A NEW ACOUSTIC PAYLOAD FOR GLIDERS

Lionel Uzan[a], Fabien Pellet[a]

[a]ALSEAMAR, 60 avenue Olivier Perroy, 13790, Rousset, FRANCE

Lionel Uzan, ALSEAMAR, 60 avenue Olivier Perroy, 13790, Rousset, FRANCE, e-mail: luzan@alseamar-alcen.com
Fabien Pellet, ALSEAMAR, 60 avenue Olivier Perroy, 13790, Rousset, FRANCE, e-mail : fpellet@alseamar-alcen.com

Abstract: *With the support of the DGA, the aim of the AGLIMMS (Acoustic GLIders Mission Management System) project, is to efficiently coordinate a fleet of underwater gliders whose missions are to obtain physical, chemical, biological and/or acoustic measurements on a large 3D sea area. This paper describes the acoustic part under development and especially the passive acoustic results with the classification part.*

Keywords: *Glider, hydrophone array, underwater acoustic, classification, deep learning*

1. INTRODUCTION

The underwater glider, as a silent platform, has opened a new way to explore passive acoustic domain. Indeed, without external propeller or moving part, it navigates using only gravity and buoyancy. So, except during transition phases (surface and deepest point), the self-generated noise is very limited.

For example, it can be used in the Marine Strategy Framework Directive (MSFD) to measure environmental noise level, or to evaluate the biological features as marine mammal's status (number, localisation…).

Other important point to take into account is that sending information is only available at surface through a satellite communication and the piloting is done by an on-shore control team.

Some acoustic payload, adapted for gliders, are already available for measuring the underwater anthropogenic noise level, or detecting few species of marine mammals, but either the power consumption is too high or the software and algorithmic part are proprietary.

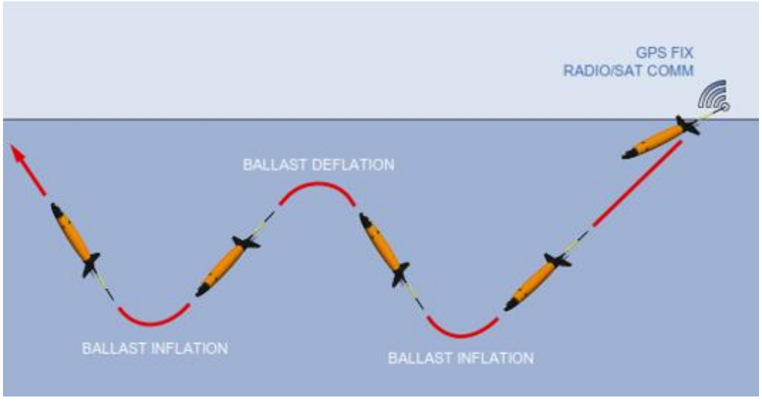

Fig.1: Glider principle

In this document, we only deal with the classification aspect, as this is a real breakthrough. Indeed, the use of deep learning inside a low power microcontroller is quite new, and it opens new possibilities to make easier the classification of acoustic events.

2. PAYLOAD DESIGN

In order to optimise the integration with the SeaExplorer glider, a new acoustic payload was developed to intend new possibilities. Indeed, the main asset of a glider is the endurance, so a special effort was done on the very low power electronic boards to maintain this point with a consumption of 1.7 W.

Moreover, to ensure a very good signal quality, the EMC point has also been taking into account. The system can deal with 8 hydrophones and this is a real breakthrough compared to the equivalent system on the market: the antenna gain (according to the mechanical design) can increase the detection range. The main specifications of the system are:

- sampling frequency up to 192 kHz
- storage on 2 TB of memory
- bandwidth: 10 Hz to 85 kHz
- ADC: 24 bits
- extra sensors input (CTD, SVP…)
- Some embedded application:

- audio recording
- environmental noise level measurement at normalized frequencies (for example 63 and 125 Hz) on 1 hydrophone
- detect an acoustic anomaly
- localize by giving a direction
- classify
- modify the mission following detection and measurement

Fig.2: Hydrophones mounted on the glider

The first mechanical design includes:

- 4 hydrophones in the nose in line array with a tuning frequency of 19200 kHz
- 4 hydrophones in planar array on the wings

On the modify mission point, two aspects will be available:

- as the glider can transmit information by satellite communication only at surface, it is planned, during a dive and in case of detection, to reach the surface as quickly as possible to send a message to the ground control.
- following sensor measurement as sound velocity, the glider could adapt its mission to stay into a favourable water layer.

3. PRESENTATION OF AN ASSESSMENT AT SEA

A campaign of measurement in the Mediterranean Sea was done between the 2nd and 10th of April, 2019.

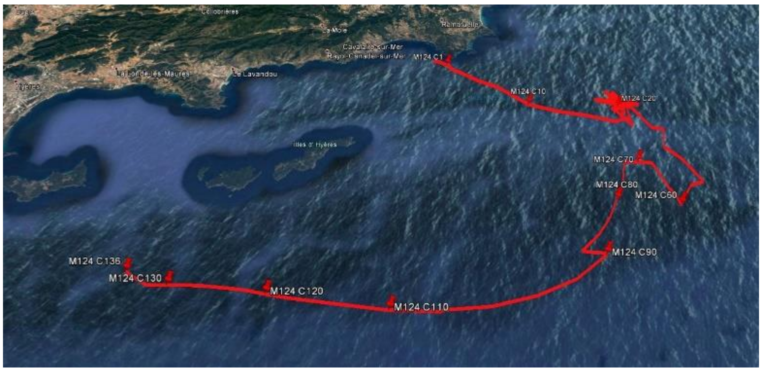

Fig.3: Track of the SeaExplorer (from Cavalaire to South of Porquerolles Island)

The main part of the measurement was done during a virtual mooring: the glider flights always around a fixed position.

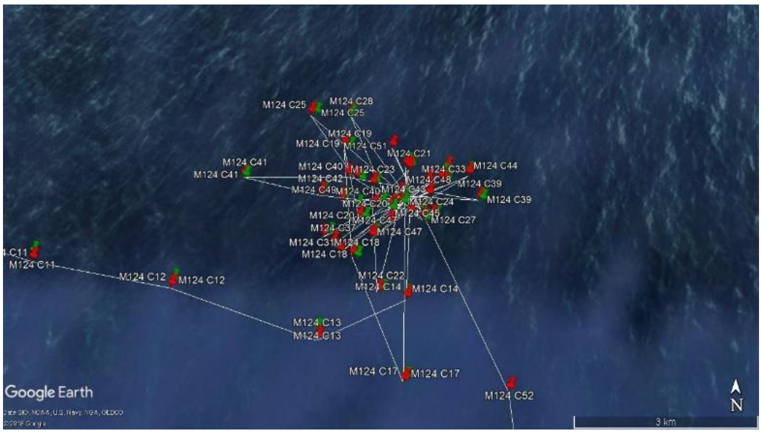

Fig.4: Virtual mooring at South of Cavalaire

There are some remarkable phases of flight that have been applied to the vehicle:

- Different vertical speed (11, 20 and 31 cm/s) for simple yo until 700 m depth: the vertical speed is modified by changing the weight in water with the ballast volume.
- Drift at several depth (100, 300 and 500 meters): during a drift the depth is controlled and some modification of the ballast volume can be done.

The recorder was configured with a sampling frequency of 96 kHz in order to save storage space.

4. SOUND CLASSIFICATION

A very important aspect of the acoustic payload developed into the AGLIMMS project, is the ability of classify acoustic events in real time. So, a particular effort was done to the choice of the microcontroller, on one hand for the best compromise power/consumption and on the other hand for the algorithmic skills. Indeed, the selected microcontroller can deal with deep learning technics as prediction using a pre-learned model.

The first step was to create a sample database for the model training, so, using the large amount of collected acoustic data, a list of categories was defined: boat, mammals click in HF (Fig. 5), dolphin whistle, rain (Fig. 6), normal ambient noise, SeaExplorer internal events (pump, actuator moves). The samples were selected manually with a proprietary software developed for this purpose. There are some samples taken for the learning.

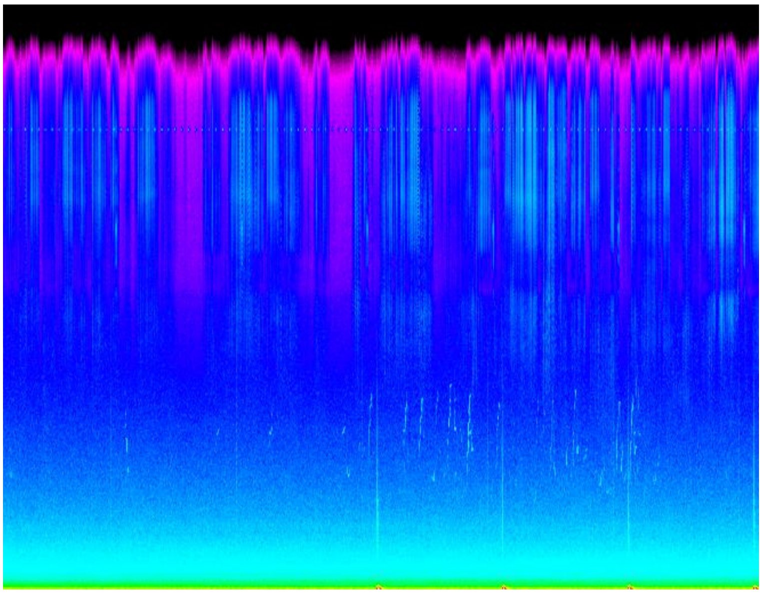

Fig. 5: Spectrogram of dolphin whistles and mammal clicks

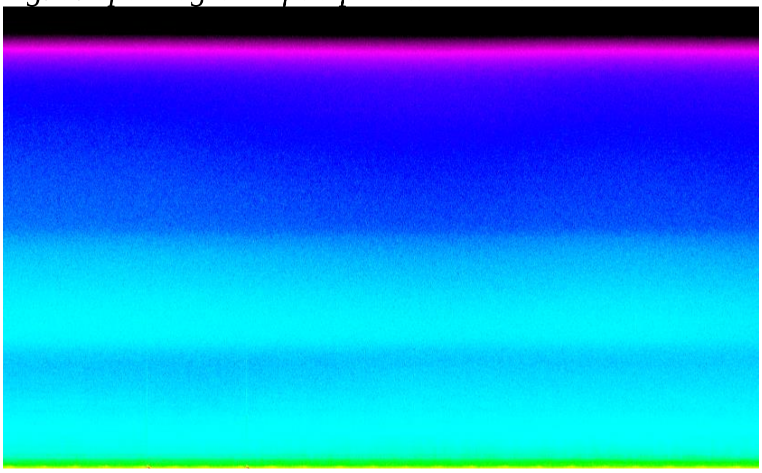

Fig. 6: Spectrogram of the underwater noise caused by the rain

In [1], several odontocetes click frequency range are described, but it seems that there is no matching with a species living in Mediterranean Sea.

The rain noise spectra shown in Fig. 7 can be compared to the spectra given in [2] with the "bump" starting at 14 kHz.

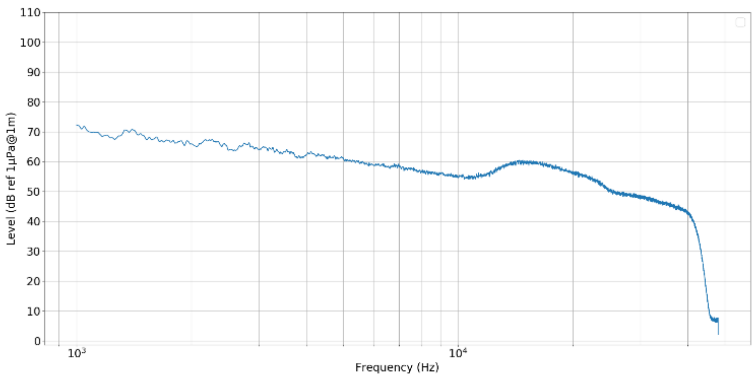

Fig. 7: Noise spectra produced by rain

Then, after the database creation, some relevant features have to be defined dealing with the model dimension:

- 1D with data vector as input,
- 2D with image as input.

The deep learning process can probably give better results with image than vector but as the microcontroller as a very limited memory size, the 1D is the only acceptable solution with a model and weight file of few dozen KB against dozens of MB.

In [3], several features are proposed, but after an evaluation of several features with the confusion matrix, a set of features was selected. For the moment, this choice cannot be revealed because performance tests are in progress in order to tune the features parameters. For example, the features used for the following results are calculated for the whole bandwidth. According to the linear hydrophone array into the nose, the bandwidth could be reduced around 19200 Hz, but it will, probably, redefined the categories.

After a training on several thousand data (with a GPU on a desktop computer), the model and the weight matrix are uploaded to the microcontroller to evaluate the performance in term of computation time as the real time aspect is critical. The calculation time to process 1 second of data is around 35 ms including the features extraction and the prediction at a sampling frequency of 96 kHz. The results are checked with the ones produced by equivalent algorithm on the desktop computer and the two delivered the same prediction for the same test sample.

To evaluate the efficiency of the deep learning technic on the classification, we superimpose on the spectrogram, the result of the prediction as color line at the top. The length of the color line is proportional to the prediction score.

The green line that can be seen in the Fig. 9 and Fig. 10 is the depth of the SeaExplorer. The actuators are categorized into "angular" and "linear" that corresponds to the movement of the battery pack. The angular movement is the rotation of this pack and this allows the vehicle to change is heading. The linear movement is the translation along the lubber line and this allows the modification of the pitch. The noise category gathers all the moment without any disturbance.

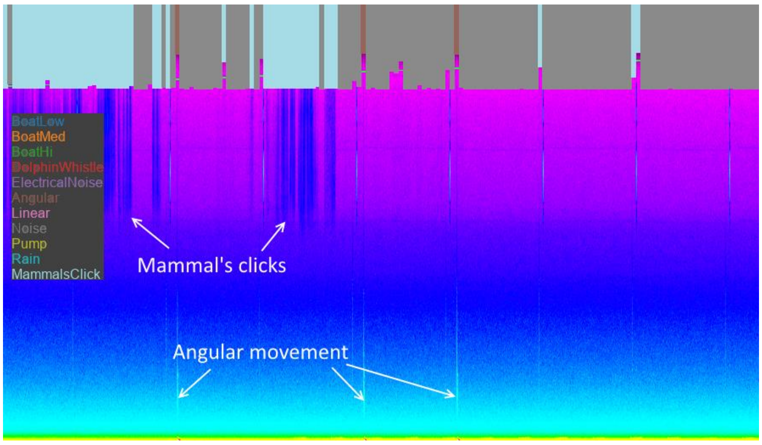

Fig. 8: Detection of mammals clicks

The boat detection is split in 3 categories (low, medium or high level) following the noise level generated. This choice is purely arbitrary and a specific study on this point must be done.

On Fig. 8, the mammal's clicks are well detected except at the end with 3 false detections: the event is classified as "MammalsClick" instead of Angular.

On Fig. 9, the deep learning prediction hesitates between the 2 levels of boat (low or medium). Probably the noise level generated by the ship(s) is as close to one as to the other category. This is reinforced by the fact that the prediction score can be low. Indeed, the prediction algorithm gives a score for each category, but two can have a relatively close score (only the maximum is displayed).

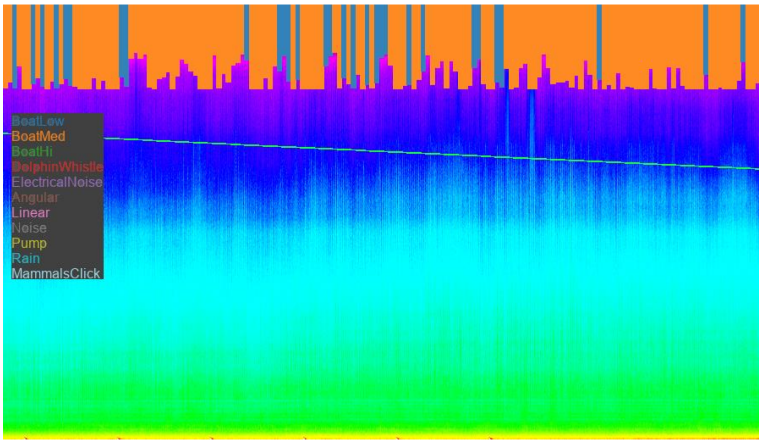

Fig. 9: Detection of boat

Finally, the rain is perfectly detected on Fig. 10.

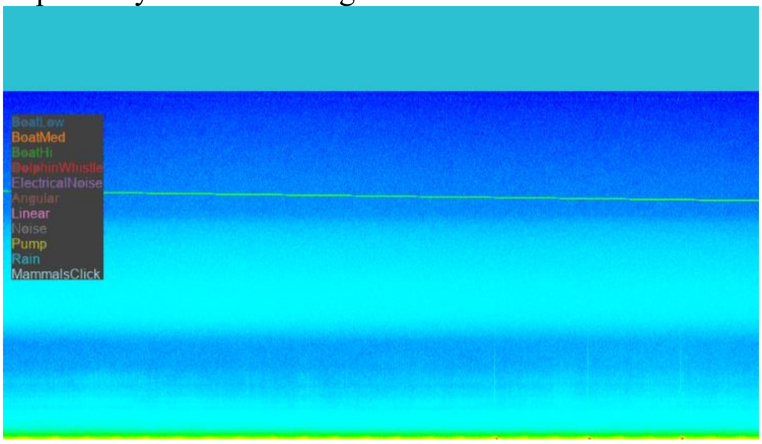

Fig. 10: Detection of rain

The classification using deep learning is quite promising because, firstly, it gives good results and secondly, because it can be embedded into microcontroller.

5. CONCLUSION

At this point, we don't use the hydrophone array to increase the detection range. Indeed, the hydrophone array in the nose is tuned for a frequency of 19200 Hz. So, coupling the array (with +6 dB as array gain) to get the direction of the source and the classification could be very interesting. The two software components are already developed into the microcontroller, but separately, so, a merge is necessary.

A demonstration with three SeaExplorer operating in a formation is planned late 2019 in the Mediterranean Sea. It will highlight the whole detection, localisation, classification process, and in case of "abnormal sound" detected (for example boat) modify the glider's behaviour to reach the surface and send an alarm message to the glider pilot on shore.

ACKNOWLEDGMENT

This work is partially founded by the French defence procurement agency DGA.

REFERENCES

[1] **Morisaka, T., & Connor, R. C.** (2007). Predation by killer whales (Orcinus orca) and the evolution of whistle loss and narrow-band high frequency clicks in odontocetes. *Journal of evolutionary biology*, *20*(4), 1439-1458

[2] **Scrimger, J. A., Evans, D. J., McBean, G. A., Farmer, D. M., & Kerman, B. R.** (1987). Underwater noise due to rain, hail, and snow. *The Journal of the Acoustical Society of America*, *81*(1), 79-86

[3] **Malfante, M., Dalla Mura, M., Mars, J. I., & Gervaise, C.** (2016). Automatic fish sounds classification. *The Journal of the Acoustical Society of America*, *139*(4), 2115-2116