AI for marine soundscapes analysis and SMART cables: New frontiers in ocean science

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Background

Current threats to oceans' health demand new approaches for description and monitoring of marine ecosystems. An important initiative is the K2D (Knowledge and Data from the Deep to Space) project, which has acoustic monitoring as a priority strategy to be implemented. Environments' soundscapes can be used to characterize marine fauna, by using hydrophones for studying benthic invertebrates and fishes, and for estimating habitat quality. However, the methods for analyzing acoustic data for soundscape ecology are still underdeveloped. Source separation (SS) techniques are powerful tools for improving information retrieval. Furthermore, feature learning can generate novel acoustic indices, which should extract more meaningful biological information than classical indices. As soundscape data volume grows, the development of efficient frameworks of SS will be necessary.

Oceans' monitoring and SMART cables

SMART (Science Monitoring and Reliable Telecommunications) cables have the potential to be a game changer in ocean monitoring, taking the spatial scale really up. Figure 1 shows the area that would be covered if the telecommunications cables to be activated in 2022 were equipped with nodes with sensors and capable of communicating with AUVs with a 1000 km autonomy.

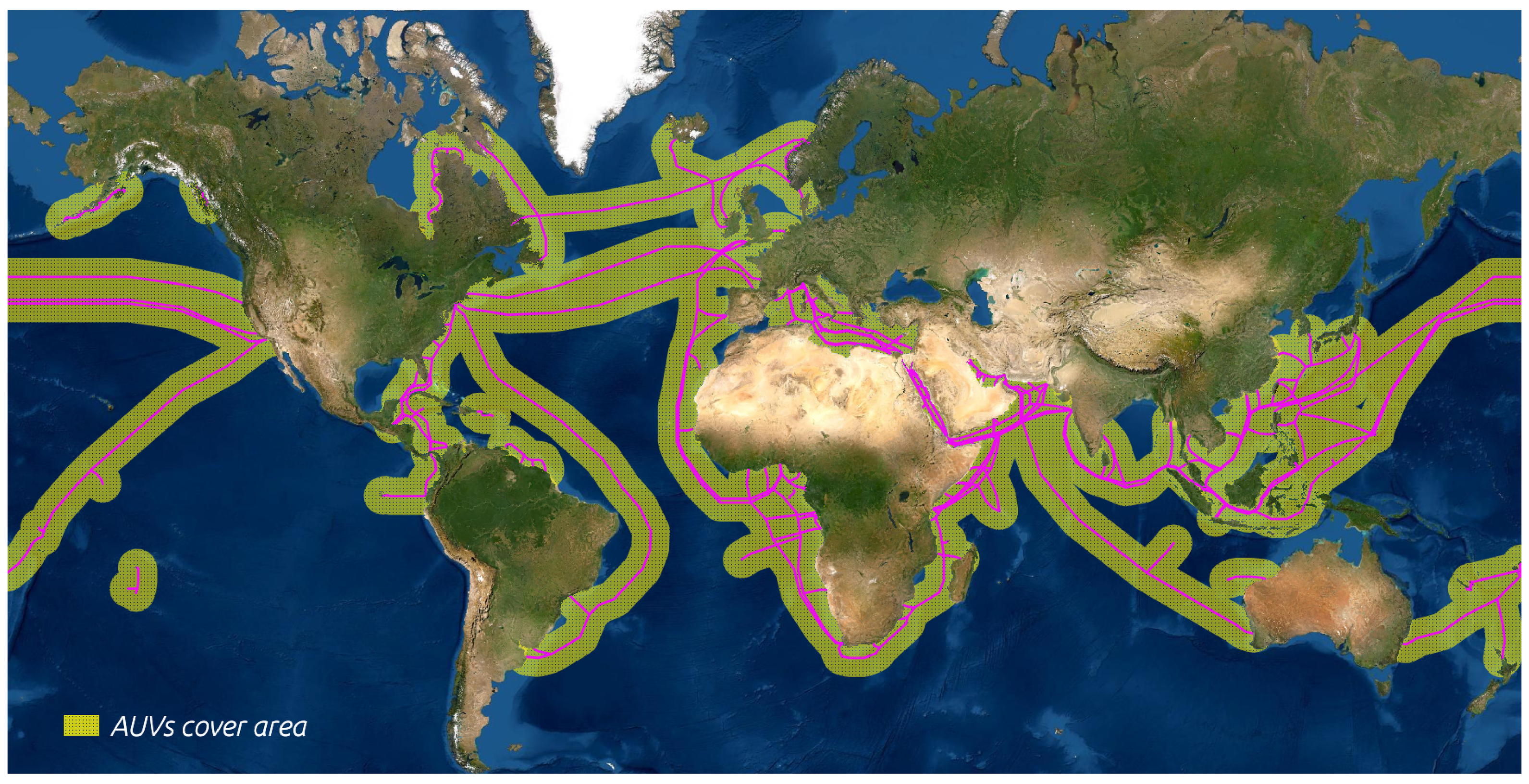

Figure 1 – SMART cables to begin operating in 2022 and area of coverage by AUVs with a 1000 km of autonomy.

Starting with small scales – The Algarve campaign

Source Separation

While the SMART cables are not a reality, projects such as K2D are important to build the foundations for their initial implementation. At K2D we are working at the development of frameworks for soundscape data analysis, so as to extract biologically meaningful information. For this, a hydrophone was deployed in 2022 at a rocky reef area in southern Portugal (Algarve) and set for continuous recording (Figure 2). After being recovered, SS was used for separating the different sound sources present in the records. The focus of this study was on the background noise, not on short duration sounds produced by, for example, passing-by fish. The SS method used is called Non-negative Matrix Factorization (NMF), more specifically, a variant called Non-negative Matrix Factor Deconvolution, based on the method presented by Smaragdis (2004). The frequencies of the different sources detected and the moments the signals appear in a small time interval are presented in Figure 3.

Figure 2 – Hydrophone deployed for data acquisition in southern Portugal, in a rocky reef area located at a depth of approximately 13 m.

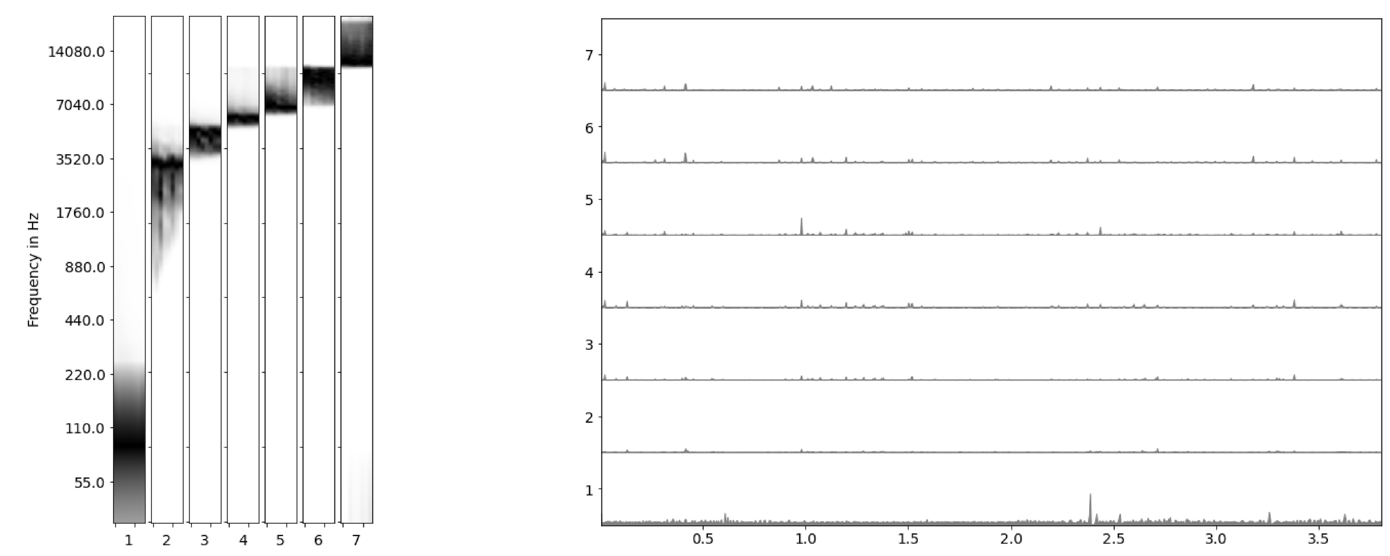

Figure 3 – The seven identified sound sources through the NMF method, with the frequencies (left) and the occurrences during a small time interval (right).

Feature learning

After obtaining the seven separate sound sources from SS, spectrograms of 1 minute intervals were extracted from each one of them, generating the data sets for training the convolutional autoencoders used for unsupervised feature learning. The feature maps generated on the last convolutional layer of the encoder composed 8 different groups, meaning roughly 8 feature types. A fully connected layer with 8 neurons in the end of the encoder was used to obtain the values for the features. Therefore, time series for the 8 features were obtained for each of the seven sound sources identified. For each source, most of these features had the same variability, showing that they could be considered portraying the same information. The time series for the two sources (the others present similar behaviors) are presented in figure 4. They clearly show two features that behave different form one another in time. Moreover, we can see that the red curve have the same behavior in both sources. The opposite happens to the blue curve, representing another feature.

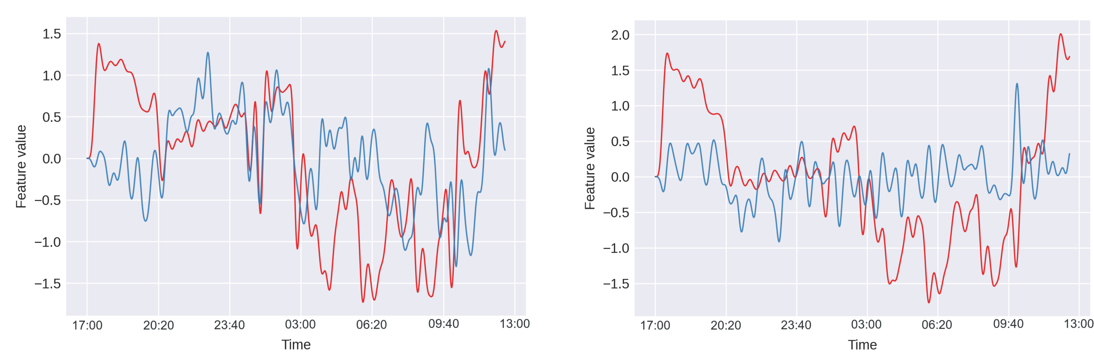

Figure 4 – Time series of the features for two sound sources obtained for July 3rd.

Conclusions and next steps

This work showed that it is possible to extract meaningful information from underwater environments in other ways than the classic acoustic indices. The framework here developed will be useful for adoption by SMART cables data centers. The integration between underwater acoustics with remote sensing and other in situ data sources, such as AUVs, has the potential to generate new ocean models. AI tools are key to achieve this, generating models with different layers that exchange data between each other (Figure 5). These can be the next generation of ocean models, based on Big Data.

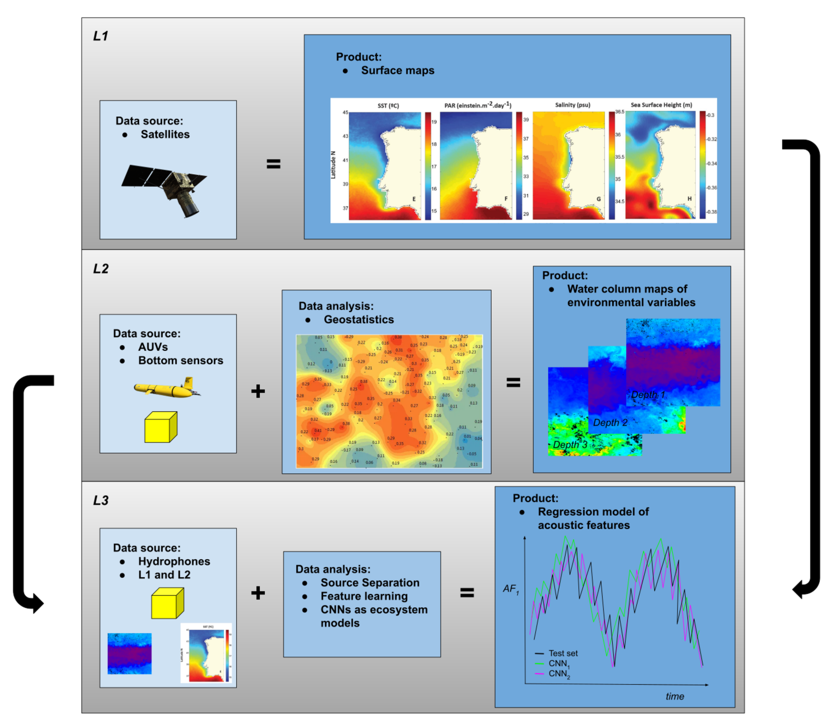

Figure 5 – Scheme for a 3 layer Big Data ocean model.

References

Smaragdis, P. (2004, September). Non-negative matrix factor deconvolution; extraction of multiple sound sources from monophonic inputs. In International Conference on Independent Component Analysis and Signal Separation (pp. 494-499). Springer, Berlin, Heidelberg

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