

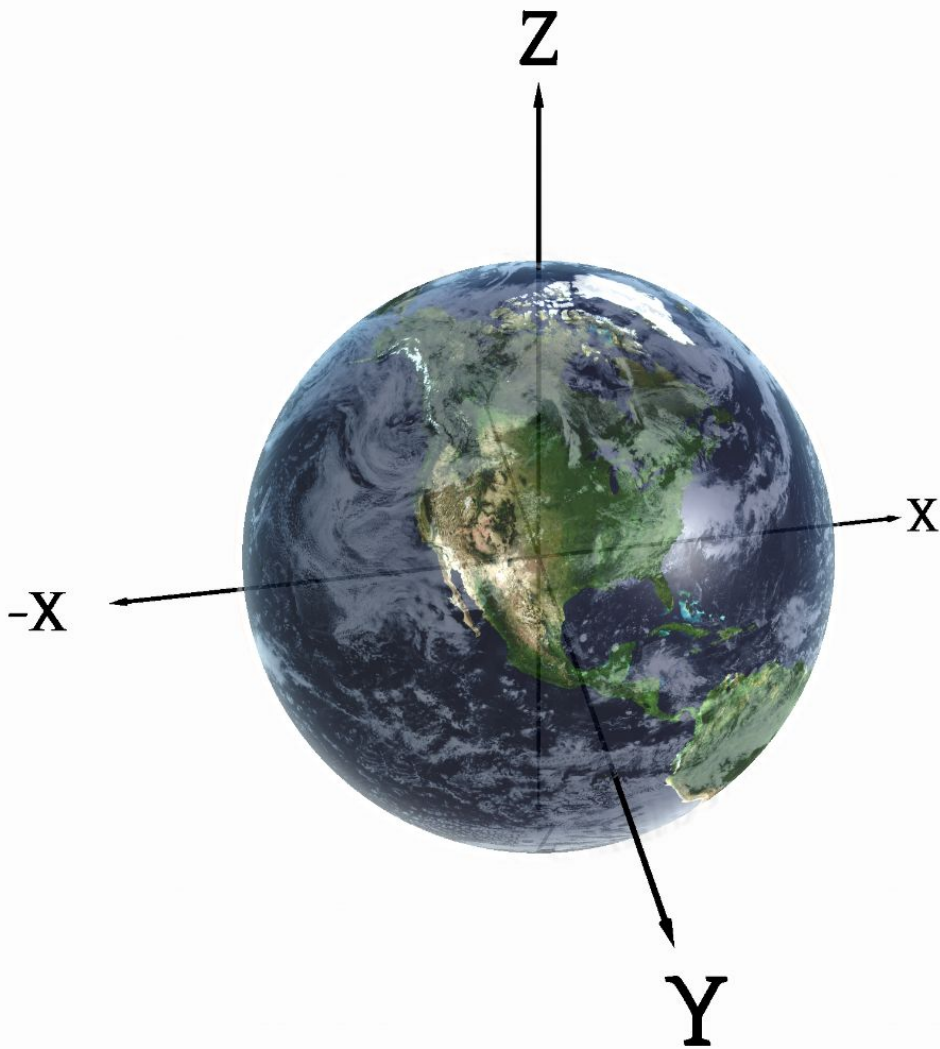
# NSF I-GUIDE

## *DeepEarth Workshop*

9th Hour of 168th Day of Year 2025  
(41.889306°, -87.619333°, 184m)

LANCE LEGEL

*CEO of Ecodash.ai*



# Welcome!

*Let's introduce ourselves and get organized...*



*Archilochus  
colubris*

# *Record of Workshop Participants*

- Professor [Shaowen Wang](#), University of Illinois Urbana-Champaign >> [NSF I-GUIDE Director](#)
- Professor [Danielle Wood](#), Notre Dame University >> [Global Adaptation Initiative](#)
- Professor [Fangzheng Lyu](#), Virginia Tech University >> [Geospatial Data Science](#)
- Dr. [Wen Zhou](#), University of Illinois Urbana-Champaign >> [GeoAI & Multimodal Simulation](#)
- Dr. [Wei Hu](#), University of Illinois Urbana-Champaign >> [Geospatial LLMs & Agents](#)
- Dr. [Elham Jebalbarez Sarbijan](#), Purdue University, [Rosen Center for Advanced Computing](#)
- Dr. [Jungha Woo](#), Purdue University, [Rosen Center for Advanced Computing](#)
- Dr. [Xin Gu](#), Texas State University >> [Geospatial Urban AI](#)
- PhD candidate [Yen-Yi Wu](#), University of Wyoming, [GeoAI + Hydrological and Climate Science](#)
- PhD candidate [Nicholas Manning](#), Michigan State University, [GeoAI & Ecology](#)
- MS candidate [Ivy Doe Kwashie](#), University of Wyoming, [GeoAI + Digital Twins for Coastal Ghana](#)
- CNA analyst [Carey Whitehair-Conde](#), CNA, [GeoAI for Wildfire Threat Detection](#)
- Ecodash.ai CEO, [Lance Legel](#), Ecodash.ai, [Director of Ecological Intelligence](#)



An aerial photograph of a landscape featuring a dense forest on the left and a building complex with several interconnected structures on the right. A dirt road or path winds through the forested area.

9:00AM - 12:00PM (3 sessions)

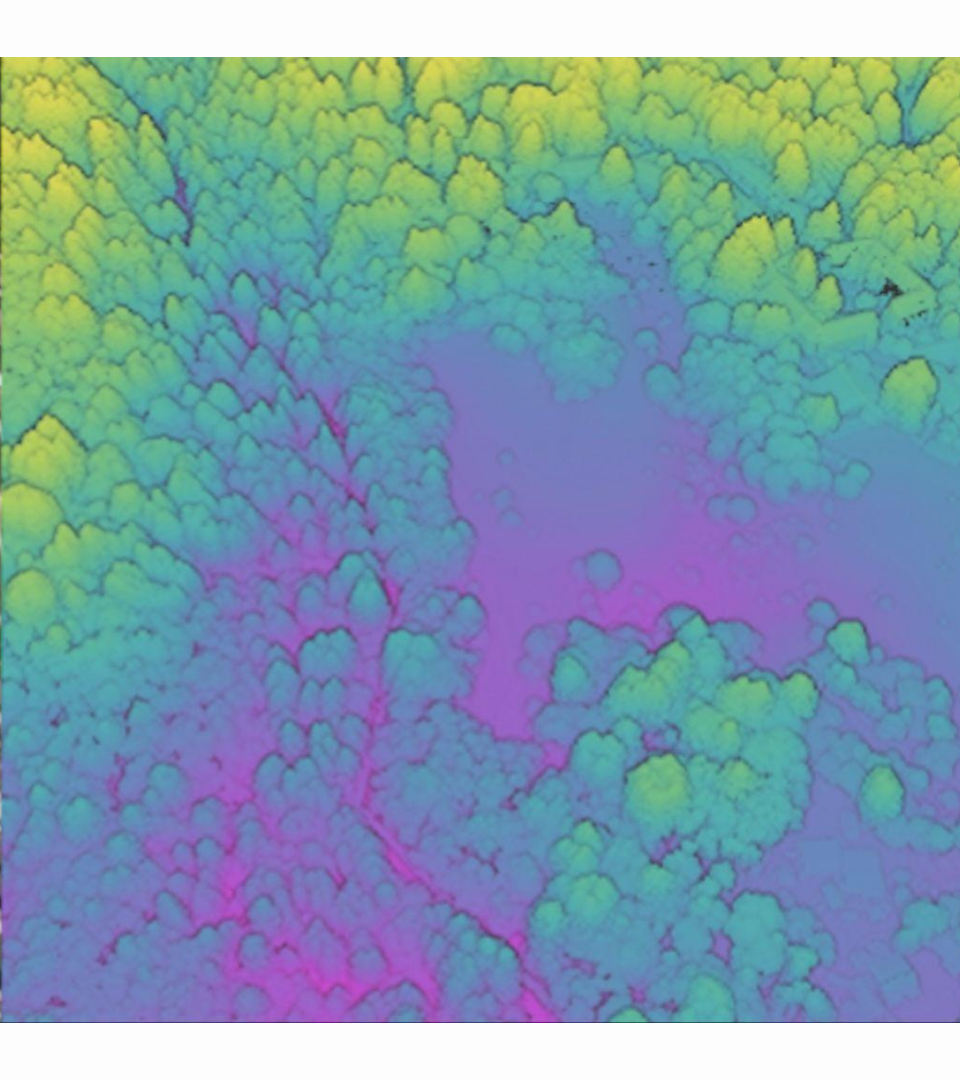
**I. State-of-the-Art Deep Learning**

- Self-Supervised
- Multimodal

**II. DeepEarth Foundation Model**

- Spatiotemporal Encoding
- Architecture & Code Examples

**III. Design Contest**

- Customize your own model
- 
- A heatmap visualization of the same aerial area shown on the left. The colors represent different values or intensities, with a color gradient ranging from purple (low) to yellow (high). The building complex and surrounding areas show higher values (yellow/green), while the forested areas show lower values (purple/blue).
- Heatmap visualization of the same area, showing a color gradient from purple/blue to yellow/green, likely representing a spatial or temporal metric.

# STATE-OF-THE-ART DEMO:

## OPENAI O3 PRO



What is happening?

Request for o3 pro  
Reasoned for 2m 47s

The photo captures a brief but telling ecological interaction:

### Scene description

- A hummingbird is hovering nearly upright, suspending itself in the air by rapid wingbeats while probing a tubular, orange-yellow flower with its bill.
- The bird's head and throat flash an iridescent magenta-rose; the back and flanks are metallic green. Those traits, plus the relatively short tail, point to a **male Anna's Hummingbird (*Calypte anna*)**, a common resident along the Pacific coast of North America.
- The flowers appear to belong to a shrub with paired, trumpet-shaped corollas—possibly a *Tecoma* or distant relative—whose morphology is well-matched to hummingbird pollination (deep tube, bright warm colors, nectar reward, little scent).

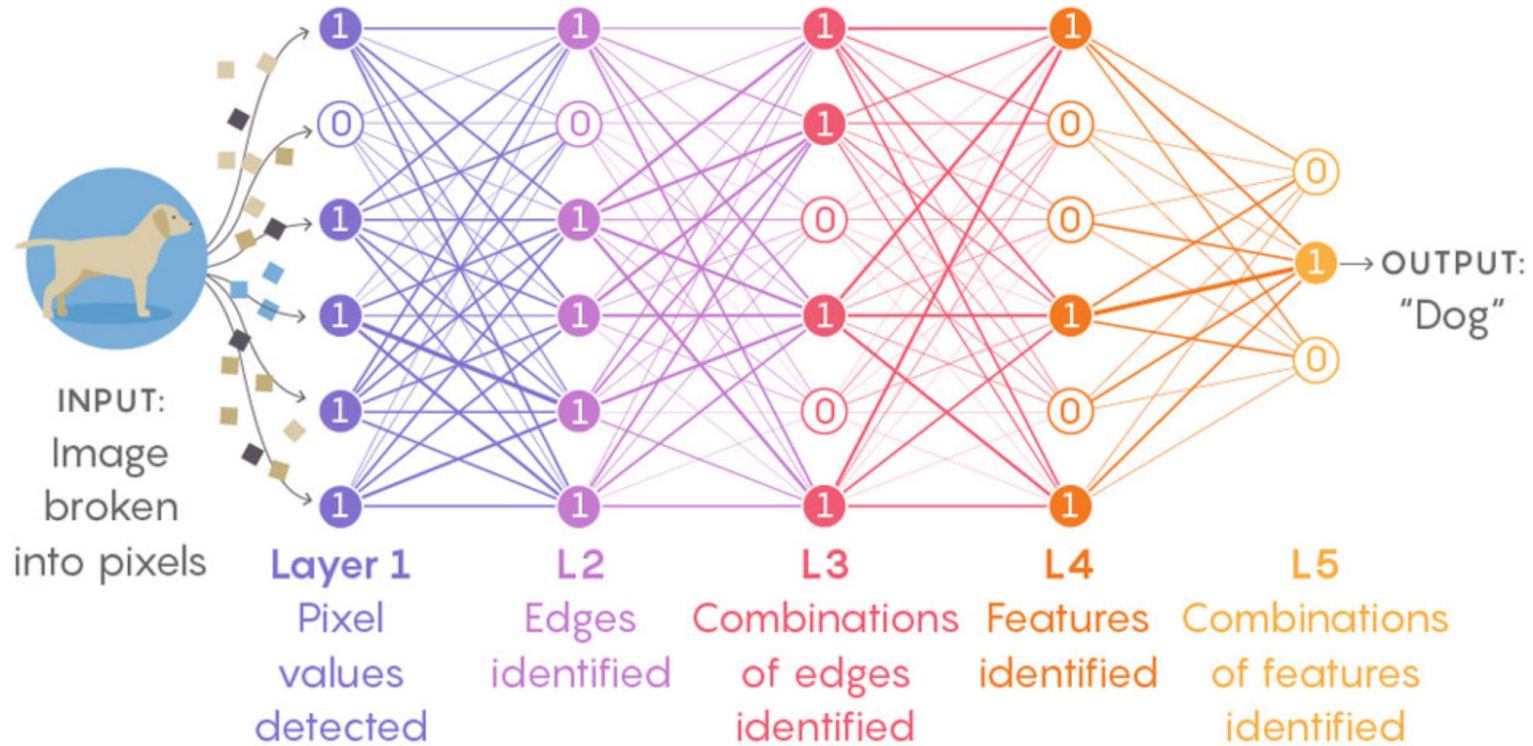
### What is happening

1. **Nectar for energy** – The hummingbird is inserting its long, specialized tongue through the corolla to lap up nectar, a high-sugar fuel that powers its extremely costly hovering flight (heart rates >1,200 bpm and wingbeats ~50 Hz).
2. **Pollination service** – As the bird feeds, its forehead and throat contact the flower's reproductive parts. Pollen grains dust the iridescent feathers and will be transferred to the next blossom it visits, completing cross-pollination. This is a classic bird-flower mutualism.
3. **Energetic micro-territorial foraging** – Male Anna's often defend small feeding territories around nectar-rich plants. The vertical perch-and-hover posture and alert eye suggest the bird may dart off momentarily to chase rivals or return to a nearby perch.

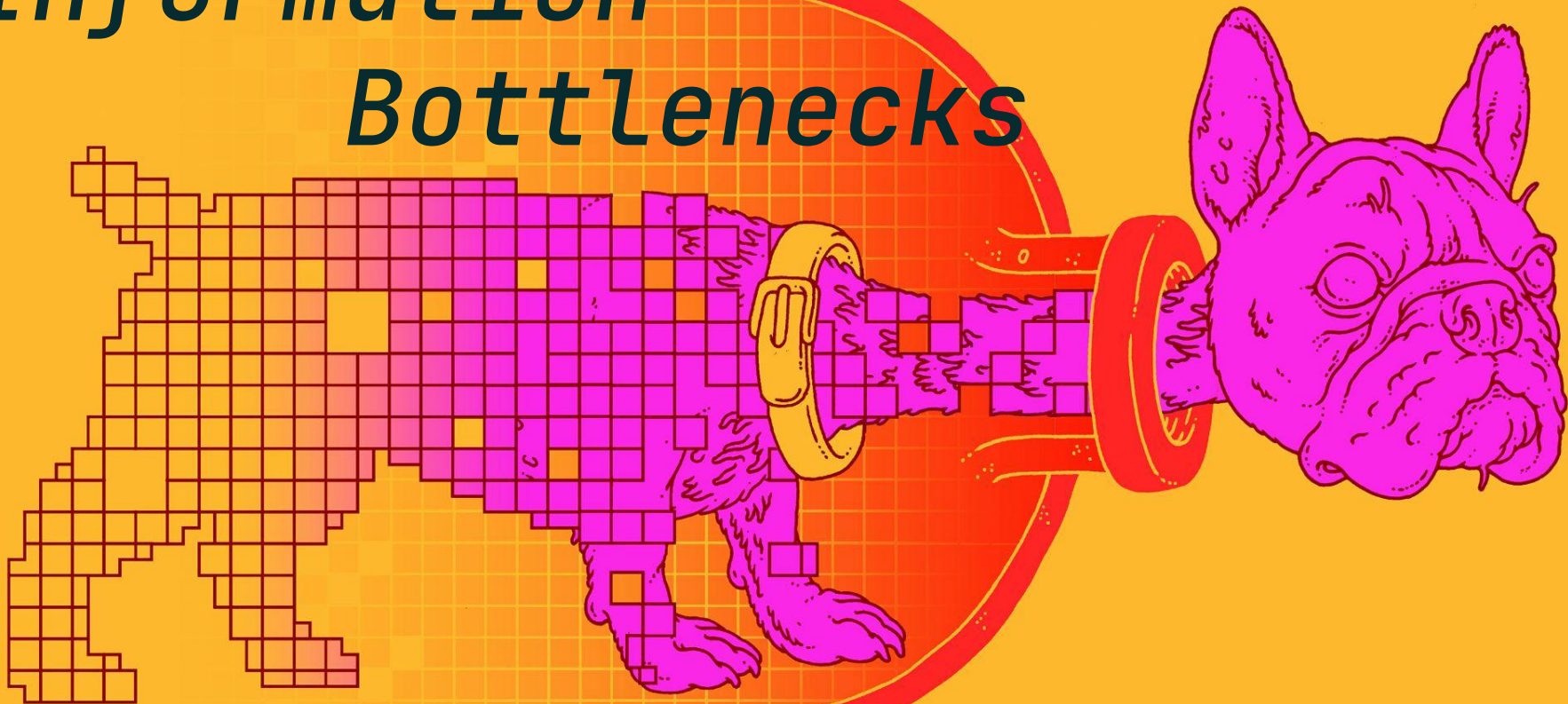
*How did we get here?*



*“In the beginning of deep learning, we had ConvNets”...*



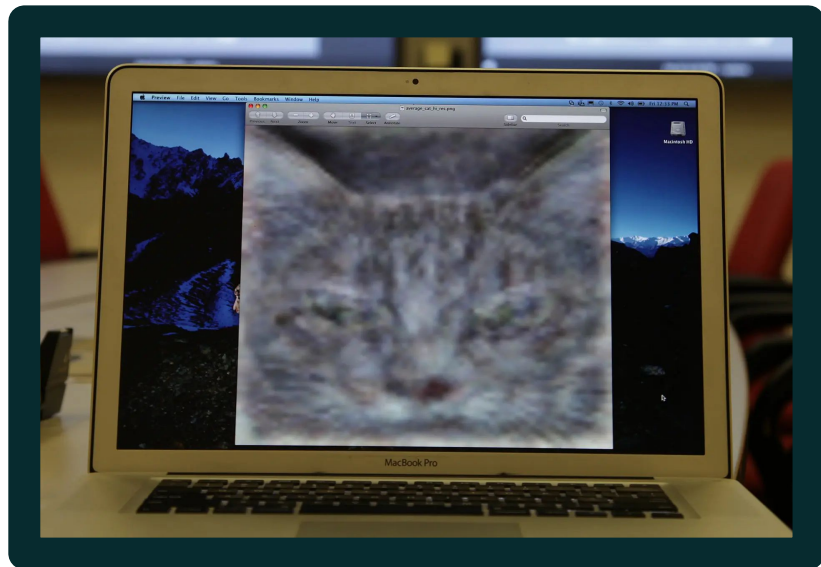
# *Information Bottlenecks*



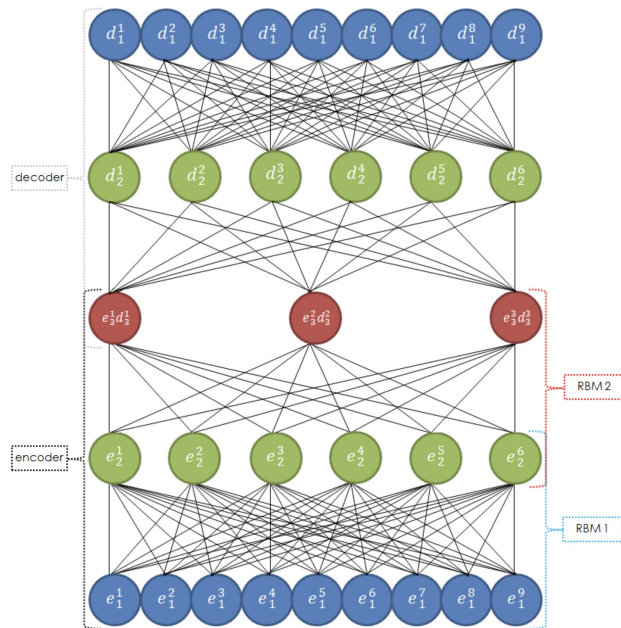
Quanta Magazine, 2017, [“New Theory Cracks Open the Black Box of Deep Learning”](#)



# Self-Supervised Learning

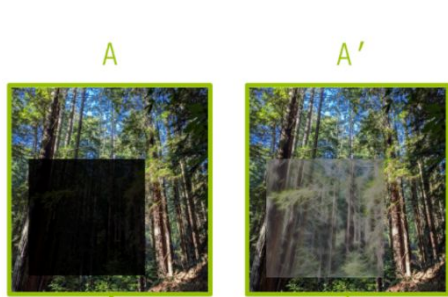


New York Times, 2012,  
["How Many Computers to Identify a Cat? 16,000"](#)

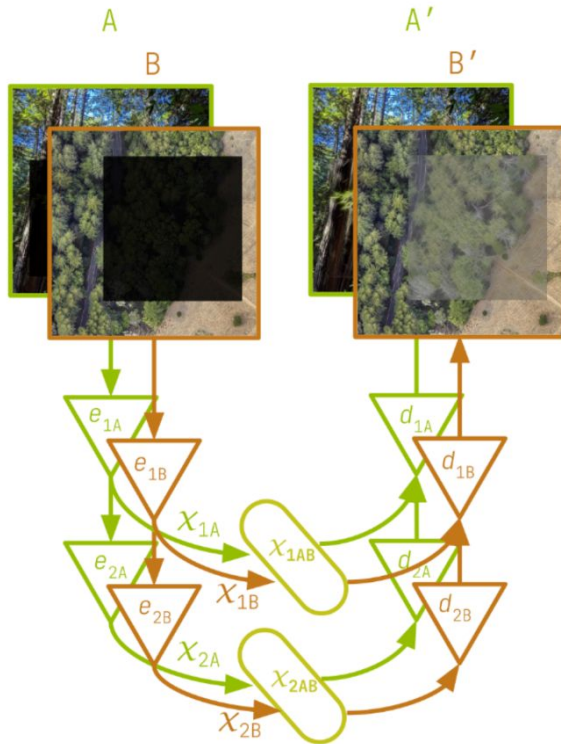


Lance Legel, Master of Science Thesis, 2013,  
["Parallelized Deep Neural Networks for Distributed Intelligent Systems"](#)

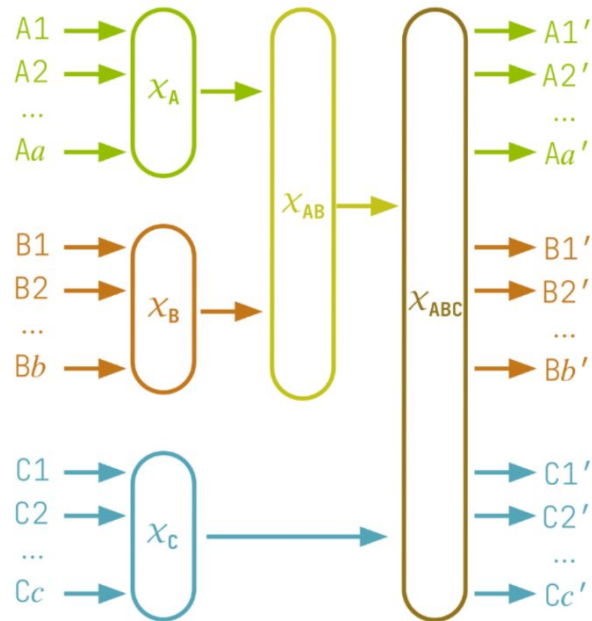
# Multimodal Deep Learning



(a) Autoencoder



(b) Inductive Autoencoder



(c) Hierarchical Inductive Autoencoder

# Break!

*Let's decompress and relax for 5 minutes...*

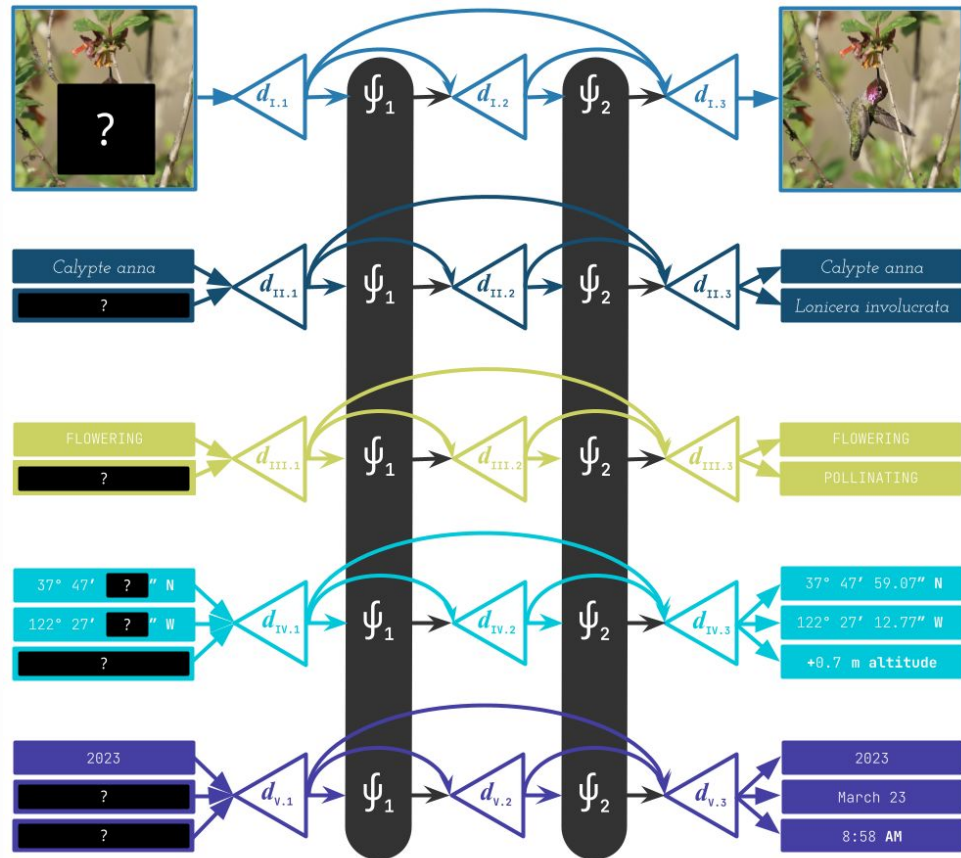


*Selasphorus  
rufus*

*Art by Petra Stanković*

# Spatiotemporal Self-Supervised Multimodality Simulator

## DeepEarth





# Questions & Roadmap (Post-Workshop Notes)

## I. Deep Geometric Vector Encoding

- v0.01 Spacetime Encoding is "Pointwise" ("Rasterized"), which is known to be both effective but also potentially very inefficient. How can we teach "vectors", "polygons", and "ranges" to the NN?

## II. Bayesian Uncertainty Encoding

- Following the workshop, there was a discussion about Gaussian Processes and the potential for explicit modeling of uncertainty. What are some elegant ways to inject uncertainty into the model?

## III. Core Infrastructure Prototyping & Testing

- As of June 19th, 2025, DeepEarth's architecture is more or less fully specified, and peer-reviewed. Collaborators are invited to become core DeepEarth model contributors to bring this to life.

## IV. Custom DeepEarth Model Development, Experiments, and Publications

- During the workshop, 6 teams presented adaptations of DeepEarth for their research domain. Let's plan to explore collaborations to potentially bring such projects to life over the next 3-6 months.

# *Key Follow-Up References*

- DeepEarth Specifications Document including Detailed Python Implementation (2025)
- Foundation Model for Ecology including Historical AI Modeling References (2024)
- Inductive Neural Networks for Ecology including Mathematical Insights & NN Diagrams (2025)
- DeepEarth Pre-Print Preview (Subject to Dramatic Change in Coming Months, 2025)
- NVIDIA Multi-Resolution Hash Encoding: Demos & Paper (2022)
- Stanford lecture on Multi-Resolution Hash Encoding (2022)
- Grid4D encoding of (x,y,z) and time via 4 tri-plane Multi-Resolution Hash Encodings (2024)
- V-JEPA 2 spatiotemporal “world” vision foundation model from Meta (Yann LeCun, 2025)
- ClimaX foundation model for Weather and Climate from Microsoft (2023)
- cBottle foundation model for 1km Atmosphere Modeling from NVIDIA (2025)
- How DeepSeek Rewrote the Transformer [MLA]: Detailing 57x Speed-Up in Transformer (2025)
- Deep Autoregressive Networks: “Universal Distribution Approximator” (2014)
- MADE: Masked Autoencoder for Distribution Estimation (2015)

Thank you!

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*Grus canadensis*

Art by Petra Stanković