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THE HIDDEN PATTERNS OF MARINE SOUNDSCAPES:A BETTER APPROACH FOR IDENTIFYING AND COUNTING SOURCES OF SOUND IN MARINE AREAS OF SPECIAL CONSERVATION.

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ABSTRACT

Marine soundscapes are complex and dynamic, with sounds generated by various sources. Machine learning has revolutionized the identification of these sources, but limited sample sizes remain a challenge. We addressed this issue by measuring sound continuously over long periods within marine areas designated under the Natura 2000 Network. Our approach combines event detection with artificial intelligence and statistical analysis to define novel smart-indices. This foundation enables further ecoacoustic analyses, including species or phenomenon identification in specific areas. Our study demonstrates the feasibility of real-time neural network classification for sound source recognition. Integrating this program into a single-board computer facilitates continuous monitoring, providing valuable insights into studied area behavior. Our approach paves the way for future research on source detection and location using sensor arrays. We have advanced our technology to support these complex approaches.

Keywords: *Marine Soundscapes, Ecoacoustics, Machine Learning.*

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1. INTRODUCTION

In the current context, monitoring and tracking of marine species is an increasingly important issue given the growing awareness of the loss of biodiversity and the impacts of climate change on marine ecosystems. Locating and tracking marine species is a complex challenge that requires the integration of advanced technologies and effective strategies.

In this sense, this article presents a platform for monitoring and tracking marine species in coastal environments. Our proposal is based on the use of embbeded machine learning and beamforming techniques to detect and discriminate the sound sources of interest, which allows us to obtain valuable information on the distribution and behaviour of marine species.

The platform we present is capable of capturing and processing data in real time, which allows us to analyse patterns and trends in the activity of marine species. Our platform is designed to be modular and scalable, allowing us to adapt it to diverse marine environments and support efforts to conserve and protect critical marine ecosystems.

1.1 Marine biodiversity and protection

The UN Convention on Biodiversity , together with the Habitat and Marine Strategy Directives, are key tools to ensure a favourable conservation status of natural habitat types [1, 2].

In the marine field, the definition of Special Zone of Conservation (ZECs) is fundamental to protect critical species and habitats. However, the monitoring and tracking of these species and habitats are complex challenges that require innovative strategies and advanced technologies.

Ecoacoustics is an important branch of biological study that uses sound to analyse the well-being of particular sound environments. In this sense, the use of machine learning and beamforming techniques to locate and segregate sound sources of interest can be a valuable approach to monitor the marine biodiversity [3].

In this paper, we present a platform for monitoring and tracking marine species in coastal environments. Our proposal is based on the use of machine learning and beamforming techniques to detect and discriminate sound sources of interest. In this article, we present the results of our study on the implementation and evaluation of this platform in a coastal port of interest. Our results show the las advances in our platform to detect and discriminate sound sources of interest, which allows us to obtain valuable information on the distribution and behaviour of marine species.

2. DETECTION AND DISCRIMINATION

Since 2005, the Orca Ocean facilities at Loro Parque in Tenerife have been equipped with a set of hydrophones for recording the vocal activity of Orcas in the pools. Since then, efforts have been made to develop instrumentation to record, detect and classify the vocalisations of these animals. The development of hardware and software to automate these tasks [4, 5] has made it possible to use this technology and approach in the sea as well.

The modular recording and processing system is called an acoustic node and consists of a Raspberry Pi-based processing system with two hats, an audio digitiser card and a UPS encapsulated in a box that is isolated from the surrounding environment. The software has been developed mostly in C++ and runs on the PiOS operating system, a specific Linux distribution. The development platform for the different processing elements is modular and is based on a library called bcflow, on top of GStreamer. This enables real-time execution of the entire processing system.

The foundation of our framework is MASE, an instrument that assesses the marine Soundscape and energy using standard ecoacoustic indices. While MASE provides valuable insights into environmental conditions [6], it has limitations in quantifying biodiversity or detecting specific species, which are key aspects we aim to address with this new approach.

The detection system segregates acoustic events from

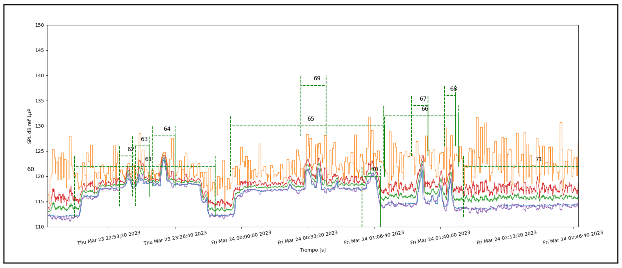

Figure 1. Events detected with a system in Santa Cruz de Tenerife Port.

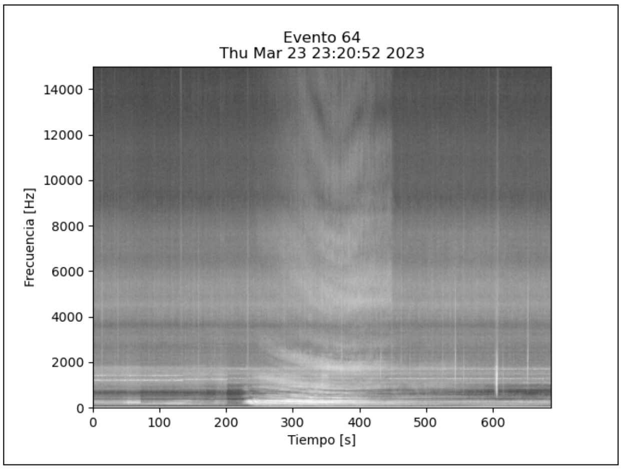

Figure 2. Spectral signature of event 64 that shows a moving motorboat over a drilling motor.

periods of silence. It is essential to understand that continuous background noise can be considered as silent intervals. An example of this type of event is shown in Fig. 1. The detection process aims to identify the presence of activity from a source at each node by analyzing changes in signal patterns. As illustrated in Fig. 2, the spectral signature information serves as input for discrimination. Following detection, the system discriminates whether the event belongs to one of the monitored source types. This information is then aggregated into indices that measure key parameters relevant to each source type. The precise timestamp marking at each node enables simultaneous estimates of location and informed indexing.

3. MACHINE LEARNING

Our modular processing architecture enables us to design diverse processing pipelines that leverage trained neural networks for various purposes. These networks are reduced-size models that facilitate rapid training and employ convolutional layers to generate a 16 −dimensional embedded space vector. This feature vector is fed into an LSTM layer, which produces a 64-element output used for dense binary classification of the source types we wish to discriminate. [7]

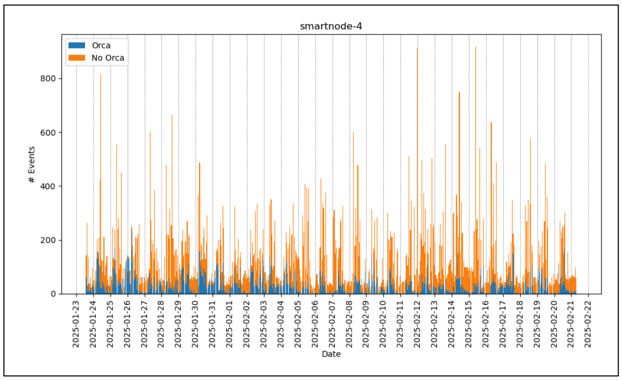

Figure 3. Discrimation of orca events with an smart-node at LP facilities.

As an example of the method's potential for other types of sources, we showcase orca discrimination training on a manually labeled dataset of 85 158 events. Fig. 3 illustrates the results of a real-time node operating in a sequential orca discrimination. The outcome is a set of richly informative indices of orca activity that can be utilized in conjunction with other metrics to inform comprehensive welfare evaluations.

The need to train these networks on specific data types, such as shrimp pistol clicks, wave crashes, or motorboat sounds, requires the tedious task of measuring and labeling concrete data types, that is work in progress.

4. CONCLUSION

In conclusion, our study has demonstrated the potential of combining event detection with machine learning and statistical analysis to define novel smart-indices for marine soundscapes. By leveraging real-time neural network classification and continuous monitoring, we have shown that it is feasible to recognize sound sources in complex marine environments. This approach can provide valuable insights into studied area behavior, paving the way for further research on source detection and location using sensor arrays.

The integration of machine learning with ecoacoustic analysis has opened up new avenues for understanding marine biodiversity and protection. Our study highlights the importance of large-scale data collection and continuous monitoring to overcome sample size limitations in machine learning applications. As we continue to advance our technology, we are well-positioned to support complex approaches that require high-resolution sensor arrays and real-time processing capabilities. Ultimately, our goal is to contribute to a deeper understanding of marine ecosystems and inform conservation efforts through the development of innovative acoustic monitoring tools.

5. ACKNOWLEDGMENTS

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