Investigating Different Geo Priors for Image Classification

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Overview

Our goal is to explore **species distribution models** as **geographical priors** for vision tasks

visually similar species

Western Bluebird

Eastern Bluebird

located in different places

Using **visual features** and **location features** to make predictions

Dataset & Evaluation

Evaluation Dataset:
282.9k iNaturalist images covering **39.3k** species
- 9.8k total images covering **2.7k** species not present in SINR training set [1]

Evaluation:
Top-1 accuracy with ground truth species labels from iNaturalist [1]

Models

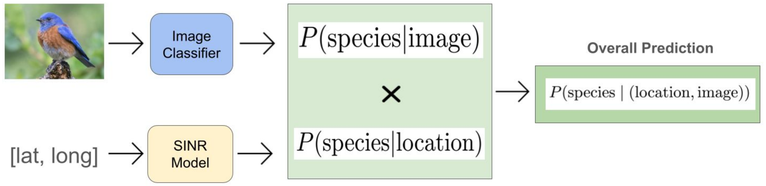
Vision model: Pretrained Xception network used by the iNaturalist community science platform.
- Can predict for **55.3k** species

Range Estimation model: SINR (Spatial Implicit Neural Representation) predicts likelihood of species presence from location coordinates.
- SINR is trained on **44.8k** species

10.5 K species have no SINR predictions

Method

Geo Prior Task: At test time, we combine the outputs of model trained for species range estimation on iNaturalist dataset with an image classifier.



Experiments

How different SINR configurations affect its usefulness as a Geo Prior

1. **Training duration** - number of epochs
2. **Model Size** - number of hidden dimensions
3. **Adding Delta** - adds a minimum presence probability [2]
4. **K-Value Adjustment** - static value for species not covered by SINR

Handling Unseen Species: The Role of the K-Value

Geo Prior Predictions

$$P(\text{species} \mid (\text{location}, \text{image})) \approx P(\text{species} \mid \text{location}) * P(\text{species} \mid \text{image})$$ [3]

Baseline Approach

$$P(\text{species} \mid \text{location}) = \begin{cases} \text{SINR}(\text{location}, \text{species}) & \text{if species is in SINR} \\ k = 1.0 & \text{otherwise} \end{cases}$$

- Assign a static **K to all unseen species**, but SINR predictions are always **< 1.0**
This unintentionally **favors unseen species** by giving them a bigger weight.

Our K-Value Experiments
- Tested smaller values (k = 0.01 - 0.2)

Results

	Method	Parameters	IUCN	S&T	GeoPrior
1	Vision Only		–	–	75.409
2	Baseline SINR	10 epochs, k =1.0	62.00	72.82	+6.6
3	Baseline SINR	20 epochs, delta = 0.001	64.35	73.58	+6.77
4	Baseline SINR	10 epochs, k = 0.02	62.00	72.78	**+9.0**

Adjusting Species Prediction Model

Experimenting with **model adjustments** (varying epochs, hidden layer dimensions, delta) **only resulted in a 0.1% increase**

Method	Epochs	S&T	IUCN	GeoPrior	+Delta
Vision Only		–	–	75.409	75.409
SINR	10	62.00	72.82	+6.6	+6.58
SINR	5	59.42	72.28	+6.26	+6.29
SINR	20	64.35	73.58	**+6.68**	**+6.77**
SINR	30	64.75	**73.60**	+6.61	+6.75
SINR	40	65.65	73.42	+6.59	+6.75
SINR	50	**65.77**	73.36	+6.57	+6.75

Table 1: **Varying Training Epochs and adding Delta.**

Performance reported as the improvement over the vision-only model. For Delta column, delta of 0.001 was added to the SINR predictions.

Method	Hidden Dim	#Epochs	S&T	IUCN	GeoPrior	+Delta
Vision Only			–	–	75.409	75.409
Default SINR	256	10	62.00	72.82	+6.6	+6.58
Even Smaller SINR	64	50	61.24	72.28	+6.32	+6.41
Smaller SINR	128	50	64.35	**74.03**	+6.65	+6.73
Baseline SINR	256	20	64.35	73.58	**+6.68**	**+6.77**
Bigger SINR	512	10	63.95	73.64	+6.64	+6.64
Even Bigger SINR	1024	15	**66.85**	72.48	+6.49	+6.71

Table 2: **Effect of Model Size and adding Delta.**

Handling Unseen Species

Method	K Value	GeoPrior
Vision Only		75.409
Baseline SINR	1.0	+6.6
Baseline SINR	0.01	+8.9
Baseline SINR	0.02	**+9.0**
Baseline SINR	0.1	+8.7
Baseline SINR	0.2	+8.3

Most **significant performance gain** came from changing how we combine predictions from the image classifier and the SINR model.

Best Result: K- 0.02 → +2.4% over the baseline

Future Directions & References

- Explore other evaluation datasets, would the K-Values be different?
- In theory, what's an ideal K-Value? The average prediction across all species at a location?
- How does perturbing the location affect performance?

[1] Cole, Elijah, et al. "Spatial implicit neural representations for global-scale species mapping." *International conference on machine learning*. PMLR, 2023.
[2] Dorm, Filip, et al. "Generating binary species range maps." *European Conference on Computer Vision*. Springer, Cham, 2025.
[3] Mac Aodha, Oisin, Elijah Cole, and Pietro Perona. "Presence-only geographical priors for fine-grained image classification." *Proceedings of the IEEE/CVF International Conference on Computer Vision*. 2019.

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