ACCURATE FISH POSITION AND ORIENTATION PARAMETERS CORRELATED TO WIDEBAND ECHO : A NEW APPROACH FOR CLASSIFICATION OF FISH SPECIES

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ABSTRACT

This work deals with the correlation between high accurate geometric parameters of a free-swimming fish in a tank, obtained by image processing, with the associated 20-140 kHz wideband sonar echo acquired simultaneously. Variations in terms of Target Strength and normalized spectral energy are studied for three species of fish, perch, roach and char, according to different geometric parameters. Classification of the three species is implemented.

1. INTRODUCTION

Classification of fish species is a current problem in sonar acoustics. Most of the time, researchers use tethered alive [MIYA 90] or anesthesized fishes [CLAY 94] to know position and orientation aspect of fish in sonar beam. But it is known that ultrasonic echo depends on physiological change of fish, therefore acquisition during unnatural conditions (not free-swimming ones) may be far from natural echoes. Some of them [FOOT 83] use free-swimming fishes and take fish images to get fish position towards transducer echo but not in a very accurate way. As fish echoes depend strongly on orientation and position of fish in the ultrasonic beam, we present here first tests to classify fish species with wideband (20-140 kHz) sonar echoes correlated with high accurate fish position and orientation. We plot variations in terms of Target Strength and normalized spectral energy according to fish position and orientation, and try to classify three lake species (perch, roach and char).

2. MEASUREMENT SITE

2.1 The tank

Our fishes are free-swimming and move in a net in a tank of 3 meters deep by 2 meters in diameter, in nearly natural conditions [Figure 1]. The tank is fitted out with a constant beamwidth sonar (made by Van Buren [VANB 83]), an hydrophon and three underwater cameras.

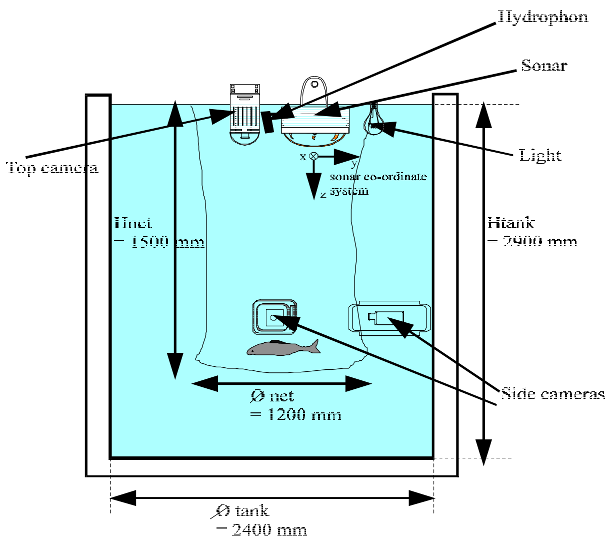


Figure 1.- Tank of experimentations.

2.2 Data collection

Our experiments perform simultaneous acoustic and behavioural observations of fish [Figure 2]. It takes about 200 ms to get three orthogonal views and one echo. We have collected about 100 acquisitions per species.

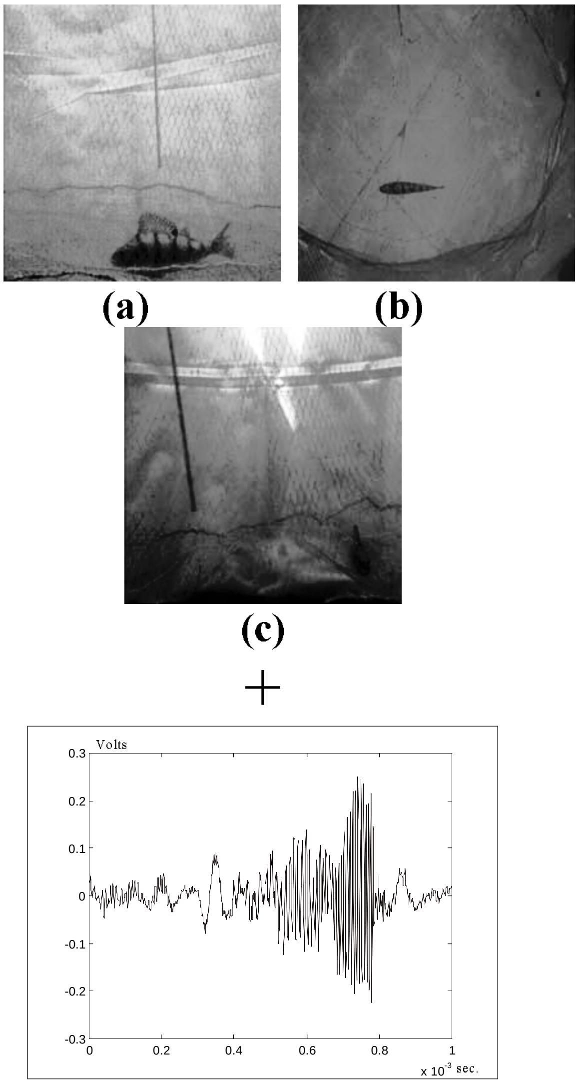


Figure 2.- Three images of a perch and its corresponding echo. (a) and (c) are 2 orthogonal side views, (b) is top view.

3. DATA PROCESSING

3.1 Parameters extraction

We proposed in a previous paper [BACE 94] a new algorithm to extract orientation, position and geometric parameters of fish. We have tested our algorithm on a phantom of fish with well-known position and orientation. We found an accuracy of 0.2 cm for centroid, 1.5° for tilt and yaw angles, and 3° for roll angle [Figure 3]. We have also proved that three cameras are necessary to extract these parameters with robustness.

From three images [Figure 2], we can reconstruct [Figure 4] and extract accurate fish parameters in every case [BACE 95].

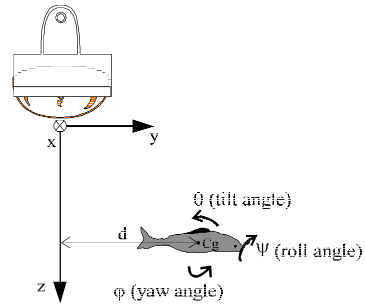


Figure 3.- Definition of θ, φ, ψ *and* C_g *(d) in sonar co-ordinate system.*

Figure 4.- Fish reconstruction with three views. Centroid is at x = 18.5 cm, y = -2.7 cm and z = 153.9 cm in sonar co-ordinate system. Positioning angles are $\theta = -6.1°$, $\varphi = -3.5°$ *and* $\psi = 3.3°$.

3.2 Different frequency forms of ultrasonic signal : Target Strength or normalized energy

With wideband sonar, each fish can be characterized by its target strength (TS) or its normalized energy in 20-140 kHz band. The TS is a well-known parameter since the first research on classification of fish species using ultrasonic echo [LOVE 71]. It is given by :

$$TS(f) = V_{yc}(f) - V_{ys}(f) - 20 \log 2d_1 + 40 \log d_2,$$

where $V_{yc}(f)$ is the spectrum in dB of the fish echo, $V_{ys}(f)$ is the spectrum in dB of the surface echo, d_1 is the upright distance between the transductor and water-to-air interface and d_2 is the upright distance between the transductor and the fish centroid.

The normalized energy gives importance to the relative aspect of the spectral signature, regardless of global energy amount. It is given by :

$$W(f) = \frac{\left|G_c(f)_{linear}\right|^2}{\sum_{f_{min}}^{f_{max}} \left|G_c(f)\right|^2} \text{ where } G_c(f) = \frac{Y_c(f)}{Y_s(f)}$$

is the transfer function of the target in the [20-150 kHz] frequencies band.

$Y_c(f)$ is the target response and $Y_s(f)$ is the surface echo response.

In order to compact our data, each signal (TS or normalized energy) is described by 28 bands of 5 kHz.

4. VARIABILITY OF THE SONAR ECHO IN THE SAME SPECIES

4.1 Variations in terms of Target Strength and normalized spectral energy according to geometric parameters

We plot variations in terms of TS and normalized energy according to θ, φ, and d. We left angle ψ aside because its extraction is not very accurate. We present below, for example, variations in terms of TS according to θ for a roach [Figure 5] and variations in terms of normalized energy according to d for a perch [Figure 6].

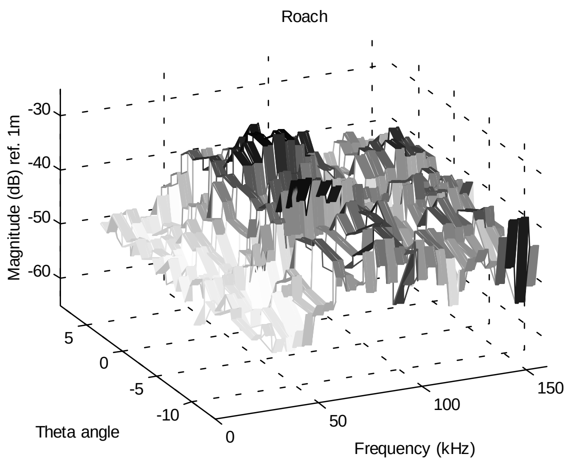


Figure 5.- Variations in terms of TS acccording to θ for a roach.

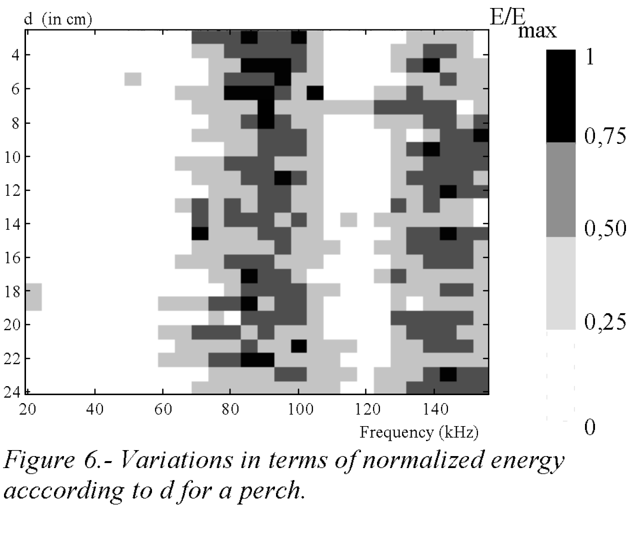


Figure 6.- Variations in terms of normalized energy acccording to d for a perch.

From our results, we note that there is a near uniformity in the three variations curves (θ, φ, and d) in terms of normalized energy for the char and the perch. Their energy is, at first sight, independent of position and orientation. However, char reacts between 70 and 100 kHz and backscatters little energy in high frequencies, whilst perch reacts both between 70 and 105 kHz and 125 and 160 kHz in high frequencies.

Independence according to position and orientation is not so well established for the roach. Roach reacts mainly between 60 and 100 kHz but in a random way. It is due to the nervous state of the roach, which is more pronounced than in the other two species. We cannot conclude that the energy of the roach was related to θ, φ, or d.

The curves of Target Strength confirm this. It does not vary much in each species and no singularities appear according to geometric parameters.

4.2 Variations in terms of Target Strength and normalized spectral energy of a fish in a constant position

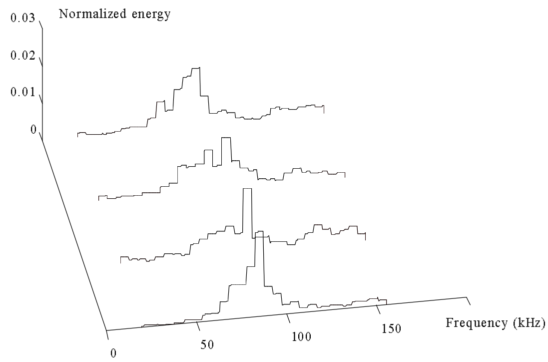


Figure 7.- Variability in normalized energy of a char in a constant position.

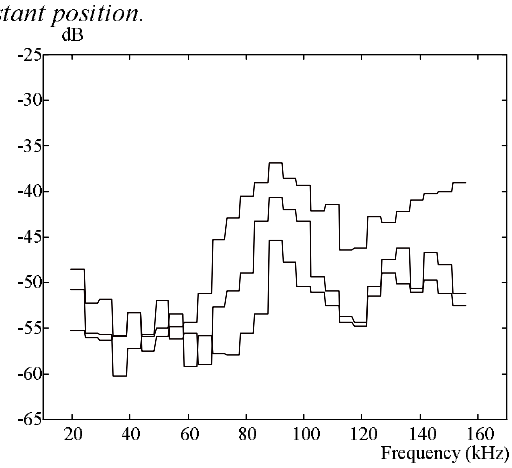


Figure 8.- Variability in target strength of a roach in a constant position.

We notice that intra-species variability is quite important for a fish in a constant position. This variation is evident in TS where it can vary up to 10 dB for a fish in a constant position. This variability is higher for the roach than for the char or the perch because its nervousness is more pronounced.

5 VARIABILITY OF THE SONAR ECHO FOR DIFFERENT SPECIES IN A CONSTANT POSITION

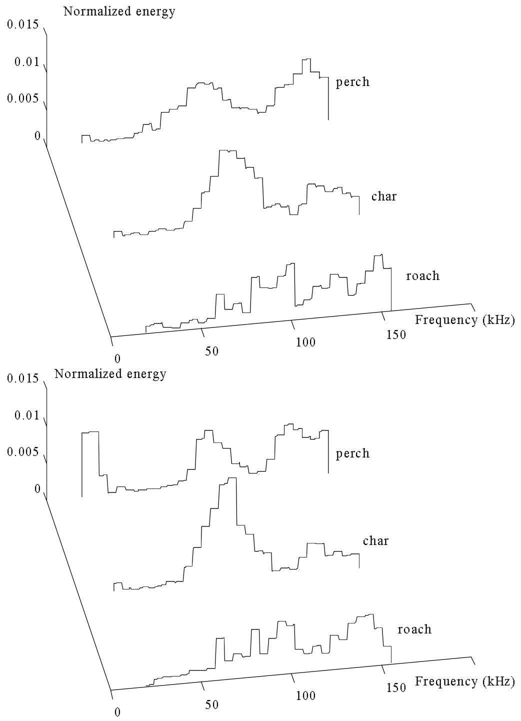
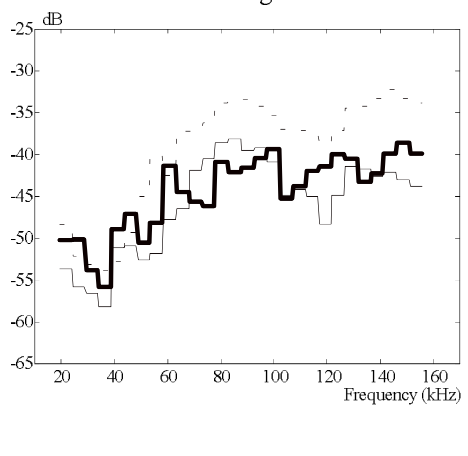


Figure 9.- Two examples of normalized energy of a roach, a char and a perch in a constant position.

At first sight, it is quite difficult to differentiate one species from the other two. From the many examples of roach, char and perch in a constant position, we have found some descriptive parameters which distinguish the three species. The char is the species in which the difference of peaks at 70-100 kHz and 135-160 kHz is always the most important and positive. The standard deviation in the 50-160 kHz band is always the highest for the char. The roach always has the smallest standard deviation in the 50-160 kHz band. Its spectrum is more indented and spread than the two other species because of its nervousness. The perch can be distinguished by a high non normalized energy in the 50-160 kHz band.

The scattering of these parameters depends more upon fish nervousness than its geometric orientation.



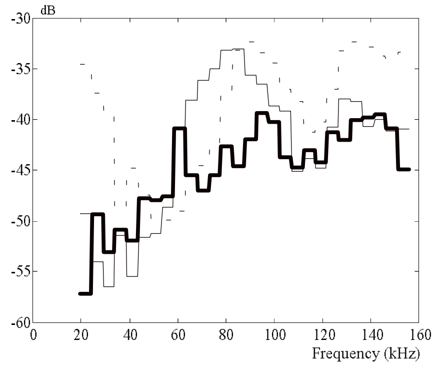


Figure 10.- Two examples of Target Strength of a roach (▬), a char (—) and a perch (---) in a constant position.

With the TS, it seems to be difficult to simply extract singularities of a species because in a constant position, intra-species variability is important.

6. CONCLUSION

In this work, we studied orientation and position influence of a fish upon its sonar echo. An initial study on a unique fish and in a constant position has shown a large echo variability due to its nervousness. This was evident from the images obtained during the ultrasonic shot. A second study on steady fishes proved that the echo variability is influenced more by fish nervousness than its position in the sonar beam. A study of three different species, with a constant geometrical position, showed differences between their ultrasonic signatures. It can be concluded that intra-species echo variability, due to fish nervousness, is too important compared to the inter-species variability, to classify species with a high degree of accuracy.

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