Detection and Classification of Marine Mammals sounds

First Month Report

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Bioacoustics

Introduction

The detection and classification of Marine Mammals acoustic emissions from audio files is a complex task that requires precise parameterisation operations to obtain the most reliable results possible.

This report provides an overview of what has been done during the first month of the internship and what remains to be done. This work concerns the project of detection and classification of marine mammals in the Hellenic Trench, in particular species of sperm whales and striped dolphins.

For this purpose, audio files of these species are available and the use of the PAMGuard software is recommended. For each file, a classification has been done by a specialist to say if it belongs to sperm whales or striped dolphins.

Figure 1: PAMGuard logo

Hands on PAMGuard Software

The use of PAMGuard requires an understanding of how the different tools work in order to be able to use them properly and also to get the most out of their capabilities. This required some familiarisation and training before the internship and especially during the first and second week. In this section, the different PAMGuard modules that have been used and the usefulness of each of them will be explained.

PAMGuard is an open-source software that allows acoustic analysis of audio files. It has various modules that enable signal processing, detection of patterns and their classification as one or more marine mammal species.

Signal processing

In order for the PAMGuard software to reach its full potential, the first important part to master is the cleaning of the audio file. This is done to reduce the ambient noise and to keep the signal of interest for further processing. This part is critical because if it is erroneous, it can call into question the entire detection and classification process that follows.

For this part, several modules exist and allow the signal to be amplified, one or more filters to be applied and an amplitude threshold to be defined.

DETECTION module

PAMGuard has two modules for detecting characteristic forms of communication in marine mammals. A Clicks detection module and a Whistle detection module.

Click detection module

This module allows the detection of clicks emitted by a sperm whale, striped dolphin or any other marine mammal whose sound frequency range falls within the detection field of the tool. This module is the one most used in the context of detection and classification work from audio files.

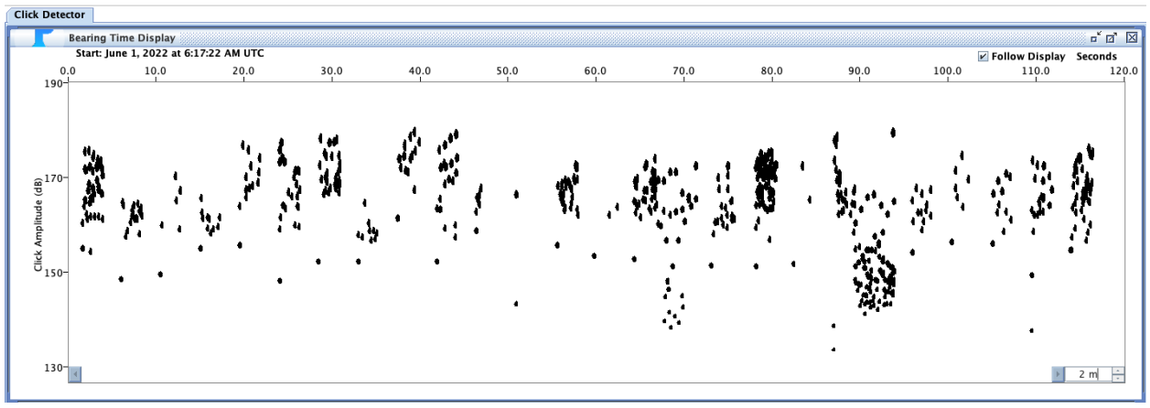

Figure 2: Clicks detection from a test file

Whistle detection module

This module allows the detection of whistles embedded in the ambient noise of the sea as well as other parasite noises. This module refers only to striped dolphins since sperm whales do not whistle.

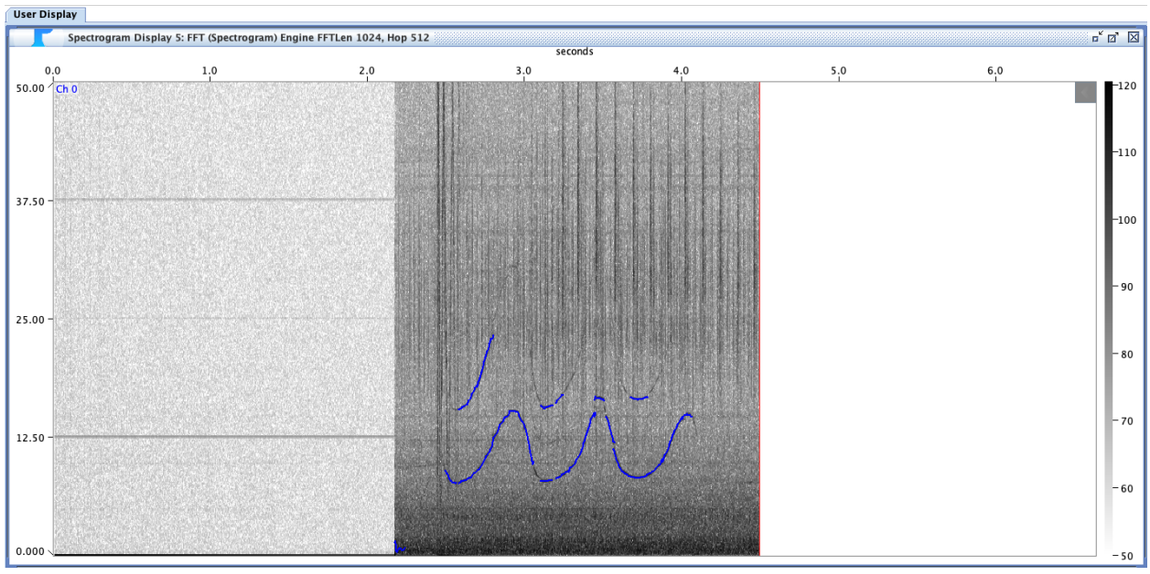

Figure 3: Whistle detection from a test file

CLASSIFICATION module

PAMGuard also has two classification modules. The first module is for the classification of Clicks. This one, integrated to the clicks detection module, allows to define frequencies and amplitudes characteristics to each species to be classified. The second module is used to classify whistles and thus determine the presence or absence of dolphins in the recordings. The parameterisation is a task that requires great rigour and precision.

Click classification module

This module of PAMGuard is the one that should be handled with much attention. Indeed, the clicks of sperm whales and striped dolphins are emitted in a very wide frequency range which does not allow a certain classification in all cases. It is therefore necessary to determine the best possible parameters to allow a satisfactory identification with the lowest possible false positive and false negative rates.

Whistle classification module

This module is useful for the identification of striped dolphins. Indeed, among the two species which interest us, only the dolphins emit whistles. The identification is thus facilitated and the implementation of this module does not seem to pose particular problems.

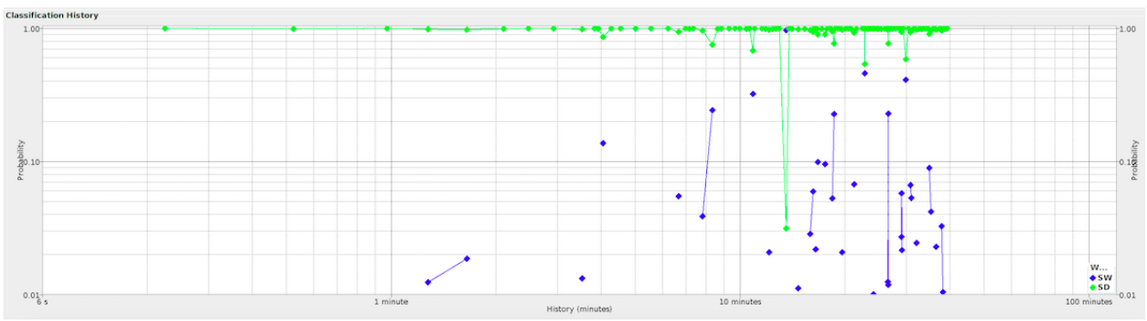

Figure 4: Probability of presence of a Striped dolphin (green) or Sperm whale (blue)

Data storage module

A final module to be taken into account is the one that will recover the data from the analysis. This module is very important for the data analysis part which comes afterwards and which can be carried out as well on MATLAB as on R.

Documentation

Sounds Characteristics

After getting to grips with the software, it was considered necessary to carry out some documentation work on the characteristics of the sounds emitted by the Sperm Whale and Striped Dolphin species.

Gathering information on this subject is an important part of finding out the differences and similarities in the way these two specific species communicate. Clicks and Whistles are the mains characteristics which we will use in this work.

Numerous books and scientific papers have identified the sound characteristics of these two species. Although they emit in a wide range of frequencies, there is a strong similarity between the emission characteristics of sperm whale and striped dolphin species. The table below summarizes the basic information collected on this subject.

	Sperm Whale (Clicks)	Striped Dolphin (Clicks)
Frequency Range	100 – 32 000 Hz	300 – 100 000 Hz
Peak Frequency	5 000 – 25 000 Hz	40 000 Hz
Mean Frequency	15 000 Hz	-
Inter Clicks Interval (ICI)	0,25 – 1,4 s	-
Rate	0,2 – 4 Clicks/s	900 Clicks/s

Figure 5: Table of characteristic parameters of the two species

References :

Todd et al., 2015, Marine Mammal Observer and Passive Acoustic Monitoring Handbook.

National Research Council. 2003. Ocean Noise and Marine Mammals. Washington, DC: The National Academies Press.

State of the art

In order to develop a working strategy, a state of the art work on detection and classification techniques of these sounds using Passive Acoustic Monitoring (PAM) was carried out. Many scientific papers have been published on the classification of marine mammals by PAM. This collection of references is important to see if there are any precedents and for possible publication later. All this information has been stored in a Trello so that it can be easily filed, retrieved, and used.

Figure 6: This space contains useful information and publications relevant to the project

Technical work

The second part of the first month's work was organized as follows:

1. Establishment of a strategy for the development of a detection and identification tool based on modules of PAMGuard.

It is very important to establish a clear development strategy to steer in the right direction from the start. A research project is based on a solid knowledge base that allows to move forward quickly in the achievement of it.

An important first task was to report on the possibilities and limitations of PAMGuard to find out what could be detected. Getting to grips with and understanding how the different parameters will influence the result is a very important task. It is therefore crucial to decide which parameters will be used in the detection and classification work.

2. Finding of the detection and identification parameters to be entered into the software to obtain the most satisfactory results.

The first strategy considered was to define two classification labels that would allow the separation of sperm whales and striped dolphins into two identifiable classes. This binary strategy seemed to be relevant at first sight (figure 7 and 8), however, the complexity of the sound signals emitted by these species does not allow to obtain good enough results for a qualitative classification.

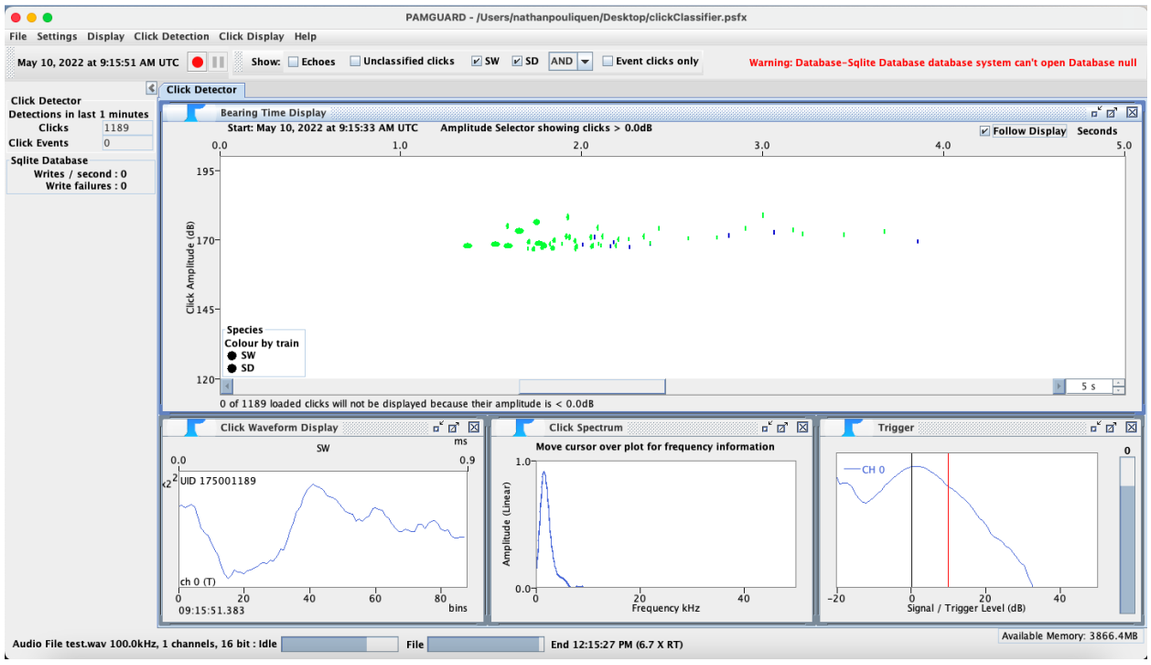

Figure 7: Classification of clicks for a sound of Striped Dolphin (green)

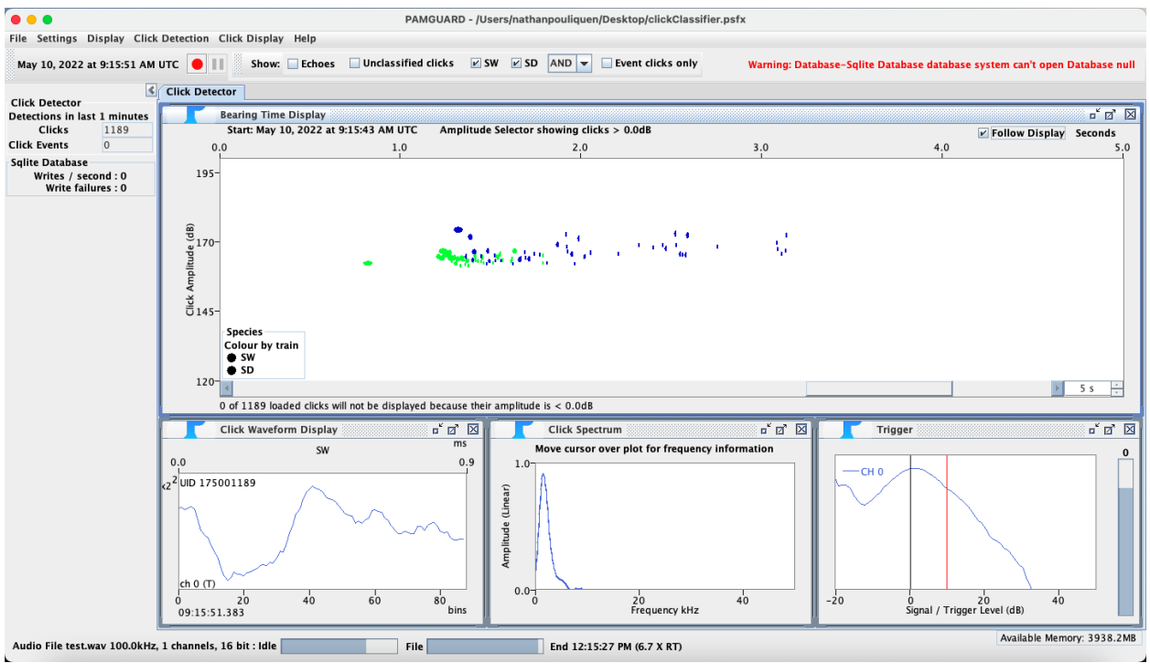

Figure 8: Classification of clicks for a sound of Sperm Whale (blue)

The second strategy was to define a larger number of labels. A label in the PAMGuard detection module is a classification tool that will locate and mark all clicks that match the detection field for which it has been defined. Using the information on sound characteristics collected, it was possible to define 7 labels in favour of identifying clicks from either sperm whales or striped dolphins.

The table below (figure 9) details the detection parameters for each of these labels:

Sperm Whale (shades of blue)	Label 1	Peak frequency 3500-4000Hz
	Label 2	Peak frequency 5000-7000Hz
	Label 3	Peak frequency 10000-15000Hz
	Label 4	Peak frequency 1000-3000Hz and Energy Bands 5000-7000Hz and 10000-15000Hz
Striped Dolphin (shades of red/orange)	Label 5	Peak frequency 19000-25000Hz
	Label 6	Peak frequency 27000-36000Hz
	Label 7	Peak frequency 1000-3000Hz and Energy Band 19000-25000Hz

Figure 9: Parameters used for each label

By adding as many relevant detection labels as possible, it is expected to obtain a higher proportion of clicks well identified as either species. This would result in a higher quality classification and greater robustness.

This multiple label technique does not give a binary response in the output. This results in a more complex classification model as can be seen below (figure 10 and 11). Labels for the classification of striped dolphin clicks are displayed in shades of red/orange while labels for the identification of sperm whale clicks are displayed in shades of blue. The parameters of each detected click will be compared to the labels and if the values match, it will be marked with the colour of the label.

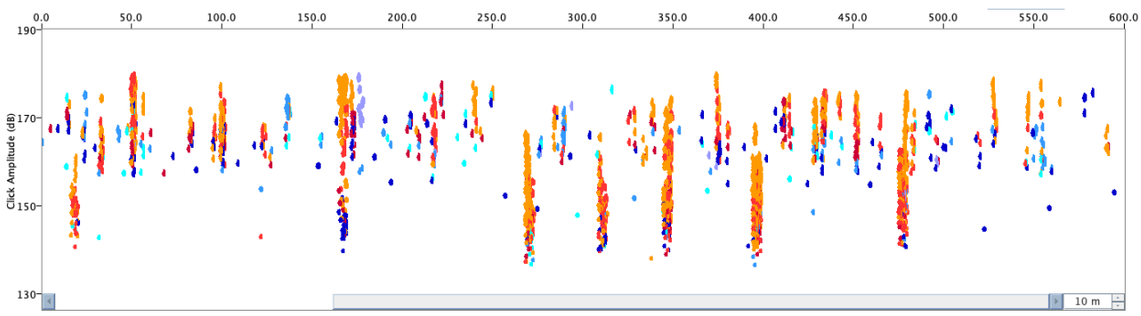

Figure 10: Classification of clicks for Striped Dolphins files

The figure above (figure 10) is the result of identifying clicks from audio files defined as being from striped dolphins. Visually, there is a strong predominance of red/orange coloured clicks. This results in a majority of labels in favour of the classification as striped dolphin.

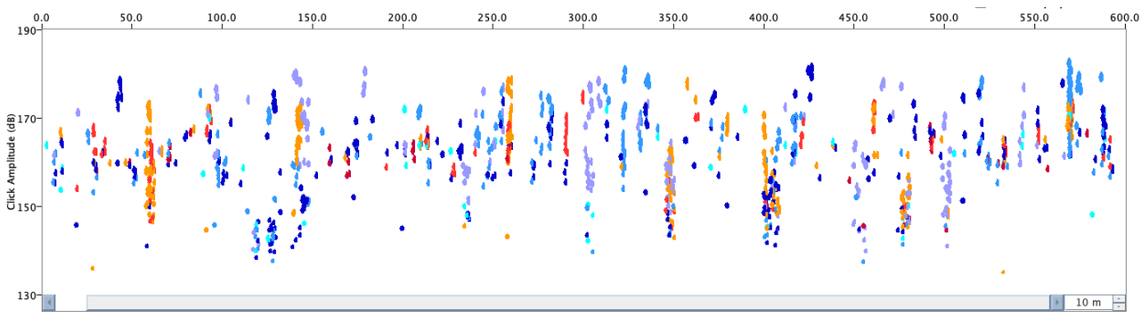

Figure 11: Classification of clicks for Sperm Whales files

The figure above (figure 11) is the result of identifying clicks from audio files defined as being from sperm whales. Visually, there is a strong predominance of blue coloured clicks. This results in a majority of labels in favour of the classification as sperm whale.

After retrieving the classification data from the PAMGuard software, it was necessary to develop an algorithm to relate the results achieved to the different labels. The technique consists of making a ratio between the data in favour of the classification of a sperm whale and those in favour of the classification of a striped dolphin. This ratio works in the form of a scoring system that increments over the audio file in favour of one species or the other. In the course of experiments with PAMGuard, it was observed that certain labels are almost exclusively present in a given species. It was therefore decided to assign a higher value to those labels whose presence allows for an almost certain classification.

After the implementation of this algorithm, a test was carried out on all the audio files. The results show that 71% of the files were correctly classified and 29% incorrectly classified (figure 11 and 12). These results are encouraging for the hypothesis that this strategy is effective in distinguishing the two species of marine mammals. Modifications in the way the ratio is performed are underway and it seems possible to obtain better results in the future. Further tests are expected to validate the accuracy and robustness of these results.

```
Score Stripped Dolphin files Score Sperm Whale files
SD_countSW = 39              SW_countSW = 70
SD_countSD = 308             SW_countSD = 114
SD_TIE = 0                   SW_TIE = 0
SD_NO_DETECTION = 0          SW_NO_DETECTION = 0
SD_NO_IDENTIFICATION = 1     SW_NO_IDENTIFICATION = 0
```

Figure 12: Results for each sppecies individually

In this figure (figure 12), the results of the files corresponding to striped dolphin and sperm whale sounds are displayed separately. We can see that the classification results for striped dolphin files are very satisfactory with a good detection of 308 files out of 347. On the other hand, the classification results for sperm whale files need to be improved. Indeed, only 70 files out of 184 are well classified.

```
Score Overall
Total_countSW = 109
Total_countSD = 422
Total_TIE = 0
Total_NO_DETECTION = 0
Total_NO_IDENTIFICATION = 1


Stats
Classification
True_Positive = 71.1864
False_Positive = 28.8136
```

Figure 13: Overall results

This figure (figure 13) shows the results for all files combined. In total, 422 files were identified as belonging to striped dolphins and 109 as belonging to sperm whales. In total, the True Classification rate is 71% and the False Classification rate is about 29%.

Conclusion and future work

During this first month, a lot of ground has already been covered. The work of documentation, state of the art and getting to grips with the various tools has been an essential step in the progress of the project and in obtaining promising initial results. There are still many stages of work to be carried out and they will involve writing a report detailing the choices made and justifying the approach envisaged.

The analysis of a second set of data will also make it possible to confirm or invalidate the first results obtained during this first month of internship.

For the following part of this course, several objectives are scheduled:

The first one is to look at a new unclassified data set in order to carry out automatic click and whistle detection operations using the PAMGuard software. The objective is to verify that the detection is effective even with another hydrophone and to validate the presence of marine mammals in the area concerned by this passive acoustic monitoring.

A second objective is to develop a new species classification algorithm using the R language and the PAMpal module. This package is used for loading, organising and processing the data produced by PAMGuard. The advantage is that PAMpal has many functions based on solid statistical bases that will be useful to classify species without having to create our own algorithm. This work will be done in collaboration with other team members who are already working on this topic.

The last task envisaged is to compare the results of the classification algorithm on MATLAB as well as those of the classification performed on R with the results of an artificial neural network algorithm already developed by a member of the team. This comparison will make it possible to verify whether the results from deep learning techniques are always superior to algorithms using classical statistical techniques.