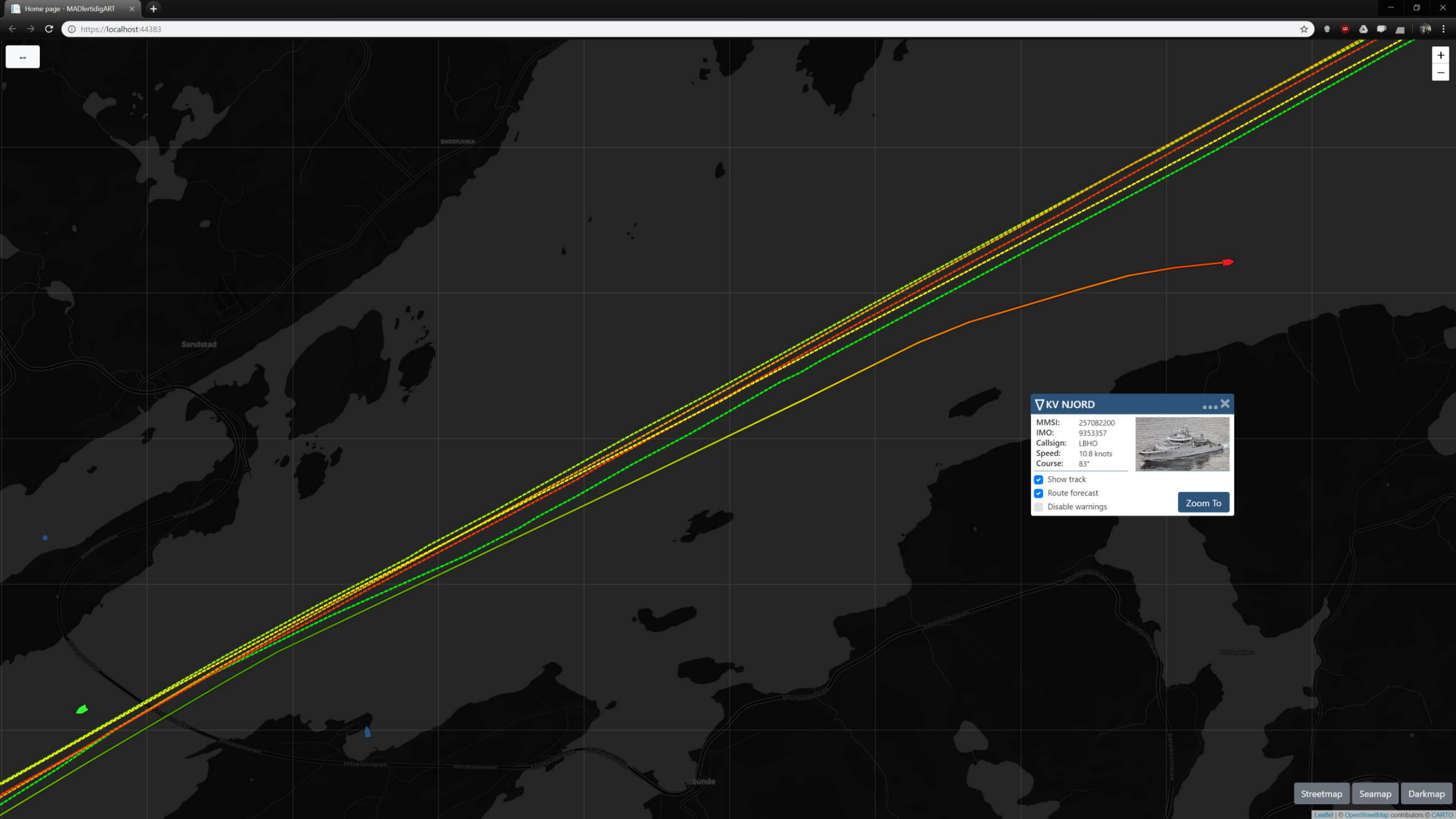
Anomaly Detection Process

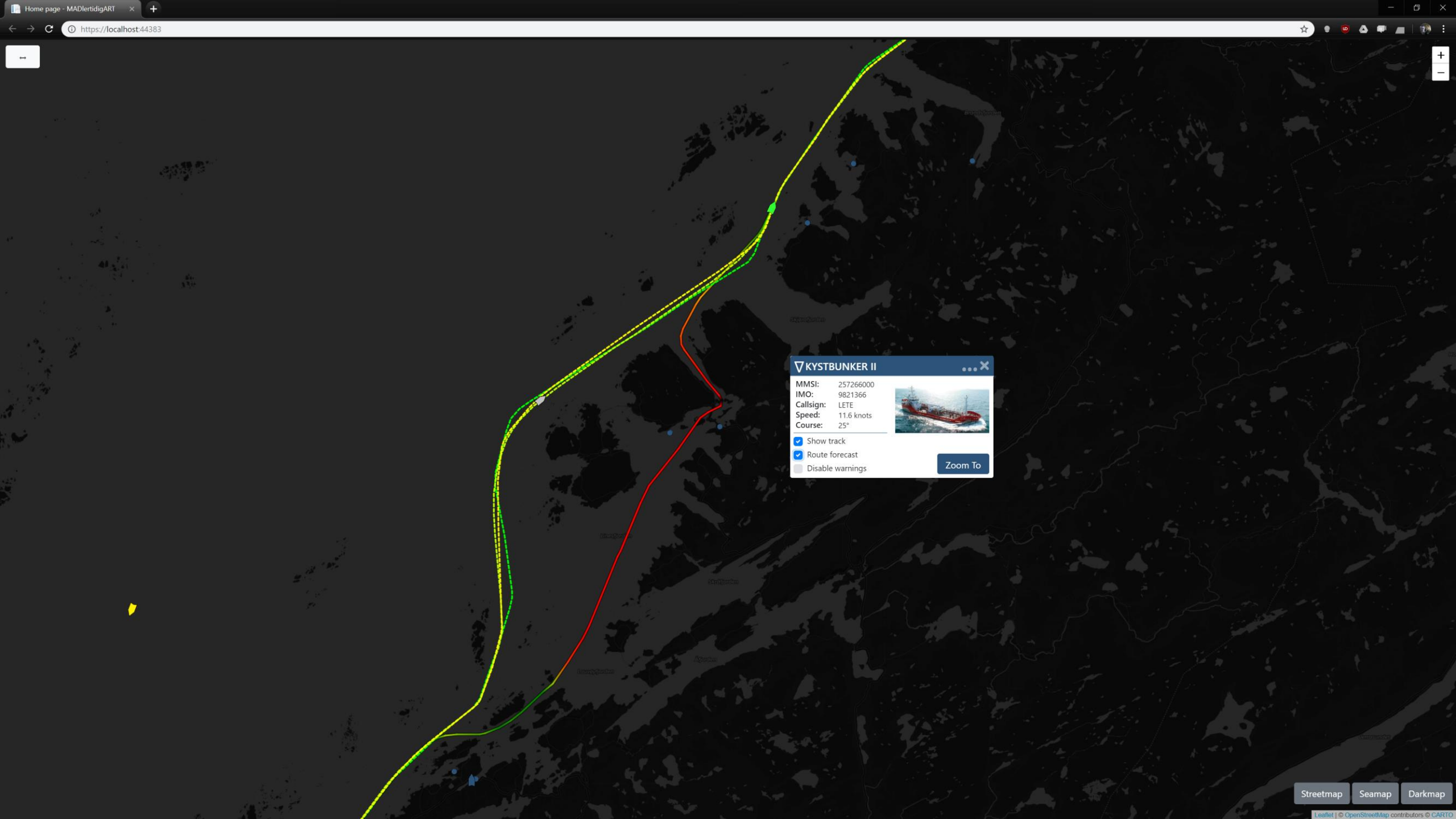


Deviation metrics:

- Distance (m)
- Relative multiples of standard deviations
- Relative multiples of max deviations


Distance to P
P
Stavanger-Bergen
Austevoll
Tysnes


Home page - MADIertidigART
https://localhost:44383
BADSTUVIKA
Sandstad
Hitratunnelen
Sunde
KV NJORD
MMSI: 257082200
IMO: 9353357
Callsign: LBHO
Speed: 10.8 knots
Course: 83°
Show track
Route forecast
Disable warnings
Zoom To
Streetmap
Seamap
Darkmap
Leaflet | © OpenStreetMap contributors © CARTO


Home page - MADlertidigART
https://localhost:44383
KYSTBUNKER II
MMSI: 257266000
IMO: 9821366
Callsign: LETE
Speed: 11.6 knots
Course: 25°
Show track
Route forecast
Disable warnings
Zoom To
Streetmap
Seamap
Darkmap
Leaflet | © OpenStreetMap contributors © CARTO

Applications for anomaly detection

Powered Grounding prediction

Illegal waste dumping

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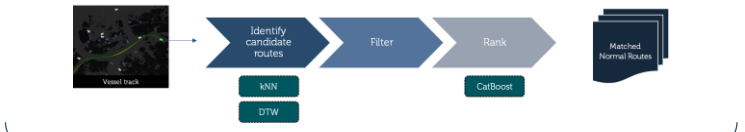
Powered Grounding Prediction

Powered Grounding Prediction Process



Destination prediction

Match closest gravity vectors

Spatial Query

Calculate deviation

Maths :/

Project geometric sector ahead of vessel

Spatial Query

Calculate distance to potential impact points

More maths :(

Home page - MADIertidigART

https://localhost:44383

Time to impact: 176sec
Distance to impact: 997.4m

VESTLAND

MMSI:	258295000
IMO:	9132038
Callsign:	LAVM7
Speed:	11 knots
Course:	340.9°

Show track
Route forecast
Disable warnings

Zoom To

Streetmap Seamap Darkmap

Leaflet | © OpenStreetMap contributors © CARTO

So.. you're saying that this combination of *machine learning*, *spatial analysis* and *maths* (☹) can warn us about ships that are about to run aground?
Exactly!

Applications for powered grounding prediction

Avert powered grounding incidents

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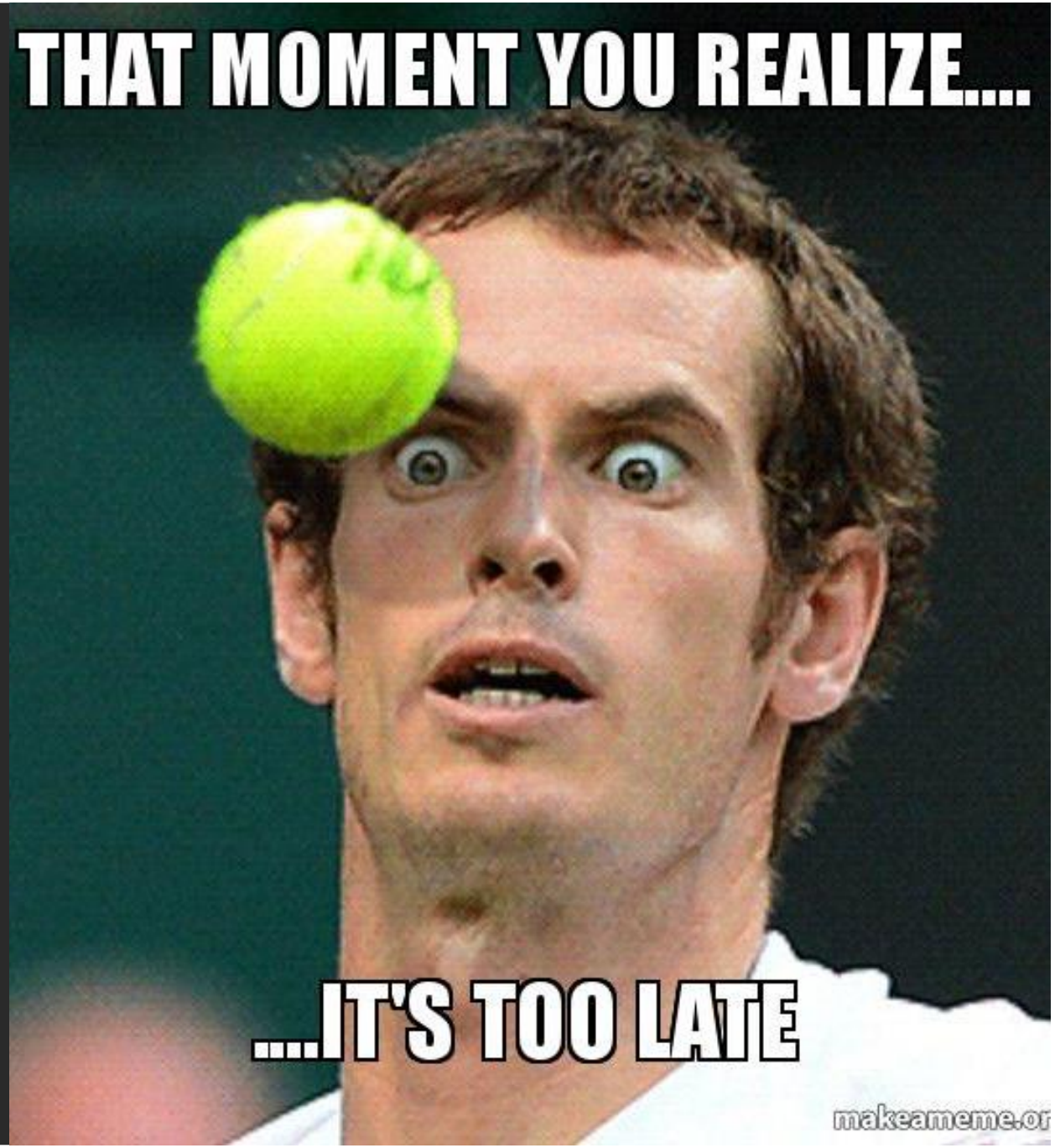
ETA Prediction



ETA Prediction

Normal Route

- Departure Port
- Arrival Port
- Linestring Geometry

Gravity Vector 01

Gravity Vector 02

Gravity Vector 03

Gravity Vector 04

...

Gravity Vector

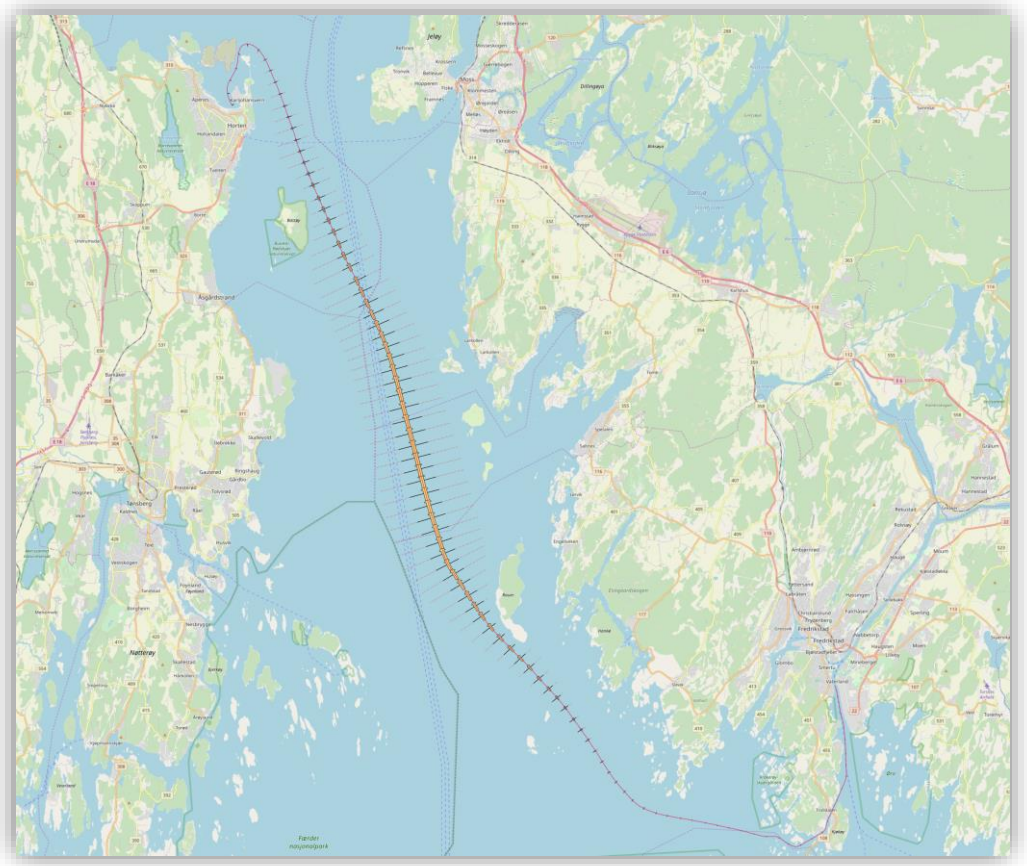
Position
- Average position (point geometry)
- Standard deviation port side
- Standard deviation starboard side
- Max. deviation port side
- Max. deviation starboard side

Speed
- Average speed
- Standard deviation
- Max. deviation

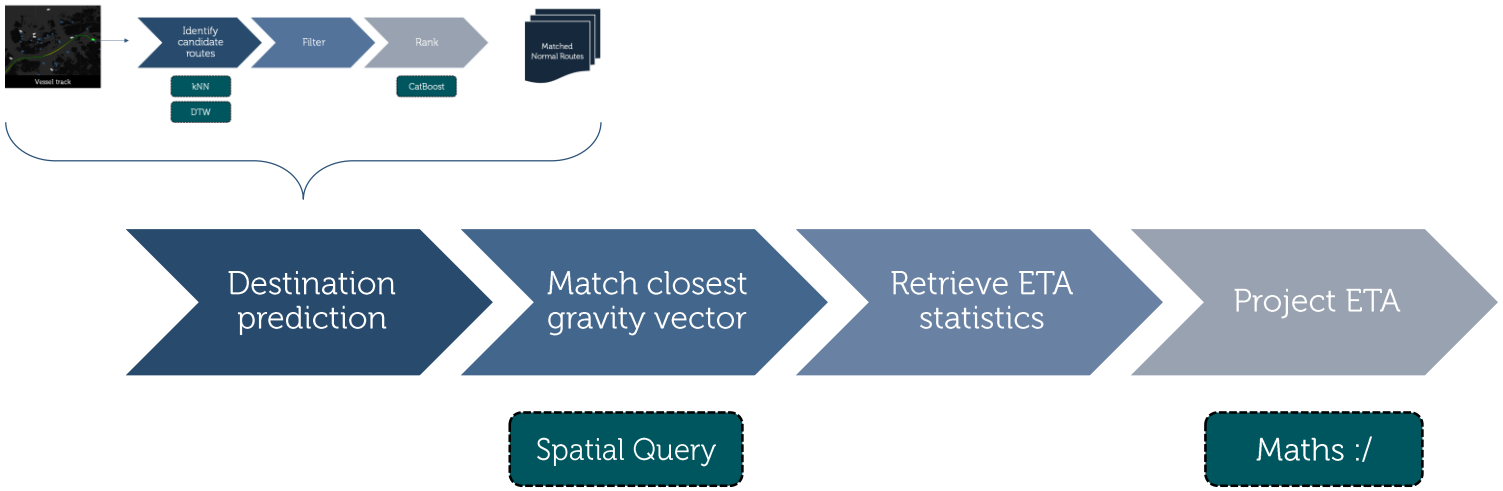
Course
- Average course
- Standard deviation
- Max. Deviation

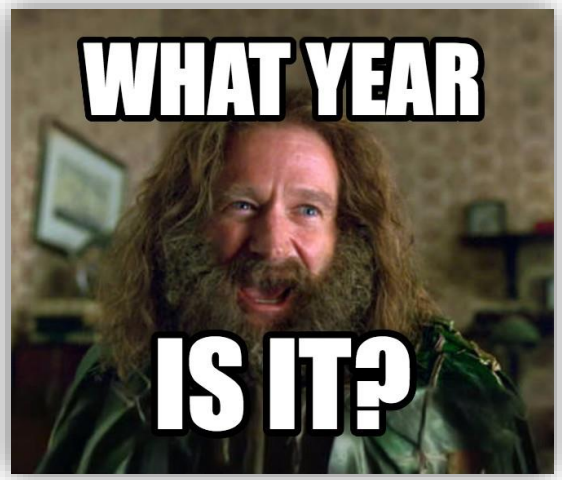
Time to arrival
- Average ETA
- Standard deviation

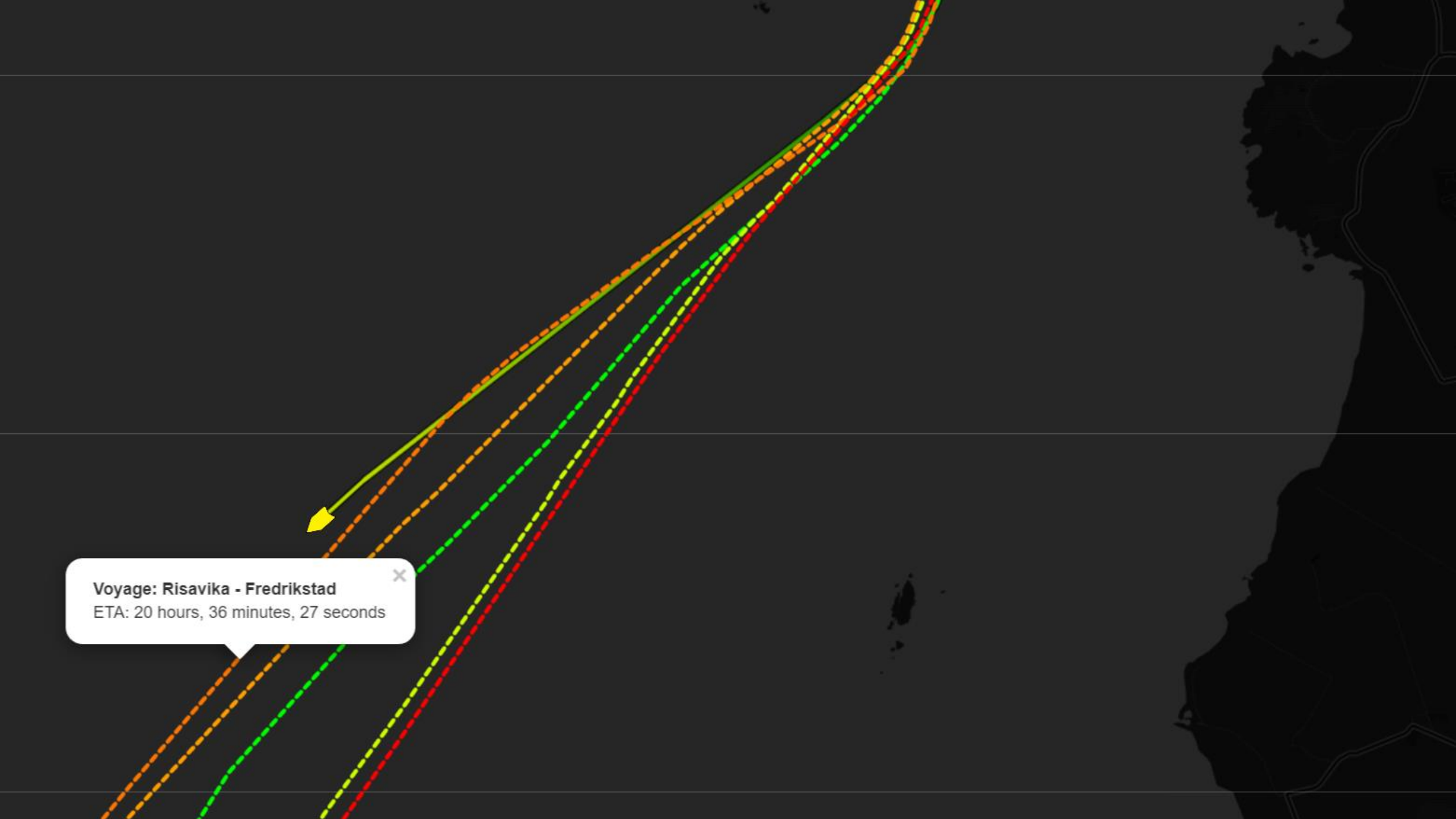
Traffic density



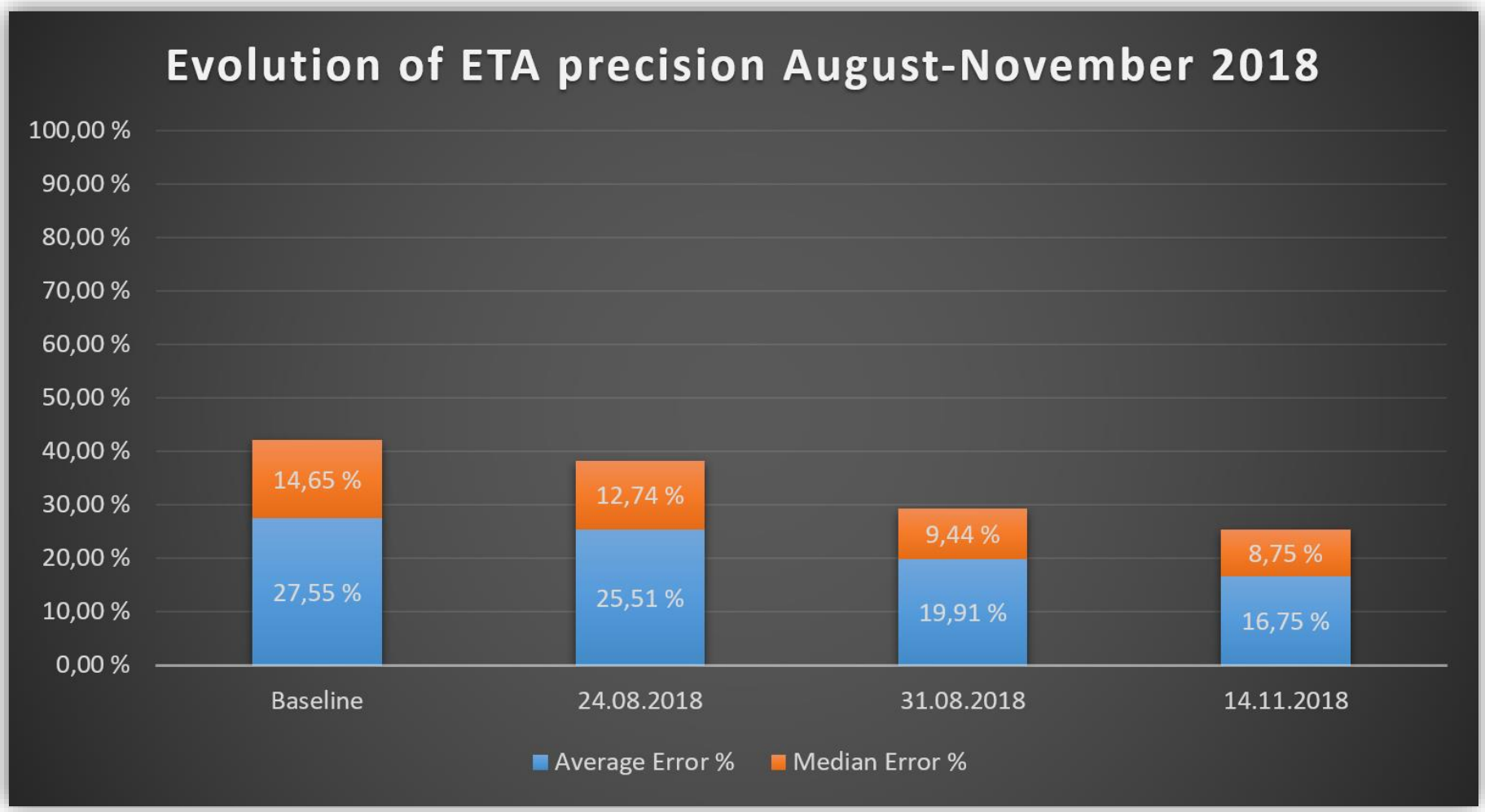
ETA Prediction Process






Voyage: Risavika - Fredrikstad
ETA: 20 hours, 36 minutes, 27 seconds

ETA Precision



Applications for ETA prediction

«Just in Time» arrivals (Ports)

Logistics planning (Ship owners)

Accurate reporting (Kystverket)

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Energy Consumption Prediction

Energy Consumption Prediction

Normal Route

- Departure Port
- Arrival Port
- Linestring Geometry

Gravity Vector 01

Gravity Vector 02

Gravity Vector 03

Gravity Vector 04

...

Gravity Vector

Position
- Average position (point geometry)
- Standard deviation port side
- Standard deviation starboard side
- Max. deviation port side
- Max. deviation starboard side

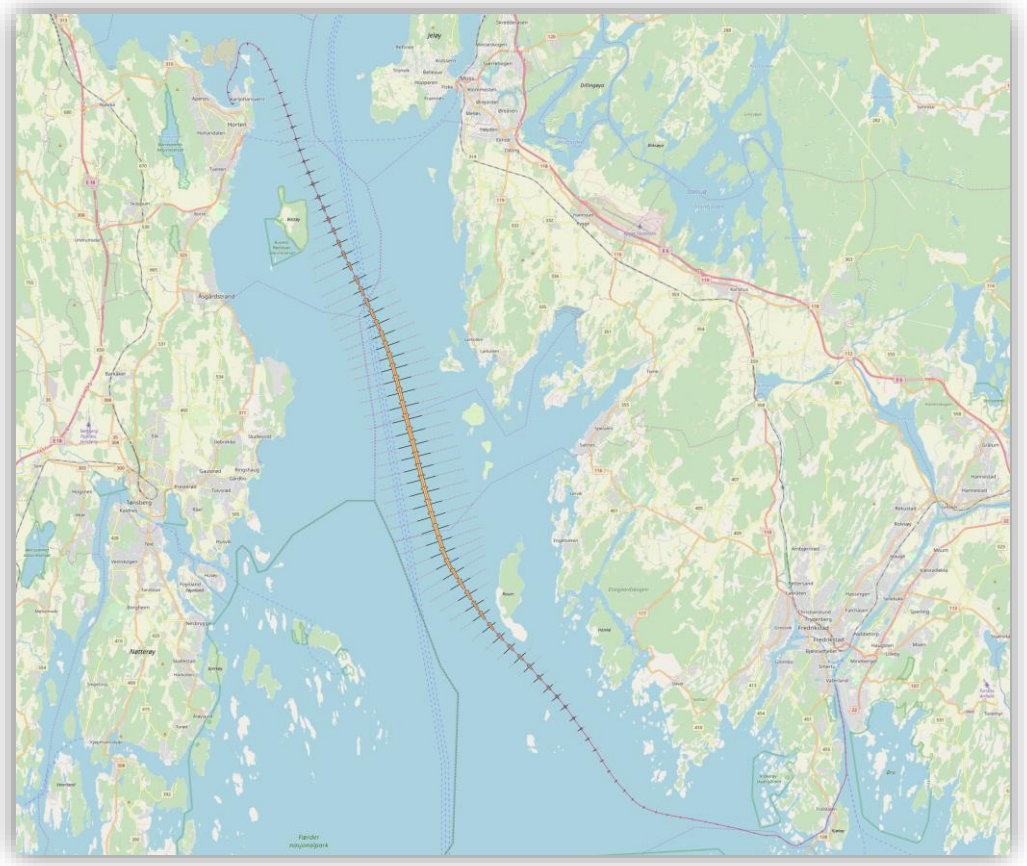
Speed
- Average speed
- Standard deviation
- Max. deviation

Course
- Average course
- Standard deviation
- Max. Deviation

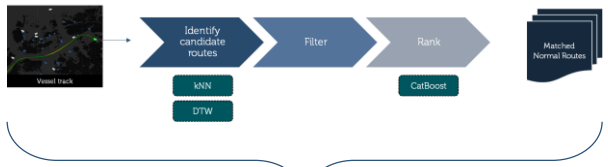
Time to arrival
- Average ETA
- Standard deviation

Energy Consumption
- Average energy consumption
- Standard deviation

Traffic density



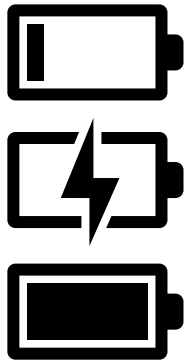
Energy Consumption Prediction Process



Destination prediction → Match closest gravity vector → Retrieve energy consumption statistics → Project energy consumption

Spatial Query

Maths :/

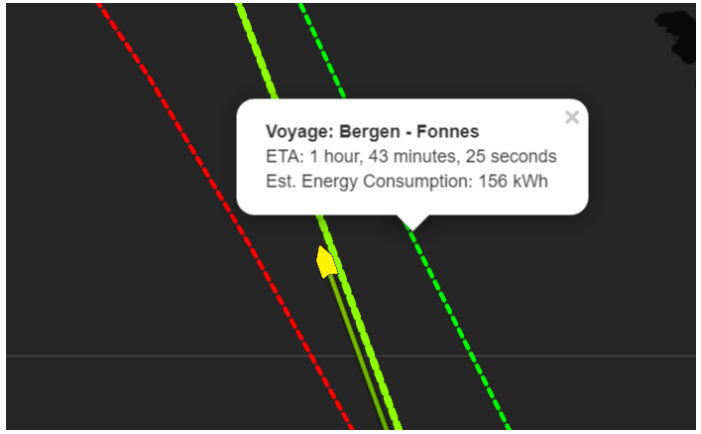


Applications for energy consumption prediction

Battery longevity

Energy planning

Generator fuel consumption estimation



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Questions!

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Thank you!

Feel free to send your anomalous vessel movements to
andreas.ravnestad@norconsult.com