A 3-D REAL-TIME ALGORITHM BASED ON ARRAY PROCESSING FOR THE LOCALIZATION OF CETACEANS

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Abstract - Hydrophone arrays permit to localize populations of cetaceans in real-time so as to study their behaviour in a non-invasive way and to work on their conservation. The most commonly used method based on time-difference-of-arrival can be challenged by space-time methods which can locate several simultaneous sources and separate them spatially.
This paper documents some results obtained qua bearing estimation of vocalizing mammals using a three-dimensional array with 4 hydrophones and various space-time methods such as the Capon and Music estimators.

Keywords - acoustic source localization, MUSIC, Capon, beamforming, bioacoustics, ocean acoustics, cetaceans

I. INTRODUCTION

Passive localization is a powerful and non invasive tool for biological and behavioural study, especially for the conservation of marine mammals. In the realms of the LIDO (Listening to the Deep-Ocean Environment) project with the underwater Nemo Station located offshore the Sicilian port of Catania at 2000m depth, more than 2000 hours of underwater recordings were gathered to be used for real-time passive detection of cetaceans based on their sound emissions. This requires a frequently updated and consistent three-dimensional estimation of their location under severe constraints such as extracting useful information from short duration broadband and directional signals buried in long sequences of evenly directional noise.

II. METHODS

Literature reveals that the prominent method for marine mammals' localization does not rely on STM but rather on a combination of time-difference of arrival (TDOA) estimation and geometrical exact solutions to provide an estimate of the position of the marine mammals. On the contrary, space-time methods such as beamforming or high resolution methods [2, 3] have been scarcely used though they have been applied with success in the field of digital communications, and even though they were actually created for underwater applications such as sonar.
After a pre-processing phase [5] which firstly detects cetacean and boat clicks and secondly provides their estimated time position, several methods, both in the TDOA and the STM class were tested and compared.
In the STM class, a Capon beamformer and a Multiple Signal Classification (MuSiC) estimator were computed. MuSiC is based on a data classification of the incoming signal into signal and noise subspace via a decomposition of the Space Covariance Matrix. The algorithms were run on short sequences (from 900 to 2000 samples) which theoretically lessens robustness but permits to separate direct and reflected path.
For real time purposes, the search space of the algorithm was reduced. Instead of finely examining the whole 3-D space, the estimation is firstly carried out for a bearing (both azimuth and elevation) with large 10 degrees steps. When a bearing is found to be redundant for several clicks, a more refined search is computed in a +/- 10 degrees zone around the first bearing estimation. Hence, the explored space is 70 % smaller than that for a 1 degree step. Using a 0.5 degree step in the refined search would still represent a 50 % decrease. This reduction, permitted by STM, makes the calculation time suitable for real-time implementation.

III. RESULTS

Our estimation was made on several sequences of recordings of five minutes containing sperm whale clicks.
It featured sharp peaks (fig.1) corresponding to a coherent series of slowly varying bearings possibly indicating motions of the animals.
On the whole, performed simulations show that applying the MuSic algorithm can provide consistent clustered estimates of bearing which can then be used for the spatial separation of several sources and their tracking based on the evolution of the estimated location.
Besides giving useful information on the source position and the position of the main reflections, the Capon beamformer also provides useful information regarding the spatial spreadth of underwater noise and its space-time variation. It was noticed that background noise is far from being evenly spread in space and has remarkable directionality.

IV. DISCUSSION & FURTHER WORK

These results could be compared to or combined with time-delays of arrival estimation in order to confirm that the bearings are correct enough and to obtain range estimation.
Indeed, TDOA estimation methods and STM do not have to be opposed; further work aims at merging the information coming from both methods [1] while maintaining low computational costs. Regarding real time-duties, it is foreseen that computation time could be reduced by optimizing the size of the search space via adaptive filtering.
Finally, reducing the selectivity of the detection phase in order to include reflections could facilitate the localization of sperm whales in terms of range which is yet missing.

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