Characterization of skin patterns in *Pseudoplatystoma Magdaleniatum*

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***Abstract*—*Pseudoplatystoma Magdaleniatum* is one of the most representative fish species from the Magdalena river basin in Colombia. This endemic catfish is highly valuable from the economic and environmental perspectives. Nevertheless, it is currently under threat because of the indiscriminate fishery and the degradation of their ecological niche. Strategies for conservation require a detailed individual description. Traditional characterization methods are invasive and time expensive. Here we introduce a novel automatic method to segment and describe the characteristic spot and stripe skin pattern of this specie. The method was evaluated on a photographic database of 50 individuals, which characteristic skin patterns were manually segmented by a trained expert. The proposed approach provides precise skin pattern segmentations and informative geometrical features of these patterns.**

I. Introduction

P. Magdaleniatum or *Bagre rayado del Magdalena* is an endemic long-whiskered catfish, which is largely distributed along the Magdalena river at Colombia [1]. This specie constitutes one of the most important resources for commercial and subsistence fisheries at Magdalena basin [2]. In addition, it plays a major role in aquatic trophic webs. This species is under threat because of indiscriminate fishery and the degradation of their ecological niches. In the last four decades the Magdalena River has suffered dramatic environmental transformations as a consequence of human activities, such as, mining activity, oil extraction and agriculture, among others. These changes have resulted in losses of habitats and degradation of the water quality, affecting native fishes [3]. In the case of *P. Magdaleniatum*, more dramatic degradations have been observed, as a consequence of the continuous and increasing fishing exploitation pressure [2]. For these reasons *P. Magdaleniatum* has been recently included *"in danger"* in the Red Book of Fish from Colombia [3].

Different strategies for conservation can be proposed to guarantee *P. Magdaleniatum* subsistence. For instance, controlled or banned fishing during certain periods, declaration of banned fishing zones, and working actions with communities [4]. These strategies should be based on a complete understanding of the specie distribution, current population state, taxonomic composition, and migratory patterns in space and time [4]. Unfortunately, these aspects remain poorly understood, due to the lack of effective strategies for *in-situ characterization of individuals*. These characterizations can be obtained by using genomic or metabolic information. However, these approaches are highly invasive and time expensive [5]. Alternatively, descriptions of individuals can be achieved by using morphological features of the characteristic skin patterns exhibited by these fishes [6], [7], [8]. Nonetheless, this approach requires highly trained experts and may have low reliability [9]. In this work, a novel automatic method to segment and describe the characteristic spot and stripe patterns of *P. Magdaleniatum* is introduced.

II. Materials and methods

A. *P. Magdaleniatum database construction*

A database of manually segmented skin patterns (spots an stripes) of 50 specimens of *P. Magdaleniatum* was constructed. This sample was obtained by accompanying the artisanal fishing process along the Magdalena River (La Dorada, Barrancabermeja, Magangué), the Cauca River (Nechí) and the San Jorge River (Cicuco) in Colombia, during the months of January to Augusts in 2014. For each location, data for 5 females and 5 males was selected. For each specimen a good quality image of the complete body fish was acquired in semi-controlled conditions. In particular, images were acquired in the right lateral photographic plane, without inclination angle under a blue background, at resolution of 4320×3240 pixels, no special illumination conditions were considered. Following, a manual segmentation of the skin patterns was performed by a trained expert with three years of experience in morphometrical assessment of this species. Finally, a rectangular area covering the body of the fish was selected by the expert

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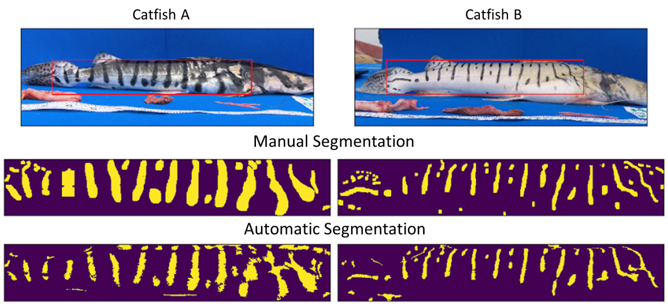

Fig. 1. *P. Magdaleniatum* example images. Top the original specimens with the region of interest delineated in red. Middle the segmentation of the skin pattern performed by the expert. Bottom the result of the proposed segmentation approach.

as a region of interest (RoI). The RoI and the skin pattern segmentation performed by the expert for two specimens is shown in Figure 1.

B. Skin pattern segmentation

For the skin pattern extraction, first the region of interest was converted to gray scale. This region was then normalized by using an adaptive histogram equalization to account for non-uniform conditions of illumination [10]. In this approach multiple local histograms are computed and then used to redistribute the lightness values locally across the image to be more uniform.

An anisotropic adaptive thresholding strategy was used to distinguish between foreground (dark skin patterns) and background (gray skin). For this, first an anisotropic diffusion of the skin pattern was computed by using the convolution between the region of interest $f(x, y)$ and a two dimensional anisotropic Gaussian kernel:

$$g(x, y) = Ae^{-(\frac{1}{2\sigma_x^2}x^2 + \frac{1}{2\sigma_y^2}y^2)} \tag{1}$$

with σ_x and σ_y the x and y variances, respectively, and A is a normalization parameter. By computing the convolution $f * g$ the information related to low frequencies in the images was extracted [10]. Following, coarse-scale features related to skin patterns were characterized by computing $h = f - f * g$. Coarse-scale features can be computed from h by using large variances, these features coincide with the skin pattern segmented by the expert (see Figure 1). In addition, *P. Magdaleniatum* skin patterns exhibit a high directional preference that can be suitably captured by the anisotropic shape selected for g. In order to model both coarse-scale and directionality the variances in g were set to $\sigma_x = 400$ and $\sigma_y = 100$. Finally, h was segmented into background and foreground by using a simple thresholding.

After segmentation, a morphological operator of closing and filling were used to achieve compact regions [10]. Small regions with least that 300 pixels were removed. Figure 1 shows in bottom two automatic segmentations obtained for the proposed method for two different specimens.

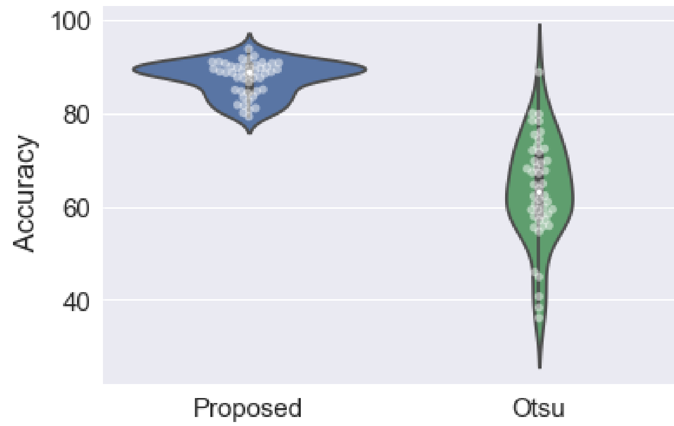

Fig. 2. Segmentation accuracies. Violin plots showing the segmentation accuracies for each specimen by using the proposed method (left in blue) and the baseline method (right in green).

C. Experimental settings

The experimental evaluation included assessment of the quality of the skin pattern segmentation algorithm, and comparison of some morphological for the automatic and the expert segmentations. For the first experiment the accuracy (true positive + true negative over positive + negative) of the segmentation was computed for each specimen by using the manual segmentation as ground truth. An Otsu binary thresholding method was used as baseline for the segmentation. For the second experiment a set of geometrical features was computed for each extracted region, and then averaged for each specimen. The correlation between the mean of each feature for the complete set of specimens was computed for manual and automatic segmentations. Features included: 1) area, 2) aspect ratio, corresponding to the ratio between the width and the height of the bounding rectangle, 3) solidity, defined as the ratio between the area of the region and the area of their convex hull, and 4) diameter, corresponding to the diameter of the circumscribed circle, of each segmented region.

III. Results

Figure 1 shows two automatic segmentation examples obtained with the proposed approach. Importantly, even if both specimens differ in their skin pattern tonalities, the proposed approach is able to properly characterize the skin pattern. As observed, the method is able to locate and trace most of the skin patterns segmented by the expert. However, in some cases it underestimates the region area.

Figure 3 shows the violin plots of the accuracy for the proposed and the Otsu segmentations for the complete set of specimens. As observed, the proposed method resulted in a higher accuracy (87.6 $\pm$ 3.6) when compared to the Otsu approach (63.5 $\pm$ 11.2). A Friedman test ($n = 46$, $p = 0.05$) confirmed that the proposed approach provided significantly higher accuracies compared to the baseline method. For these results 4 images were discarded because of bad quality of the mask delineated by the expert.

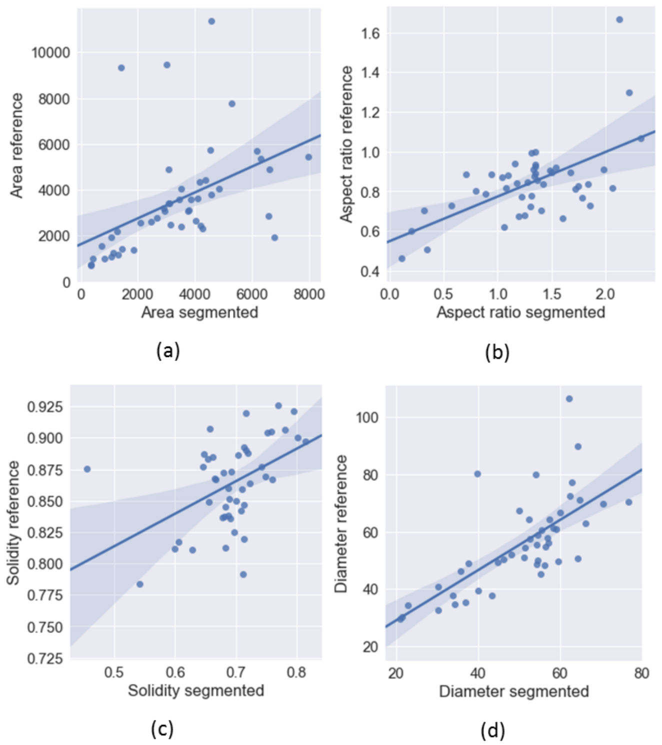

Fig. 3. Morphological feature correlations. Correlations between different morphological features segmented a) area, b) aspect ratio, c) solidity and d) diameter. In y-axis the features computed from the spots delineated by the expert and in x-axis the ones computed by the proposed approach.

Figure 3 shows the scatter plots between the mean of the geometric features for the reference regions (expert) and the regions segmented by the proposed approach. As observed, the proposed method resulted in good values of correlation for the evaluated geometrical features. In particular, the correlation values were 0.46, 0.60, 0.48 and 0.71, for area, aspect ratio, solidity and diameter, respectively.

IV. Conclusion and discussion

We introduced a novel strategy to automatically characterize skin patterns in *P. Magdaleniatum*. The strategy was tested in real conditions resulting in an accurate alternative. The approach requires minimal technical requirements, including, simple geometrical considerations, a standardized blue background and no special illumination conditions. Therefore, the possible applications of this technology are wide. This approach can be used for regional characterization of the specie based on the objective morphological descriptions herein proposed. This technology can also be implemented into a mobile application that anyone can use to photo-identificate genre and origin region of any given catfish, as a part of a citizen science initiative [11], [12]. This application would represent a powerful tool for fishing national authorities to evaluate the current state of the resource, providing objective evidence to formulate more sustainable exploitation policies [13]. The proposed methods can also be adapted to the problem of fish recapturing, i.e., individuals should be recognized automatically, when met again [7]. However, this problem would require exploring pattern classification algorithms. In addition, as skin patterns are highly characteristic of many fish species, therefore this technology can be also adapted to these new settings as well, resulting in a powerful approach for fish characterization in general.

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