Advancing Marine Mammal Detection Algorithms with Acoustic Gliders in TRIDENT project

Introduction

Acoustic communication is a widespread phenomenon in the animal kingdom, with numerous species relying on sound signals for purposes like species and individual recognition, reproduction, and territorial defense . This mode of communication is observed across various taxa, including insects, frogs, fish, birds, and mammals such as cetaceans (Wilkins et al., 2013). The geographical variation in acoustic communication is prevalent in many species, and factors driving this variation include environmental conditions, genetic differences, geographic distance, and population isolation (Ey and Fischer, 2009 ; Campbell et al., 2010). Marine mammals, such as cetaceans, produce remarkable diversity of vocalizations at both interspecific and intraspecific levels (May-Collado and Wartzok, 2008; Papale et al., 2015). These vocalizations serve specific purposes and are crucial for their social interactions, group cohesion, predation, navigation, and reproduction. Cetaceans produce various types of sounds, including whistles, burst-pulses, and echolocation clicks, each with its unique functions (Zimmer, 2011). The classification of these sounds is often based on human perception and can vary across species and geographic regions. Cetaceans are known for their social nature and their ability to communicate within their groups and even with different species, employing different vocalizations to adapt to specific contexts (May-Collado and Wartzok, 2008). Echolocation is another critical aspect of their acoustic behavior, helping them navigate and detect objects or prey in the ocean.

Large cetaceans undertake extensive journeys across the oceans, spanning vast distances from tropical regions to the Arctic or across the expansive Pacific Ocean. Due to the great distances they travel, they are heavily dependent on sound for navigation, locating food and communicating within their group. However, the oceans have become increasingly polluted with anthropogenic noise, primarily originating from shipping and other human activities. This increasing underwater noise is a major threat to cetaceans and other marine species (Duarte et al., 2021 ; Delory et al., 2023). In this context, the application of acoustic gliders, autonomous underwater vehicles with unique capabilities, becomes a pivotal tool for passive acoustic monitoring (PAM) of marine ecosystems (Gibb et al., 2019). Using acoustic gliders to collect acoustic data in the marine environment, particularly for monitoring and studying marine mammals, is an approach that has both scientific curiosity and environmental protection concerns (Baumgartner et al., 2020). Acoustic gliders offer a discrete and non-intrusive means of capturing the acoustic landscape of the ocean, enabling assessment of the presence, behaviors, and vocalizations of marine mammals over extended periods of time and large geographical areas.

Scientific research is driven by the need to understand and conserve marine ecosystems in the face of increasing anthropogenic pressures. The knowledge gained from acoustic glider data not only contributes to fundamental understanding of marine mammals but is also an essential resource for conservation efforts (Baumgartner et al., 2020). To exploit the full potential of acoustic gliders in this field of research, it is imperative to address the challenges of on-board data processing and post-mission data analysis, to enable automatic detection, analysis, and identification of acoustic events. Furthermore, the ultimate goal of this scientific research is to develop innovative techniques capable of simultaneously detecting, classifying, and even identifying species-specific vocalizations, in order to improve our ability to monitor and protect the complex diversity of marine life that inhabits our oceans. In this context, this research strives to harmonize technological advances with the urgency of environmental management to advance our understanding of marine mammal acoustics and enhance their conservation in a world increasingly dominated by human activities.

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Motivations

Understanding the primary challenge of developing algorithms for the detection of biological sounds from data is a driving force in my professional aims. This challenge is intrinsically tied to comprehending the health of marine ecosystems in the face of the anthropogenic pressures emanating from noise pollution. To effectively address this challenge, it is essential to design detection methods that facilitate the comprehensive analysis of acoustic data, shedding light on the presence of biological entities and the potential consequences of human activities. My motivation to undertake this research project and develop a signal detection algorithm stem from a deep-seated desire to gain a thorough understanding of these intricate processes. Nevertheless, the accurate detection of these sounds in acoustic recordings presents a formidable task due to the presence of background noise, the dynamic nature of ocean conditions influenced by noise pollution resulting from human activities, and the inherent variability of biological signals. To enhance the understanding of these phenomena and maximize the utilization of acoustic data for marine research and conservation, it is crucial to optimize algorithms for acoustic signal processing. The ultimate goal is to develop advanced techniques for the comprehensive comprehension of marine biological sounds, utilizing methodologies such as threshold detection, pattern recognition, or machine learning approaches, all with the aim of obtaining more precise results and contributing to the preservation of marine biodiversity. The current frontier in algorithm development is of great interest to me as I set out to understand the complex research in acoustics.

1 – Why do we use acoustic gliders for listening to marine mammals at sea ?

A technique developed in the last decades, consists in using passive acoustic monitoring (PAM), and inferring about the status of cetaceans by just listening to their vocalizations (Zimmer et al., 2011 ; Usman et al., 2020). In some cases it is possible to attach an acoustic recorder (tag) to the animal's body and, when tags are recovered, learn about its behavior from the recorded sounds (Tyack et al., 2003). But these remain relatively rare cases and the most common practice is to listen from distance either with static/moored single recorders (Luo et al., 2016), or using moving platforms such as remote operate vehicles (ROV), autonomous underwater vehicles (AUV) (Goldstein et al., 2010) or gliders (Baumgartner et al., 2020). ROV are inherently limited since they are umbilical-operated and therefore require a surface platform (ship). Small or medium size AUV have severe range limitations and produce noise that interferes with the passive recording (Bingham et al., 2012). Finally gliders can travel in open ocean during long periods and are relatively silent. With the appropriate configuration gliders can cover long distances while sending snippets of data at regular (and programmable) intervals (Baumgartner et al., 2020).

2 – What processing for acoustic glider data ?

The efficient usage of acoustic gliders for cetaceans observation and conservation faces several challenges. One is the on board data processing and the other is the post-processing, after glider recovery. The objective of on-board processing is to reduce data to be transmitted while using the least energy as possible. Data reduction is normally done by 1) estimating average sound levels in pre-determined frequency bands and 2) detecting relevant vocalization events. This process should be fully automatic and fail proof. Post-processing aims at a detailed analysis of the full recorded data set and correlation with the detected events during on-board processing. Post-processing is a playback of the mission trial and listing findings for future reporting. This analysis may lead to future improvements such as on-board data analysis-based glider missions where the glider decides to change course or diving parameters, based on the analysis of the acquired and processed data during the mission itself.

It is therefore of paramount importance to automatically detect, analyze and, if possible, identify acoustic events for on-board acoustic glider processing. This is currently done using a variety of techniques ranging from simple energy detectors (Jesus, 2019), energy detectors and machine learning (Sabara et al., 2020), simultaneous detection, localization and tracking (Poupard et al., 2019) and sparse subspace mask detectors that also provide species identification (Socheleau et al.,2015), among others.

3 – What do we expect to obtain from acoustic glider data ?

Acoustic glider data may provide two crucial types of information: one is the sound level over the useful frequency band for model field-calibration; the other is proof of presence, localization (eventually tracking) and identification of large cetaceans in open sea and during long periods of time (up to 6 – 12 months). Sound levels histograms for each 1/3 octave frequency band are sort of routine for acoustic platforms. Target detection and differentiation / classification is a much more difficult task that requires improvement and further research in at least two aspects: simultaneous detection and species identification and building new or improving existing libraries of species sounds and their variations. Vocalization variations represent a challenge that requires flexible parameterized models with coefficients to be estimated by data matching. Existing data sets both online and on our own institution may be used for modeling and testing purposes. A new data set will be acquired during the TRIDENT project (https://deepseatrident.eu/ funded by EU HORIZON program) baseline survey sea trial, in February 2024.

4 – Time plan

- Month 1-2 (January-February): Understanding the Project and the Environment
  → Familiarization with the research team and organization
  → Literature review on the detection of marine and anthropogenic biological sounds
  → Understanding of available acoustic data and existing processing tools
- Month 3-4 (March-April): Algorithm design and development
  → Identification of specific requirements for detection algorithms
  → Initial design and development of algorithms
  → Preliminary tests on example data
- Month 5 (May): Optimization and Validation of Algorithms + Interpretation of results for thesis
  → Algorithm optimization based on preliminary test results
  → Validation of algorithms using more extensive and varied data
  → Analysis of detection results and performance evaluation
  → Finalize thesis and prepare oral presentation
- Month 6 (June): End of internship
  → Submission of thesis in early June (1 week before oral exam: no exact date yet)
  → Return to France on the weekend of June 8-9 for the internship oral, which takes place on June 12 and 13

Structure information

SiPLAB (http://www.siplab.fct.ualg.pt/) is a group of professors, researchers and university students interested in signal processing, underwater acoustics, and communications. It is part of the Signal Processing Group (SIPg) of the ISR- "Instituto de Sistemas e Robótica" and is itself a member of the LARSys Associated Laboratory. Marsensing Lda. is a spin-off from SiPLAB, with which it has special links and partnerships. SiPLAB has its own computing facilities and underwater acoustics equipment. SiPLAB is located at the University of Algarve, in the Faculty of Science and Technology on the Gambelas campus.

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