An Interpretable AI Model for Sex Classification of Delta Smelt Based on Phenotypic Appearance

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Abstract

Accurate sex identification in fish is essential for optimizing breeding and operational strategies in aquaculture. This study presents an approach for recognizing the sex of Delta Smelt using an interpretable deep neural network (DNN), based on subtle phenotypic differences between females and males across different stages of their life cycle.

Introduction

Importance The Delta Smelt, an endangered species, plays a crucial role in maintaining the biodiversity, genetic diversity, and ecological balance of California.

Current methods Traditionally, invasive biological techniques were used to determine the sex of fish. While effective, these methods often caused harm to the fish. Therefore, non-invasive techniques for gender recognition serve as a beneficial approach to mitigating harm to endangered fish species.

Methodology

This study developed a noninvasive method to determine the sex of Delta Smelt using an **explainable AI model** based on **computer vision**, mainly utilized the following key modules:

- **Zero-shot segmentation** based on Grounding DINO and Segment Anything Model (**SAM**)
- **Image augmentation**: RandomHorizontalFlip, Rotation, RandomCrop and RandomErasing
- Convolutional Neural Network (**CNN**) or Vision Transformers (**ViT**)
- **Prototree** archtecture

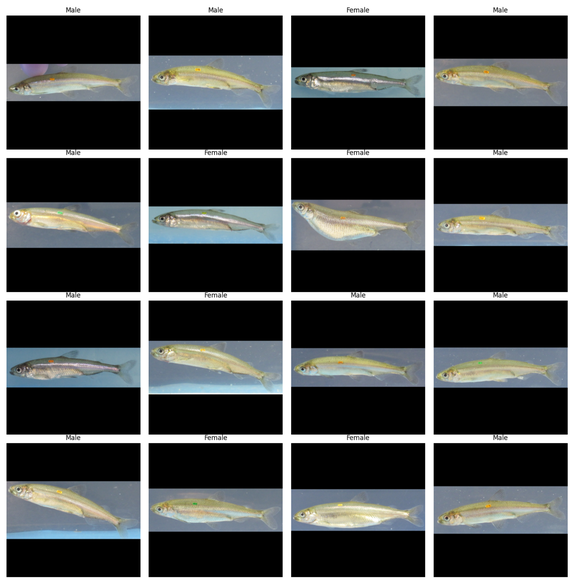

Figure 1. Delta Smelt Data

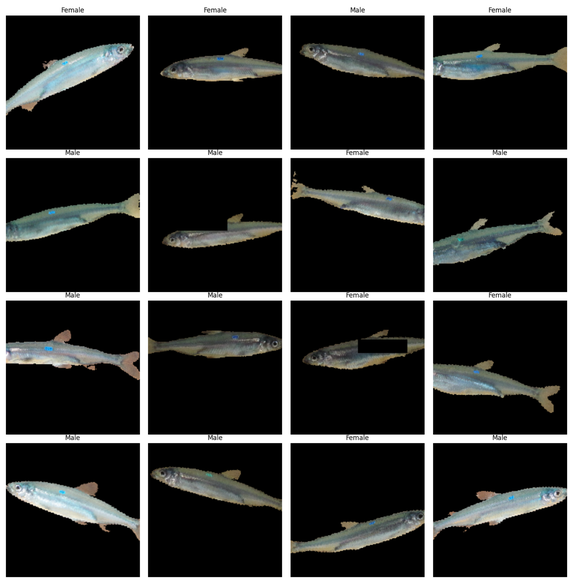

Figure 2. Image Augmentation

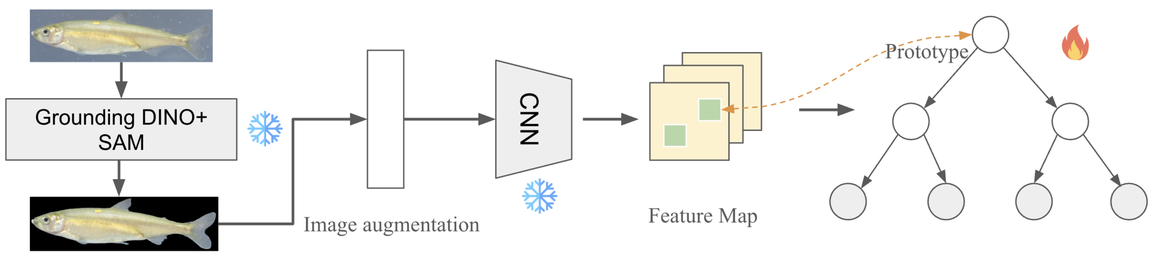

Figure 3. Model Architecture: A Soft Neuron Decision Tree Based on Segmentation

Results - Interpretability and Visualization

We visualized the decision-making process of the model for Delta Smelt gender recognition.

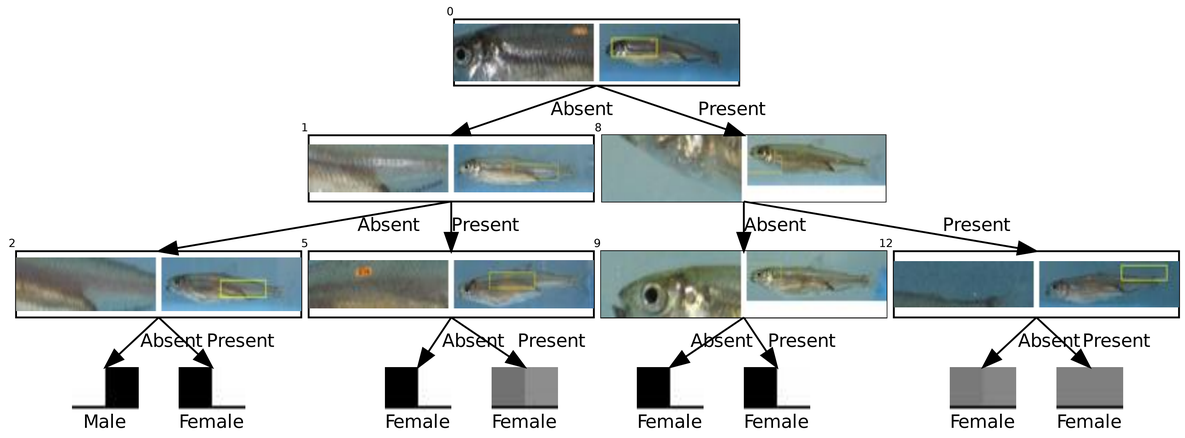

Figure 4. Deterministic Reasoning of Soft Decision Tree

Figure 5. Deterministic Reasoning of Hard Decision Tree

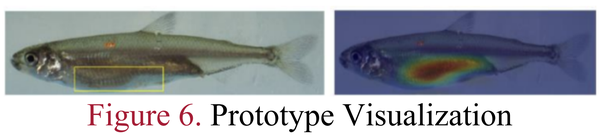

Figure 6. Prototype Visualization

Results - Evaluation

We trained the tree neurons in the ProtoTree model and compared its performance with that of the fine-tuned ResNet50 and ViT-Base-Path16-224 models

Table 1. Comparison of Model Performance on the Delta Smelt Test Dataset

Model	Session 1 (%)		Session 2 (%)		Session 3 (%)	
	Accuracy	F1 Score	Accuracy	F1 Score	Accuracy	F1 Score
ResNet50	49.21	48.88	54.40	52.34	79.71	78.40
ViT	51.50	50.46	81.60	81.60	85.50	84.57
Segmentation + ProtoTree	54.76	54.62	74.40	74.27	81.16	79.43

Discussion

The Prototree model based on segmentation struggles to distinguish the gender of Delta Smelt before spawning (Session1), likely due to the absence of distinct features in the early stages and the limited number of sample images. At times, it is challenging to interpret the patterns learned by certain prototypes. However, this method holds potential for training and developing applications for gender recognition in a wider range of fish species

Conclusion

The study demonstrates the effectiveness of deep neural network in classifying the gender of Delta Smelt at the beginning and during spawning. Additionally, the transparency of the decision-making process enhances interpretability, providing researchers with a clear basis for accepting or questioning the model predicted results.

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