Poznań University of Economics and Business
OFFIS Institute for Information Technology

MarTERA
HANSA

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Application of AI and In-memory Computing for Extracting Vessel Movement Patterns from Historical Data

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Costa Concordia Disaster

January 13th, 2012

Taken by Roberto Vongher, CC BY-SA 3.0, Wikimedia Commons

> Italian cruise ship Costa Concordia ran aground and overturned after striking an underwater rock off

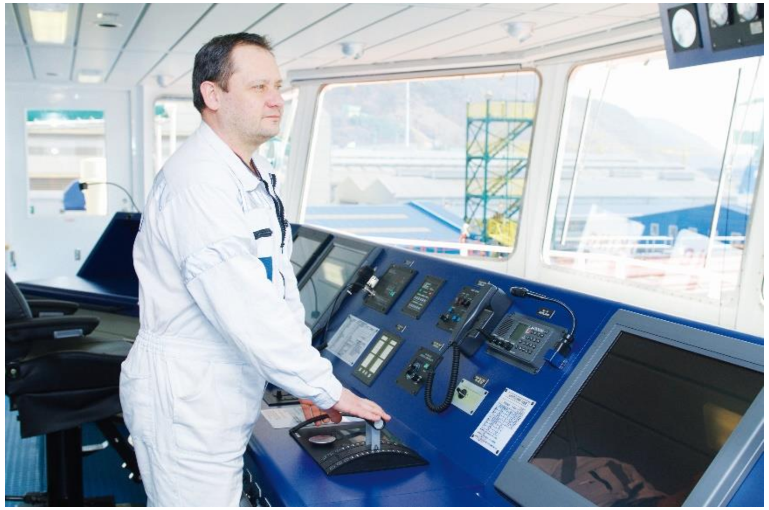
> 4,252 people on board, 32 deaths

> Total cost of the disaster estimated at approx. $2 billion (3x construction cost)

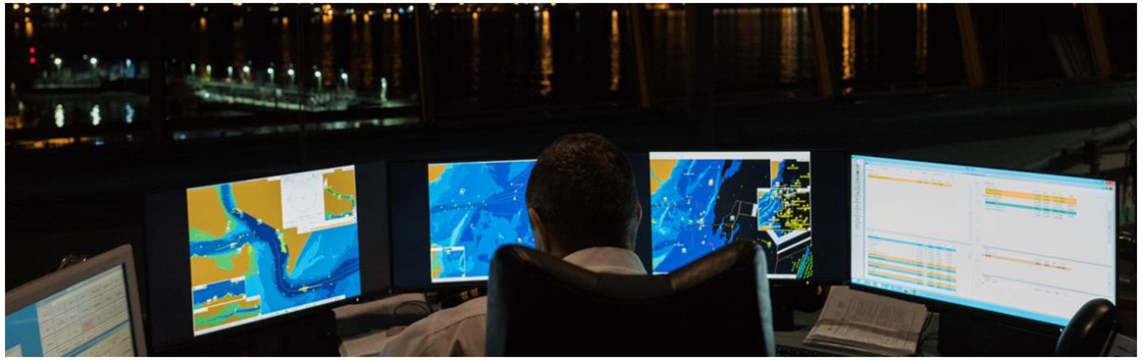
> Navigation by sight and experience

Working questions

On-board



On-shore

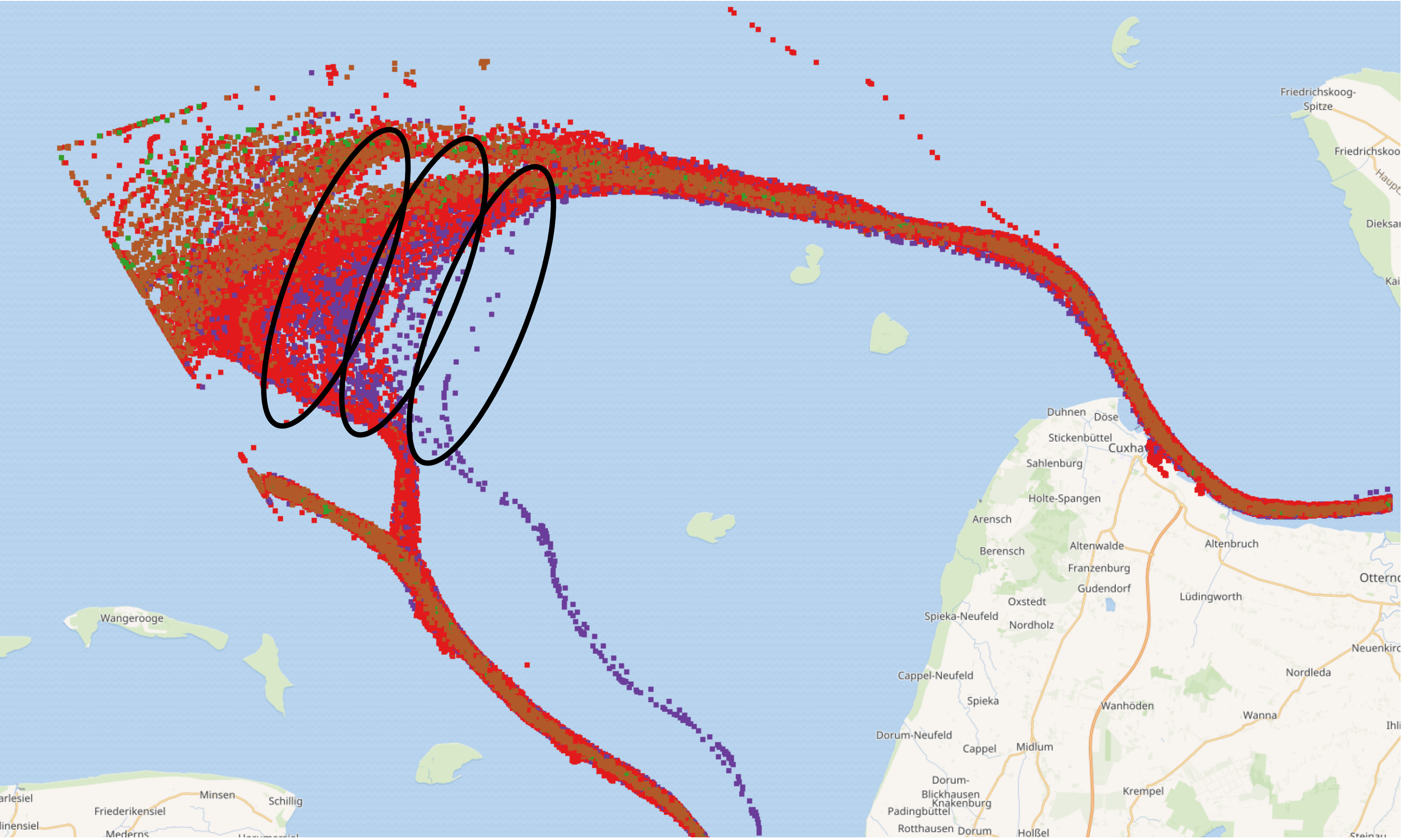


https://hha.co.uk/wp-content/uploads/2017/01/af_8-2400x750.png

> **Route checking functionality**
>
> > How can navigators be supported during route planning and monitoring to avoid unsafe waters?

> **Anomaly Detection**
>
> > How can potentially dangerous vessel behavior be automatically detected on-shore?

Concept of recommended routing corridor

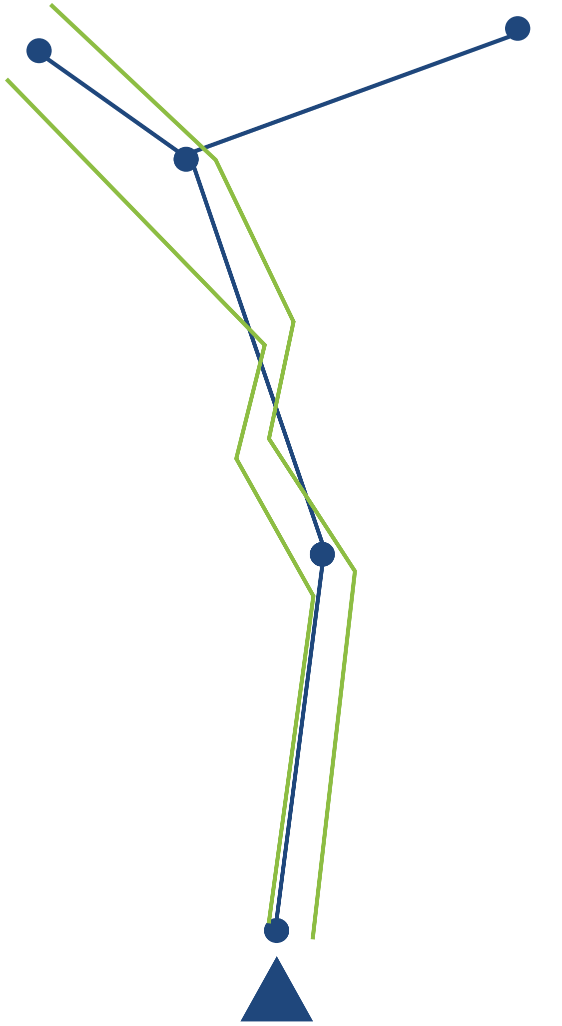


„A recommended corridor (RC) describes a safe route from a port of departure or ship position to destination. This corridor is most commonly used by ships with similar attributes (…) and under similar weather conditions (…).“

Also considers:

> *Direction of travelling/obligation to pass right*

Route Planning



Route checking functionality

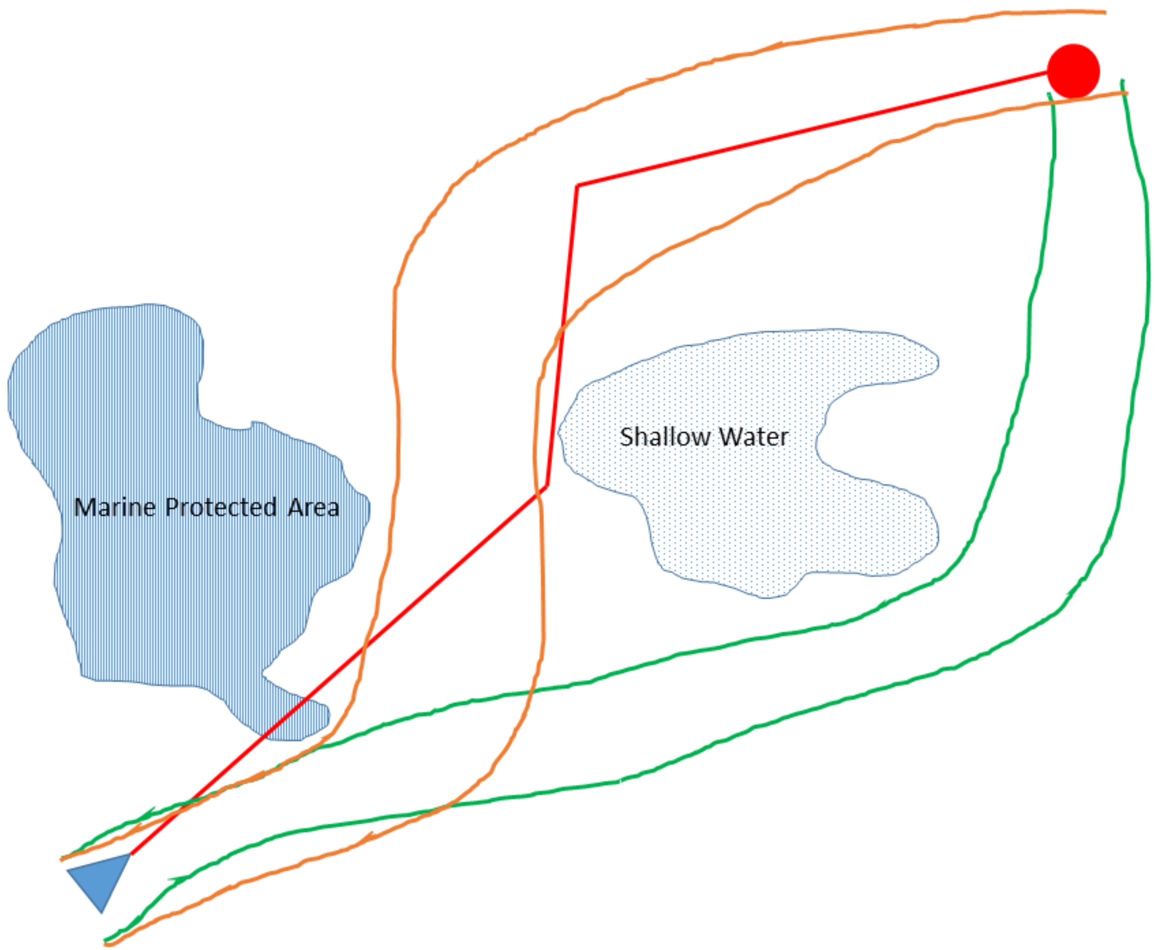
> Checks an intended route against where similar vessels have sailed in the past

> Considering vessel's attributes like type of vessel, draught or length

> Considering environmental influences like current or wind

Recommended Routing Corridor Concept → Data Preparation & Integration → Data Analysis and Anomaly Detection → System Integration and Demonstration → Exploitation

Concept of recommended routing corridor



Key:

Unsafe planned route

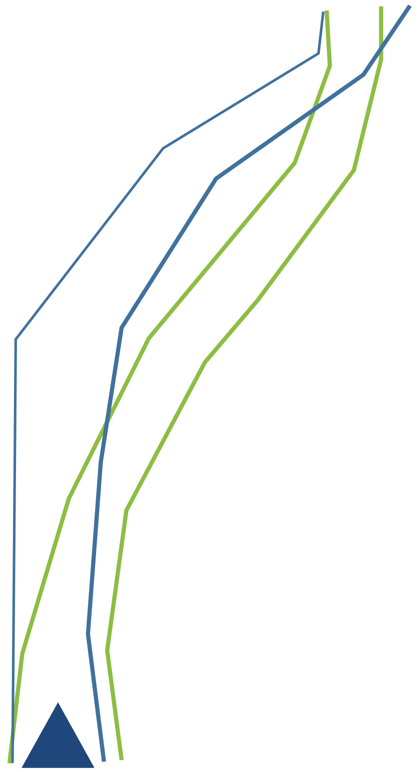
RC alternative 1

RC alternative 2

Anomaly Detection

Bad weather route

Good weather route



> Is the current vessel position inside the RC, recommended for the current weather conditions?

> Is the vessel faster/slower as usual?

Recommended Routing Corridor Concept → Data Preparation & Integration → Data Analysis and Anomaly Detection → System Integration and Demonstration → Exploitation

Why AI/machine learning is need

- huge volume and velocity of data
  - about 1 GB (gigabyte) of data daily
- classical operational research (OR) algorithms do not scale
  - time necessary to compute increases significantly when size of input increases
- more complex scenarios
  - calculations need to be repeated with additional constraints

The method for traffic patterns extraction

- **all possible routes represented as a mesh (a network)**
  - nodes
    - maneuvering points identified by CUSUM
    - then clustered using genetic algorithm (GA) -> waypoints
      - run on a partitioned data (k-d trees)
  - edges
    - nearest waypoints need to be identified for each AIS position
    - reconstruction based on trajectories
    - several filtering and quality methods implemented

* CUSUM – cumulative sum control chart, the method used in statistical quality control for change detection

Edge reconstruction - refinement

> **FILTERAIS**

  > selects a subset of data for a given vessel type (e.g. tanker) or weather conditions (e.g. heavy wind)

  > used to build a mesh from a subset of points, e.g. only important maneuver points as identified by CUSUM

> **FILTERTRAJECTORY**

  > the function is applied to trajectories of a ship

  > selects points fulfilling a condition in trajectories, e.g. only points that are sent within specific time period

> **FILTEREDGES**

  > select edges fulfilling a condition, e.g. can filter out edges that are too long (e.g. distance > 100 Nm) or are very rare (e.g. followed by only a single ship)

Scope of data

Historical vessel movements

> AIS* data from 2017 to 2018
>
> geographical coverage: the German Bight and the Baltic Sea

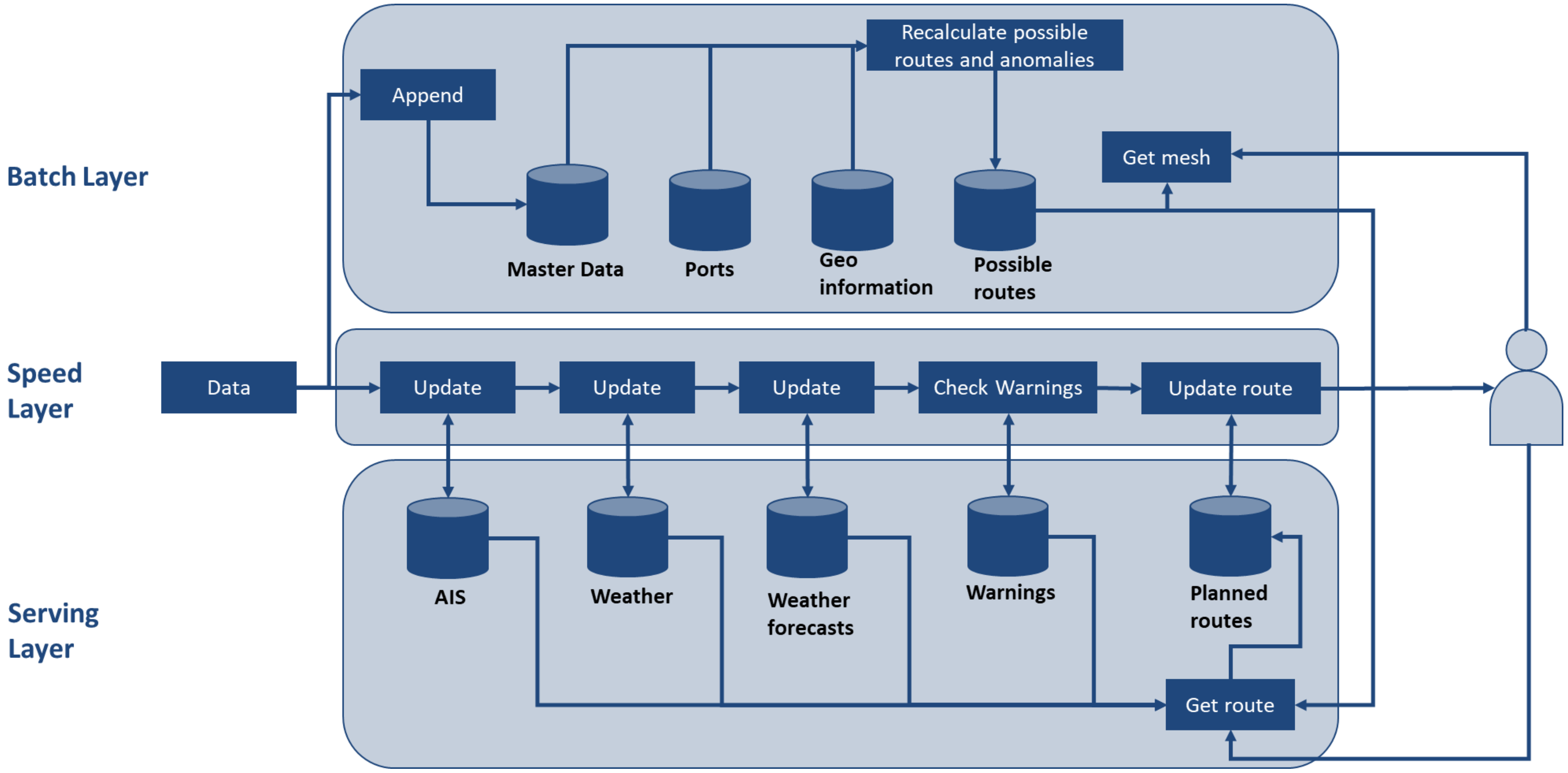
Weather data

> sea weather data obtained from Copernicus

* AIS – Automatic Identification System, used by vessels to report their positions, originally used for collision avoidance

System architecture

- > Pattern extraction is costly
- > Patterns can change as soon as new data is available
- > Request must be answered within seconds
- > Lambda Architecture - a *data processing architecture* to separate slow operations (pattern extraction) from current requests



Implementation

- Apache Spark for calculations
  - Spark is a unified analytics engine for big data processing
- Python as an implementation language
  - PySpark (implementation of Spark in Python)
  - k-nearest neighbour (kNN) from scikit-learn
  - optimization based on user-defined functions (Pandas UDF)
- performance:
  - good implementation decisions can result in performance 100,000x faster than naïve solutions

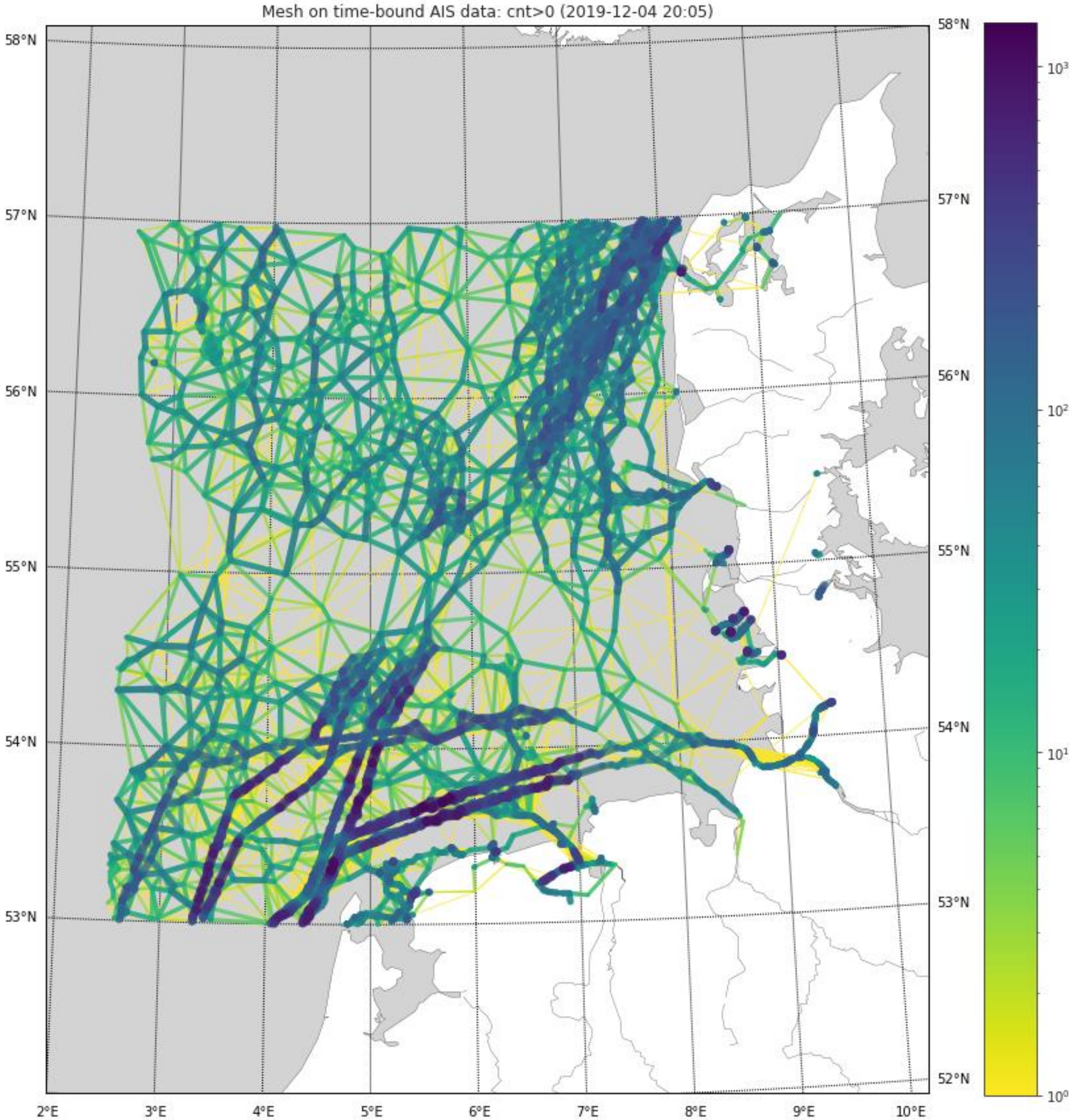
Method	Throughput (rows/s)
kNN, iteration over RDD with flatMap	7.3
kNN, with UDF	399
Brute-force search, with UDF	16,508
kNN Minkowski, with Pandas UDF	1,517,969
kNN haversine, with Pandas UDF	824

Results

> edges generated from about 1.5 million notifications of vessel positions

> the darker the edge, the more vessels travelled between the nodes

> number of edges in this example: 156,103



Summary

> predictive voyage planning as a prerequisite for safe and efficient vessel operations
> recommended corridor (RC) - the method for representing the context-sensitive vessel movement patterns
> mesh – generated on real historical AIS data
> significant work devoted to improving performance
> potential for on-board and on-shore operators

Acknowledgement

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