Density Local Discriminant Bases for the analysis of otolith morphology in fish identification applications

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I. Introduction

Otoliths are calcified structures which are found in the labyrinthic cavities of all teleostean fish ear. Its morphology is so peculiar that allows both the classification of specimens and the estimation of age in fish identification applications (Fig. 1). The study and analysis of this object has become so important in the last decades that millions of otoliths are catalogued every year to control the management of marine resources [1].

In biology, the automated classification of species by means of computer analysis and image processing techniques has been one of the most challenging tasks since the middle of the 80's. Specifically, in the field of otolith-based fish identification there has been an increasing interest in finding specific differential characters whereas in age applications it is interesting to develop image processing methods that can detect the annual rings of the intensity profile efficiently (Fig. 2).

Since observable characters - such as length, height, weight, peak values, etc - are not always appropriate, Fourier analysis has become the main tool to highlight intra-specific/inter-specific irregularities and to detect the oscillations of annual rings. However, this transform is defined by an integral over the whole curve which restricts the analysis to frequency components.

In this, thesis we have developed a new semi-automated methodology (*Density Local Discriminant Bases* - DLDB), based on the discrete *wavelet packet* transform, which highlights the part of the contour shape that presents the differences. Its potential lies in the ability, to map irregularities as a function of the original domain, which allows structural descriptions to be made in the position of the frequency components. We calculated the density distribution of wavelet coefficients in order to determine class differences.

We obtained good results when comparing common cod (*G. morhua*) and hake (*M. merluccius*) with respect to classical methodology [2]. These are two of the most exploited species of the Mediterranean Sea and the world. We also obtained good results determining the age of plaice (*P. platessa*).

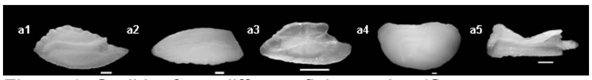
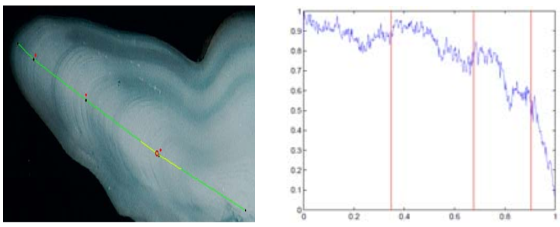


Figure 1. Otoliths from different fish species (Source: AFORO website: www.csic.es/aforo/).



(a) (b)

Figure 2.(a) Example of manual ring count for plaice otoliths and (b) Extraction of intensity profile.

II. Materials and Methods

- *Image and contour data preprocessing*

A total of 258 previously acquired otolith images of cod and hake specimens were used to obtain the x-y coordinate points of the contour profile. These species are known because they present remarkable differences in their otoliths. They had enough resolution (640x480 pixels) and were converted to a homogeneous black background in order to extract the radial profile by means of the Otzu method. All radials were resampled to a dyadic rate (256 samples) so as to allow a fast recursive implementation of the wavelet transform and the first harmonic of the Fourier ellipse was used for minimizing the effects of spatial rotation, image orientation and contour starting point over the wavelet coefficients. Additionally, the intensity profiles of 193 plaice otoliths were captured for ageing applications.

- *Feature extraction*

Our proposed method for feature extraction and class discrimination (DLDB) presents three main improvements with respect to the original proposal [2]:

First, it evaluates the wavelet coefficients based on their histogram density estimation, rather than the energy or the magnitude of coefficients. This change was introduced to enhance the separability of the small component which turned out to be more realistic than the magnitude of coefficients to determine the classes of the experiment.

Secondly, the original bottom-up tree node search was changed by a top-down strategy whose selection is based on the evaluation of its best node element. This modification was introduced to prevent this search from concealing the coefficients within the node that possess great discrimination capacity with respect to the rest.

Finally, the Kullback-Liebler metric was changed by a version supported on the Battacharyaa's affinity measure. The new expression allowed obtaining a normalized value of discrimination capacity (between 0 and 1) which made possible the comparison of efficiency between coefficients and different standard wavelet dictionaries.

The histogram bin width was left to the default configuration settings determined by the Sturge's rule. The best base shape (or wavelet library) was picked after evaluating the discriminant measure corresponding to the five most representative coefficients of all standard libraries in the software package. The momentums of *location* and *frequency*, and their deviation, were calculated for each coefficient and used to highlight the selected part of the contour by DLDB.

For ageing applications, an automated demodulating method was developed to preprocess the intensity profile before passing them thorough DLDB. This algorithm uses measures of periodicity based on the autocorrelation to find the optimal demodulation of the intensity profile.

- *Fish Identification and age estimation*

The Learning Vector Quantization classifier (LVQ) was used to assign classes to specimens: the specie or age class, depending on the application. The Standard Euclidean Distance was set as the default metric for the training and testing phase. Both 'hold-out' and 'cross-validation methods were used to estimate identification accuracy in our experiments.

All of our feature extraction algorithms were developed in MATLAB code, except for LVQ which was obtained from the author's web page [3].

III. Results and conclusions

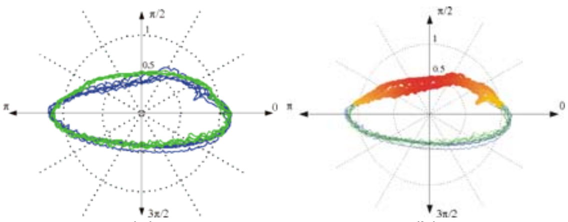
The new methodology was used in our experiments. Some of our goals consisted in comparing the performance with respect to classical feature extraction methodology, study interspecific and intraspecific relationships of hake otoliths and improving the estimation of age, among others.

Figure 3 shows common shapes for cod and hake and the selected regions, by DLDB, using the best coefficient. This feature, which is clearly located in the differentiated part of both species, known as dorso-caudal and rostral-area, allowed determining the correct class of all specimens. Although similar identification results could be obtained with classical methodology, unlike linear discriminant analysis (LDA), one of the main contributions of our methodology is the additional information that is provided to biologist regarding otolith morphology.

For example, the selected regions of cod otoliths are, clearly, more concave, have larger radial and have less oscillating behavior than their counterparts in hake otoliths. These regions matched with the selected characteristics by DLDB.

Table 1 lists the discrimination power (DLDB$_5$) and identification accuracy (A_7) for some interspecific and intraspecific experiments from hake species of the world. These results show one of the most important properties that, in our opinion, feature extraction methods should have in relation with classification methods: normalized discrimination measures should grow with identification success, as far as possible. For example, if the measure is normalized between 0 and 1, a two class experiment should provide similar results within the range of 50% and 100%, respectively.

Figure 4 shows the profile for the plaice otolith of Fig. 2, after using our demodulating method proposed in this thesis. When the original method [2] was replaced and the original input profiles were substituted by our demodulated profiles, identification results for plaice increased from 73% up to 90%. The otoliths were from five different years class groups, comprising: one year or less, two, three, four and five years or more.



(a) (b)

Figure 3. Example of feature selection by DLDB with cod (green) and hake (blue) otoliths. (a) Original normalized contours. (b) Location support of the best DLDB coefficient.

Experiment	* DLDB$_5$	A_7 (%)	Std(A_7)
Intra-specific			
M. merluccius	0.377	77.6	1.3
M. bilinearis	0.85	90.1	2.9
M. gayi	0.65	84.5	2.3
M. productus	0.37	69.3	2.9
Inter-specific			
M. albidus – M. bilinearis	1	100	0.0
M. capensis – M. paradoxus	0.72	88.9	1.7
M. polli – M. senegalensis	1	99.4	2.0
M. gayi – M- australis	0.61	78.9	3.3

Table 1. Identification results for different *Merluccius* species considering the best five DLDB coefficients. * Normalized discrimination power.

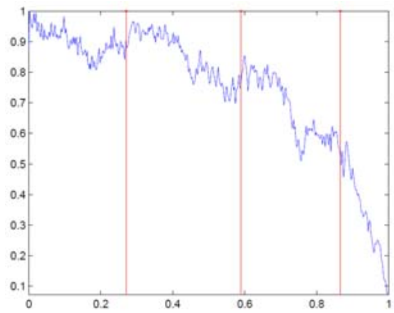


Figure 4. Example of demodulation of an otolith intensity profile. After demodulation, each year period has the same interval.

Part of this work was funded by the AFISA European project (Automated FIsh Ageing, project nº 044132) and some of the algorithms presented above were integrated within the software package TNPC v4.0 from Noesis.

IV. Acknowledgements

The author would like to thank the members of the, IFREMER institute, Ronan Fablet, Helen de Pontual and Sebastian Carbini, who participated in the project and provided the images that made this work possible, and the members of the AFORO team at the ICM Research Institute for their comments and ideas on the technical implementation of the algorithms involved.

V. References

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