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Extended Abstract

Using Discrete Wavelet Transform to Model Whistle Contours for Dolphin Species Classification †

Paula Lopez-Otero [1,‡,*], Laura Docio-Fernandez [2,‡] and Antonio Cardenal-López [2,‡]

1 Information Retrieval Lab, CITIC, Universidade da Coruña, 15071 A Coruña, Spain
2 Multimedia Technology Group, atlanTTic Research Center, Universidade de Vigo, E36310 Vigo, Spain; ldocio@gts.uvigo.es (L.D.-F.); cardenal@gts.uvigo.es (A.C.-L.)
* Correspondence: paula.lopez.otero@udc.gal; Tel.: +34-981-670000 (ext. 1276)
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‡ These authors contributed equally to this work.

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Abstract: This work proposes the use of features based on the discrete wavelet transform (DWT) for dolphin species classification. These features are compared with other previously used in the literature, and the experiments carried out in a database featuring four different species of cetaceans (three dolphins and a pilot whale) showed that the use of DWT features led to improved classification performance.

Keywords: cetacean classification; whistle contour; discrete wavelet transform

1. Introduction

The health of marine mammal populations is often considered an indicator of overall marine ecosystem health and resilience [1], which makes it interesting to develop automatic tools to detect and classify cetacean species. Cetaceans produce characteristic sounds, such as whistles and clicks, that are used for different tasks such as navigation, communication or hunting [2]. The whistles are short narrow bandwidth sounds of short duration, and they consist in omnidirectional tones that vary with time, sometimes presenting a strong harmonic structure. In addition, whistle patterns vary between species due to physiological differences or environmental conditions, among others [3], making it possible to distinguish cetacean species using these sounds.

Several efforts for classifying cetacean species using whistle contours have been made. In [4] and [5], different parameters extracted from whistles were used to train a species classifier. Other features were explored in [6], such as the number of harmonics and frequency ratios. A statistical analysis of the discrimination capability of these features for classifying some dolphin species can be found in [7]. Other researchers used cepstral coefficients (CCs) for this task [8]. With respect to the classification strategy, some researchers rely on classifiers such as discriminant function analysis or classification and regression trees [3], while the use of Gaussian mixture models (GMMs) is also common [8,9]. In this work, a set of statistics obtained from the discrete wavelet transform of whistle contours is proposed for cetacean species classification.

2. Materials and Methods

In this work, four different cetacean species are considered: common dolphin *Delphinus delphis* (DDE), striped dolphin *Stenella coeruleoalba* (SCO), common bottlenose dolphin *Tursiops truncatus* (TTR) and long-finned pilot whale *Globicephala melas* (GME). A set of whistles was extracted as proposed in [9], which led to 24, 15, 15 and 23 whistles of DDE, GME, SCO and TTR, respectively. These whistles were extracted from a set of recordings collected by CEMMA (http://www.cemma.org/) (Indemares

Life 07/NAT/E/000732 project (http://www.indemares.es)) in the Northwest of Spain (Galician Bank and Avilés Canyon) in 2010 and 2011.

The use of the discrete wavelet transform (DWT) for whistle characterization is proposed in this paper. The DWT is a multi-resolution technique that decomposes a time series into subsequences at different resolution scales providing data into high and low-frequency components. At high frequency, the wavelets can capture discontinuities, ruptures and singularities in the original data. At low frequency, the wavelet characterizes the coarse structure of the data to identify the long-term trends. Thus, the wavelet analysis allows to extract the hidden and significant temporal features of the original data. The first step consists in decomposing the original signal into approximation (CA) and detail (CD) coefficients by convolving the signal with a low-pass filter (LP) and a high-pass filter (HP), respectively. The low-pass filtered signal is the input for the next iteration level and so on. The approximation coefficients contain the general trend (the low-frequency components) of the signal, and the detail coefficients contain its local variations (the high-frequency components).

The analysis of whistle contours using DWT was carried out as follows: first the whistle contours were processed with a DWT (Daubechies-5 wavelet) and both approximation (a) and detail (d) coefficients were extracted from these raw contours and its logarithm version in four levels. Then, several features were obtained: percentage of energy of a and d coefficients in each level; relative wavelet energy and wavelet entropy; Shannon energy entropy and log-energy entropy of a and d in each level; RMS and standard deviation of a and d in each level; mean, standard deviation, skewness and kurtosis of the Teager-Kaiser Energy Operator (TKEO) [10] of a and d in each level.

3. Results

Four different systems were assessed:

- CC. Cepstral coefficients combined with a likelihood classifier based on GMMs as proposed in [8]. CCs were computed using 51 filters separated 500 Hz from each other, and uniformly distributed between 4 KHz and 30 KHz. The features were extracted every 1 ms using a 7 ms window.
- Whistle countour. Contour estimation consists in estimating the exact frequency of each whistle, aiming at obtaining an accurate detection of all the whistles in a signal. The frequency of whistle contours can be extracted using the unpredictability measure described in [9]. As in the case of CCs, the classification stage using whistle contours can be carried out by means of maximum posterior probability computation, as in [9].
- Whistle contour statistics (similarly to [3]): beginning and end frequencies, minimum and maximum frequencies, duration, slope of the beginning and end sweeps, number of inflection points, number of steps, frequency range. Support vector machine classifier with Gaussian kernel was used to perform species classification.
- Discrete wavelet transform as described in Section 2.

Table 1 shows the results of cetacean classification using the aforementioned systems following a leave-one-out strategy (the reported accuracies were obtained with the optimal parameters of each classifier). The outstanding performance of CCs for this classification task was proven to be misleading since the features are capturing information relative to the channel: this was demonstrated by means of a location-independent experiment, where these features showed an accuracy of 33.33%. In addition, an analysis of the confusion matrices of the different systems showed that DWT features were the only ones that achieved an accuracy above 50% for all classes.

Table 1. Accuracies obtained in the cetacean species classification experiment using four different systems.

Features	Accuracy
CC	86.59%
Whistle contour	55.84%
Whistle contour statistics	63.64%
Discrete wavelet transform	68.83%

4. Conclusions

This paper proposed the use of features extracted from the discrete wavelet transform for cetacean species classification using whistle contours. A comparison of these features with other approaches found in the literature showed an absolute improvement of 13% with respect to using the frequencies of the whistle contours and of 5% with respect to using a set of statistics extracted from the whistle contours. Nevertheless, the overall classification accuracy was around 69%, so there is still room for improvement.

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