Combined Color Semantics and Deep Learning for the Automatic Detection of Dolphin Dorsal Fins

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Introduction

Motivations

- Large demand for algorithms that can help domain experts in the analysis of huge image datasets for ecological studies
- Vital importance of the study of cetaceans
- Recent publication of an algorithm for the automated photo-identification of Risso's dolphins [1]

Contribution

Development of a Matlab routine able to automatically detect dolphin dorsal fins in images, based on a new, efficient algorithm which combines domain analysis and deep learning [2].

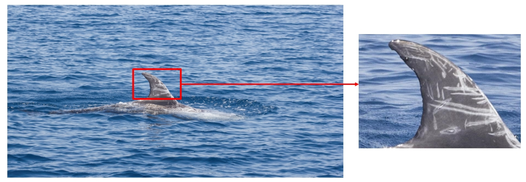

Figure 1: Visual representation of the problem

Data

Figure 2: (Left) Tursiops truncatus, (Right) Grampus griseus (Risso's dolphin)

Tursiops and Risso's dolphins images collected by two private reasearch associations:

- $\sim 10,000$ pictures taken in the Gulf of Taranto (Northern Ionian Sea) between 2013 and 2018
- $\sim 14,000$ pictures taken near Pico island (Atlantic Ocean) in 2018

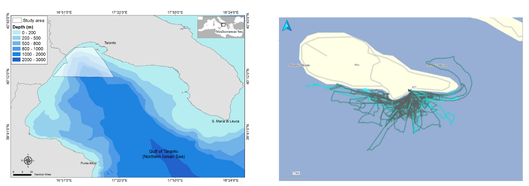

Figure 3: Study areas

Methods

Two-stage solution

1. Image preprocessing (region proposals)
2. Binary classification (recognition of dorsal fins)

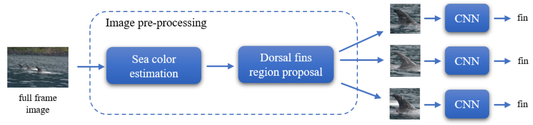

Figure 4: Block diagram of the proposed algorithm

Image preprocessing

Identify κ different models in the CIE L*a*b* color space

Color models

$$m_i = (\sigma_i, P_i)_{i=1}^{\kappa}$$

Descriptor of the sea

$$\sigma_i = \left\{ \left(L_i^{\text{low}}, L_i^{\text{up}}\right), \left(a_i^{\text{low}}, a_i^{\text{up}}\right), \left(b_i^{\text{low}}, b_i^{\text{up}}\right) \right\}$$

3D Polyhedron (dorsal fins)

$$P_i = \left\{ (L_j, a_j, b_j)_{j=1}^{N_i} \right\}$$

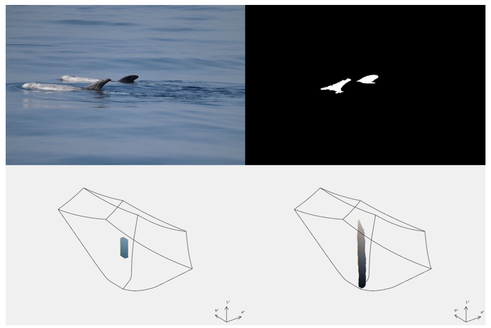

Figure 5: Example of segmentation

Preprocessing of image I:

1. Model assignment (sea color estimation):

$$i^{\star} = \arg\max_{i=1}^{\kappa} \sum_{j,k} \mathbb{1}\left\{ I_{jk} \in \text{sea}(\sigma_i) \right\}$$

2. Region proposals (binary mask with $P_{i^{\star}}$, morphological operations, size refinement, aspect ratio filter)

Binary classification

Create a dataset with the image preprocessing algorithm and train a convolutional neural network (CNN) to recognize dorsal fins

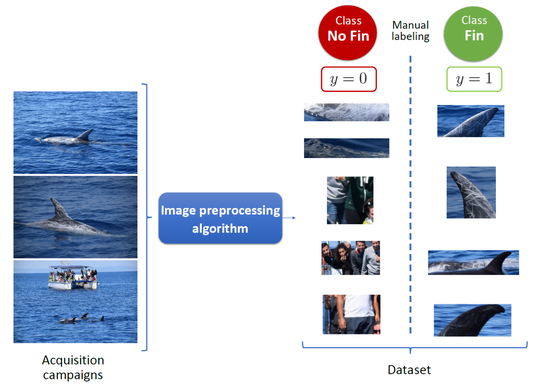

Figure 6: Dataset creation

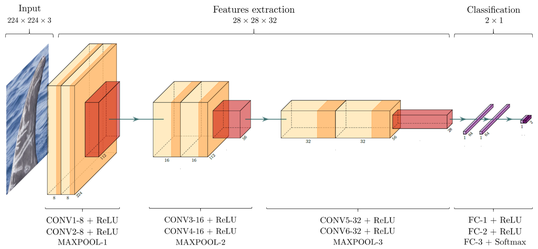

Figure 7: Custom convolutional neural network: 23 layers with 3×3 kernels

Regularized cross entropy minimization

$$\min_{w,b} \sum_{i=1}^{t} \log\left(\frac{e^{f_{y_i}(x_i;w,b)}}{\sum_{j=1}^{2} e^{f_j(x_i;w,b)}} \right) + \lambda \|w\|^2$$

Results

Experiment 1. Creation of $\kappa = 5$ models by applying a semi-automated iterative procedure on a small subset of images ($\sim 2,000$). Comparison of the results to an alternative approach based on Otsu's method.

Experiment 2. Training and validation of a custom CNN on $15,228$ cropped images from the Gulf of Taranto (random split 80-20%).

Experiment 3. Assessment of the performances of the CNN on $20,888$ cropped images from Pico island.

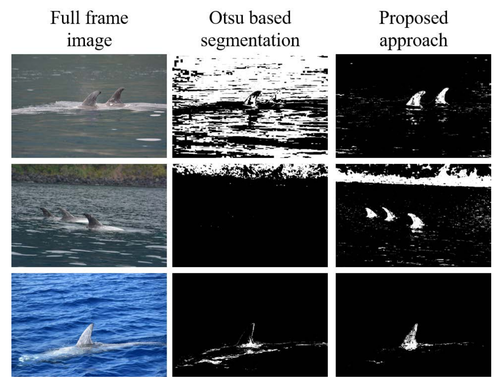

Figure 8: Qualitative analysis of the proposed segmentation method

	Accuracy	Sensitivity	Specificity
Validation$^{(\star)}$	99%	99%	99%
Test$^{(\dagger)}$	92%	85%	95%

Table 1: Performances of the classification. $(\star)$ 5-fold cross validation strategy: mean values over 5 CNNs. $(\dagger)$ major voting: 4 CNNs out of 5. Training time single CNN: $\sim$3h 20 mins on Intel Core i5-6400T, 8 GB RAM, Nvidia GeForce 930M with 2 GB

Conclusions

- High flexibility in splitting the region proposal task from the classification task (introduction of domain knowledge)
- High performances with a resource efficient CNN
- Feasibility of the proposed approach to enable large scale ecological studies of dolphins

Future works. (i) Test in different operating conditions. (ii) Extend the methodology to biological investigations of different species.

References

[1] Maglietta R. et. al. Dolfin: an innovative digital platform for studying risso's dolphins in the northern ionian sea (north-eastern central mediterranean). *Scientific reports*, 8(1):1–11, 2018.

[2] Renò V. et. al. Combined color semantics and deep learning for the automatic detection of dolphin dorsal fins. *Electronics*, 9(5):758, 2020.

Acknowledgements

Figure 2: credits to animalbase.uni-goettingen.de, associacioc-etacea.org. Figure 7: credits to Haris Iqbal.