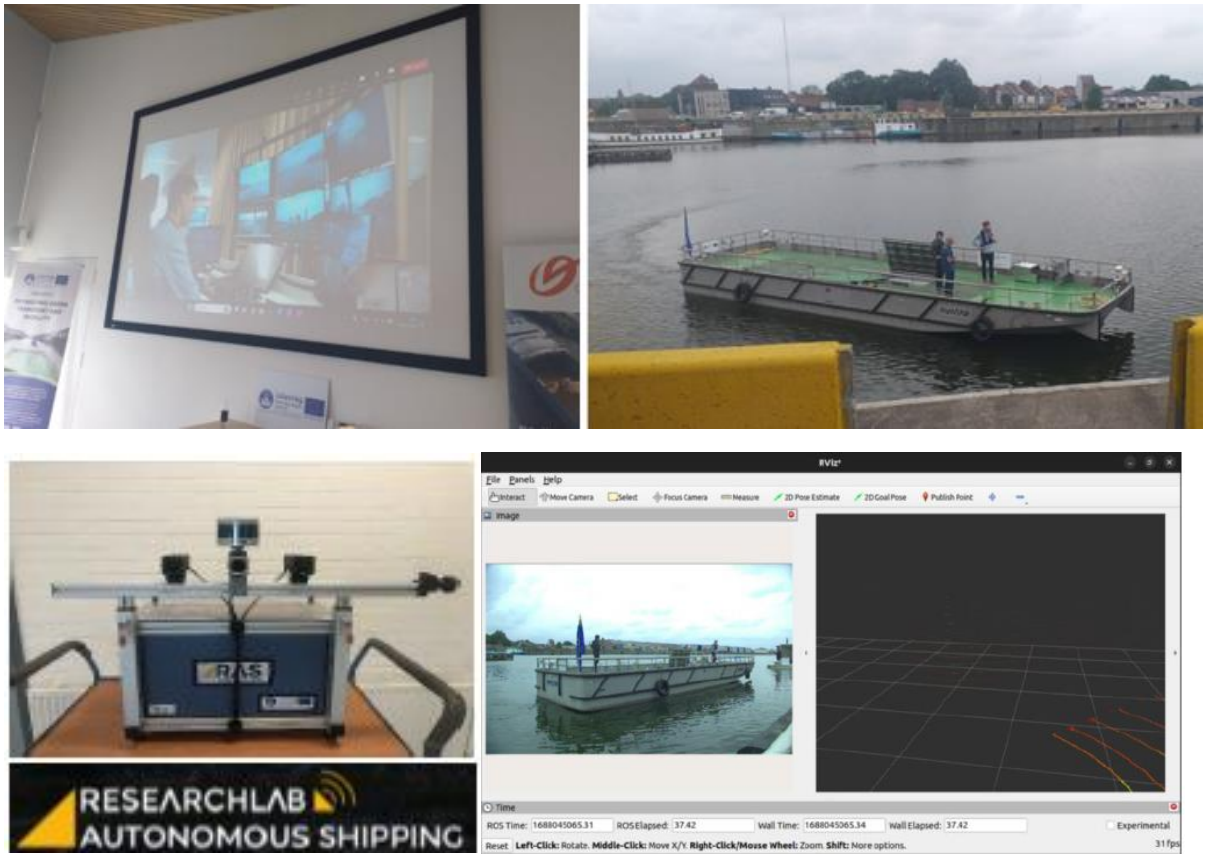

Integrating the AVATAR-vessel and the Green Wave in an urban environment

Within the framework of the Interreg NSR project AVATAR work package 6

AVATAR is a project co-funded by the
Interreg North Sea Region programme 2014-2020

Colophon

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See also: AVATAR website and Linkedin

Project partners AVATAR:

1. Introduction

The massive under-exploitation of inland waterways (IWW) in the North Sea Region (NSR), especially in and around urban environments, provides opportunities for technological innovations. The AVATAR project aims to deploy (highly) zero-emission automated vessels that can do regular trips between the urban consolidation centers outside of a city and inner city hubs.

The original AVATAR project ("call 11") aimed to tackle challenges of city freight distribution by developing, testing and assessing adequate technologies and business models for urban (highly) autonomous zero-emission Inland waterway transport (IWT) solutions. Through this, the project unlocks the economic potential of urban vessels and corresponding waterways, increases available solutions for full-cycle automation and sets up a sustainable supply chain model for urban goods distribution and waste return.

The goal of the AVATAR extension ("call 12") is to set up the market-proof foundation of an autonomous open source fleet to be used for city freight distribution (inland waterways). The current AVATAR project served as a basis and has been extended with the needed building stones (topics). Therefore, additional topics have been introduced as well as new project partners are involved.

The current AVATAR ("call 11") project focused on one vessel with one operator, the extension focused on multiple vessels with multiple operators in a real life testbed.

In this report, focus is on:

- ⇨ Testing the interaction of the AVATAR-vessel and the Green Wave
- ⇨ Testing the mobile equipment of other operators
- ⇨ Testing the application of Artificial Intelligence
- ⇨ Testing charging units

2. Testing the interaction of the AVATAR-vessel and the Green Wave

Goal of this test was that the AVATAR vessel would be controlled by SEAFAR, and the Green Wave will follow. During project period 6 the AVATAR vessel has been completed just in time (end June 2023), making it possible to do test sailings with the AVATAR vessel, controlled by SEAFAR. During the final project event, this has also been shown to the public. This also implied that it was not possible anymore to perform tests with the AVATAR vessel (controlled by SEAFAR) and the Green Wave simultaneously during the project period (ending June 2023). Anyhow, tests of the interaction will be performed in autumn 2023.

On 21/9/2023, a sailing test with different vessels (including the AVATAR vessel) took place in Ghent, see here.

RISE developed an analysis framework for AIS-data, with the following purpose:

1) to assess the possible usage of AIS-data in autonomous shipping;
2) to assess the performance of the operations in autonomous shipping.

For assessing the performance of the operations there are several options of KPIs based on AIS data. For the purpose of city distribution, the evaluation of the route between quays and the time spent at the quays (loading/unloading points) are relevant assessments for setting the schedule of different routes.

The AIS system was originally designed for radar augmentation and vessel traffic services, but AIS data can be used to collect information about traffic in a given area, which can be exploited in research, thereby has AIS become a source of big data.

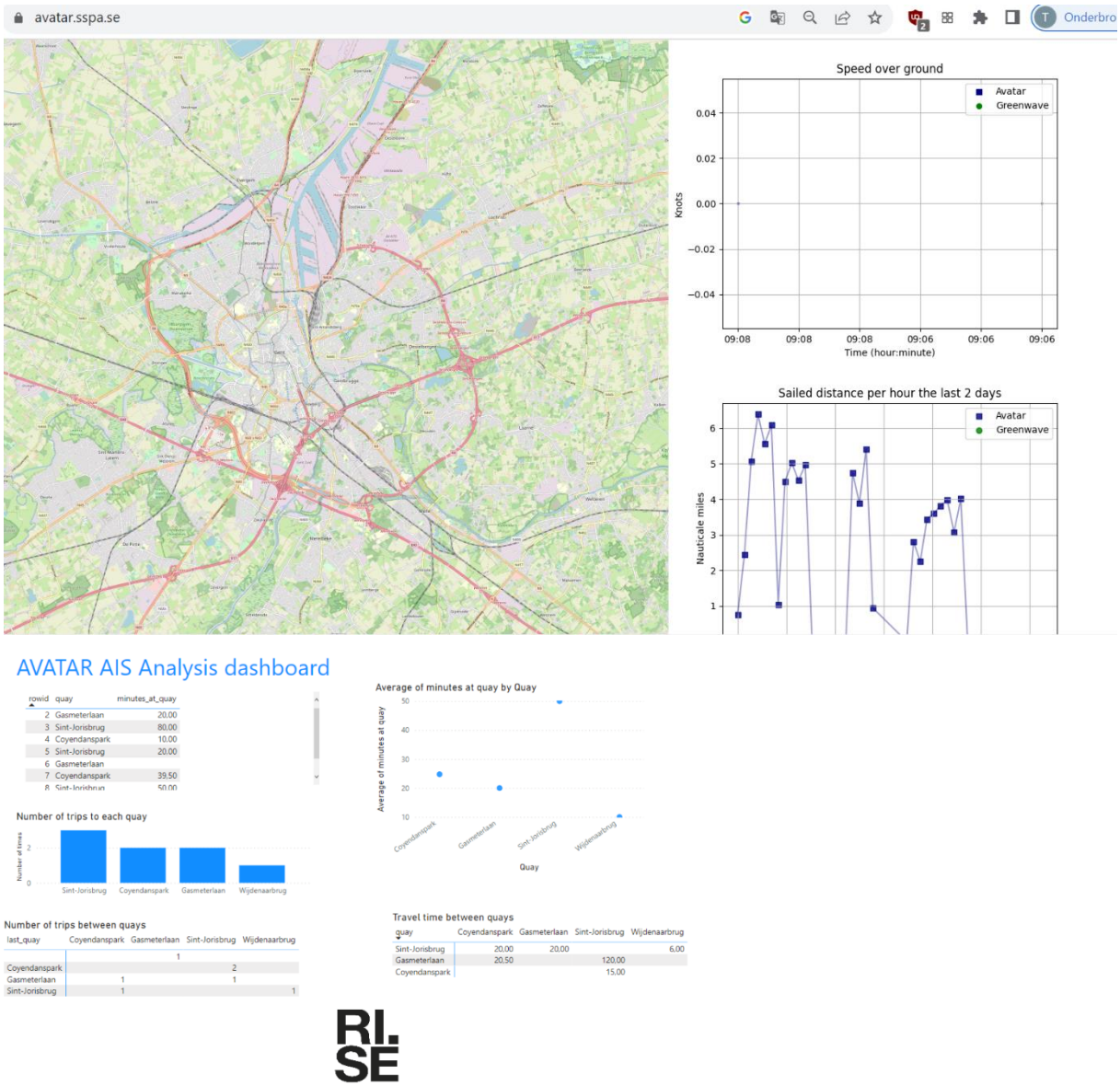
For more than a decade, researchers have used AIS data to a greater extent to analyse maritime traffic in several areas such as ship surveillance, tracking, security, collisions, shipping noise levels, and vessel emissions.

To assess the performance of the operations there are several options of KPIs based on AIS data.

For the purpose of city distribution, the evaluation of the route between quays and the time spent at the quays are relevant KPIs.

The sailing trip on the route can be divided into a number of “sub-trips” between two quays. For each sub-trip it is relevant to both assess no of total trips, sailing time between the quays and the speed between the quays.

For this purpose, RISE created an online application to monitor the movements of the vessels; also including a dashboard.



3. Testing the mobile equipment of other operators

This section refers to the involvement of SEAFAR in the project. SEAFAR technology has been installed on the new AVATAR vessel in order to control the new AVATAR vessel (in Ghent) from the SEAFAR remote control center in Antwerp. Succesful tests and demonstrations took place in June 2023 (also during the final AVATAR event).

The interfaces have been installed onboard the vessel and the connections were done with the SEAFAR system. Some of the controlled parts include the engine, rudder, bow and

thruster, lights and the horn. Seamless transmission of environmental data captured from the vessel's surroundings to the remote operation center stands as a pivotal function.

This activity also included following activities by SEAFAR and E. Van Wingen: programming, and testing of compatibility between the AVATAR vessel and SEAFAR.

Demonstration

The final event of AVATAR took place on June 29 and 30. On both days Seafar has provided a presentation about semi-autonomous vessels. Furthermore, a live demonstration was provided in the afternoons. The captain at Seafar headquarter remote operation center in Antwerp has remotely sailed the vessel in Gent, the final event venue. The demonstration started by safety check, going through the list of control system elements. Then, the captain started sailing the vessel to a specific point and returning to the starting point.

The demonstrations were successful. The video footprint was collected by a drone flying above the vessel. The video call with remote operation center was also recorded.

Adding Seafar Control System and Integrate it with the vessel

To be able to remotely sail a vessel, different elements are involved. One element is the control system. The control system should be able to receive commands from the remote operation center and transfer the command to the relevant module on the vessel. The interfaces are installed onboard the vessel and the connections are done with Seafar system. Some of the controlled parts include engine, rudder, bow and thruster, lights and the horn.

Building the communication

Seamless transmission of environmental data captured from the vessel's surroundings to the remote operation center stands as a pivotal function. This data, a crucial element for remote operation, finds its purpose in being rendered comprehensible to the remote captain. The foundation for this synchronization relies on a network connection that is not only robust but unwaveringly stable.

With this objective in mind, Seafar has installed network infrastructure directly on board the vessel. This dedicated network apparatus serves as the faciliy through which the collected data from an array of sensors all the way to the remote operation center.

Central to this implementation is the utilization of 4G/LTE technology, notably employed within the AVATAR project. This technology forms the bedrock of communication, promising efficiency and reliability. It ensures that the data are transferred to the remote operation center for translation into a coherent narrative for the remote captain's informed decision-making. The fusion of technology, network solution, and precision engineering converges within this system, forming a crucial bridge between the vessel's immediate reality and the remote captain's distant perspective.

Visualization and Control at ROC

The received data should be provided to the remote captain to make the decisions and steer the vessel. We have considered one of the stations at Seafar headquarter in Antwerp for this purpose. However, considering the special design of AVATAR navigation system, modifications were required in the remote station. For example, the interface for the control device was considered and improved in a way to translate the command from captain to navigation methodology onboard the vessel.

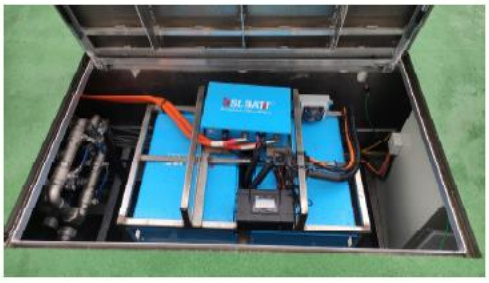
Pictures (source: E. Van Wingen):

Installation of propulsion batteries

Load balancing tanks pipe work

Inside view in one of the control panels

Touch screen as MMI webpanel



Propulsion batteries installed in a SS rack on board

Drive train and rear bow thruster

Detail of Seafar Equipment for autonomous sailing

4. Testing the application of Artificial Intelligence

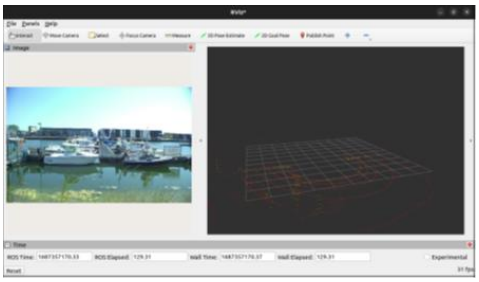
The TUD portable sensor box for computer vision has been designed, developed and tested at the TUD RAS. System integration and testing on board of the AVATAR vessel has been successfully conducted during the project final demonstration in Ghent.

To test the applications of computer vision and Artificial Intelligence (AI) for integrating the AVATAR zero-emission vessels and their autonomous processes, the project partner TU Delft developed an open source Vision SensorBox, covering the hardware and software design through the preliminary results gained during the AVATAR project. The design and codes are available on the GitHub page of the Research Lab Autonomous Shipping (RAS) of TU Delft.

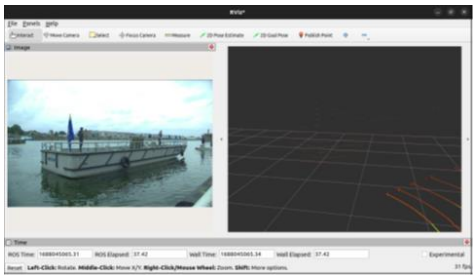
The hardware components of the Vision SensorBox include a frame constructed of aluminum profiles, panels and accessories, a monocular camera, a stereovision setup, a LiDAR sensor, a network router for remote communication, and a power supply. The software has been developed under full ROS package, including the functions of running, launching and commanding the sensors, recording sensor data and playing back the datasets.

Based on the applications of the Vision SensorBox, the potentials of computer vision and AI in gaining autonomous situational awareness were well founded and have been identified during three testing and demonstration scenarios. The testing results can be seen by the monocular camera data and the LiDAR data via the ROS visualization interfaces as follows:

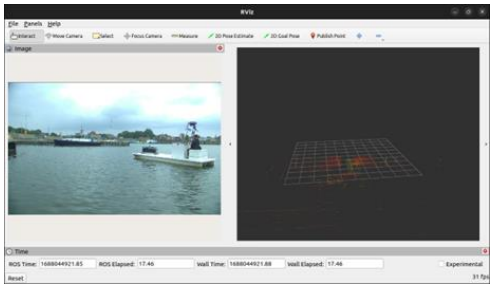
Scenario 1: Detection from the river bank of the Marina in Vlissingen



Scenario 2: Detection of the AVATAR vessel from the waterside of the Rigakaai North Sea Port Ghent



Scenario 3: Detection of the Maverick (KU Leuven) vessel from onboard the AVATAR vessel in Ghent



To conclude, the developed Vision SensorBox and testing results proved the capacity to gather vision and LiDAR data onboard from full scale partner vessels. The data sets can be utilised for computer vision and AI algorithms for situational awareness in the field of autonomous shipping in urban environment. The Vision SensorBox provides a platform to deploy these algorithms for real-time experimentation. The design of this Vision SensorBox and its supplementary code are being offered open-source to the wider scientific community to catalyse research in this field.

During the AVATAR final event, the Vision SensorBox, developed by TUD during the project, has been installed on the AVATAR vessel and tested in real life sailing. The data and images received from the Vision SensorBox and the results of applying AI to improve the safety of sailing has been shown on a monitor on the quay. The data collected from all the tests will be further used for assessing the performances of the AVATAR urban freight vessels together with project partners.

5. Testing charging units

The energy use case in AVATAR Interreg North Sea Region is focused on city freight distribution vessels sailing during daytime and charging the batteries at night (using a ICE CHP running on hydrogen). While the ICE CHP is charging the vessels, heat is released. In the AVATAR approach, this heat will be stored in a buffer tank that is part of a central heating installation. More info is available here, here and here. Special attention goes to the capacity of the electricity grid, local energy production and stress on the basics of the public grid. The role of energy efficient applications has been underlined.

What is it about ?

Autonomous vessels (no skipper on board!) developed to enable zero CO2 urban freight distribution, running on green power derived from hydrogen, without energy losses. No longer a science fiction story of what it might be looking like in the future, but a real life application that is operating efficiently.

In WP4, the energy use case has been explained from a theoretical point of view (including cost calculations) whereas in WP6 focus was on the practical implementation of the concept (live as a demo during the final AVATAR event). WP6 stands for the technical energy concept of the WP4 energy use case live as a demo. For this purpose, it was necessary to install the hydrogen powered ICE CHP (cogeneration) on H2 at the hub of the AVATAR vessels.

The CHP works optimally at the highest efficiency (lowest H2 consumption) thanks to a hybrid configuration. Therefore, the existing H2 CHP from a grid connected operating device has been transformed into a stand alone operating device (this has been done by replacing the asynchronous alternator by a synchronous alternator).

A hybrid control software for the hybrid AVATAR battery charge solutions has been developed. A sufficient risk analysis was needed to obtain the necessary permits prepared by an independent body experienced in H2 solutions (collaboration with KIWA).

In order to connect the AVATAR vessel to the onshore charging installation (on H2), a charging station (pole) was developed. The complete solution from H2 for charging the AVATAR vessels was set up and tested during the AVATAR final event.

Pictures (source: E. Van Wingen)

EVW's ICE on H2 CHP converted for Island operation and charging of batteries tested at the factory in Evergem (B)

AVATAR charging station/pole suitable for charging vessels batteries

End of Interreg NSR AVATAR : EVW's job done ! In this picture :

Autonomuous electric sailing vessel

Charging infrastructure from H2 to charging batteries at zero g CO2 (Energy Use Case)

E. Van Wingen demonstrated the complete chain from well to wheel (in AVATAR wheel stands for propeller).

Summarizing:

The Demo set-up in Ghent :

• H2 storage container : green hydrogen, produced by a local H2 producer (Nippon, see https://cm.nippongases.com/nl-nl/nieuws/terranova-project) as a solution to store renewable energy supporting the balance on the public grid, avoiding black out and avoiding huge investments in the public grid to be financed in Flanders via the electricity bill by the end user.

• EVW H2 CHP container, adapted for island operation and prepared in accordance with safety regulations in consultation with KIWA

The locally produced green hydrogen, converted into useful energy (heat and electricity) at the highest energy efficiency and at 0 gr CO2.

• The hybrid cabinet allowing to operate the ICE CHP at its optimum efficiency. (technology can be compared with plug in hybrid cars, simply said : the ICE doesn't have to run all the time, but when it runs, it runs in the best conditions allowing to convert the H2 at the highest possible efficiency into useful power.

• The charging station/pole, the interface between the energy source and the vessel (or car , or bike , …)

• The fleet of electric vessel for urban distribution sailing around emission free

The demonstration of a 0 g CO2 well-to-wheel H2 solution was the first of its kind in Flanders. For the first time in Flanders, a deeply wider sustainable local H2 solution chain that works from A to Z was presented to the public. Most demos in this field so far only dealt with one or two of the steps, but not all of them. (for ex. an H2 vehicle together with a H2 filling station)

According to Jean-Pierre Van Wingen, "the lack of interest shown by our politicians is a sign of who in Flanders is setting the course for the energy transition. These are set out by the monopoly utilities, which unfortunately cannot be called independent in Flanders and in whose interest it is to safeguard the public grid from too much energy efficient local production and consumption. Ultimately, it is in the interest of these utilities that electric power is distributed through public grids, with unavoidable loss of efficiency. It is unfortunately their core business and the way to finance their shareholders, our cities and our communities."

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