#ARPAproject

Maritime Autonomous Systems

Selected highlights from the ARPA project

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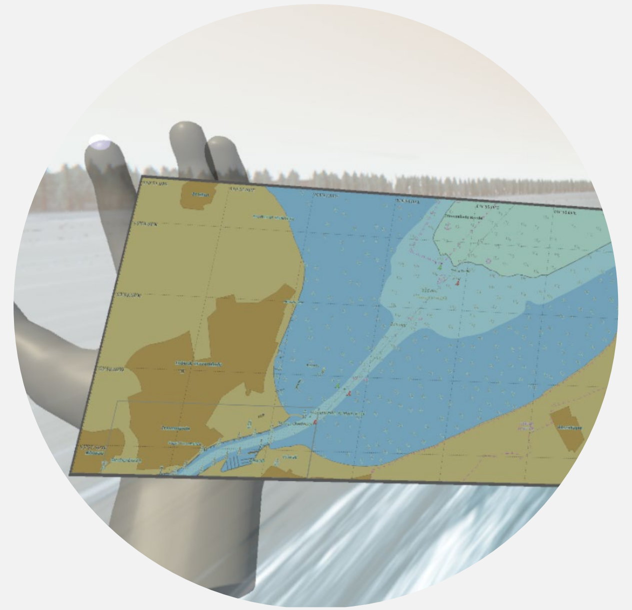
Selected Highlights from the ARPA Project



XR Remote Pilotage

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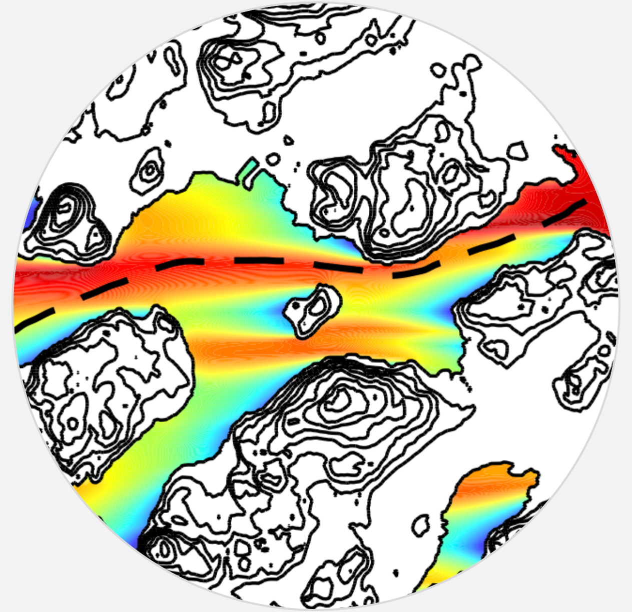

Fairway Wind Simulations

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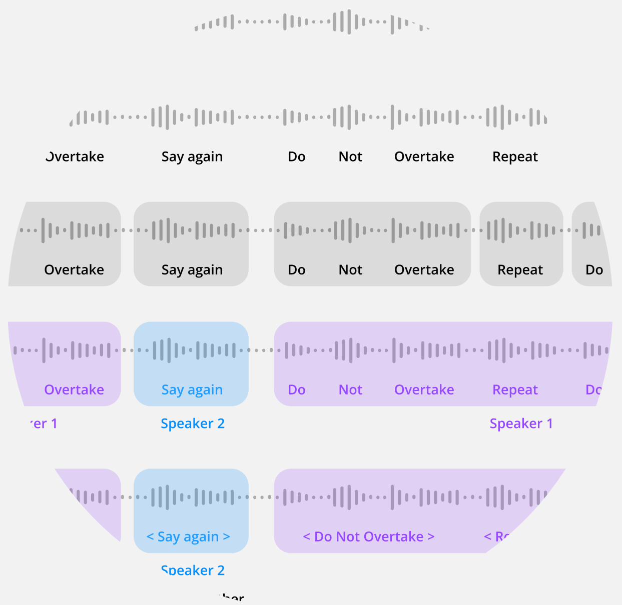

Maritime Automatic Speech Recognition

- Automatic Transcription of VHF Communications
- Speaker Recognition
- SMCP mapping

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XR Remote Pilotage

A proof-of-concept for **XR-assisted remote pilotage** has been created to enhance situational awareness during remote operations. This concept involves a VR interface for pilots on the shore communicating with XR and tablet applications used by the ship's captain. **The aim has been to incorporate functionalities that cannot easily be replaced by verbal-only communication.** The setup necessitates transferring navigation data and a 360-degree camera feed from the ship to the shore.

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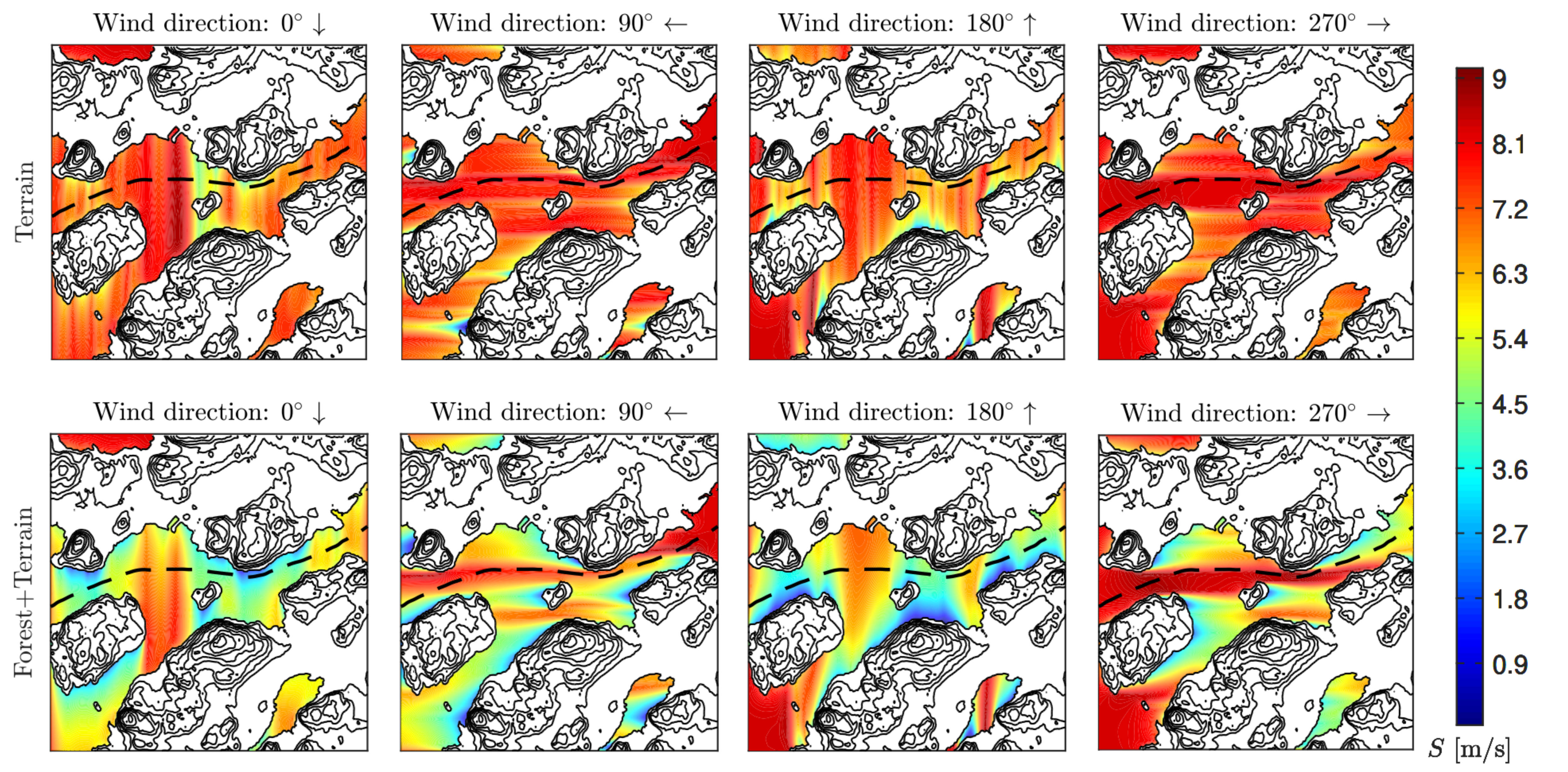
Fairway Wind Simulations

We carried out Computational Fluid Dynamics (CFD) simulations for wind flows over a site in the Turku Archipelago and Mariehamn harbor, in Finland. **We assessed local wind conditions along the fairway with the intent of improving safe passage for large vessels**. All simulations were carried out with and without the surrounding forests to elucidate the role of forests in shaping



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Fairway Wind Simulations

Paper 1. Automated mesh generation for kilometer-scale atmospheric flow simulations.

Paper 2. Assessing the impact of forests on local wind conditions in archipelagos.

Paper 3. In preparation

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Automated geometry and hexahedral mesh generation for kilometer-scale atmospheric flow simulations

Eero Immonen[1], Dennis Bengs, Mikael Manngård and Johan Westö

Summary This article introduces a methodology for automatic generation of geometries and meshes for kilometer-scale Atmospheric Boundary Layer (ABL) flow simulations, with topography and elevation. The proposed programmatic (hence automatable) *template morphing approach* facilitates interpolation of scattered point cloud terrain data on a template geometry domain, morphing a high-quality quadrilateral template mesh for the interpolated geometry, and setup as well as execution of Computational Fluid Dynamics (CFD) flow simulation. The proposed method specifically addresses the previously reported problems of sustaining an ABL structure across the simulation domain by imposing the velocity and turbulence properties on all vertical surfaces. We present a validation study for the proposed method on an artificial Gaussian hill terrain. A real-world localized wind forecast application from the Turku Archipelago, Finland, is also presented, using open terrain data from National Land Survey of Finland. Such localized wind forecasts aim to assist ships in autonomous navigation and maneuvering in complex port or fairway environments, which is the motivation for this study.

Key words: automatic geometry creation, automatic meshing, spatial discretization, Computational Fluid Dynamics, CFD, Atmospheric Boundary Layer, ABL

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ASSESSING THE IMPACT OF FORESTS ON LOCAL WIND CONDITIONS IN ARCHIPELAGOS: A CFD STUDY

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KEYWORDS

CFD, Archipelagos, Complex terrains, Forest effects, Wind flow analysis, Turbulence.

ABSTRACT

Ship fairways in archipelagos pass close to small islands with complex terrain and forests. In such areas, local wind conditions deviate from regional forecasts, creating a complex and challenging environment when navigating large vessels. In this article, we carried out Computational Fluid Dynamics (CFD) simulations for wind flows over a site in the Turku Archipelago, in Finland. We assessed local wind conditions along the fairway with the intent of improving safe passage for large vessels. All simulations were carried out with and without the surrounding forests to elucidate the role of forests in shaping the local wind and turbulence conditions over the site. Our results show that in some regions of the fairway, forests can lower the wind speed to one-third of the magnitude obtained by using terrain-only models. Moreover, turbulence can locally be increased sixfold. We expect that these results will facilitate the development of new smart fairways for ensuring safe navigation through the archipelago in the future.

to evaluate the operational limits of vessels in varying wind conditions as they traverse the fairway.

A key step towards realizing the above vision is to acquire knowledge about local wind conditions along the fairway. Weather forecasts and weather stations together provide an estimate of the regional wind conditions, but this information needs to be refined to local conditions along the fairway. Computational Fluid Dynamics (CFD) simulations constitute a promising approach for accomplishing this goal, as such simulations have previously been successfully used to predict localized wind flows over complex terrains (Chaudhari et al., 2014; Blocken et al., 2015; Conan et al., 2016; Chaudhari et al., 2016; Dhunny et al., 2017; Temel et al., 2018; Chaudhari et al., 2018; Ravensbergen et al., 2020). However, earlier studies were mainly carried out for wind resources assessment over terrains without forests, or in port areas dominated by man-made structures (Ricci et al., 2019, 2020, 2023). In archipelagos, wind flows are instead expected to be influenced by the combined effects of surrounding terrain and forests. As forests are porous, a certain amount of wind penetrates through them. As a result, the wind conditions, after a forest patch, would be different as compared to the flow behind a solid terrain. There is thus a need for CFD studies estimating and

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Maritime Automatic Speech Recognition

Maritime automatic speech recognition is designed to **transcribe and interpret spoken language in maritime environments** accurately. We developed a concept for automated transcription and speaker recognition for VHF communications. The proposed framework relies on state-of-the-art open-source models for speaker-speaker and text embedding and similarity clustering.

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Maritime Automatic Speech Recognition

Example audio

Transcription

So this is Mars approach, you've been closed down, feature of channel 1, we'll see you next time, bye bye Thank you for your cooperation, we'll see you next time, bye bye.

OpenAI

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Maritime Automatic Speech Recognition

- What is the person saying?
- Who is the person speaking?
- Who is the person speaking to?
- Why is the person speaking?
- Is the person speaking according to protocol?
- Assess the emotions of the speaker.

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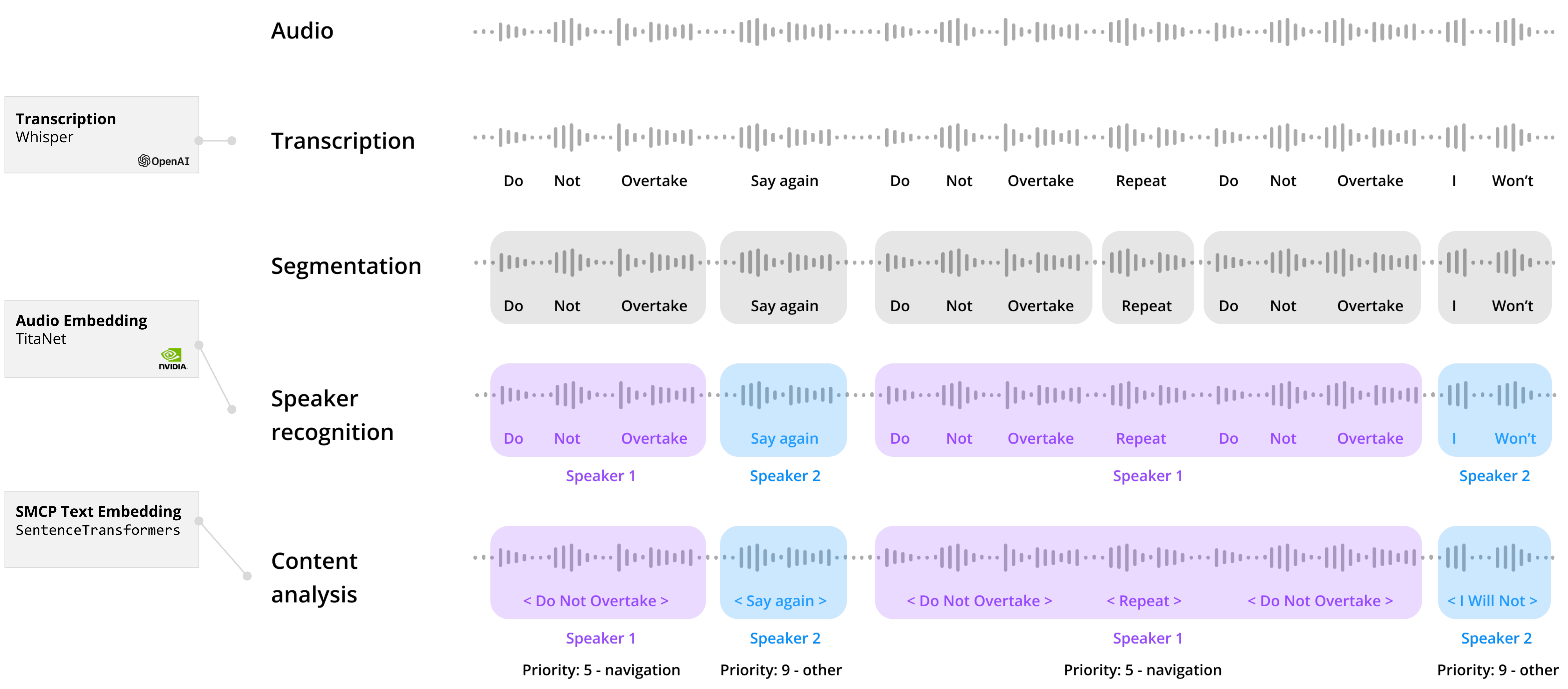
Maritime Automatic Speech Recognition



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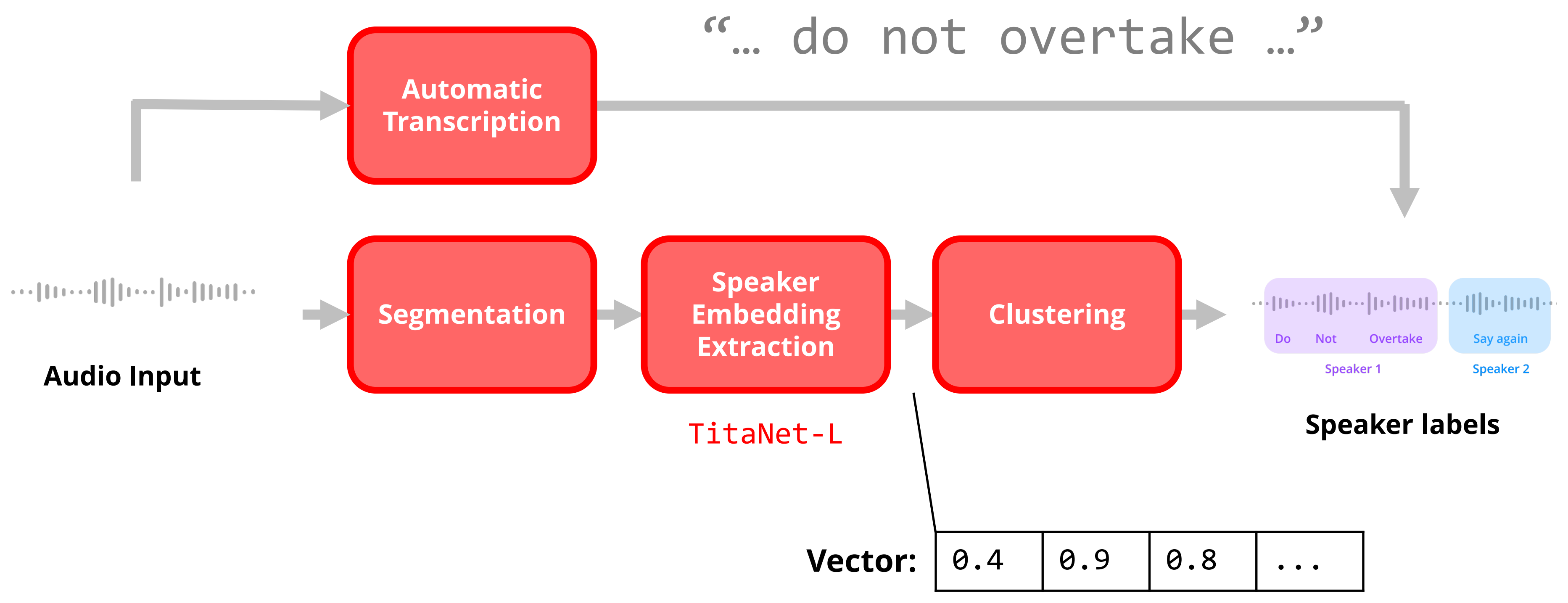
Speaker Embeddings & Clustering

- Speaker recognition is aimed at **identifying or speakers based on their unique vocal characteristics**.
- **Speaker embeddings are vector representations** of a speaker's voice characteristics.
- We use Nvidias **TitaNet-L** to embed audio segments.

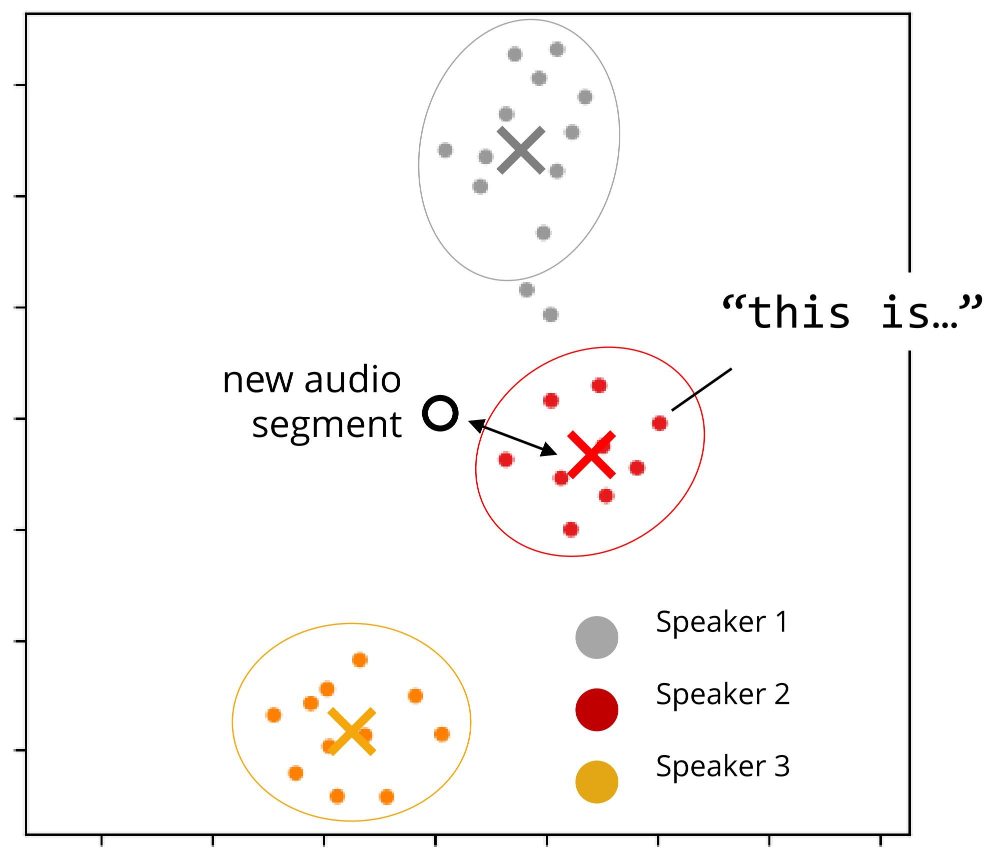


Speaker Embeddings & Clustering

Speaker clustering

- Clusters the audio according to the identity of the speaker.
- Assign speaker labels based on similarity score.
- If a speaker identifies himself, all audio segments within the cluster can be labelled.
- Visualized using `UMAP`.

UMAP representation



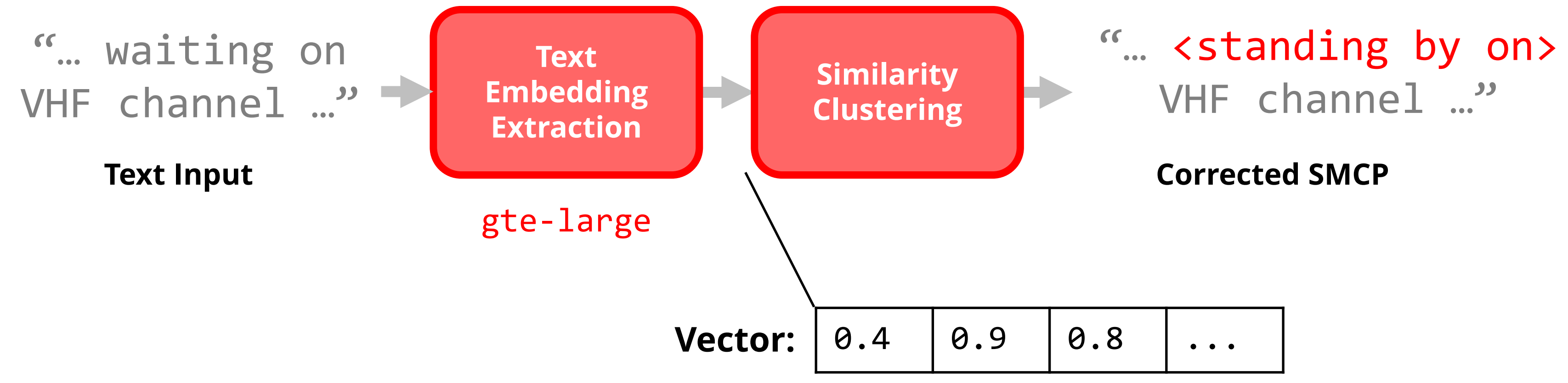
Context Analysis & SMCP mapping

- Direct **word spotting** to find keywords.
- **Sentence Transformers** to match SMCP
- **Large language models** to improve the quality of transcriptions.

IMO Standard Marine Communication Phrases (SMCP)

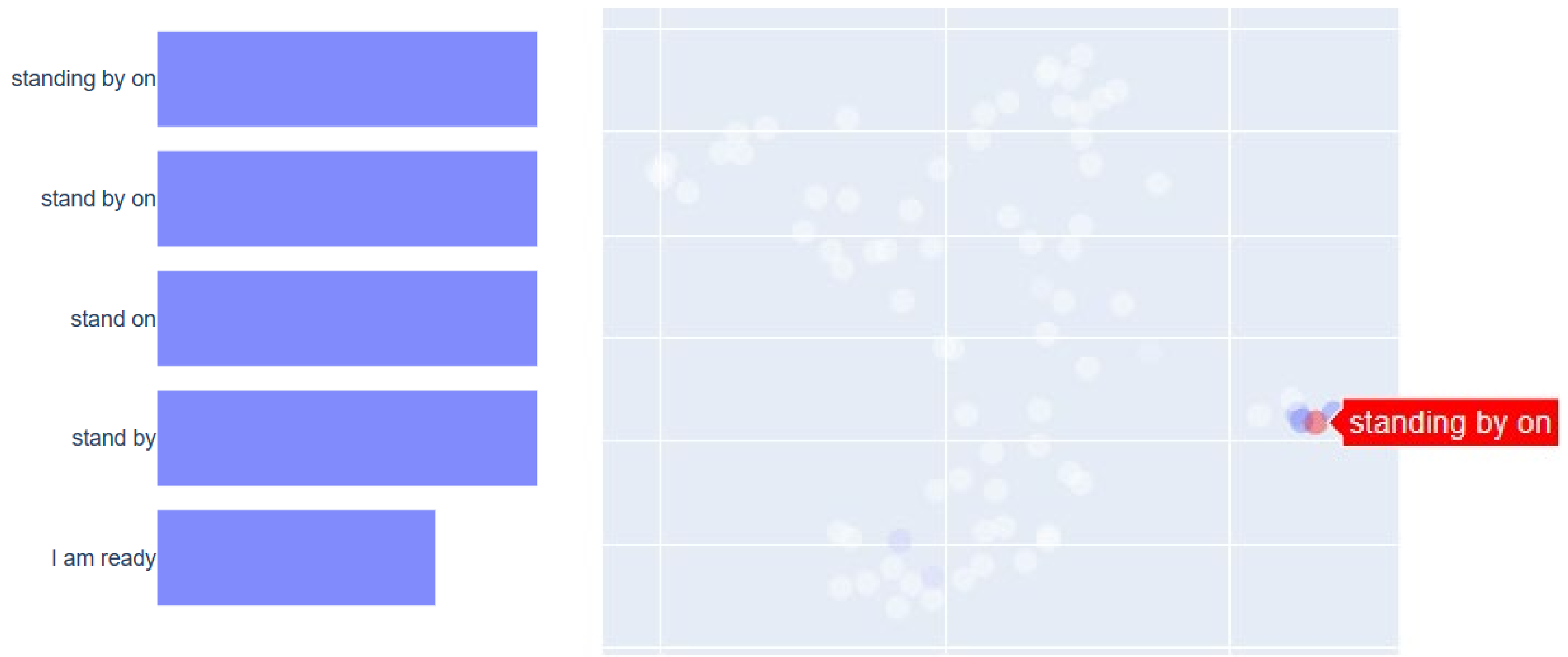
Standard for communicating on VHF radio.

Seafarers are not following SMCP!



Context Analysis & SMCP mapping

… waiting on …



Created an embedding of SMCP using `SentenceTransformers`.

Clustered based on similarity.

Visualized using `UMAP`.

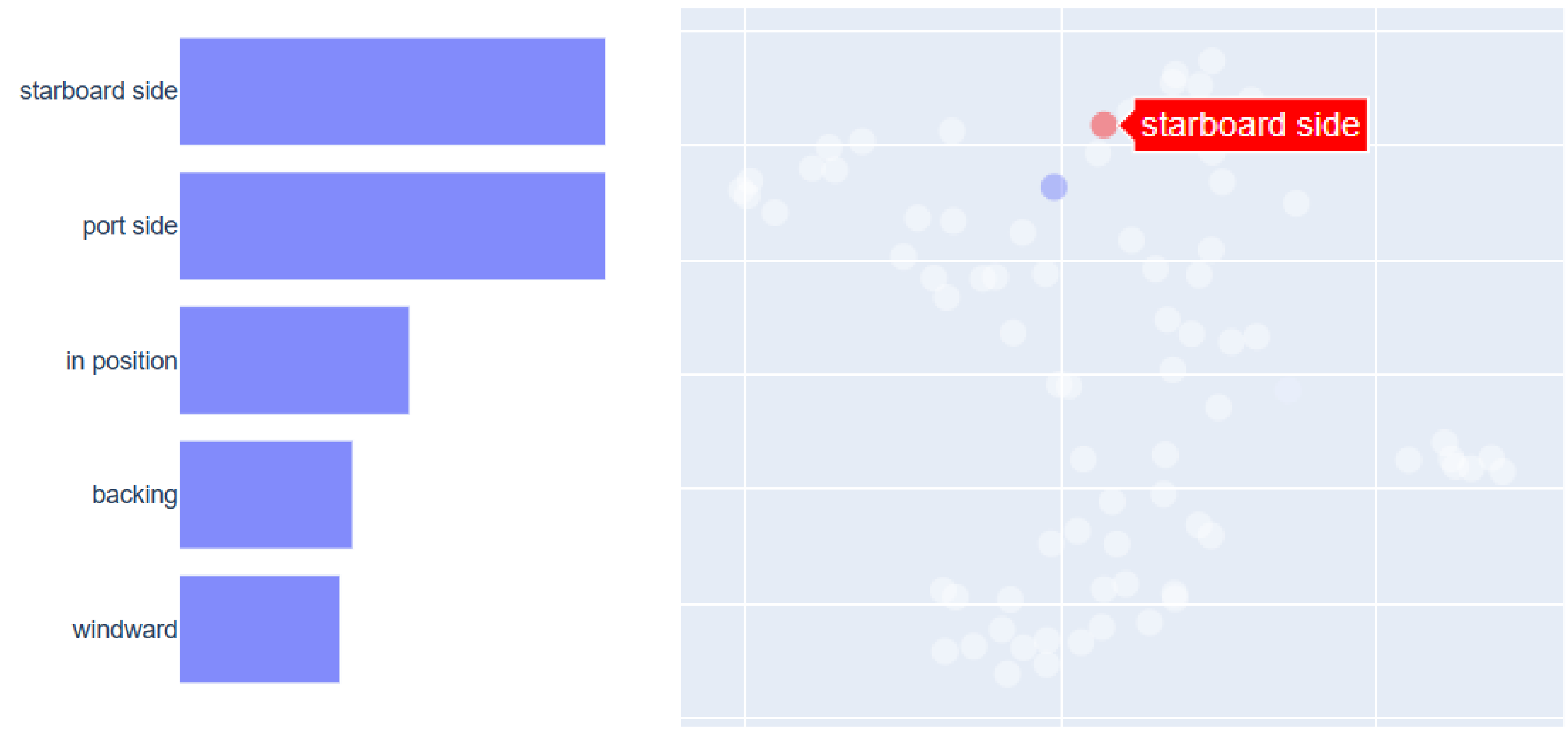
Context Analysis & SMCP mapping

Created an embedding of SMCP using `SentenceTransformers.`

Clustered based on similarity.

Visualized using `UMAP.`

… left side …



Maritime Automatic Speech Recognition

Example audio

Transcription

So this is Mars approach, you've been closed down, feature of channel 1, we'll see you next time, bye bye Thank you for your cooperation, we'll see you next time, bye bye.

OpenAI

SMCP corrected

Maas: <this is> *maas approach*. You can now <stop standing by> on *VHF channel 1*.
Unknown speaker: <thank you>.

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