Bioacoustic analysis of marine mammal sounds using signal processing methods

Internship offer

Supervisor: Adrien Meynard, Laboratoire de Physique, ENS de Lyon.
Contact: adrien.meynard@ens-lyon.fr

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Background: Bioacoustics is the study of sounds produced by animals. One branch of bioacoustics seeks to identify and discriminate between closely related species by determining species-specific markers. For example, BirdNET[1] is a mobile application, recently developed by the Cornell Lab of Ornithology, which allows you to determine with good precision the species to which a bird belongs from the recording of its song. Bioacousticians are also interested in the question of how to identify a specific individual among its congeners of the same species. Ecoacoustics, also known as acoustic ecology, involves assessing the biodiversity of an area based on the sounds captured in that environment. Bringing these two related fields together, the researchers wondered whether recordings of a wolf pack in a mountainous region could be used to determine the number of individuals making up the pack [4]. The aim was to identify a signature that characterizes the howling of each individual wolf.

Because of its historical connection with biology, bioacoustics has yet to exploit all the signal processing tools at its disposal to perform the desired tasks. Indeed, the measurements chosen by bioacousticians are often empirical, and rarely linked to a simple mathematical or physical model that would provide a better understanding of the dynamics involved in the production of these sounds. Signal processing is a discipline whose applications have historically been linked mainly to engineering: telecommunications, the oil industry for oilfield sounding, medical imaging, among others.However, signal processing offers many advantages for improving the analysis and processing of bioacoustic sounds. In particular, time-frequency analysis is a powerful tool for the analysis of non-stationary signals, capable of bringing out the underlying dynamics [1].

Goal: The aim of this internship will be to use a signal non-stationarity model to characterize the sounds produced by marine mammals [3].

The model adopted is as follows. Starting from a stationary signal with a given power spectral density, a time warping operation breaks the stationarity of the signal. In other words, the model adopted takes the form

$$Y(t) = \mathcal{D}_\gamma[X](t), \tag{1}$$

where $Y(t)$ denotes the measured signal, $\mathcal{D}_\gamma$ denotes the *time warping* operator parameterized by the function γ, and $X(t)$ the underlying stationary signal. This model has been studied in detail previously [2]. We have demonstrated that a particular time-frequency representation, called the *wavelet transform*, can separate the contribution of the stationary signal from that of the time warping operator. We have proposed an algorithm, named JEFAS[2], to estimate them independently. As shown in Figure 1, the decomposition of a sound produced by a dolphin was successfully obtained using this method.

[1] https://birdnet.cornell.edu/
[2] https://github.com/AdMeynard/JEFAS

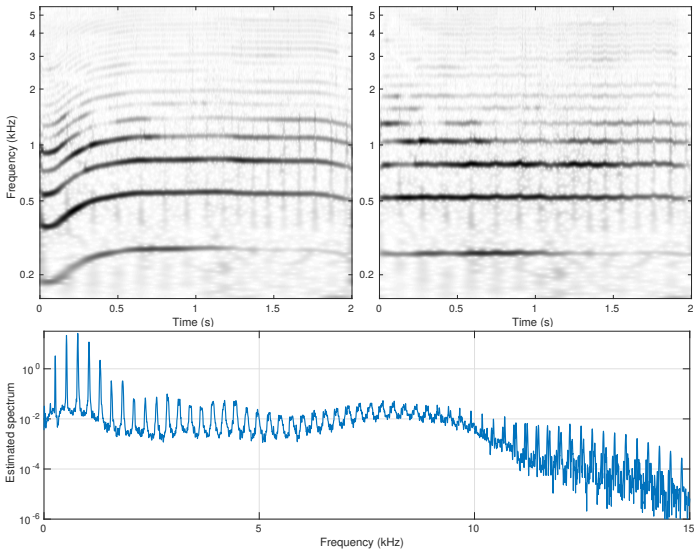

Figure 1: Analysis of the sound produced by a dolphin. Top: wavelet transforms of the original signal (left) and the estimated underlying stationary signal (right). Bottom: power spectral density estimated from the underlying stationary signal obtained by JEFAS.

During the internship, the student will have to learn the estimation algorithm and master the conditions necessary for its convergence. He/She will then have to exploit a database of recordings of sounds produced by marine mammals[3] to evaluate the species for which the model (1) is relevant. More suitable models may then be discussed and implemented. Depending on the initial results, we will use the model outputs to propose an interspecies or intraspecies characterization. In the first case, we will seek to answer the question: *What fundamental characteristics of these sounds distinguish two closely related species?* In the second case, we will seek to answer the question: *Can the features extracted by our algorithm from these sounds distinguish two individuals of the same species?* In both cases, a classification algorithm can be implemented.

References

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[3] John C. Montgomery and Craig A. Radford. Marine bioacoustics. *Current Biology*, 27(11):R502–R507, 2017.

[4] Daniela Passilongo, Luca Mattioli, Elena Bassi, László Szabó, and Marco Apollonio . Visualizing sound: counting wolves by using a spectral view of the chorus howling. *Frontiers in Zoology*, 12(22), 2015.

[3] `https://cis.whoi.edu/science/B/whalesounds/index.cfm`