An Intelligent AUV for Marine Animal Tracking and Passive Acoustic Monitoring

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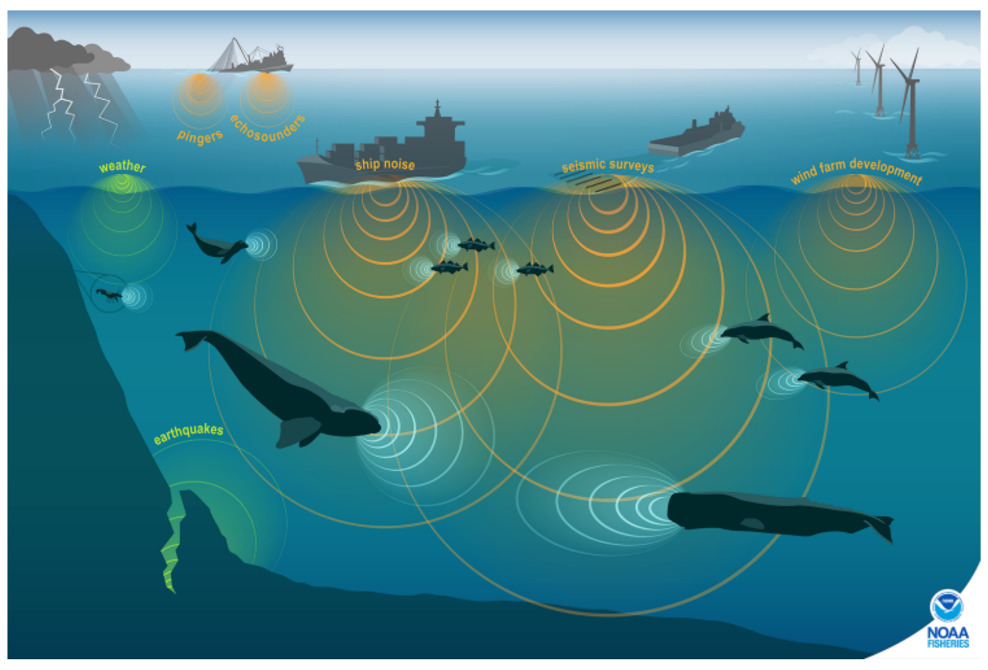
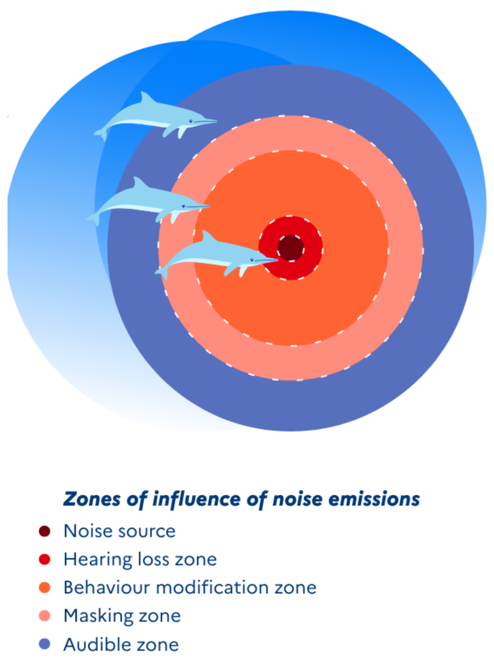
CONTEXT

The conservation of biodiversity in marine ecosystems is important for the health of our oceans. Understanding the effects of anthropocentric noise pollution is important for mitigating damage of ecosystems in the context of man-made disturbances and climate change. Passive acoustic monitoring (PAM) is favoured for investigating animal behaviour with minimal interference, as well as for sound classification [1]. Additionally, acoustic tagging provides a method for long-term tracking of marine animals. Traditional utilisation of these methods can be time-consuming, costly and require great human effort. An autonomous underwater vehicle (AUV) specialized in tracking marine animals using acoustics would pave the way for new scientific outcomes in this field [2].



(a) Noise pollution in marine environments



(b) The impact of noise pollution on animals

Figure 1. Contextualising the need for acoustic monitoring and intervention in marine environments

MOTIVATION

AUVs have larger payload capacity, allowing for greater data collection with higher accuracy than traditional methods [3, 2]. They can lower operational cost, increase mission safety and reproducibility with longer deployment periods [4], which is essential for measuring valuable information of noise impacts on marine ecosystem health [5]. Acoustic tracking and monitoring methods are favourable for their relative cost-efficacy, flexibility and non-intrusive nature [1].

RESEARCH OBJECTIVES

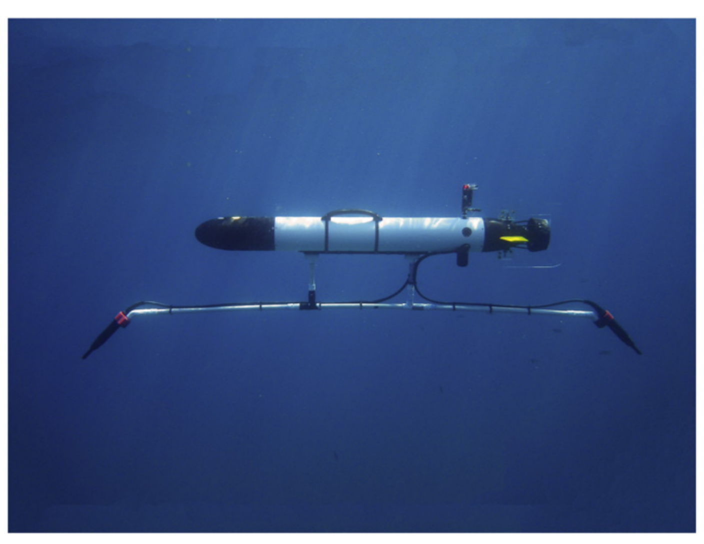
The proposed project aims to meet all or one of the objectives:

1. Design and implement a prototype AUV system using acoustics, directional sensors and autonomous vehicles, capable of following a marine animal tagged with an acoustic tag.
2. Develop a machine learning (ML) model to classify and detect sounds so as to evaluate the presence of noise pollution, and draw connections to the behaviour of the tracked animal(s), determined with objective 1.

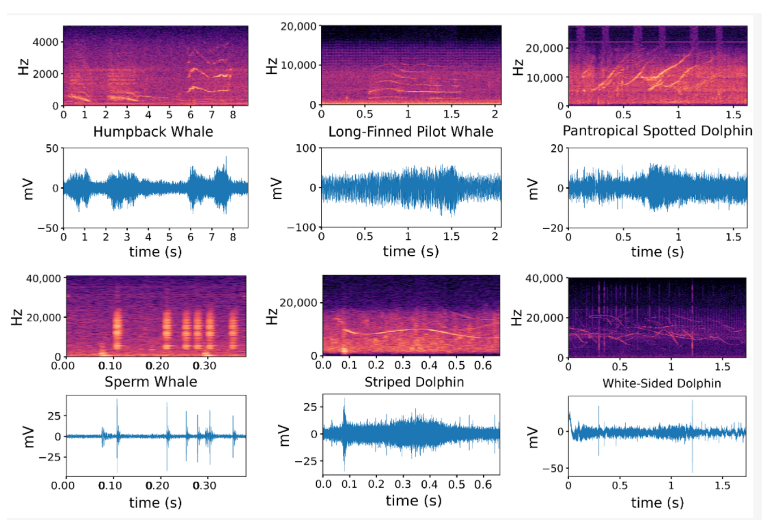
BACKGROUND

Relevant information for how an AUV might be fitted with sensors to track acoustic tags:

- Calculate the angle between the AUV and the acoustic tag by measuring the difference in time of arrival between the two hydrophones.
- Utilise the AUV heading and position to determine the bearing angle from the AUV to the tag.
- The AUV is able to estimate the distance to the tag by calculating the estimated time of flight.
- This distance an dangle knowledge can then be used to locate the tag and follow its trajectory e.g. through a particle filter.



(a) AUV equipped with a hydrophone



(b) Spectrogram: Raw audio is represented as a non-linear, energy curve as a function of time and frequency on a 2D grid.

Figure 2. Methods for tracking and monitoring

In terms of methods for developing a sound detection and classification model, popular methods for bioacoustic ML models use spectrograms as input data to a convolutional neural network (CNN) [6].

STATE OF THE ART

The viability and utility of autonomous underwater vehicles for the acoustic telemetry tracking of marine organisms – White et al. (2016)

- Successfully tracked a leopard shark with two modes – getting close to the tag and circling it.
- Maintained spatial accuracy, generating more locations per unit time than a human tracker (121 %).
- Localised moving targets very well.
- Maintained distance from target so as to not influence the behaviour.
- Achieved fine temporal scale.

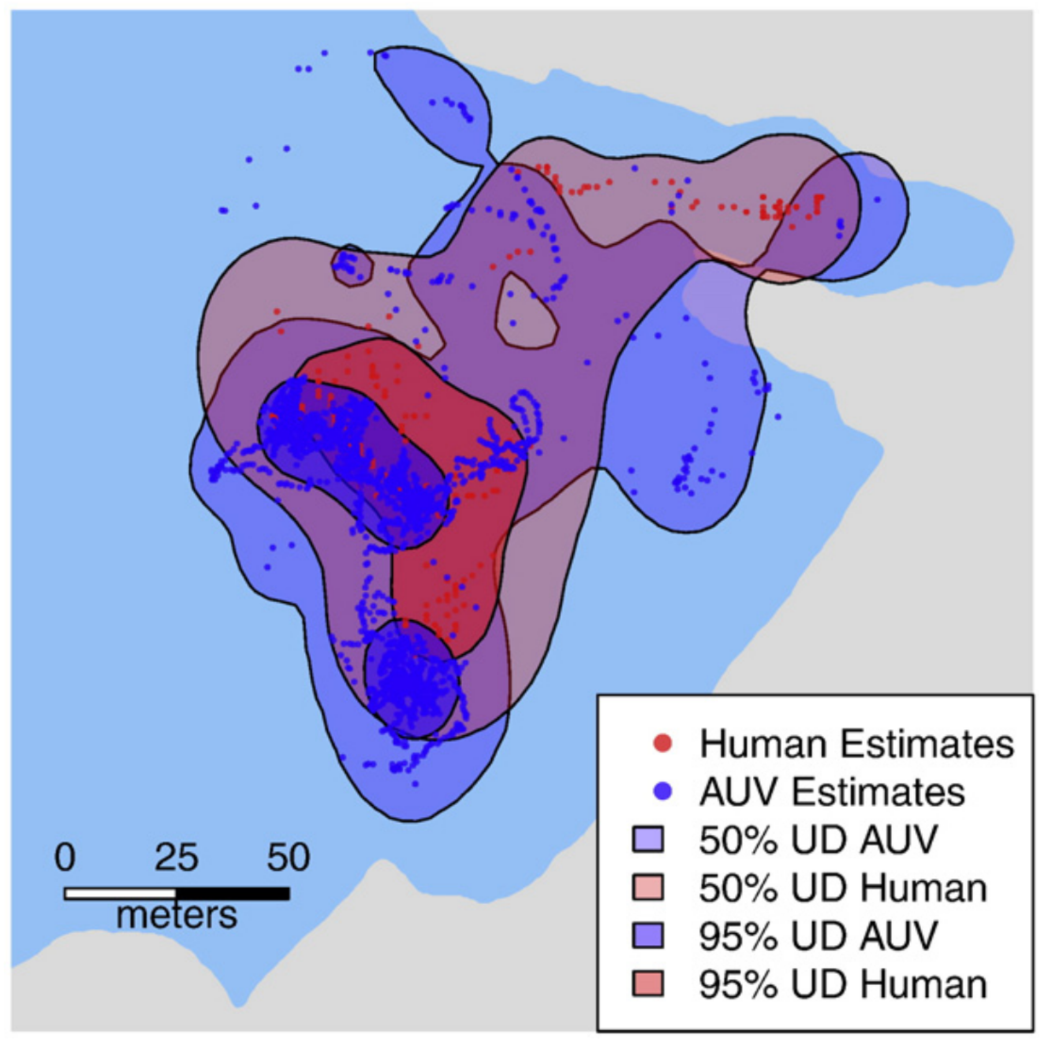


Fig. 3. Shark utilization distribution. Location estimates generated by the AUV (blue circles) and by the human tracker (red circles). The 95% utilization distribution for the AUV (light blue) and human tracker (light red) and 50% utilization distribution for the AUV (dark blue) and human tracker (dark red), showing high overlap between the two methods.

Techniques to Overcome Data Scarcity in Deep Learning for Passive Acoustic Monitoring of Marine Mammals – Pandovese (2023)

- A lack of annotated data is a bottleneck for effective deep learning PAM models.
- Effective solutions include transfer learning and data augmentation in deep neural networks.
- Promising future solutions to test include generative adversarial networks, active learning, auto-regressive models and incorporating wider temporal context – a task applicable for an AUV with adequate sensors.

PROPOSED CONTRIBUTIONS

I propose to make some or all of the following contributions:

- **Reproduce the state of the art:** Use their system [2] as a guide for the design of the AUV acoustic tracking system, because of their detailed system overview and good benchmarks. This includes the choice of sensors, control algorithms and hardware-software interface.
- **Extend the system:** Implement a future work recommendation such as improving the obstacle avoidance control. Another extension might be the inclusion of an embedded recorder for certain frequency bands to collect data for PAM models.
- **Produce a working simulation:** Validate the design and implementation through simulation.
- **Conduct field experiments:** Further validate the system physically by applying it to a particular tracking task in a marine environment, where collaboration with a marine scientist could be important.
- **Investigate and implement a PAM model:** Implement an appropriate model to categorise sound for the purpose of critically analysing links between the tracked behaviour and the presence of man-made noise.

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