Experiments and actions on the pilot projects 3 until 30.06.2024

1. Development of Sea State Classification Models

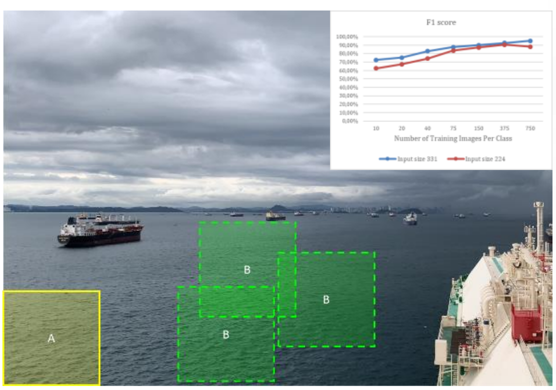
The key objectives of our pilot project include construction of algorithms and adaptation of artificial intelligence models that will contribute to navigational safety, assist in decision-making during navigation and ultimately contribute to autonomous navigation capabilities.

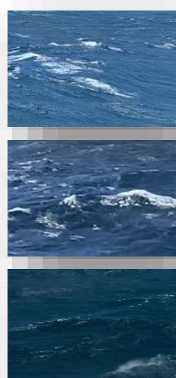
The project focuses on two specific computer vision tasks:

- recognition of sea state conditions captured by a stationary camera

- detection of small objects at sea that are undetectable by radar or standard sensors.

For the development of computer vision models, collecting real training data was crucial, but we also synthesized data to increase the quantity of samples especially for rougher sea states that are more difficult to obtain.





Below are the key activities that we have carried out so far through the project for building a Sea State Recognition Model:

• **Data Collection and Analysis**: We collected high-definition video data during three voyages on oceangoing vessels. This data covered multiple geographic locations and included related sensor signals such as wind speed, angle, heading, and speed over ground. Video data of different sea states was essential for training the sea state classification models.

• **Manual Estimation of Sea States**: We manually estimated the sea state in the videos based on the Beaufort and Douglas scales, including wave heights and angles. These estimates were used to annotate the data needed for model training.

• **Safety and Operational Knowledge**: We consulted a marine expert to provide key insights into the operational envelope of the vessels. This ensured that our research targeted the maximum sea state conditions that ships regularly encounter.

• **Development of Sea State Classification Models**: We selected deep neural network architectures suitable for building a sea state recognition model. After testing various architectures with different hyperparameter settings on our test set, we chose the appropriate ones. We then fine-tuned the models from pretrained weights and build a CV model based on expert input.

A maritime expert helped identifying the gaps in the current maritime operations, particularly where traditional methods of sea state estimation are either infeasible or inaccurate. This feedback contributed to the development of a novel approach using computer vision (CV) for real-time sea state recognition.

• **Assessment of Model Performance**: we evaluated the models for their accuracy and practical usability in real-world maritime environments.

2. Building synthetic images of different sea states

We developed the SeaStateSynth method for generating and fine-tuning adaptive maritime synthsets for sea state classification and built the accompanying pipeline with 7 interconnected modules:

1. Optical calibration - for matching the focal distance, crop position and area of synthesized and real images;
2. Waves generator - fine-tuned for generating 8 Beaufort classes (1-8), outputting waves spectra for each class;
3. Foam simulator - particle simulation based on waves spectra, outputting foam particles;
4. Reference object motion simulator - for adding swimmers, boats, and ships into the 3D scene and calculating their motion according to the waves, used as a visual size reference while fine-tuning the waves generator;
5. Lighting - cloudless physical sky, fine-tuned for different sun heights and solar azimuths, used as a light source for rendering;
6. XPU rendering - a combination of CPU and GPU parallelized pipelines able to render each synthesized image in 1.8 s;

7. Classification - integrated classifier trained on real data and used for evaluation of synthesized images.

By applying the described method, we generated 3 synthsets. Each one contains 51,840 images divided into 8 balanced classes and differs from the others by visual characteristics of the waves influenced by the distance from the shore (3, 30, and 300 km). The final synthset (UNIRI-SeaState-S) is composed of 150 randomly selected images, using 30 km images for lower sea states (1-3 Beaufort) and 300 km images for the higher ones (4-8 Beaufort), based on best-achieved classification results.

3. Building synthetic images for small Object detection

Building upon the SeaStateSynth pipeline, we included 5 additional modules to synthesize richly annotated images containing small objects in the sea:

1. Voxelizer - for evaluating 3D geometry in 10-32 px resolution;
2. Mo-cap retarget - for animating swimmers using mo-cap data;
3. Shipyard - procedural generator of different sea vessels based on 92 parameters;
11. Instancer - for efficient positioning of small objects in the image;
12. Annotator - Cryptomatte masks and depth maps generator, outputting rich annotations.

We are currently fine-tuning the entire pipeline to produce a synthset for small object detection.

Building a Small Object Recognition Model:

• **Data Collection and Analysis:** During three voyages on oceangoing vessels, a high-definition video data at several anchorage locations were captured to record objects around the ship. This data was primarily focusing on classifying large objects and distinguishing them from smaller boats passing through the anchorage.

• **Annotation of objects:** A subset of images from our videos taken at anchorage locations and from publicly available of shore mounted cameras was manually annotated with bounding boxes to create an initial dataset suitable for training the models for detection of small objects in the sea.

• **Development of Sea State Classification Models**: We selected deep neural network architectures that could be adequate to build a model for small object detection. We tested different architectures on our test dataset with different settings and configurations and selected the most appropriate according to performance and recognition speed. Then we fine-tuned the pretrained transformer model on our annotated data and built and tested a CV model. A maritime expert provided helpful input throughout the development of the small object recognition model, to ensure its usability in real-world applications.