STEREO TO FIVE-CHANNELS BOMBYX SONOBUOYS : FROM FOUR YEARS CETACEAN MONITORING TO REAL-TIME ANTI-COLLISION SYSTEM

Best P.[1] **Marzetti S.**[3] **Poupard M.**[1] **Ferrari M.**[1] **Paris S.**1
Marxer R.[1] **Philippe O.**[2] **Giés V.**[3] **Barchasz V.**3 **Glotin H.**[1]
[1] Univ. Toulon, AMU, CNRS, LIS, DYNI, Marseille, France
[2] OSEAN SAS, Pradet, France
[3] SMIoT INPS Toulon, France
paul.best@univ-tln.fr, glotin@univ-tln.fr

1. INTRODUCTION

Sperm whale groups live and hunt in the Pelagos sanctuary all year round. It is believed that they make use of canyons and steep sea floors to ease their hunt for prey. The south side of the Port-Cros island is an ideal place to observe these animals, being near the coast for easier installation, as well as right next to Sperm whales' hunting grounds such as the Stoechades Canyon among others. In this area, the sea floor drops to -2000 meters in a few kilometers. In this paper, we describe two versions of a passive acoustic monitoring project that started in 2013 called Bombyx [1]. Passive acoustic monitoring describes the approach of animal biology studies via acoustic surveillance (placing microphones or hydrophones and listening to the acoustic activity of animals). For animals like Sperm whales, who rely on sound for not only communication but also navigation in the darkness of the depths, passive acoustic monitoring is most relevant. Multi hydrophones arrays allow the triangulation of the acoustic emitters, and thus to follow the animal's movement from a distance. In this paper, we will demonstrate several advancements in monitoring methods, all made possible by the Bombyx project.

2. BOMBYX 1

2.1 Material

The first implementation of the Bombyx project took form as an underwater buoy Fig.1, floating 25 meters deep, anchored on a 275 meters deep sea floor. The buoy is autonomous, relying on battery power, recording for dozens of days for several recording sessions. This approach offers a greater observability compared to listening from a boat or from a station connected to land via cable. The two hydrophones recorded at 50kHz using the JASON sound card [6] for a total of 112 days spread over 4 years.

2.2 Method

For such a large amount of data, the task of analysis in search for acoustic presence of Sperm whales is far from trivial. It is not possible for human annotators to listen to every piece of recording, and automatic detectors are not

Figure 1. Bombyx 1 during installation with its 2 hydrophones.

reliable enough yet to base behavioral statistics upon. To allow an efficient browse of the large amount of recordings, we developed a custom made interface shown in Fig.2 [2]. This interface first relies on a high recall but low precision click detector. By applying a Teager Kaiser energy operator on the signal after a band pass filter centered at 12.5 kHz [3], most Sperm whale clicks are detected, among other acoustic impulses such as pilot whale's clicks, engine sounds and others. We then computed the TDOA of those detected impulses between the two hydrophones. The scatter plot of TDOAs over time allows the identification of moving acoustic emission. Such an interface allows to go through 10 hours of signal in one look, easily identifying any potential moving acoustic emitter, which Sperm whales usually are. To then distinguish between Sperm whales and other moving acoustic emitters (boats or pilot whales), our interface allows to select a detected impulse, and to plot the spectrogram of its surrounding signal as well as listening to it.
This interface allowed the construction of a dataset consisting of 2312 Sperm whale samples, 154 pilot whale samples, and 3087 noise samples. Each of these belong to individual tracks.

3. BOMBYX 2

3.1 Material

The second implementation of the Bombyx project is yet to be placed into the water, in 2021 Fig.3. This time, a

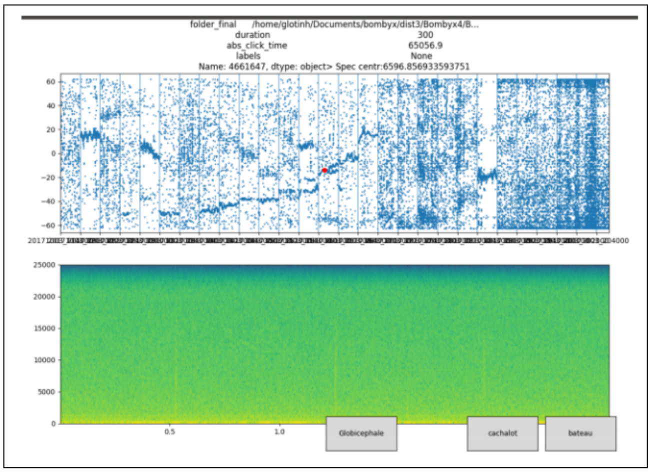

Figure 2. Annotation tool for the bombyx project. On top, the TDOA of each detected click versus time. At the bottom, the spectrogram of the sound surrounding the selected click (in red). The 3 buttons serve to annotate the selected click as Sperm whale, pilot whale, or noise.

floatability variation system will allow for both 20 meters deep recording and surface wireless data transmission, for an estimated battery life of 6 month. This real time data transmission is necessary since this buoy will serve as an alert system for Sperm whale and fin whale presence, reducing the collision risks via speed regulation or course modification. An array of 5 hydrophones will allow not only for azymuth esmitation, but also elevation, and distance of the acoustic source. The buoy will be equipped with a PIC32MZ micro-processor coupled with the JASON sound card [6] allowing for high frequency recording and embedded computations such as convolutional neural network forward pass, while consuming energy.

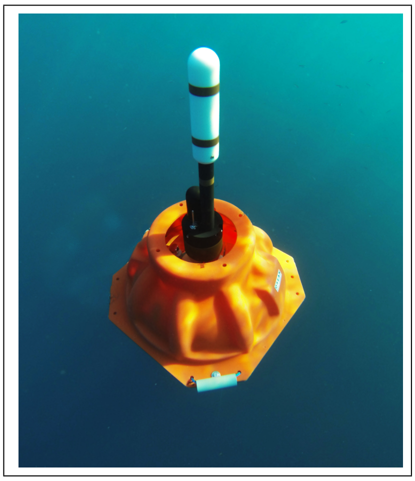

Figure 3. Bombyx 2 with the 4G transmitter and the floatability variation system. The 5 hydrophones array is fixed at the bottom.

3.2 Method

The data collected and annotated during Bombyx 1 served to optimize an analog detection system as well as to train a convolutional neural network Fig.4 for Sperm whale detection. The analog detection system makes use of band pass and low pass filters to compare the energy above 8kHz with the background noise level. High frequency energy peaks are thus detected as potential Sperm whale clicks. The peaks' duration and periodicity are checked against the possible ranges for Sperm whale clicks using a state machine. This analog detection system showed an area under curve of 75% on the Bombyx 1 annotated data. This allows for an ultra low power (17A) always on detector.
The following verification of the acoustic emissions makes use of a convolutional neural network for a more robust classification of the detected acoustic impulse [5]. A low complexity network of approximately 10 thousand parameters, with a Mel-Spectrum frontend followed by 3 depthwise convolution layers of 64 features each was designed. Trained on the Bombyx 1 data, and tested on the 2017 recordings (none of which were present in training), the model showed a performance of 98% of AUC on the training set and 92% of AUC on the test set. After validation

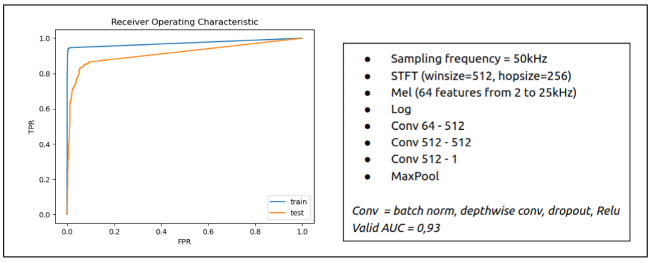

Figure 4. left ROC curve of the CNN binary classifier of Sperm whales, right topology of the network.

by the CNN, the times of arrivals of several Sperm whale clicks will be recorded using the analog detector at a time resolution of 50ns. All the hydrophones will be pointing in the same direction (downwards), allowing for the difference of phase method to infer the 3 dimensional position of the acoustic source at each click [4]. Integrating the inferred positions over several dozens of clicks will allow for a more robust estimation. The buoy will then rise to the surface and transmit to our lab the recorded times of arrival as well as sampled signals via 4G. After human verification, until the robustness of the system is validated, the alerts of Sperm whale or fin whale presence will be transmitted to authorities, and measures will be taken to minimize the collision risk accordingly.

4. ACKNOWLEDGEMENT

We thank Region PACA and Programma Interreg Italia-Francia Marittimo 2014-2020, Projet GIAS / Progetto GIAS, Whale anti collision alert system for support to P. BEST Phd. We thank SMIoT UTLN and INPS for sound card co-development and low power AI. We thank ANR-20-CHIA-0014-01 national Chair in Artificial Intelligence ADSIL(H. Glotin), and ANR-18-CE40-0014 SMILES.

5. REFERENCES

[1] Glotin et al. ”Projet VAMOS : Visées aériennes de mammifères marins jointes aux observations acoustiques sous-marines de la bouée BOMBYX et Antarès: nouveaux modèles en suivis et lois allométriques du Physeter macrocephalus, Ziphius cavirostris et autres cétacés” Pelagos Sanctuary Research Reports, `http://sabiod.org/pub/PELAGOS_VAMOS.pdf`, Univ. Toulon, 2017

[2] M. Poupard ”Contributions en Méthodes Bioacoustiques Multiéchelles.” PhD Thesis Université de Toulon, 2020.

[3] Kandia, V. and Stylianou, Y. ”Detection of Sperm whale clicks based on the teager–kaiser energy operator.” Applied Acoustics, 67(11-12) :1144–1163, 2016.

[4] Poupard, M., et al. Real-time passive acoustic 3D tracking of deep diving cetacean by small non-uniform mobile surface antenna. International Conference on Acoustics, Speech and Signal Processing (ICASSP). IEEE, 2019.

[5] Ferrari, M., et al. ”DOCC10: Open access dataset of marine mammal transient studies and end-to-end CNN classification.” International Joint Conference on Neural Networks (IJCNN). IEEE, 2020.

[6] Barchasz, V. and Giés, V. and Marzetti, S. and Glotin, H. Qualilife HighBlue : a smart low power high performance recorder for long term and or precise biodiversity surveys The Proc. of the Acustica Symp. 2020. European Acoustics Association and Society of France.