Leopold (IMARES) and Kees C. J. Camphuysen (Royal NIOZ).
This study was funded by the Spanish Ministry of the Environment under contract 083/SDGTB/2007

REFERENCES

[1] W. J. Richardson, C. R. Greene Jr., C. I. Malme, and D. H. Thomson, Marine mammals and noise. San Diego, CA.: Academic Press, 1995.

[2]P. D. Jepson, M. Arbelo, R. Deaville, I. A. P. Patterson, P. Castro, J. R. Baker, E. Degollada, H. M. Ross, P. Herraez, A. M. Pocknell, F. Rodriguez, F. E. Howie, A. Espinosa, R. J. Reid, J. R. Jaber, V. Martin, A. A. Cunningham, and A. Fernandez, "Gas-bubble lesions in stranded cetaceans - Was sonar responsible for a spate of whale deaths after an Atlantic military exercise?," Nature, vol. 425, pp. 575-576, Oct 2003.

[3] M. H. Lurie, H. Davis, and J. E. Hawkins Jr, "Acoustic trauma of the organ of Corti in the guinea pig," Laryngoscope, vol. 54, pp. 375-386, 1944.

[4] E. G. Wever, J. G. McCormick, J. Palin, and S. H. Ridgway, "Cochlea of Dolphin, Tursiops-Truncatus - General Morphology," Proceedings of the National Academy of Sciences of the United States of America, vol. 68, pp. 2381-&, 1971.

[5] E. G. Wever, J. G. McCormick, J. Palin, and S. H. Ridgway, "Cochlea of Dolphin, Tursiops-Truncatus .2. Basilar Membrane," Proceedings of the National Academy of Sciences of the United States of America, vol. 68, pp. 2708-&, 1971.

[6] E. G. Wever, J. G. McCormick, J. Palin, and S. H. Ridgway, "Cochlea of Dolphin .3. Tursiops-Truncatus - Hair Cells and Ganglion Cells," Proceedings of the National Academy of Sciences of the United States of America, vol. 68, pp. 2908-&, 1971.

[7] D. R. Ketten and D. Wartzok, "Three-dimensional reconstructions of the dolphin ear," in Sensory Abilities of Cetaceans, J. Thomas and R. Kastelein, Eds. New York: Plenum Press, 1990, pp. 81-105.

[8] D. R. Ketten, "The cetacean ear: form frequency and evolution.," in Marine Mammal Sensory Systems, J. A. Thomas, R. A. Kastelein, and A. Y. Supin, Eds. New York: Plenum, 1992, pp. 56-69.

[9] D. R. Ketten, "Functional analyses of whale ears: adaptations for underwater hearing," in Oceans' 94 Proceedings, 1994, pp. 264-270.

[10] M. Morell, E. Degollada, J. M. Alonso, T. Jauniaux, and M. André, Decalcifying odontocete ears following a routine protocol with RDO®, Journal of Experimental Marine Biology and Ecology in press.

REAL TIME CLASSIFICATION OF SPERM WHALE CLICKS AND SHIPPING IMPULSES FROM FIXED OCEAN OBSERVATORIES.

Serge Zaugg, Mike van der Schaar, Ludwig Houégnigan, Michel André
Laboratori d'Aplicacions Bioacústiques, Universitat Politècnica de Catalunya, 08800 Vilanova i la Geltrú, Espanya.
www.lab.upc.es

Abstract - The automated acoustic detection of cetaceans in real time is an important tool to study their behaviour and distribution and for activating mitigation measures in the context of harmful anthropogenic activities at sea. Acoustic data from the NEMO ONDE deep sea observatory (Sicily) indicated that sperm whale clicks were present in 15 % of the recordings and impulsive ship noise in 10 %. The ship noise poses a serious challenge to the detection of sperm whale clicks, since it is an important source of false positives. As part of an integrated classification system, we present a classification module aimed at the automated and real time classification of impulses from sperm whales and shipping. The achieved classification performance indicates that it reliably separates a large proportion of sperm whale clicks from shipping impulses.

Keywords - Signal processing, bioacoustics, ocean observatories, shipping noise.

I. INTRODUCTION

The automated acoustic detection of cetaceans in real time is an important tool to study their behaviour and distribution in the field and for activating mitigation measures related to human activities that are potentially harmful to them. However the classification in a fully automated way is challenging due to the diversity of acoustic events and background noises. Acoustic data from the NEMO ONDE deep sea antenna (-2000 m) indicated that impulsive ship noise was present in 10 % of the recordings and sperm whale clicks in 15 %. The ship impulses pose a serious challenge to the detection of sperm whale clicks, since they often share similar time frequency properties and hence could be the cause of many false positive detections.

As part of an integrated classification system, we present a classification module for the automated and real time classification of clicks from sperm whales and click-like sounds produced by shipping. The system also addresses the classification of other acoustic events (e.g. cetacean calls, ultrasonic cetacean clicks, tonal sounds from ships), which are not discussed here.

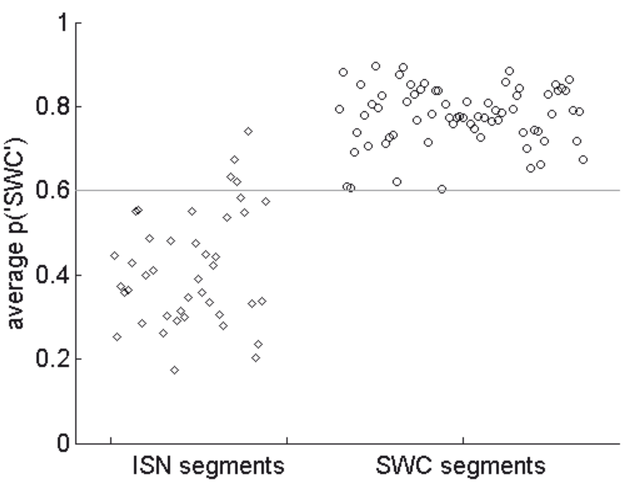
(right) Fig. 1. The predicted probability of being a Sperm Whale Click p(SWC) has been averaged for each segment and is plotted as diamonds (ISN) and circles (SWC). For illustration a possible decision threshold is drawn at p = 0.6.

II. METHODS

The data used to assess the module's accuracy consisted of 42 and 70 segments containing Impulsive Ship Noise (ISN) and Sperm Whale Clicks (SWC) respectively. These segments have been chosen manually from data recorded at the NEMO ONDE deep sea observatory between 6 and 20 of May 2005.

The module is composed of two stages: The first stage, detects segments that contain mid frequency impulses and returns their location. The second stage only processes segments that contain a sufficient number of mid frequency impulses. It first extracts a set of features, which describe the temporal and spectral shape of each impulse. Then, it uses a feed forward neural network that returns, for each impulse, an estimated probability of being a Sperm Whale Click, p(SWC).

In order to assess the classification accuracy, a cross validation was performed, where data from an entire day was left out for testing and the remaining data used to train the neural net.



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.

Serge Zaugg, Mike van der Schaar, Ludwig Houégnigan, Michel André

Laboratori d'Aplicacions Bioacústiques, Universitat Politècnica de Catalunya, 08800 Vilanova i la Geltrú, Espanya.

www.lab.upc.es

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.

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).