III. RESULTS

In order to obtain a decision value representing the whole segments, the average of p(SWC) was computed for each segment (Fig. 1). When a threshold is set at p = 0.6, such that all SWC-segments were correctly classified, 4 out of 42 ISN-segments were falsely predicted to contain SWCs.

IV. DISCUSSION

The first stage detects segments containing SWCs but also many segments with ISN. Therefore this detector cannot be used as a proper SWC detector. Its main usefulness is to selectively return a reduced volume of data to the second stage, which divides the data into SWCs and ISN. The classification obtained from long data series could be used to estimate the relative changes in sperm whale presence around an observatory.

V. ACKNOWLEDGEMENT

This project is funded under the European Commission contract FP6-2005-Global-4 - ESONET 036851-2. The LIDO consortium is formed by: Universitat Politècnica de Catalunya (UPC); Instituto Nazionale di Geofisica e Vulcanologia (INGV); Instituto Nazionale di Fisica Nucleare (INFN); Consejo Superior de Investigaciones Científicas (CSIC); Tecnomare; dBScale; Universidade de Lisboa (UL); Centro Interdisciplinare di Bioacustica e Ricerche Ambientali (CIBRA); Consiglio Nazionale delle Ricerche (CNR); Technische Universität Berlin (TUB); Zentrum für Marine Umweltwissenschaften (MARUM).

AN AUTOMATED, REAL TIME CLASSIFICATION SYSTEM FOR BIOLOGICAL AND ANTHROPOGENIC SOUNDS FROM FIXED OCEAN OBSERVATORIES.

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Abstract - The automated, real time classification of acoustic events in the marine environment is an important tool to study anthropogenic sound pollution, marine mammals and for mitigating human activities that are potentially harmful. We present a real time classification system targeted at many important groups of acoustic events (clicks, buzzes, calls, whistles from several cetacean species, tonal and impulsive shipping noise and explosions). The achieved classification performance indicates that the system will be useful to pre-process the very large data volume that can be gathered during long term acoustic monitoring campaigns or to detect the presence of cetaceans in real time for mitigation.

Keywords - Signal processing, ocean acoustics, bioacoustics, ocean observatories.

I. INTRODUCTION

Passive acoustic monitoring (PAM) of the marine environment has important applications for the study and monitoring of marine mammals and to understand how anthropogenic sounds affect marine life. PAM can be implemented continuously and over extended time periods, thereby enabling the recording of large and representative datasets. However, PAM campaigns inevitably result in a high rate of audio data acquisition. This can be problematic when the data needs to be transmitted, stored and analysed.

In case of continuous and long term PAM from fixed ocean observatories, it is generally expected that long sections of the data stream may not contain any acoustic events of interest. It is then desirable to automatically identify the interesting sections of the data.

The automated detection of a particular acoustic event in the marine environment is challenging for many reasons: (1) The large baseline level of background noise reduces the ability to detect weak acoustic events with a reasonably small false positive rate. (2) The intensity and the spectrum of the background noise is generally variable over time periods of hours or even minutes due to changes in sea state or local anthropogenic activity. (3) The occurrence of non-targeted events may falsely trigger a detector or, conversely, suppress the detection of a targeted event. (4) Targeted events such as cetacean vocalisations and sounds from shipping are very variable per se.

II. METHODS

The detection system is composed of two stages: The first stage, made of several detection algorithms, detects segments that contain acoustic events and tags them according to broad classes (e.g. low frequency impulses, ultrasonic impulses, short tonal sounds). The second stage, made of several classification algorithms, classifies events that have been detected in the first stage into more specific classes, which have practical relevance (e.g. impulsive ship noise, ultrasonic cetacean clicks, cetacean buzzes, whistles).

The accuracy of the system was assessed on a test data set that is representative of a diversity of situations that are to be expected at ocean observatories: It contains recordings from several geographic areas; impulsive, tonal and broadband ship-sounds; sounds from airguns/explosions; cetacean clicks, creaks and buzzes; cetacean whistles and calls; segments with only ambient background noise.

III. RESULTS

The first stage reliably tagged segments according to broad classes: short tonal sounds (whistles and calls of cetacean), constant tonal sounds (sounds produced by shipping), low frequency impulses (airgun, explosions), mid-frequency impulses (sperm whale clicks, impulsive ship noise), high frequency impulses (ultrasonic clicks from cetaceans, impulsive ship noise). The second stage reliably classified events that have been detected in the first stage into more specific classes. Cetacean calls were classified according to their frequency. Mid and high frequency impulses were classified as sperm whale clicks, ultrasonic cetacean clicks and impulsive ship noise. Fast bursts of impulses (e.g. creaks, buzzes) were identified. Fig. 1 shows how the system detects and classifies impulses.

IV. DISCUSSION

The palette of detected events is highly relevant when studying marine mammals and their interaction with anthropogenic noise. The detection system has been shown to work reliably under diverse and challenging situations expected during PAM campaigns at ocean observatories. This system will be useful to pre-process the very large data volume that can be gathered during long term acoustic monitoring campaigns or to detect the presence of cetaceans in real time to activate mitigation measures.

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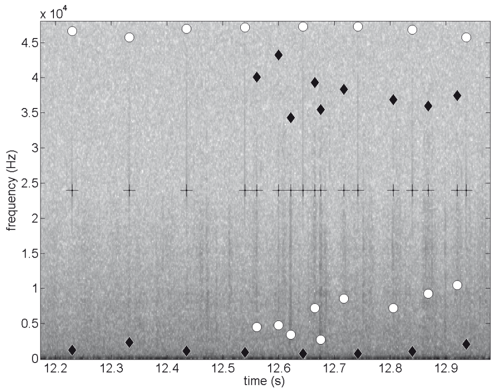

Fig. 1. Spectrogram of a segment with ultrasonic cetacean clicks (UCC) and impulsive ship noise (ISN). The detection of impulses in the band 20-46 kHz are plotted as black crosses (arbitrarily plotted at 24 kHz). At this stage UCC and ISN are confounded. The second stage classifier returns the estimated probability of being a UCC or ISN, plotted as white circles and black diamonds respectively (0 kHz: p=0, 48 kHz: p=1). By setting a threshold at p=0.5 the regular train of UCCs is separated from the ISN.

ARCHITECTURE FOR THE REAL-TIME MONITORING OF NOISE POLLUTION AND MARINE MAMMAL ACTIVITY

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Abstract - As acoustic pollution in the oceans is increasing, it is becoming more important to monitor it, with special attention on its effects on the behaviour of cetaceans. In the near future governments may require constant monitoring during sea construction projects or operations. One major construction activity in the coming years will be the construction of wind farms. Not only will these farms produce a constant low level noise in their direct environment while operating, but the building of the foundations necessary to support the wind mills will produce impulsive noise dangerous to any cetaceans in the area and lethal to, for example, fish larvae. For these reasons, noise monitoring has become one of the objectives of the European Seafloor Observation Network (ESONET), to investigate the level of noise produced around European coastlines and its impact on the environment and cetaceans especially.

Presented is the architecture for noise and marine mammal monitoring as it is currently implemented in ESONET through the LIDO (Listening to the Deep Ocean Environment) project. LIDO will detect in real-time changes in the background noise levels and register acoustic events (natural, biological and anthropogenic), and identify and track the sources when possible. As the system will be implemented in varying environments, a modular design is used that can be adapted easily, based on local requirements. While the system will most often run from a shore station, a more limited version is developed that can run autonomously with minimal power requirements.

Keywords – real-time monitoring, acoustic pollution

I. INTRODUCTION

The LIDO (Listening to the Deep-Ocean Environment) acoustic data management will be first implemented in the east of Sicily at a test site operated by the Laboratori Nazionali del Sud of the INFN, as part of a platform for the detection of geohazards and neutrinos, located at 2100 m, about 25 km offshore the Port of Catania (Sicily, Italy). Recordings are made on four channels at 96 kHz and are digitized at 32 bit at the hydrophone array. The digital data is then sent to a harbour station through an optical cable where it first arrives at the Acoustic Data Server (ADS). This server has a graphical user interface that allows an operator to see a spectrogram of the incoming data and is responsible for distributing the data on shore. The ADS will forward the data to real-time analysing servers operated by the UPC and CIBRA and a local Raw Acoustic Data Server (RADS). The RADS takes care of buffering and compressing the data before sending it over a wireless link to the LNS. Additionally, a Processed Acoustic Data Server (PADS) can be used by the analysis systems to temporarily store analysis results before they are sent to the LNS. The raw acoustic data will be stored permanently at the LNS in the Main Acoustic Data Server (MADS) where it can be accessed by collaborators. Other data, such as the analysis results, can be distributed through a webserver to the internet. The UPC data analysis is performed in two stages. The first stage is designed to be able to run on an autonomous system, close to the hydrophone array itself. It makes a quick decision on the contents of a data segment. If it does not find any interesting signal (impulse sound, frequency modulation, constant tonals), it will discard the segment and only keep some statistical information on the noise level found. If the system is configured to make the information available to the public in real-time, a spectrogram and 1-channel compressed audio stream are retained as well. The resulting information and data segments that are considered interesting can either be stored locally or transmitted directly to shore for a second stage analysis. For LIDO, this stage is done in the harbour station. At the second stage, sound sources are identified, located and tracked. Impulse sources can be located if the system has enough channels available, based on the time delay of arrival at the hydrophones. Accumulation of information at this stage may give more precise locations over time, and will allow tracking of the sources. Sources will be identified as natural events, shipping traffic (with possibly the type of ship), or the animal species that produced the sound. In order to correctly identify the sources a catalogue will have to be compiled with information of the natural and anthropogenic sound sources in the area.

From the streaming server at the LNS in Catania, a number of data streams will be made available. Apart from the analysis results that are sent to the LAB to be stored in a database, the server will also provide a compressed audio stream and analysis results to the general public. Conforming to the Sensor ML standard, sensor and hardware information will be made available from the website. Additionally, it is foreseen that Sensor Alert Services will be made available where visitors can subscribe to receive notification of specific events (e.g. cetacean presence or high background noise levels). The web server at the LAB collects analysis information from all platforms that have implemented the LIDO framework. This will allow correlation analysis between events or to find long term trends at a specific site as well as between different sites. The information will be available to the general public through graphical representation, together with a library of compressed audio recorded at the platforms for educational purposes. Furthermore, a flash client will be available to visitors that can be used to access the real-time data streams directly from a platform.

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