



VesselAI Synergy and Contributions to the AloD Platform

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AIoD TCB Meeting

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- 1. Overview of the VesselAI project**
- 2. VesselAI and AloD synergies**
- 3. VesselAI contributions on the AloD Platform**
 - **AI Assets Catalog**
 - **AI4Experiments Platform**

VesselAI Fact sheet

VesselAI	Enabling Maritime Digitalisation by extreme-scale analytics, AI and Digital Twins
Project Number	957237
Starting Date	01/01/2021
Project Duration	36 months
Call (part) Identifier	H2020-EU.2.1.1. Leadership in enabling and industrial technologies - ICT
Topic	ICT-51-2020 - Big Data technologies and extreme-scale analytics - Research and Innovation action
Budget	€ 5.998.877,50 (Funding: 100%)

The VesselAI Consortium is strong and diverse



6 pilot partners pioneers in the maritime technology and intelligence

7 technical partners with expertise in:

- Data engineering and analytics
- HPC technologies and AI acceleration hardware
- Artificial Intelligence



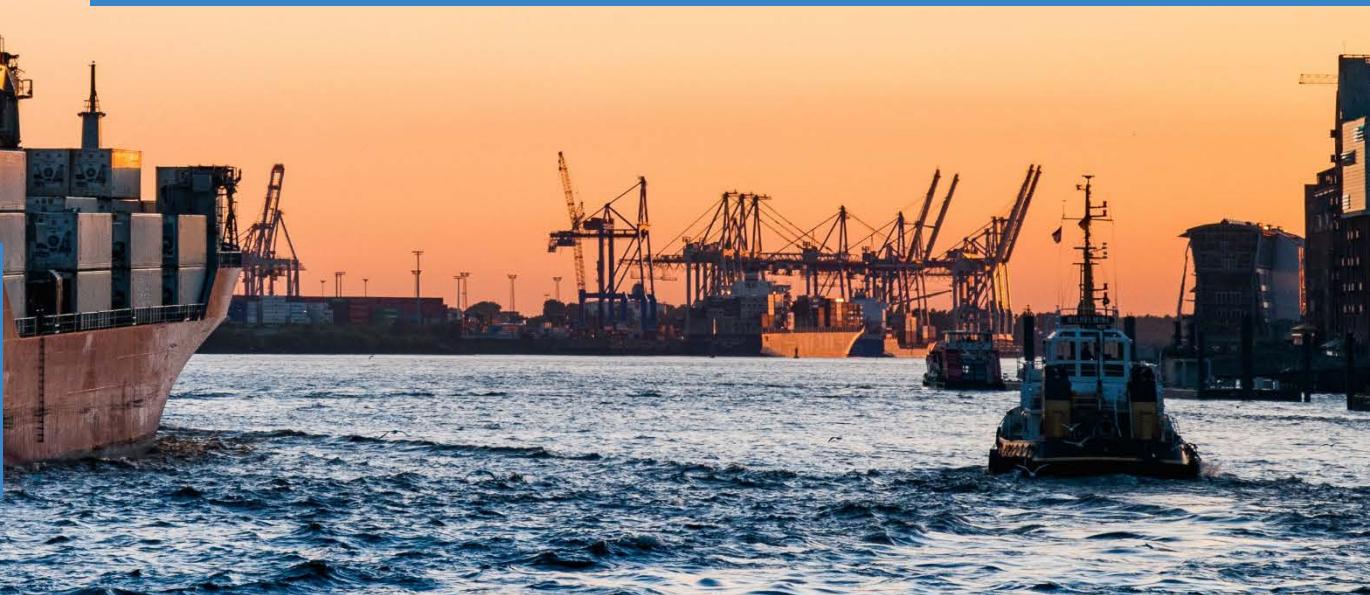
**Artificial Intelligence, HPC and Big Data
in the forefront of Maritime digital transformation**

23,000 incidents with a ship were recorded in European territorial seas 2011-2018 (EMSA)
65.8% was attributed to human error



Shipping emissions are projected to increase by 50% to 250% by 2050

Shipping emits around 940 million tonnes of CO2 annually
= about 2.5% of global greenhouse gas (GHG) emissions
(IMO GHG study)



Significant Challenges for the Maritime Industry in 2023

Business challenges

- Big players got bigger, smaller are squeezed out (covid-19 aftermath)
- Lack of experienced personnel
- Embracing Technology
- Congestion at the ports and slowing down the shipping process.
- Increased delivery time, higher shipping rates



Energy Crisis

- Russia-Ukraine war has boosted the high prices of oil and gas
- Chartering fuels into Europe is crucial in filling gaps in both petroleum and maritime fuel supply chains.
- Maritime Fueling Innovation is required

Climate crisis

- Russia-Ukraine conflict is ongoing and derails the Climate Agenda
- Shipping industry faces new standards on carbon emissions from 2023
- IMO target of a 40% reduction in carbon emissions — compared to 2008 levels — by 2030



Distributed and extreme-scale data processing

e.g.Hadoop, in-memory DBs, Streaming SQL, parallel processing



Machine and Deep Learning Reinforcement Learning

e.g.ANN, CNN, RNN, secure, federated learning, AutoML



HPC and AI Computing

e.g.HPC-AI convergence, TPUs, Neuromorphic Processors



Untapped opportunities for a diverse range of current maritime applications

- Vessel traffic monitoring and management
- Ship energy system design and operation
- Autonomous shipping
- Fleet intelligence
- Route optimization
- Fuel consumption
- Predictive Maintenance

Key Challenges

- **Integrating physics-based and data-driven simulations**, using state-of-the-art analytics, machine learning models (ML) and HPC technologies **for the next-generation Digital Twins**
- **Efficient ingestion, cleansing, and enrichment of extreme-scale** data sets (e.g., video streaming) from different sources is a complex and resource-intensive process
- Complexity and accuracy of **creating, training, validating and deploying** AI models for heterogeneous and large-scale requirements
- Unexploited opportunities have arisen for **enhancing HPC architectures with AI-acceleration** that would be key for Maritime Industry use cases

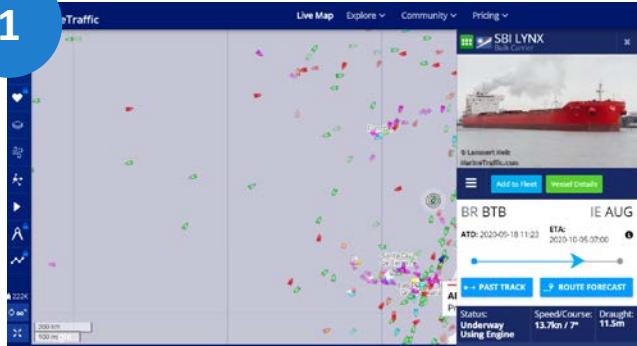
VesselAI Vision

Develop, validate and demonstrate a novel holistic framework based on a combination of the state-of-the-art **HPC, Big Data and AI technologies**,

capable of **performing extreme-scale and distributed analytics for fueling the next-generation digital twins** and maritime applications, including:

- vessel motion and behavior modelling analysis and prediction,
- ship energy system design and optimisation
- unmanned vessels
- route optimisation
- fleet intelligence

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Ship Modelling for global vessel traffic monitoring and management



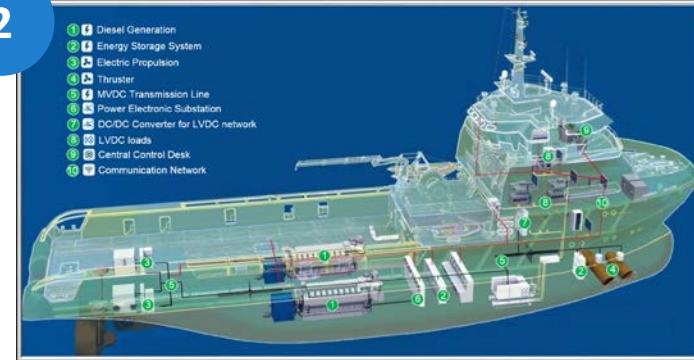
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Autonomous ships in short sea transport



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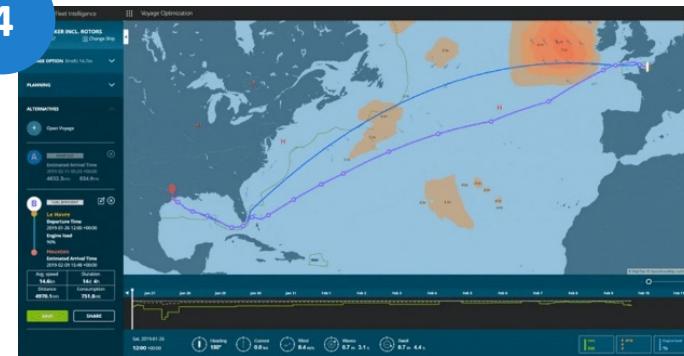


Globally Optimal Design of Ship Energy Systems



VesselAI Pilot Cases

4



Weather Routing and Fleet Intelligence Service in Shipping



AI Services

A suite of pre-trained AI models and services for the Maritime Sector.



Business Cases

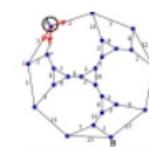
A showcase of our innovative AI solutions for the Maritime Industry.



A suite of pre-trained AI models and services for the Maritime Sector.

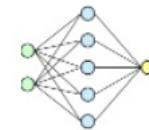
AI Services

The VesselAI platform offers a variety of services



Route Forecasting (Clustering & Graph Theory)

This functionality aims at effectively forecasting vessels' future locations by accurately discovering representative tracks (common paths followed by several vessels). The technique that is used works by receiving as input the current location of a particular vessel along with its destination port and forecasts the path that the vessel will follow till its arrival at the destination port.



Route Forecasting (ANNs)

This service tackles the problem of Vessel Route Forecasting (VRF), i.e. the prediction of the anticipated locations of a vessel taking into account its own and the population's motion history, by using Neural Networks (NNs), which can leverage from the "explosion" of vessel surveillance information.



Flow Forecasting

This service tackles the problem of Vessel Traffic Flow Forecasting (VTFF), i.e. forecasting the number of vessels in a specific sea area and time period, by applying grid-based analysis over traffic flow sequences and/or future vessel locations predicted by VRF techniques.





A showcase of our innovative AI solutions for the Maritime Industry.

Business Cases

The VesselAI platform offers a variety of services



MarineTraffic Global Route Forecasting

This use case is related to the forecasting of the route for one or more vessels using the VesselAI services, while visualizing the outcome of the prediction (predicted trajectory) through the MT platform user interface. This test cases ensures that the user is able to get accurate forecasted route for a specific vessel or a set of vessels or even the current and the predicted traffic of an area (port area or open sea area).



MarineTraffic Collision Detection

This use case focuses on validating that the user is able to be notified in time for potential vessel collisions by leveraging accurate vessel route predictions of the first use case of MT.



Ship Energy System Conceptual Design Optimisation

The aim of the pilot is to develop an HPC-powered energy system design and operation platform to automate the ship energy system conceptual design process, with dynamic simulation and optimization in the loop of the decision-support process.



 Home AI Services Business Cases Data Analytics Advanced Tools My Profile Sign OutDashboard > Services > **Data Analytics**

Data Analytic tools to explore and visualize data, experiment with models and create AI pipelines.

Data Analytics

The VesselAI platform offers a variety of services



Visualise Data / Create Reports

This module is responsible for the visual representation of the stored data and the results produced from the analytical components, including model's efficiency and explainability.



Queries Interface to MonetDB / Presto

This service enables users to perform queries against the VesselAI storage.

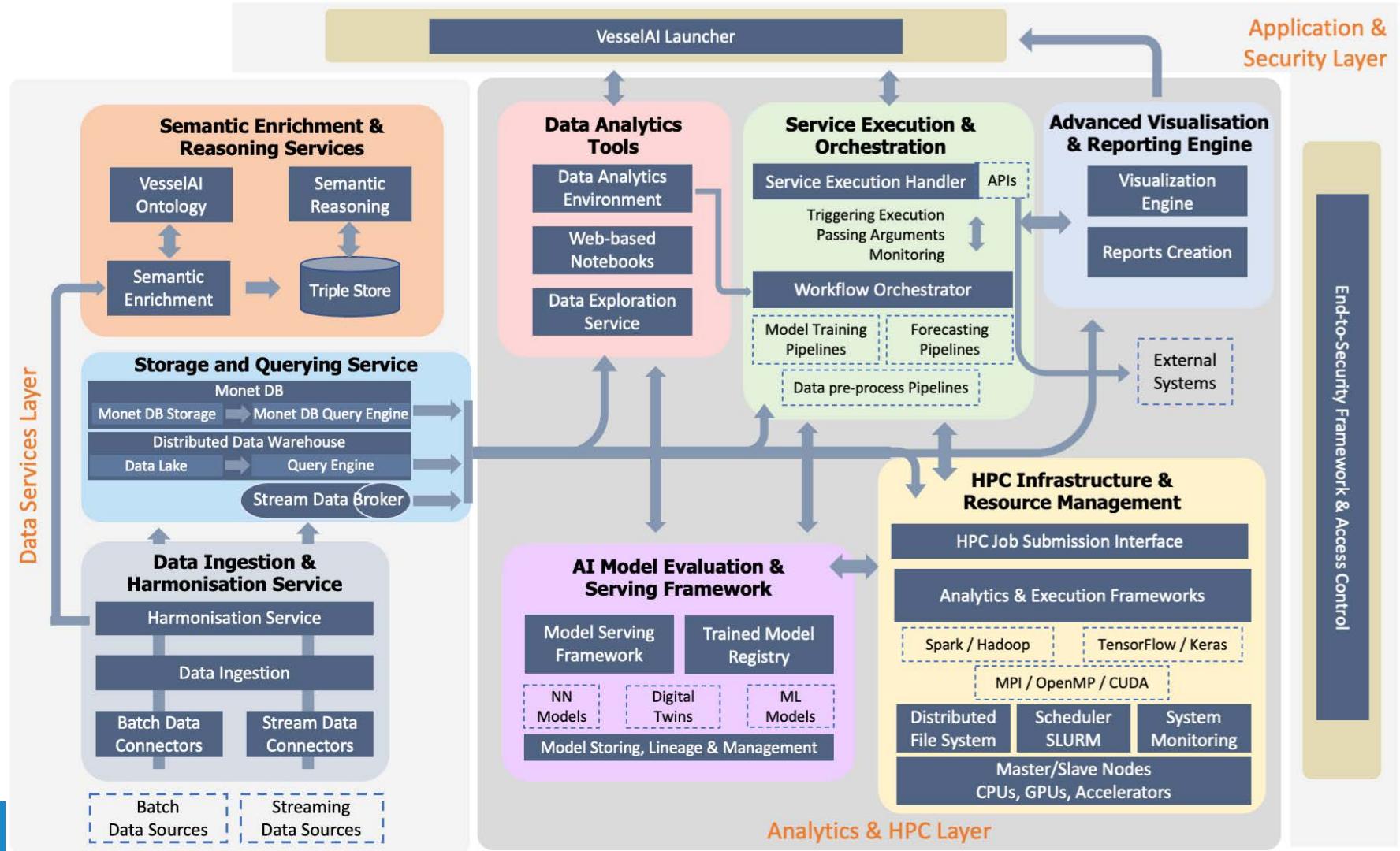


SPARQL / Reasoning Service

This service enables the ability for users to perform semantic queries and reasoning.



VesselAI Architecture



VesselAI Tools / Assets

- VesselAI Launcher
- AI Model Evaluation & Serving Framework (MLflow – Minio)
- Advanced Visualisation & Reporting Engine (Superset, NTUA's Visualiser)
- Service Execution & Orchestration (Airflow, Service Execution Handler)
- Big Data Warehouse (Minio, Hive, Trino)
- Data Analytics Environment
- Security Framework (Keycloak, Security Enabler)
- Data Ingestion and Harmonisation Service
- Stream Broker (Kafka, KafkaDrop)
- Monet DB
- Semantic Enrichment Service (RDFgen)
- Triplestore
- Reasoning Engine (stLD, CEP)
- Data Exploration Service
- Jupyter Notebook

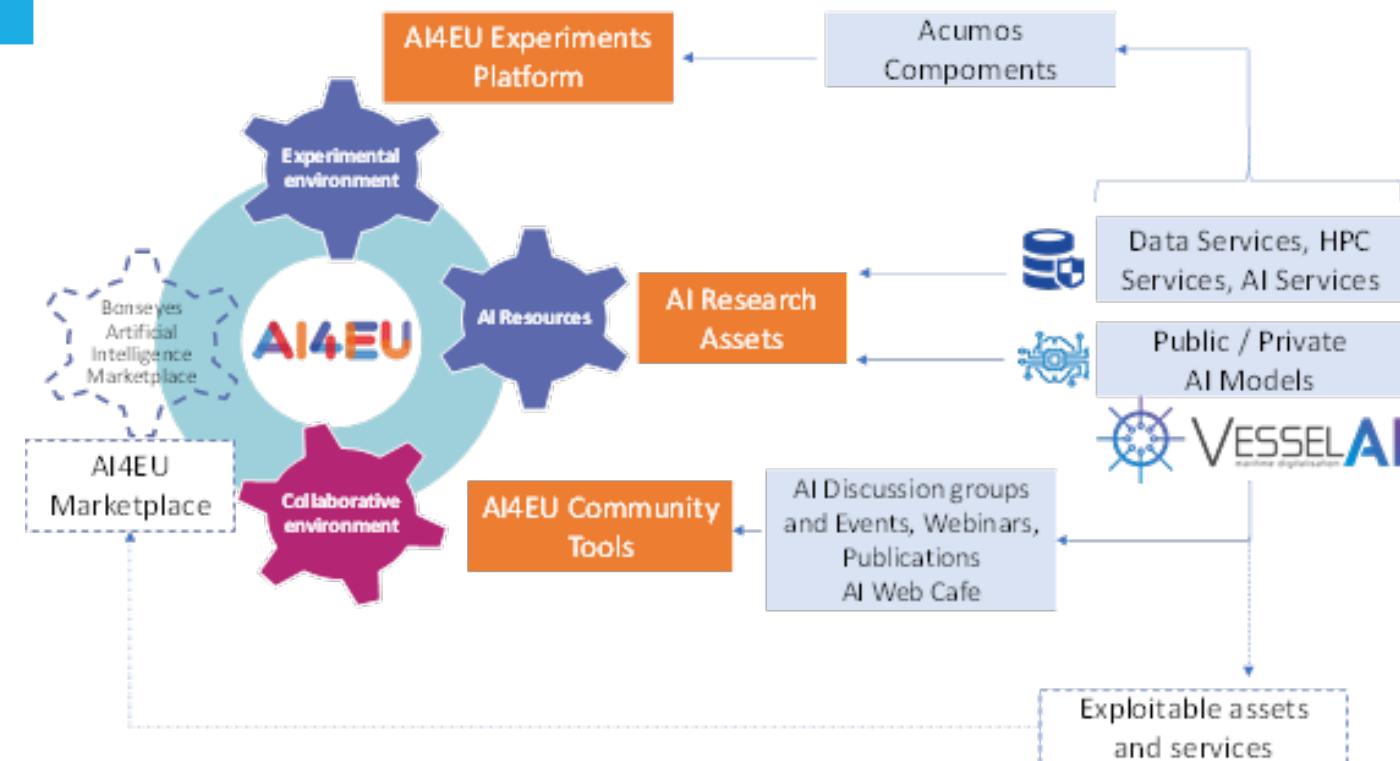
Synergies with AloD

- Enrichment of AloD platform with VesselAI assets (especially for the Maritime Sector section of the AloD Platform)
 - Datasets
 - AI models
 - Developed Tools and frameworks (ingestion, training, serving, HPC, data exploration and visualization), optimized for maritime use cases and beyond
- Networking / Dissemination – VesselAI aims to be a very active member of AloD community
- Synergies for AI ethics / TrustworthyAI (in sync with I-NERGY and ICT-49)
- Synergies for AIOD Exploitation

VesselAI Contributions on AloD

Before making contributions

- Explored AloD (then AI4EU) platform offerings – *purpose and implementation of AI Assets Catalog, AI4Experiments*
- Elicited and provided specifications for publishing and onboarding VesselAI ecosystem, assets and services onto the AIOD platform
- Identified a set of VesselAI assets to enrich the AIOD platform



- ✓ *Maritime Sector added as a business category on the platform*
- ✓ *D4.1 Specification of the AI-on-demand Platform Extensions and Research Activities – V1.00*
- ✓ *D4.2 Specification of the AI-on-demand Platform Extensions and Research Activities – V2.00*

VesselAI contributions on AloD

- VesselAI project and ecosystem

The screenshot shows the VesselAI project page on the AI on Demand platform. The top navigation bar includes links for Discover, Use, Learn, Contribute, About, and a search bar. The main content area features the VesselAI logo and the text: "Enabling Maritime Digitalisation by extreme-scale analytics, AI and Digital Twins". A description states: "VesselAI aims at realising a holistic, beyond the state-of-the-art AI-empowered framework for decision-support models, data analytics and visualisations to build digital twins and maritime applications for a diverse set of cases with high impact, including simulating and predicting vessel behaviour and manoeuvring (including the human factor), ship energy design optimisation, autonomous shipping and fleet intelligence". Below this is a "Funding Call" section with a link to the EC funding opportunity portal. The "Business Categories" section lists "Maritime Sector" with a date range from 01.01.2021 to 31.12.2023. At the bottom, there is a logo for VesselAI and a link to their website: vessel-ai.eu.

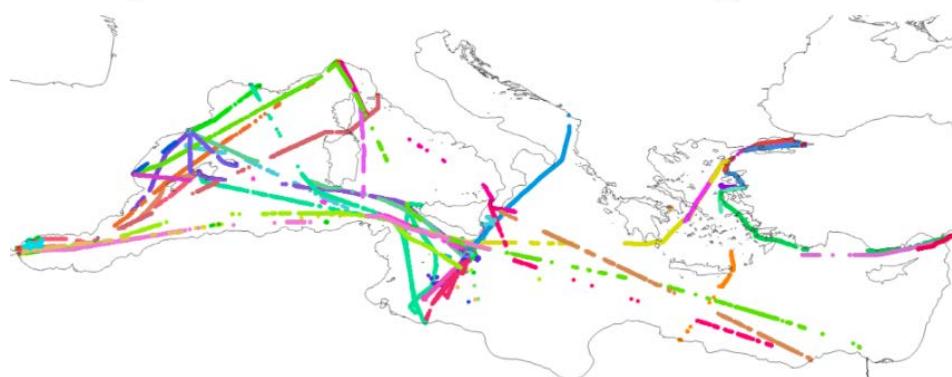
The screenshot shows a list of assets related to the VesselAI project. The top navigation bar is identical to the VesselAI project page. The main content area is titled "Assets related to VesselAI" and includes a filter bar with options like -All-, AI Assets, Case Study, Education, Event, News, Open Calls, and Organization. The list includes:

- EPU N.T.U.A.** Decision Support Systems Laboratory - National Technical University of Athens. Includes tags: AI ethics, AI services, Automated reasoning, Computer vision, Constraints and satisfiability, Machine learning, Optimisation, Planning and scheduling, Agriculture, Cloud, Edge and Infrastructure, Energy, Healthcare, Manufacturing, Maritime Sector, Public Services, Education Institution. Read more.
- University of Helsinki**. Includes tags: AI services, Machine learning, Education Institution. Read more.
- NAPA Group (Napa Ltd)**. Includes tags: Machine learning, Optimisation, Maritime Sector, Company. Read more.
- VTT**. Includes tags: AI ethics, AI services, Computer vision, Connected and automated vehicles, Machine learning, Natural language processing, Optimisation, Planning and scheduling, Robotics and automation, Agriculture, Cloud, Edge and Infrastructure, Earth Observation, Energy, Healthcare, Manufacturing, Maritime Sector, Public Services, Telecommunications, Transportation, Research Institution. Read more.
- MarineTraffic**. Includes tags: AI services, Automated reasoning, Computer vision, Connected and automated vehicles, Knowledge Representation, Machine learning, Multi-agent systems, Maritime Sector, Transportation, Company. Read more.
- University of Piraeus Research Centre (UPRC) - Data Science Lab (DataStories)**. Includes tags: AI services, Knowledge Representation, Machine learning, Optimisation, Education Institution. Read more.

VesselAI contributions on AI Assets Catalog

- Maritime Datasets

- Currently links to 2 public Automatic Identification System (AIS) datasets provided by MT
 - More to be added by UPRC
- AIS allows vessels to broadcast their identification information, characteristics and destination, along with other information originating from on-board devices and sensors, e.g. location, speed and heading
- AIS messages are broadcast periodically and can be received by other vessels equipped with AIS transceivers, as well as by on-the-ground or satellite-based sensors



1

Temporal Coverage: 1/04/2015-28/04/2015
Spatial Coverage: Mediterranean Sea

2

Temporal Coverage: 24h period (starting from 29/02/2020 10PM UTC)
Spatial Coverage: single receiver located near port of Piraeus (Greece)

AI models of VesselAI

Vessel Route/Traffic Forecasting	Vessel Traffic	Shore Control Decision Support in Oslo Fjord	Ship Design Optimization	Route planning	CO ₂ Emission, Fuel consumption
<p>Long route (MT)</p> <ul style="list-style-type: none"> • EnvCLUS, EnvCLUS* – clustering and graph theory <p>Short route (UPRC)</p> <ul style="list-style-type: none"> • VRF – ANN 	<ul style="list-style-type: none"> • Traffic Flow (UPRC) <ul style="list-style-type: none"> • VTFF — VRF & ANN • MaSEC • Vessel Traffic Density (UNINOVA) 	<p>Route prediction (SINOCE, SINTEF, KNC)</p> <ul style="list-style-type: none"> • Route clustering – DBSCAN • Route forecasting – Autoregressive RNN <p>Anomaly Detection (SINTEF, SINOCE, KNC)</p> <p>Collision Risk Assessment (UPRC)</p> <ul style="list-style-type: none"> • VCRA – ANN 	<p>Ship energy system performance (VTT)</p> <ul style="list-style-type: none"> • Surrogate models to provide an estimate of objective value – Gaussian process regression models (full/sparse variational, variational nearest neighbour) <p>Ship Engine information (VTT)</p> <ul style="list-style-type: none"> • Information extraction from PDF - keyword matching, clustering & NN 	<p>Port Infrastructure (UH)</p> <ul style="list-style-type: none"> • Port mooring, anchorage identification – DBSCAN and genetic algorithm <p>Weather routing (UH)</p> <ul style="list-style-type: none"> • Time dependant path finding - Dijkstra algorithm • Point-based fuel flow prediction with real-time weather forecast – ANN • Rerouting decision model - ANN 	<ul style="list-style-type: none"> • CO₂ Emission (NTUA) – linear/Ridge/Lasso/SGD regression, random forest, SVM • Fuel Consumption (NTUA) – Regression and timeseries forecasting

VesselAI contributions on AI Assets Catalog

- AI models
 - Currently links to 5 AI models (papers, code, executable) covering different maritime use cases
 - More to be added after VesselAI platform release 2

Detecting representative trajectories from global AIS data - MT (Paper)

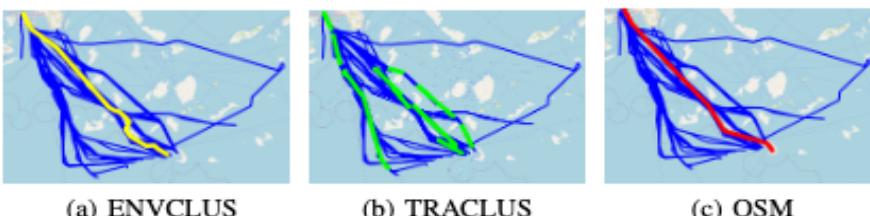
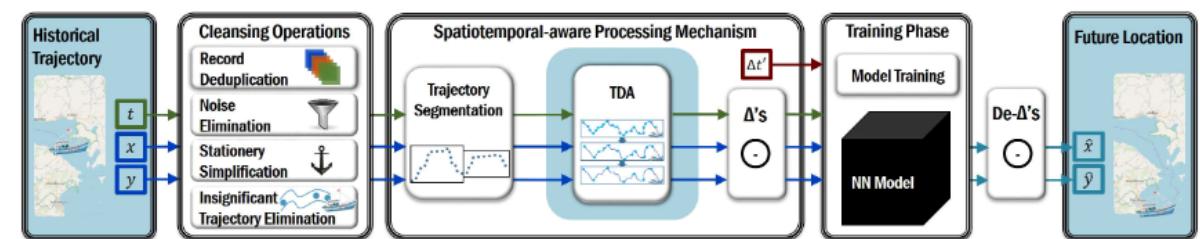


Fig. 8: Results for the route Piraeus → Santorini

LSTM NN-based Framework for Vessel Location Forecasting -UPRC (Code)



Mooring DBSCAN - UH (Code)



- Information extraction from technical specification PDF - VTT (code)
- Ship energy system design optimisation – VTT (description)
- ...

VesselAI contributions on AI4Experiments

- VesselAI services

- Currently implemented a demonstrator AI pipeline using AI4Experiments design studio
- Most to be added after VesselAI platform release 2
 - Dockerised service for data ingestion and harmonization (AIS, weather) – UNINOVA

AI pipeline solution built using AI4Experiments Design Studio



Step 1	Create Model Service	(e.g. a service that trains models or provides a prediction)
Step 2	Create Protocol Buffer	(defines the service in the protobuf protocol – to abstract input and output for interoperability)
Step 3	Generate gRPC Server and Client stubs	(create gRPC client and Server stubs using Protobuf)
Step 4-5	Implementation of Client and Server	(develop the client and server methods based on the requirements)
Step 6-7	Dockerisation	(Containerize the solution in a Docker image and upload to the docker registry)
Step 8	Onboarding	(Insert input to the onboarding form at AI4EU experiments platform)

Conclusion

- VesselAI will continue to enrich the AloD platform with its other selected assets
- VesselAI will continue to follow the development progress of AloD platform

VesselAI Assets & Services	Description	Partner(s)
[ML Model] Port mooring with DBSCAN	Implementation of DBSCAN algorithm that extracts mooring places out of AIS messages	UH
[ML Model] Weather routing	Implementation of a retro-optimization model for the weather routing problem	UH
[ML Model] Fuel Consumption model	Implementation of the Fuel consumption prediction service.	NTUA
[ML Model] Ship recognition using CNN	Implementation of ship recognition service using convolutional neural networks (CNN).	NTUA
[ML Model] CO2 Emissions model	Implementation of a regression models that predict the CO2 emissions for each type of vessel.	NTUA
[Code] Query Builder	A modular and advanced query builder that enables data scientists to easily explore and combine the underlying datasets of defined storage, create, and perform complex queries on top of them through a convenient web interface.	NTUA
[ML model] Vessel Route Forecasting (VRF)	Implementation of the VRF model using artificial neural networks (ANN) that provide future positions of the vessels within a specific amount of time.	UPRC
[ML model] Vessel Traffic Flow Forecasting (VTFF)	Implementation of the VTFF model using ANN that forecasts the inflow and outflow of vessels within a given region.	UPRC
[ML model] Vessel Collision Risk Assessment (VCRA)	Implementation of the VCRA model that address conflict detection and conflict resolution problems to ensure collision avoidance.	UPRC
[Dataset] Maritime datasets	Link to open AIS dataset will be added in AI Catalog	UPRC
[ML model] Vessel Route Forecasting	Links to the descriptions of the VRF models produced by MT with experimental results (2 models)	MT
[Dataset] Maritime datasets	Links to public maritime datasets (2 public datasets)	MT
[ML model] Ship energy system design optimisation	Implementation of ML model that provides an estimate of the lifecycle costs and emissions of different ship energy system configurations at design time.	VTT
[Executable] Tabular information extraction tool	Implementation of ML based tool that extract numerical specifications of energy system components from PDF technical documentation.	VTT
[Docker container] Services for data ingestion (AIS, Weather)	Dockerized services for batch and stream data ingestion and harmonization (AIS and Weather data) to a database instance of choice. It enables ingestion of generic data sources related to both AIS and Weather data and subsequent harmonization to specific data formats, through the use of mapping schemas that can be used to transform the data in terms of schema, data types and units.	UNINNOVA
[Executable] AIS pre-processing & trajectory extraction tool	Code that can conduct basic filtering and aggregation and interpolation of AIS data to complete trajectories.	SINOCE, KNC, SINDIG
[ML model] Trajectory clustering model	Trajectory clustering algorithm that clusters historical trajectories based on similar starting and stopping points using DBSCAN.	SINOCE, KNC, SINDIG
[ML model] Vessel Route Prediction in Oslo fjord	Based on a clustering of historical ship traffic in the Oslo fjord in Norway, a number of distinct routes can be determined. For each distinct route, an ML-based regression model is trained to predict the future 55-minute behavior of a given vessel. Such predictions aim to support collision avoidance, as well as the situational awareness of shore control centre operators.	SINOCE, KNC, SINDIG
[ML model] Anomaly detection model	The model will be able to identify anomalous ship behavior in the Oslo fjord.	SINOCE, KNC, SINDIG



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