Conference Abstract

Extracting Landmark and Trait Information from Segmented Digital Specimen Images Generated by Artificial Neural Networks

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Abstract

We have been successfully developing Artificial Intelligence (AI) models for automatically classifying fish species using neural networks over the last three years during the "Biology Guided Neural Network" (BGNN) project*[1]. We continue our efforts in another broader project, "Imageomics: A New Frontier of Biological Information Powered by Knowledge-Guided Machine Learning"*[2]. One of the main topics in the Imageomics Project is "Morphological Barcoding". Within the Morphological Barcoding study, we are trying to build a gold standard method to identify species in different taxonomic groups based on their external morphology. This list of characters will contain, but not be limited to, landmarks, quantitative traits such as measurements of distances, areas, angles, proportions, colors, histograms, patterns, shapes, and outlines. The taxonomic groups will be limited by the data available, and we will be using fish as the topic of interest in this preliminary study.

In this current study, we have focused on extracting morphological characters that are relying on anatomical features of fish, such as location of the eye, body length, and area of the head. We developed a schematic workflow to describe how we processed the data and extract the information (Fig. 1). We performed our analysis on the segmented images

produced by Karpatne Team within the BGNN project (Bart et al. 2021). Segmentation analysis was performed using Artificial Neural Networks - Semantic Segmentation (Long et al. 2015); the list of segments to be detected were given as eye, head, trunk, caudal fin, pectoral fin, dorsal fin, anal fin, pelvic fin for fish.
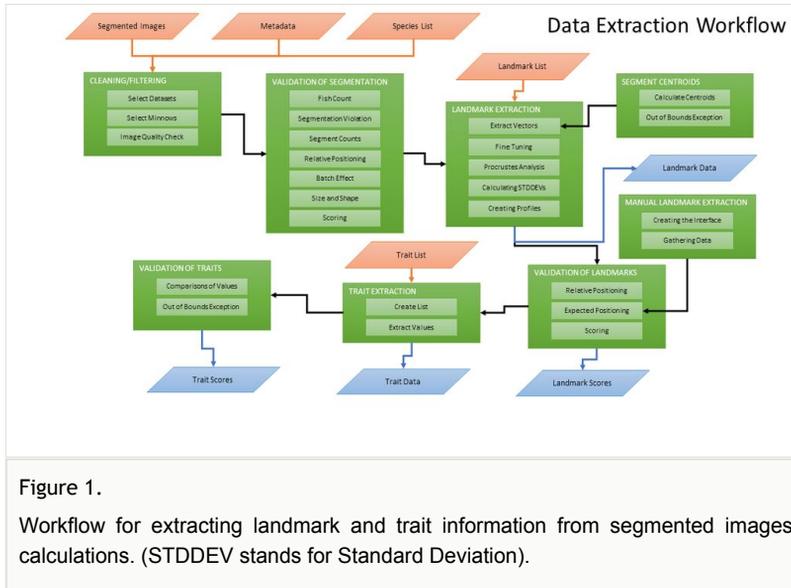

Figure 1.

Workflow for extracting landmark and trait information from segmented images and score calculations. (STDDEV stands for Standard Deviation).

Segmented images, metadata and species lists were given as input to the workflow. During the cleaning and filtering subroutines, a subset of data was created by filtering down to the desired segmented images with corresponding metadata. In the validation step, segmented images were checked by comparing the number of specimens in the original image to the separate bounding-boxed specimen images, noting: violations in the segmentations, counts of segments, comparisons of relative positions of the segments among one another, traces of batch effect; comparisons according to their size and shape and finally based on these validation criteria each segmented image was assigned a score from 1 to 5 similar to Adobe XMP Basic namespace.

The landmarks and the traits to be used in the study were extracted from the current literature, while mindful that some of the features may not be extracted successfully computationally. By using the landmark list, landmarks have been extracted by adapting the descriptions from the literature on to the segments, such as picking the left most point on the head as the tip of snout and top left point on the pelvic fin as base of the pelvic fin. These 2D vectors (coordinates), are then fine tuned by adjusting their positions to be on the outline of the fish, since most of the landmarks are located on the outline. Procrustes analysis*[3] was performed to scale all of the measurements together and point clouds were generated. These vectors were stored as landmark data. Segment centroids were also treated as landmarks. Extracted landmarks were validated by comparing their relative position among each other, and then if available, compared with their manually captured position. A score was assigned based on these comparisons, similar to the segmentation

validation score. Based on the trait list definitions, traits were extracted by measuring the distances between two landmarks, angles between three landmarks, areas between three or more landmarks, areas of the segments, ratios between two distances or areas and between a distance and a square rooted area and then stored as trait data. Finally these values were compared within their own species clusters for errors and whether the values were still within the bounds. Trait scores were calculated from these error calculations similar to segmentation scores aiming selecting good quality scores for further analysis such as Principal Component Analysis.

Our work on extraction of features from segmented digital specimen images has shown that the accuracy of the traits such as measurements, areas, and angles depends on the accuracy of the landmarks. Accuracy of the landmarks is highly dependent on segmentation of the parts of the specimen. The landmarks that are located on the outline of the body (combination of head and trunk segments of the fish) are found to be more accurate comparing to the landmarks that represents inner features such as mouth and pectoral fin in some taxonomic groups. However, eye location is almost always accurate, since it is based on the centroid of the eye segment. In the remaining part of this study we will improve the score calculation for segments, images, landmarks and traits and calculate the accuracy of the scores by comparing the statistical results obtained by analysis of the landmark and trait data.

Keywords

machine learning, morphometrics, fish, digitized biocollections

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Ethics and security

The original data used in this study is provided by Great Lakes Invasives Network Project and protected under the license CC BY-NC 3.0.

Author contributions

HB lead the data harvesting and trait extraction part of the project, AK lead the segmentation part, YB and XW harvested the data, built cyberinfrastructure, created metadata, MM provided the segmented images, YB and BA created the trait extraction workflow and extracted the traits.

References

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Endnotes

[*1] https://bgnn.tulane.edu/
[*2] https://imageomics.osu.edu/
[*3] https://en.wikipedia.org/wiki/Procrustes_analysis