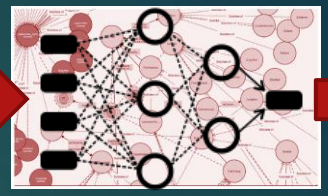
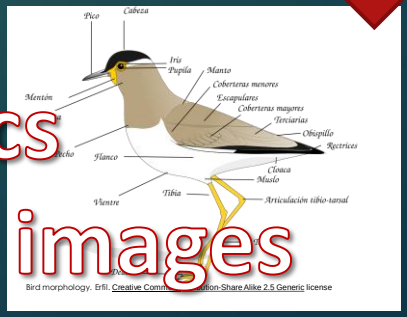
HDR Institute: NSF

Imageomics: A New Frontier of Biological Information Powered by Knowledge-Guided Machine Learning

imageomics.org





-omics from images

Bird morphology. Erfil, Creative Commons Attribution-Share Alike 2.5 Generic license

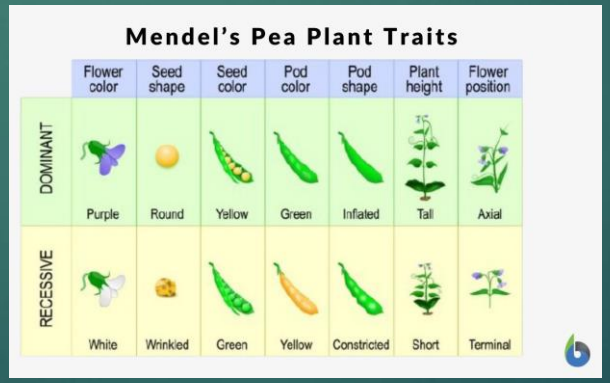
Imageomics(.org):

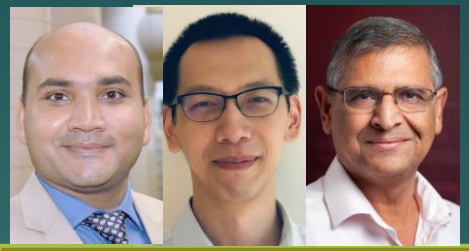
An interdisciplinary scientific field focused on understanding biology of organisms, particularly the biological traits and observable phenotype, from images.

Traits (biology) | noun, singular: trait

- [tɹeɪts]
- characteristics of an organism, describing its physiology, morphology, health, life history, demographic status, and behavior (e.g., beak color, stripe pattern, fin curvature, fused teeth, scarring, size at birth, pollen feeding). Traits are determined by genes, the environment, and the interactions among them.

We need to make traits computable





A. Karpatne, X. Jia, V. Kumar

Knowledge-guided Machine Learning: Current Trends and Future Prospects. 2024

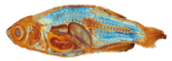
Sparse, imperfect, heterogeneous data

Imageomics Data

3D Textured Model

Digital Xray

3D mCT w/ Contrast



Videos in the Wild

Curated Images

Text, Geo, Molecular...

Text descriptions

Redbreast sunfish

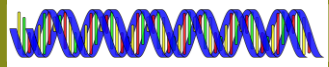
Fish

The redbreast sunfish is a species of freshwater fish in the sunfish family of order Perciformes. The type species of its genus, it is native to the river systems of eastern Canada and the United States. The redbreast sunfish reaches a maximum recorded length of about 30 cm, with a maximum recorded weight of 2.3 lb.

Wikipedia

Geospatial

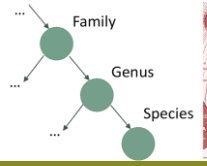
Molecular



Knowledge-Guided ML

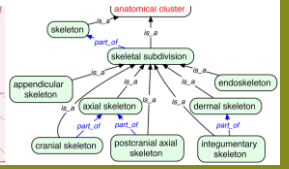
Biological Structures

Phylogeny

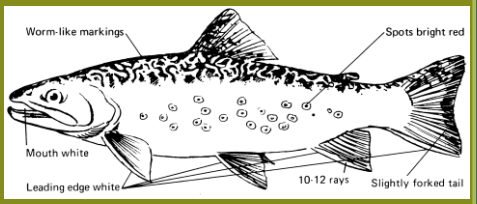


Trait Ontology

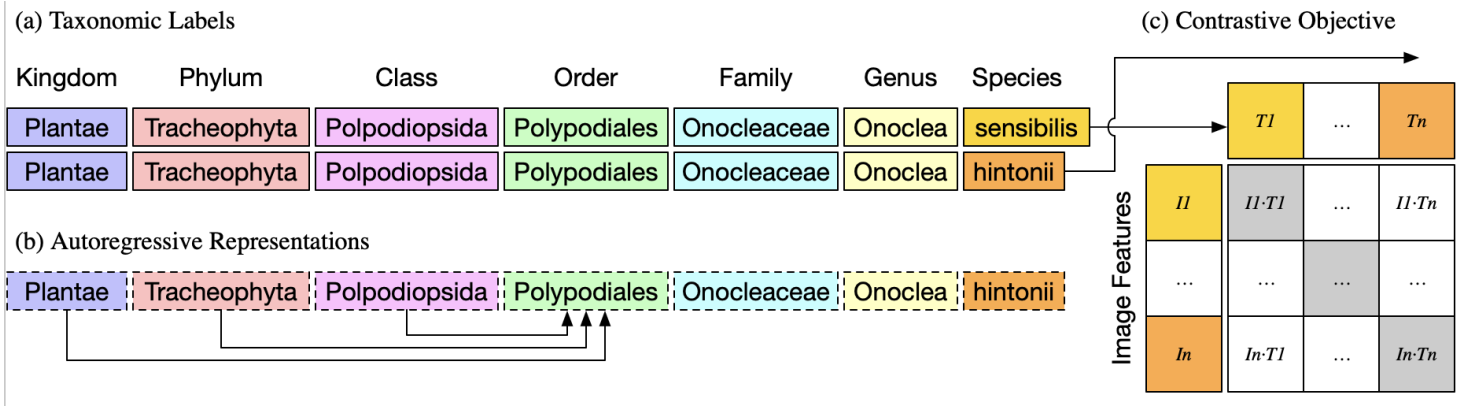
Ethograms, etc.



Explainable AI



BioCLIP: A Vision Foundation Model for the Tree of Life

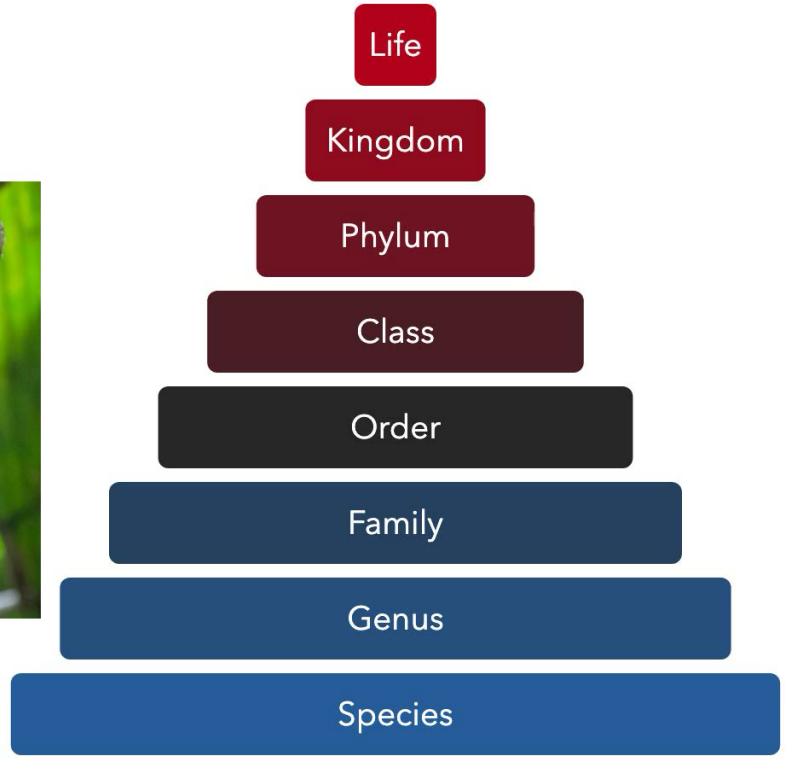


Samuel Stevens, Jiaman (Lisa) Wu, Matt Thompson, Elizabeth Campolongo, Chan Hee (Luke) Song, David Carlyn, Li Dong, Wasila Dahdul, Charles Stewart, Tanya Berger-Wolf, Wei-Lun (Harry) Chao, **Yu Su**

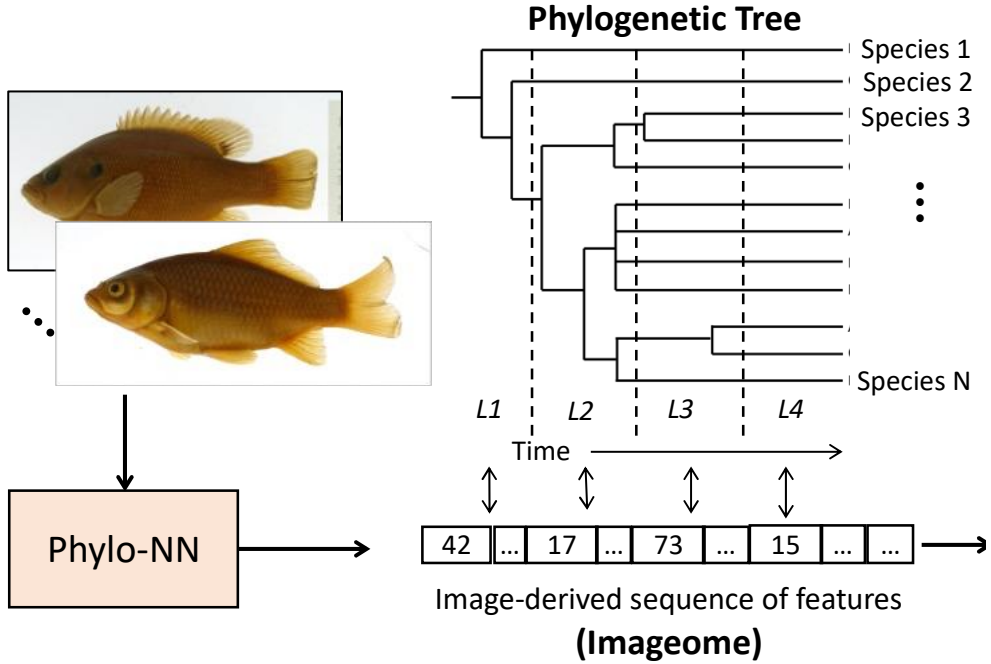
CVPR 2024

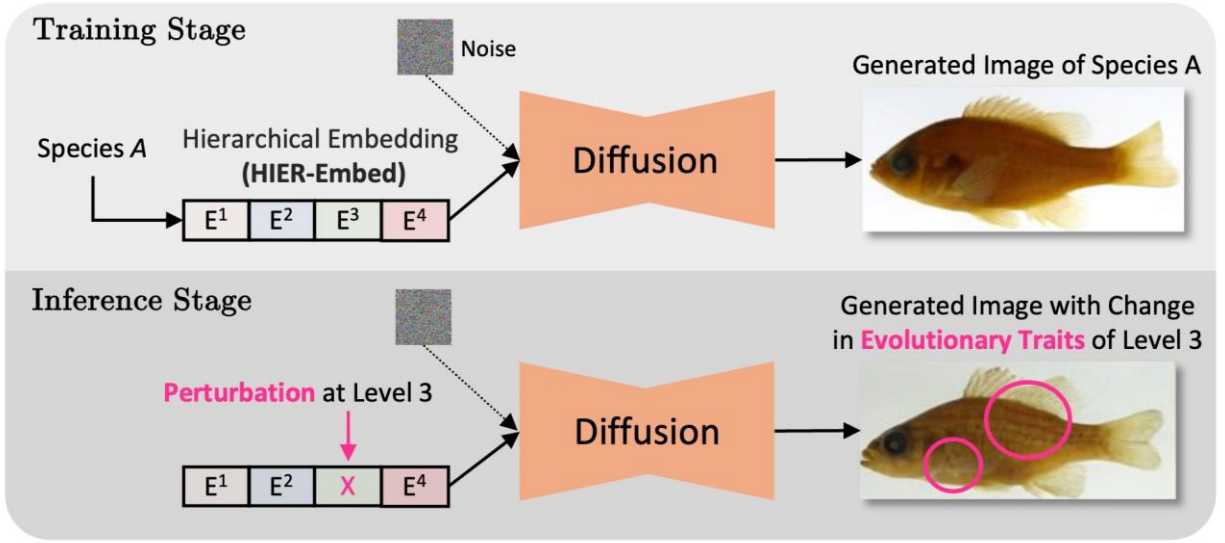
imageomics.github.io/bioclip

10M images, ~450K species



Phylo-NN & Phylo-Diffusion: Trait Evolution From Images





Mohannad Elhamod*, Mridul Khurana, Harish Babu Manogaran, Josef Uyeda, Meghan Balk, Wasila Dahdul, Yasin Bakis, Henry Bart, Paula Mabee, Hilmar Lapp, James Balhoff, Caleb Charpentier, David Carlyn, Wei-Lun Chao, Charles Stewart, Daniel Rubenstein, Tanya Berger-Wolf, Anuj Karpatne

Discovering Novel Biological Traits From Images Using Phylogeny-Guided Neural Networks [KDD'23]

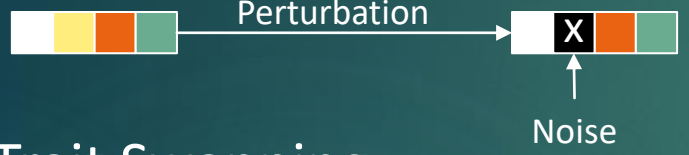
Mridul Khurana, Arka Daw, M. Maruf. et al

Hierarchical Conditioning of Diffusion Models Using Tree-of-Life for Studying Species Evolution [ECCV'24]

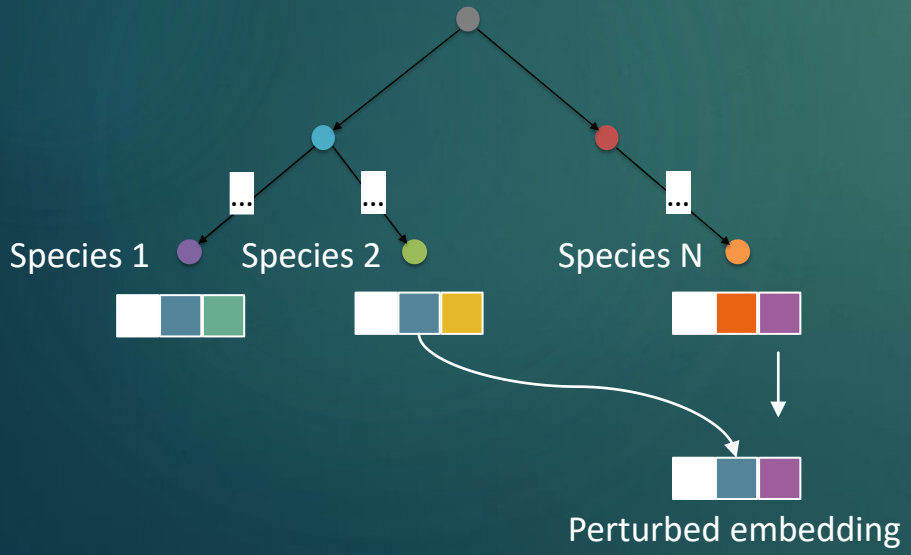
imageomics.github.io/phylo-diffusion/

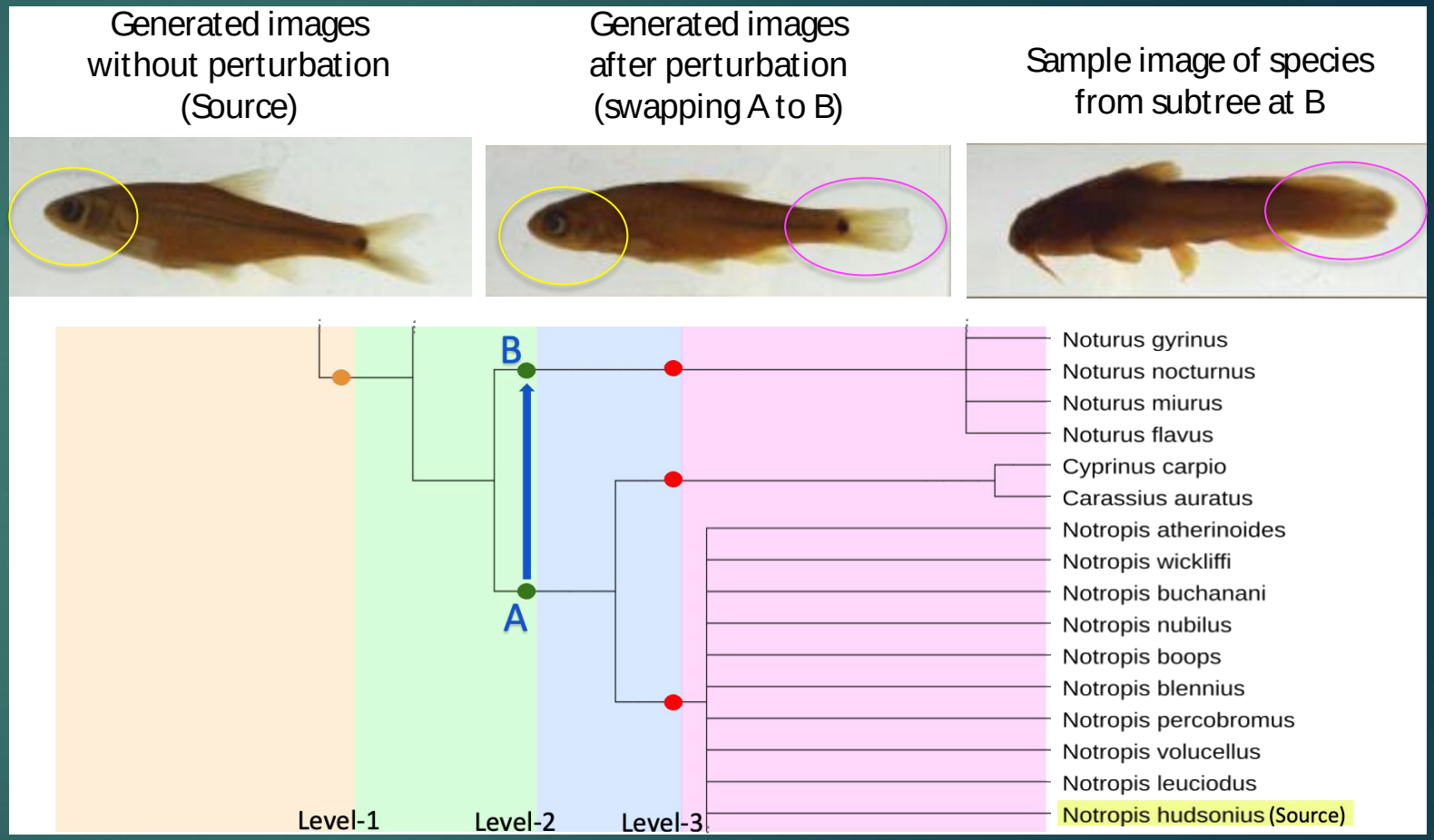
Imageome experiments

1. Trait Masking
   - Replace components with noise
   - Analogous to “Gene Knockout”



2. Trait Swapping
   - Replace components with siblings
   - Analogous to “CRISPR experiments”

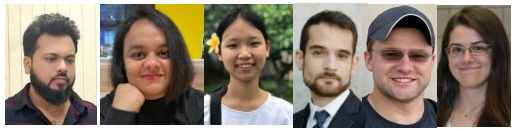


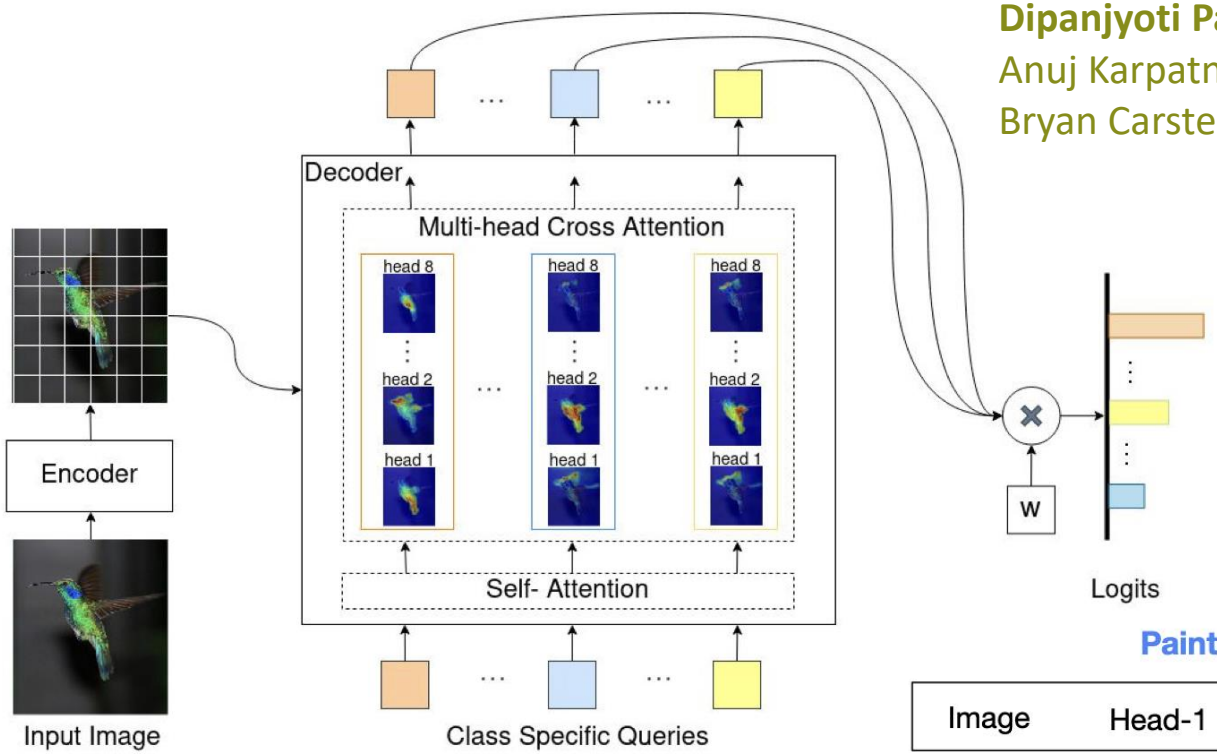


Phylo-Diffusion generates novel hypotheses of trait evolution directly from images

INTR – INterpretable TRansformer for Trait Discovery

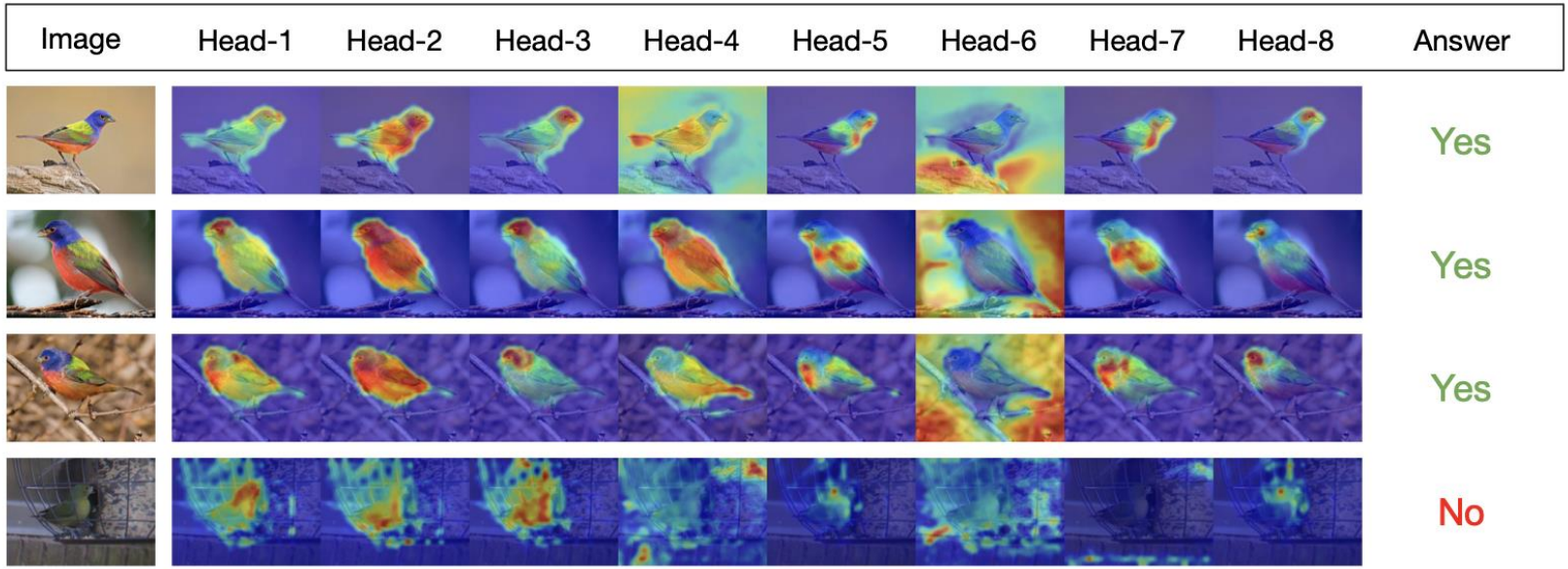
Dipanjyoti Paul, Arpita Chowdhury, Xinqi Xiong, Samuel Stevens, Kaiya L Provost, Anuj Karpatne, Charles Stewart, Tanya Berger-Wolf, Feng-Ju Chang, David Carlyn, Bryan Carstens, Dan Rubenstein, Yu Su, **Wei-Lun (Harry) Chao** **ICLR 2024**



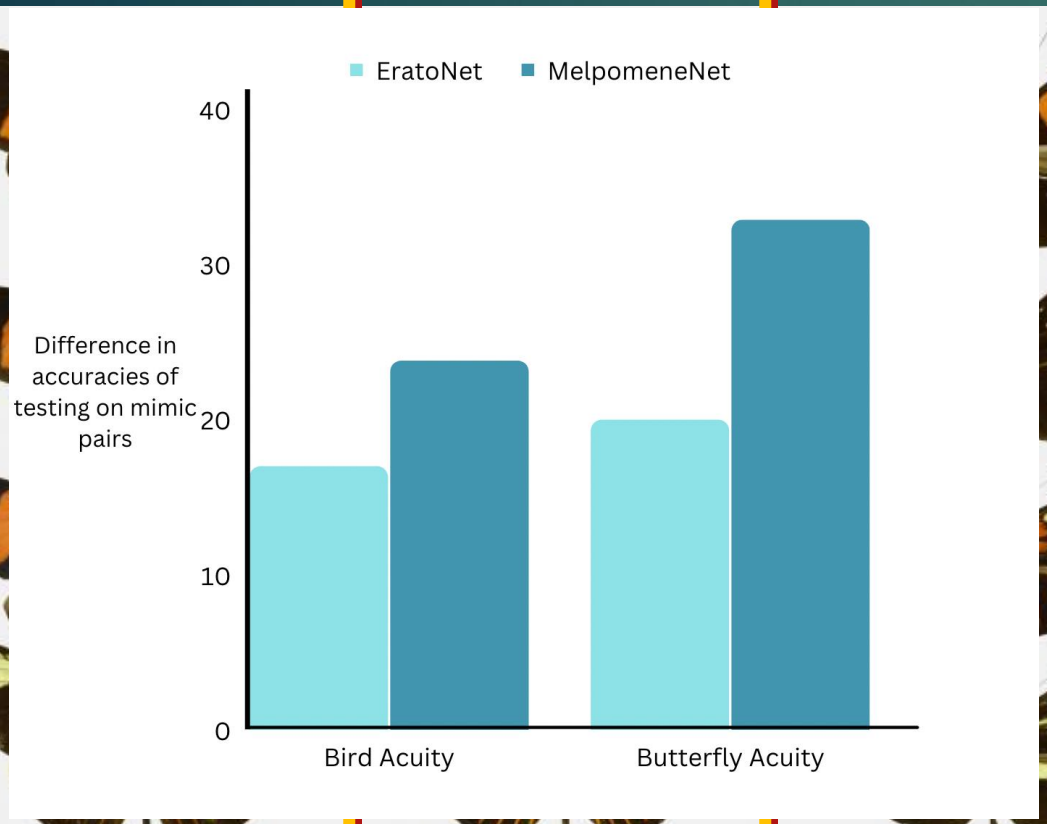


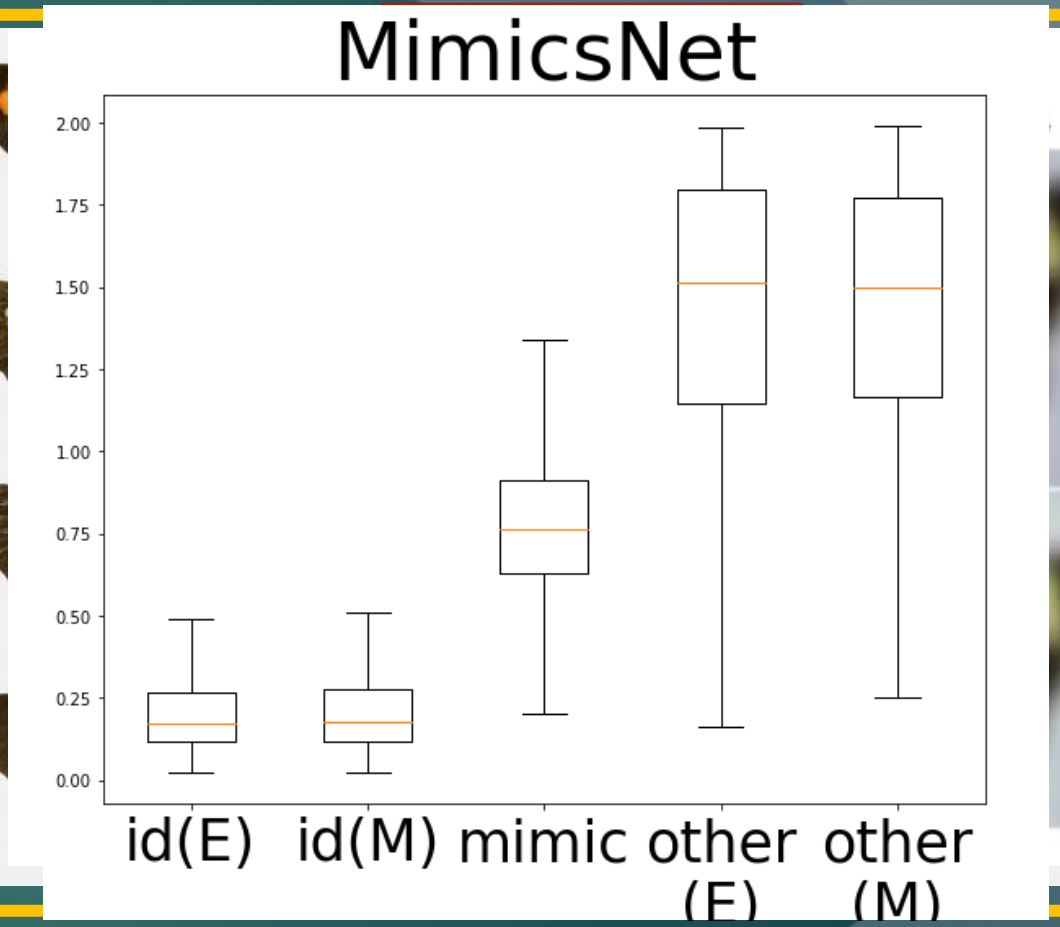
https://github.com/Imageomics/INTR

Painted Bunting!! Do you see yourself? How do you interpret your decision?



Mimicry in the right light (Species Traits)



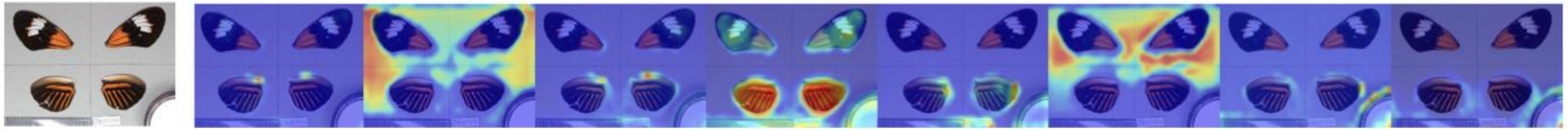


Christopher Lawernce, Reshma Ramesh Babu, Krzysztof Kozak, Harry Chao, David Carlyn, Mo ElHamod, Anuj Karpatne, Jihung Kil, Owen McMillan, Dan Rubenstein, Yu Su, Luke Song, Sam Stevens, Kris Chuck Stewart, Yael Stochel, Tanya Berger-Wolf

CV4Animals@CVPR 2022, Traitfest, Leipifest, …

Finding traits

Heliconius melpomene, compared with all query



Heliconius melpomene, only compared with Heliconius elevatus

https://github.com/Imageomics/INTR

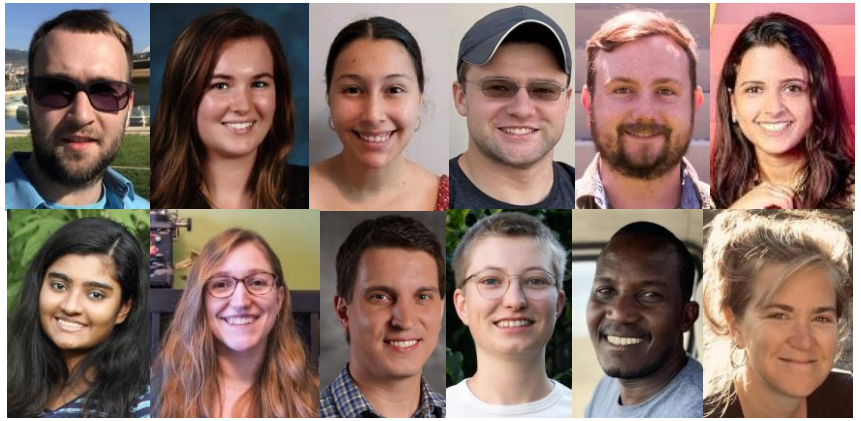
Experiential Introduction to AI and Ecology

LABORATORY REAGENT
Ethanol Absolute
Birds of East Africa

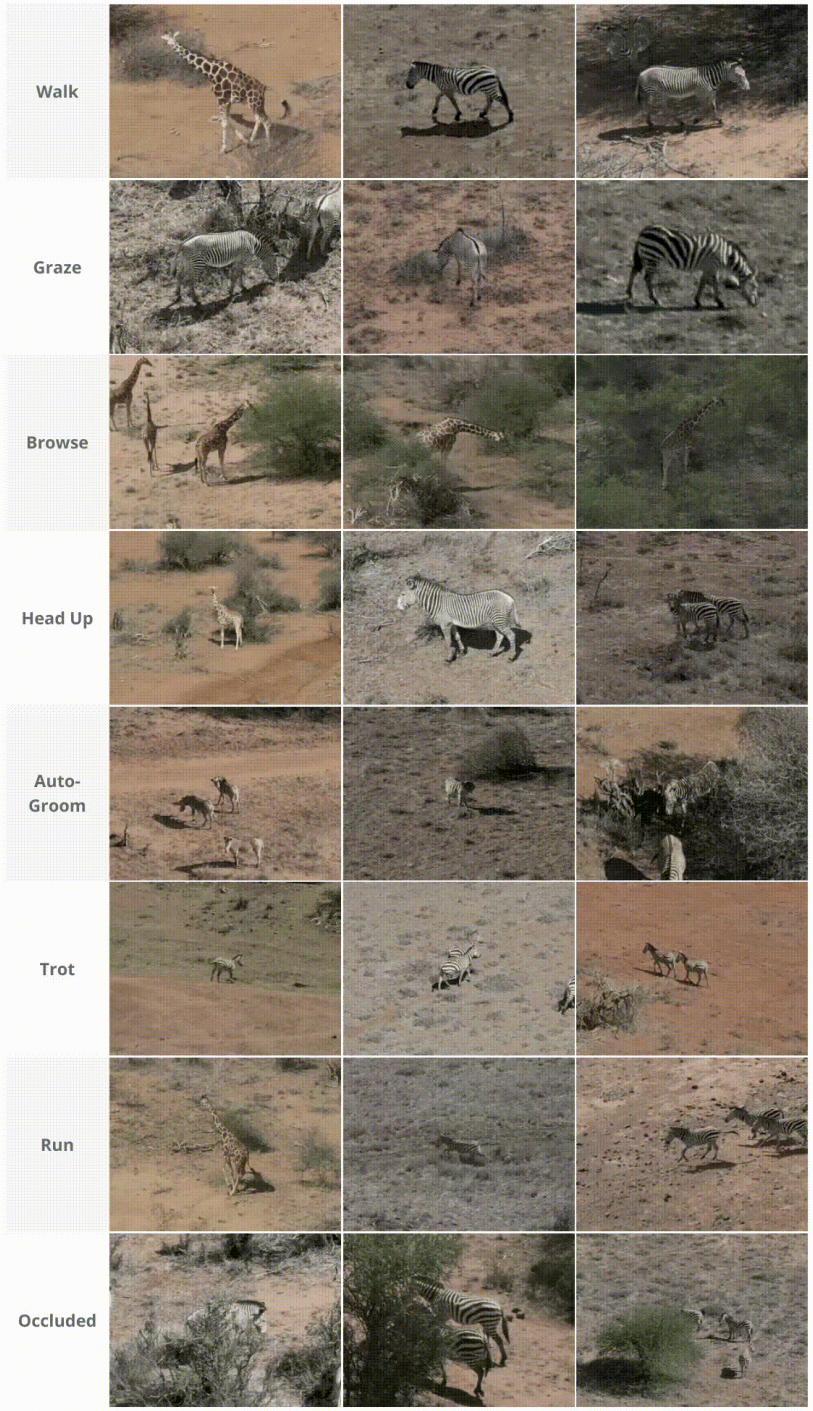
KABR: In-Situ Dataset for Kenyan Animal Behavior Recognition from drone videos

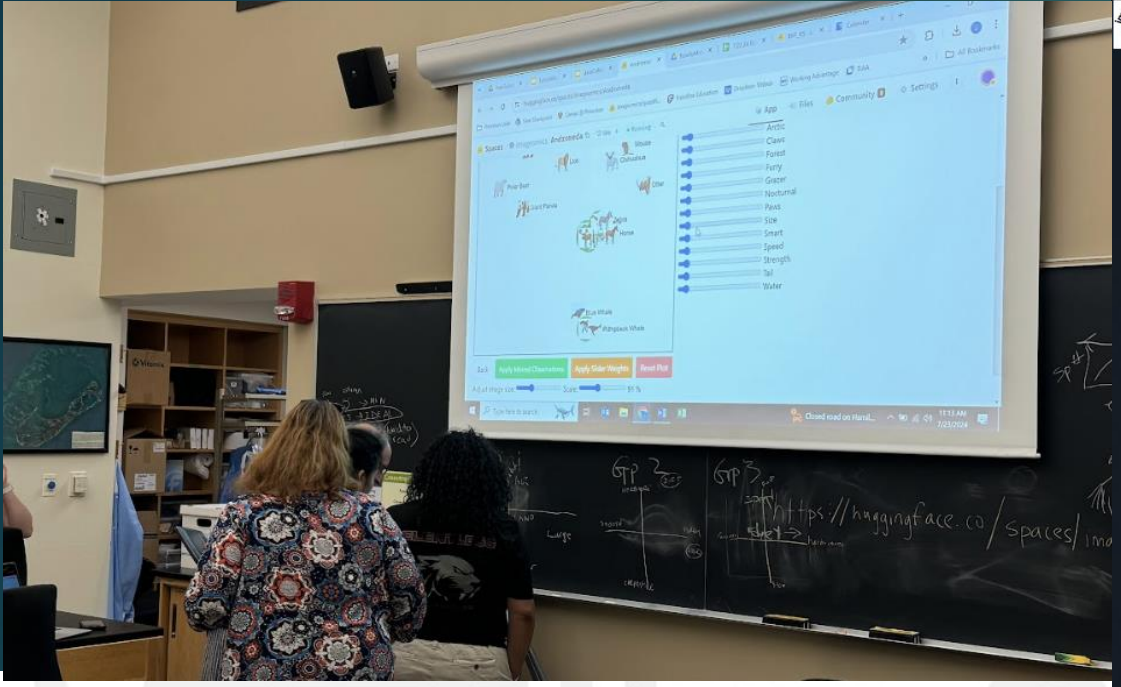
Maksim Kholiavchenko, **Jenna Kline**, Michelle Ramirez, Sam Stevens, Alec Sheets, Reshma Ramesh Babu, Namrata Banerji, Elizabeth Campolongo, Matthew Thompson, Nina Van Tiel, Jackson Miliko, Eduardo Bessa, Isla Duporge, Tanya Berger-Wolf, Daniel Rubenstein, Charles Stewart

WACV'24, CV4Animals'24



https://dirtmaxim.github.io/kabr/




https://huggingface.co/spaces/

BEETLEPALOOZA
2024

Imageomics-AAAI-24
Home
Call for Participation
Committee
FIRST WORKSHOP ON
IMAGEOMICS
(Imageomics-AAAI-24)
Discovering Biological Knowledge from Images using AI
Held as part of AAAI 2024
February 26, 2024, 9 am to 12.30 pm
Room 203, Vancouver Convention Centre – West Building | Vancouver, BC, Canada

ML for Species Classification
"white-tailed deer"

Impact

imageomics.org

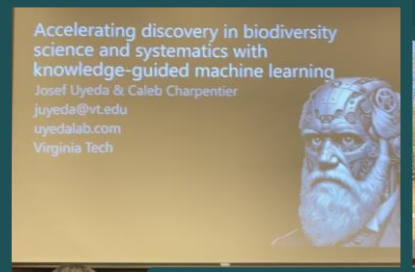
CVPR'24
Best Student
Paper Award

100+
publications
and
presentations

9+11
published (HF)
models and
datasets

Community:
- 150+ members
- Datapalooza & Beetlepalooza
- Experiential AI & ecology course
- Interdisciplinary training
- NextGen fellows and grads

Workshops:
- AAAI
- Highschool science teachers
- Middle school camp
- Conservation practitioners



AI for nature
open challenges:

- Adding domain knowledge (KGML)
- Focus on the long tail, open set, distribution shift
- Novelty discovery
- Quantifying uncertainty
- Multimodal data analysis
- Model composition…
- …including domain models
- Human-machine partnership by design