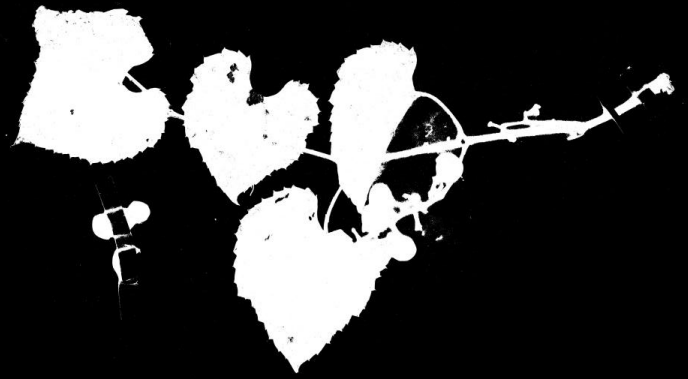
Deep Learning Image Clustering to Aid Species Delimitation Within the *Vitis arizonica* complex.



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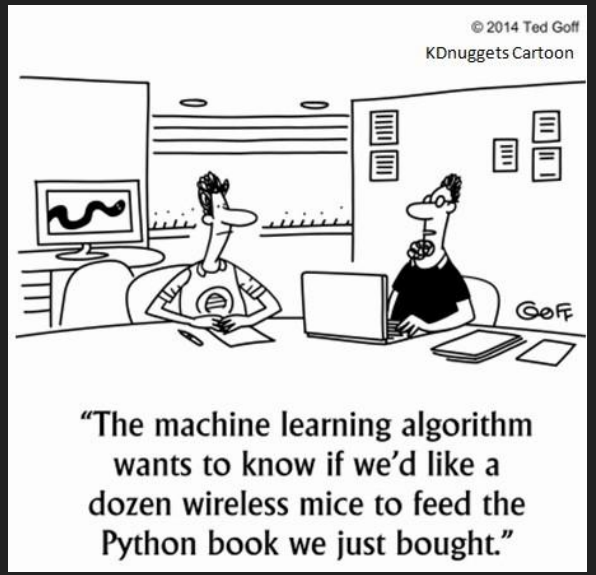
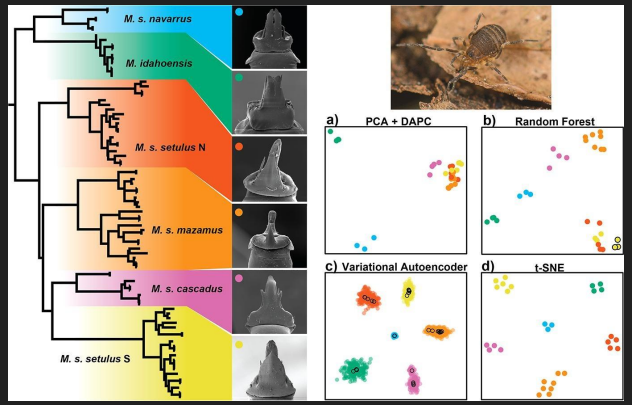
Smithsonian

Outline

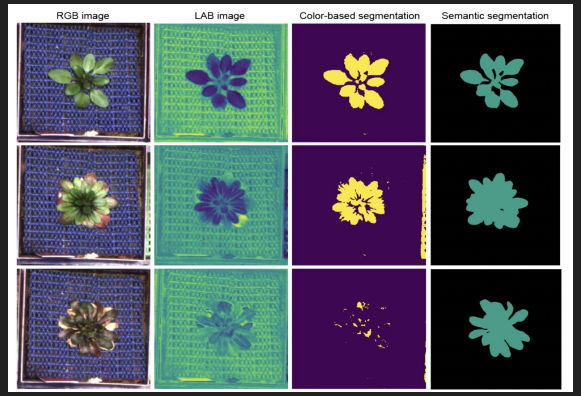
- Machine Learning and Deep Learning
- Research and Goals
- Our Data
- ML and DL Biases
- Preprocessing
- Deep Convolutional Embedded Clustering
- Results
- Further Work/Conclusions
- Plug for OSS Project



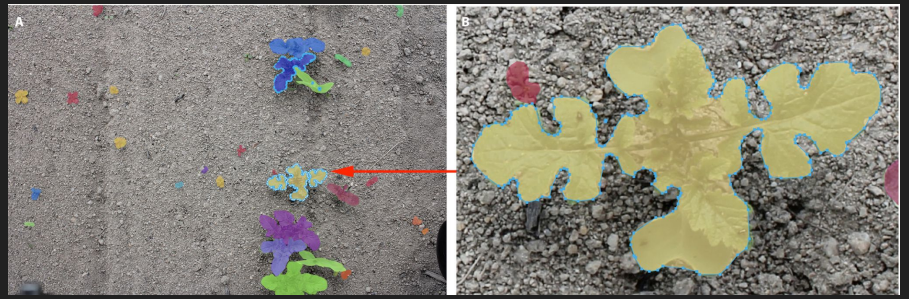
Machine Learning and Deep Learning



Shahan Derkarabetian et al. 2020
A demonstration of unsupervised machine learning in species delimitation



Hüther et al. 2020
araDEEPopsis: From images to phenotypic traits
using deep transfer learning

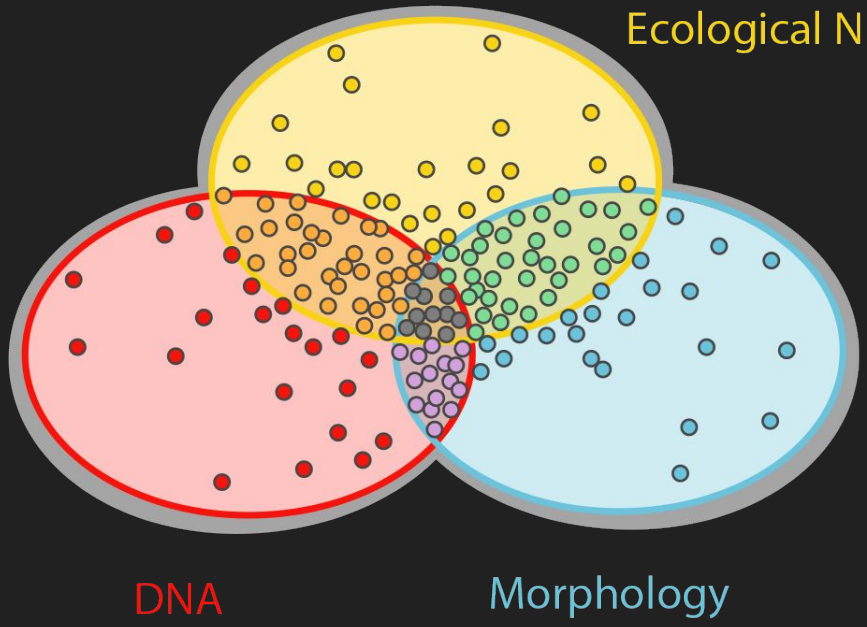


Champ et al. 2020
Instance segmentation for the fine detection of crop and weed plants by precision agricultural robots

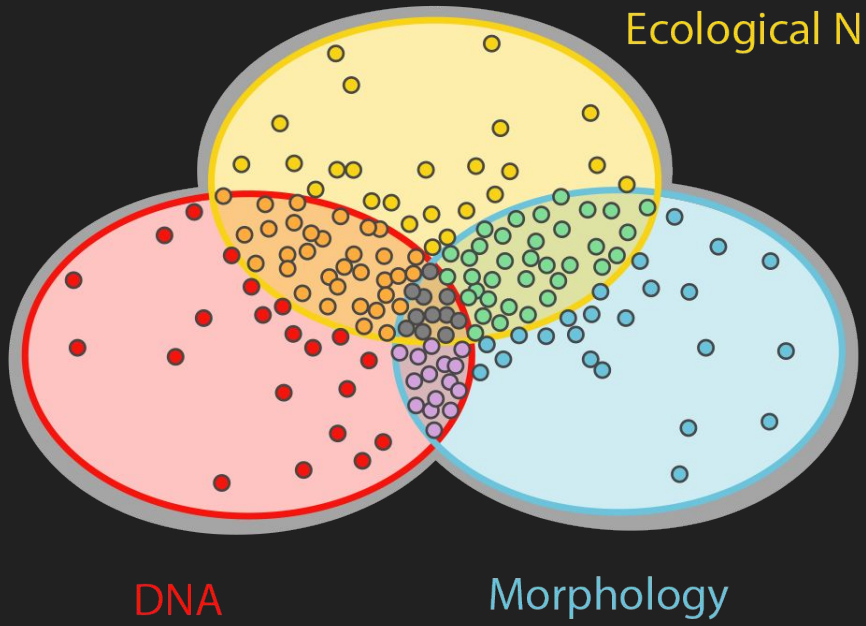
Research Goals and Outcomes

- Identify a deep learning workflow which can cluster herbarium sheet imagery in a way which signals species delimitation.
- Ideally clustering will be able to identify which specimen are most likely to return significant results from DNA sequencing
- Eventually incorporating tools like Leaf Machine to automate, and leverage large amounts of data from sources like iDigBio, GBIF

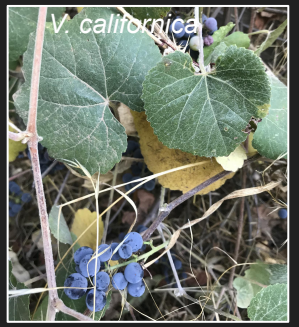
Species Delimitation



Species Delimitation



Vitis arizonica complex

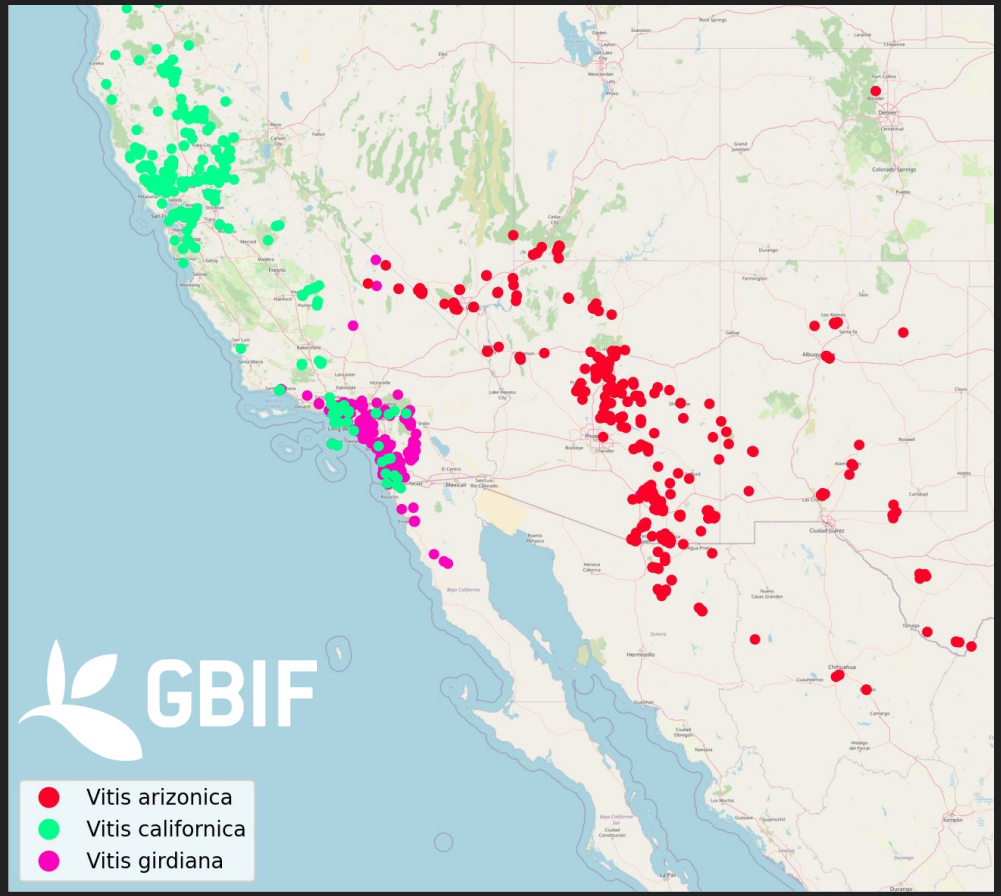


Methods: Our Data

Methods: Our Data

	SI	RSA	ASU	Total
Vitis arizonica Engelm	65	29	117	211
Vitis girdiana Munson	0	39	0	39
Vitus california Benth	0	27	0	27
Total	65	95	117	277

Species Distribution Map



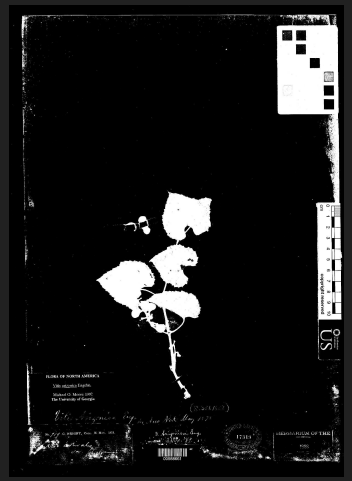
ML and DL biases

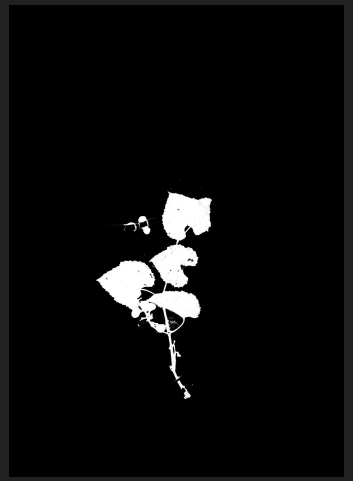
Visual Heterogeneity

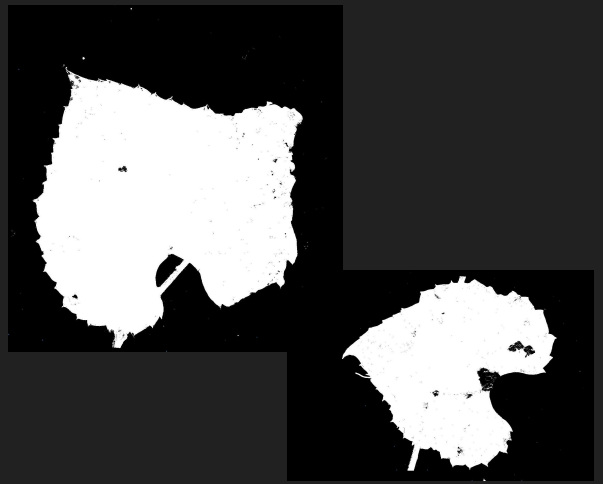
- Mounting techniques
- Age of specimens
- Imaging set-up

Methods: Preprocessing

- The goal is to remove any biasing information
  - Camera settings, lighting conditions, labels are all features that obstruct morphological signal.
  - Clustering on the segmentation masks captures the leaf morphological traits of the specimen, while removing biasing information.





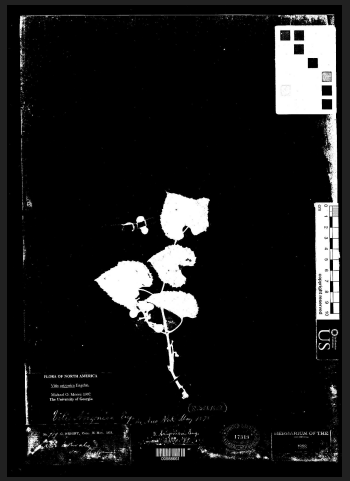


Methods: Preprocessing

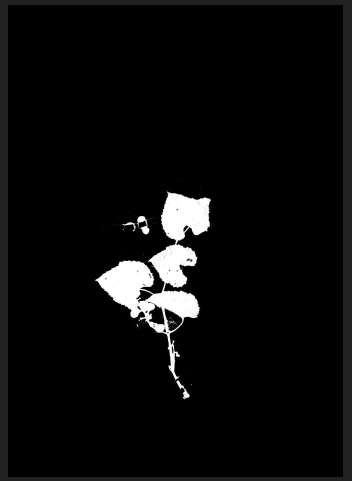
- Tools are in production for generating segmentation masks automatically (Leaf Machine 2)

- Masks for this project were generated adapting a workflow from *Generating segmentation masks of herbarium specimens and a data set for training segmentation models using deep learning* (White and Dikow, et al 2020)

Global Otsu Binarization

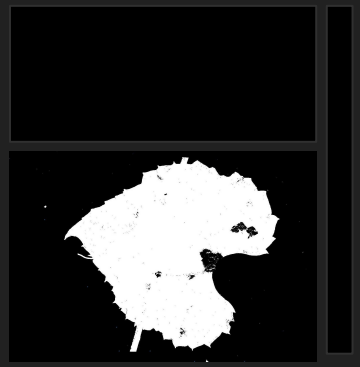


PhotoShop Batch Processing



Resize + Leaf Instance Crop

Border Padding + Final Resize
(retains relative size)

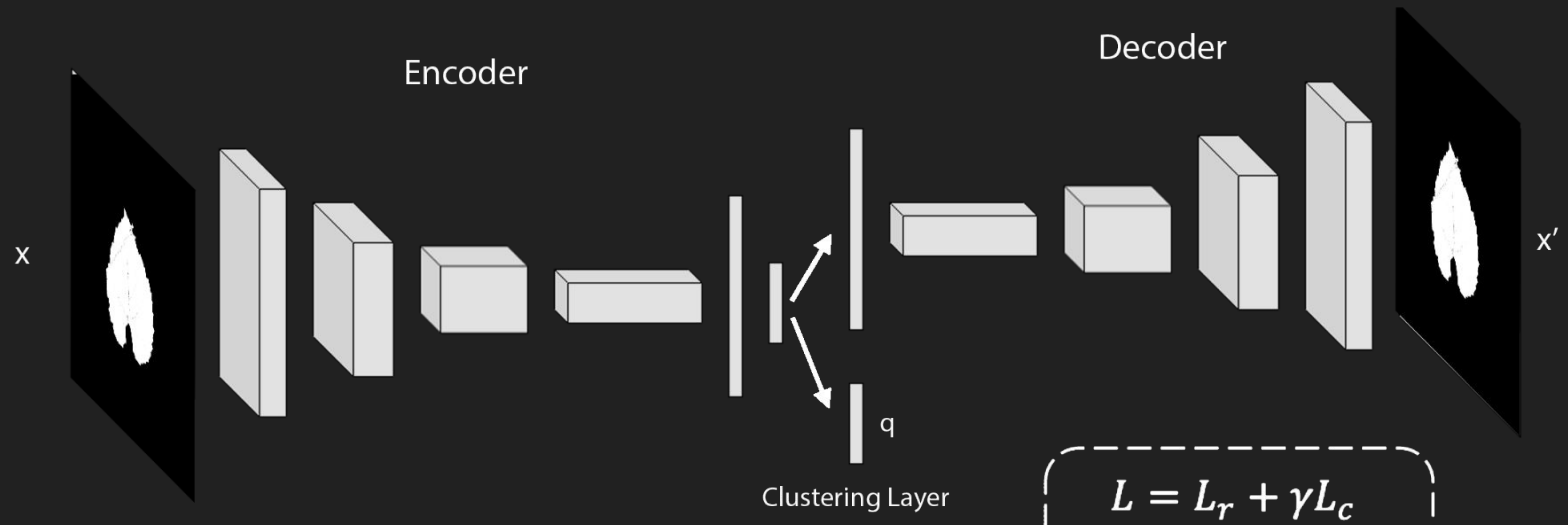


Methods: Image Clustering

- The Deep Learning Algorithm that we are using for clustering is called Deep Convolutional Embedded Clustering (Guo, Liu, et. al. 2017).
  - (pretraining) A Deep Convolutional AutoEncoder is trained on the data.
    - K-means is used in the latent space to identify n cluster centers.
  - (clustering) A Clustering layer is then incorporated alongside the latent space which maps embedded points in the latent space to a Student's t-distribution with n-dimensions.
    - KL Divergence is added to the loss function.
    - Cluster centers are updated alongside AE weights.

- Autoencoders preserve local structure of data in the latent space.
- Convolutional Layers learn image features.

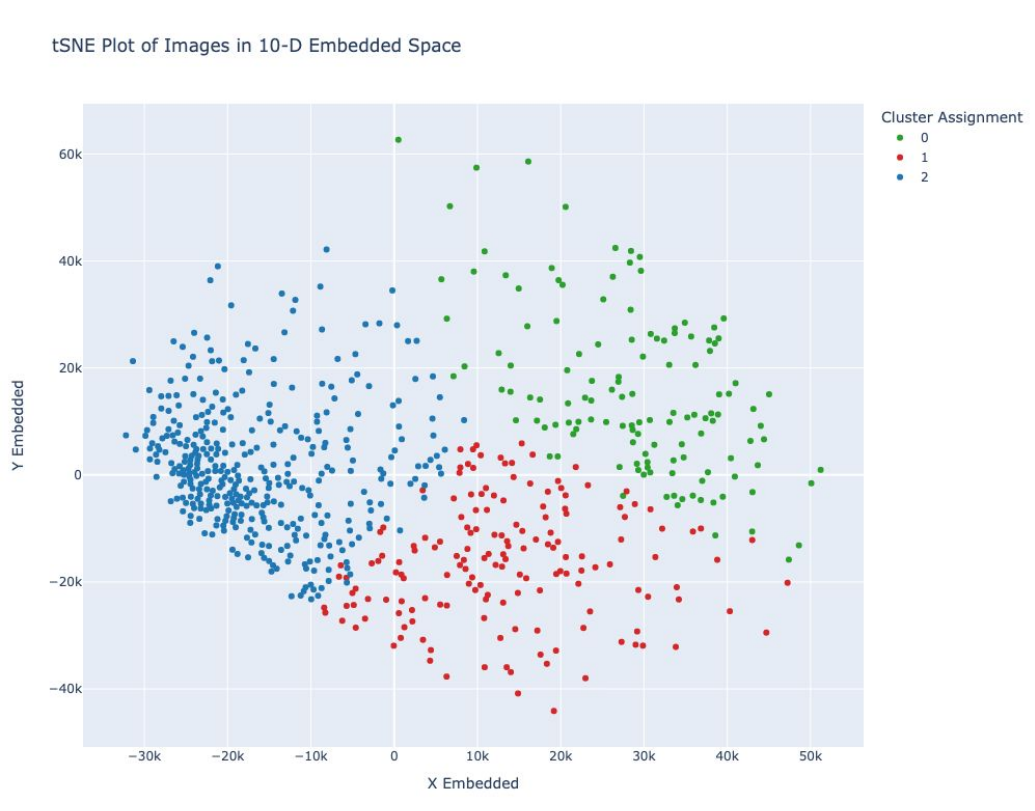
Methods: Image Clustering



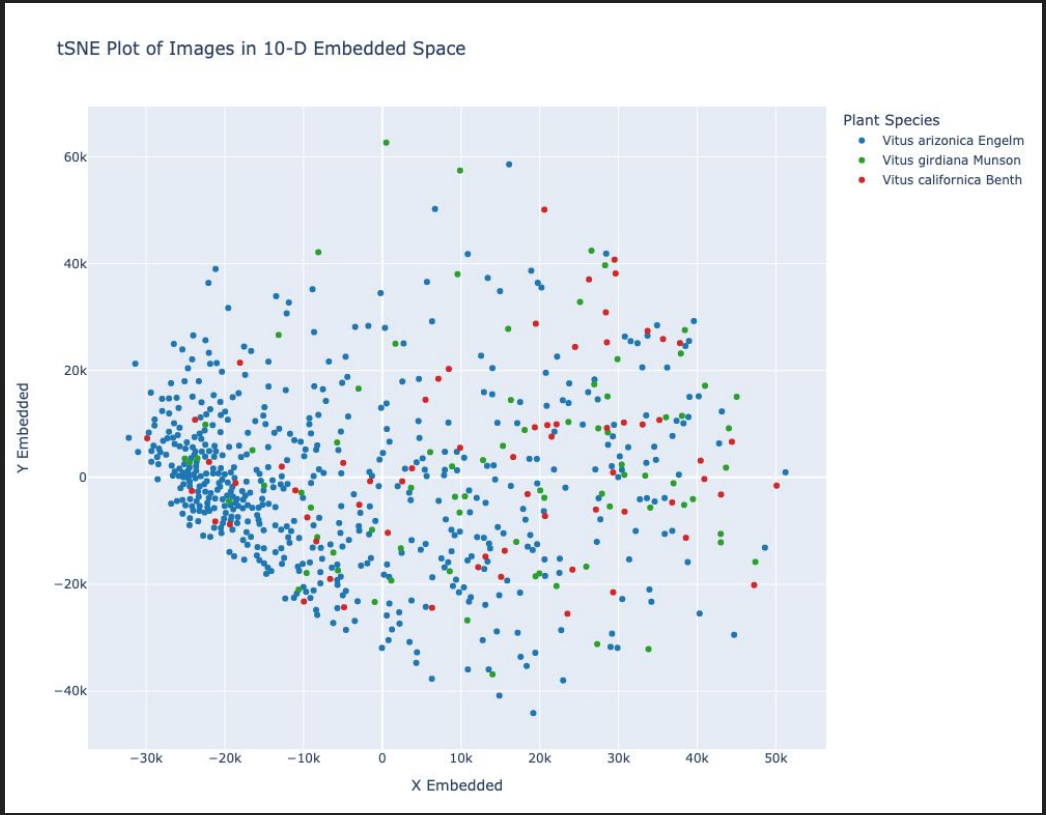
$$L = L_r + \gamma L_c$$
$$L_r = |x - x'|_2^2$$
$$L_c = KL(p||q)$$

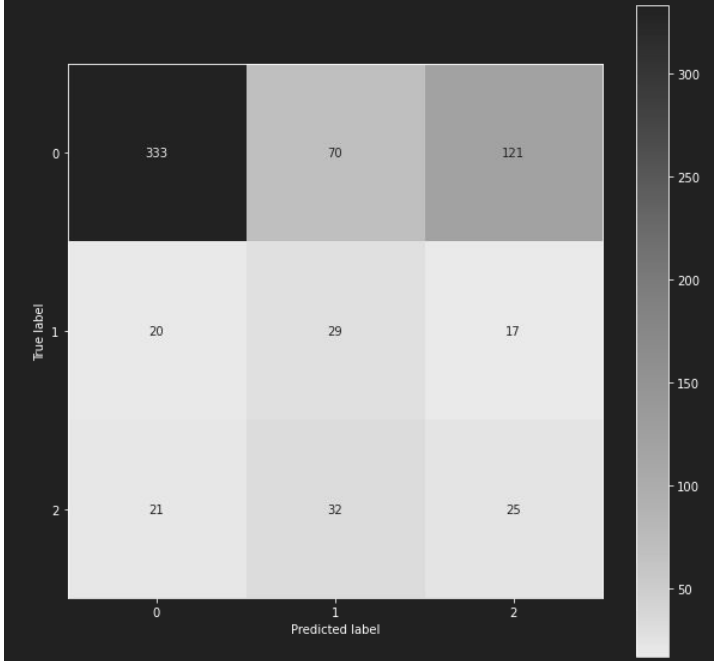
Deep Clustering with Convolutional Autoencoders (Xifeng Guo, Xinwang Liu, et.al 2017)

Results

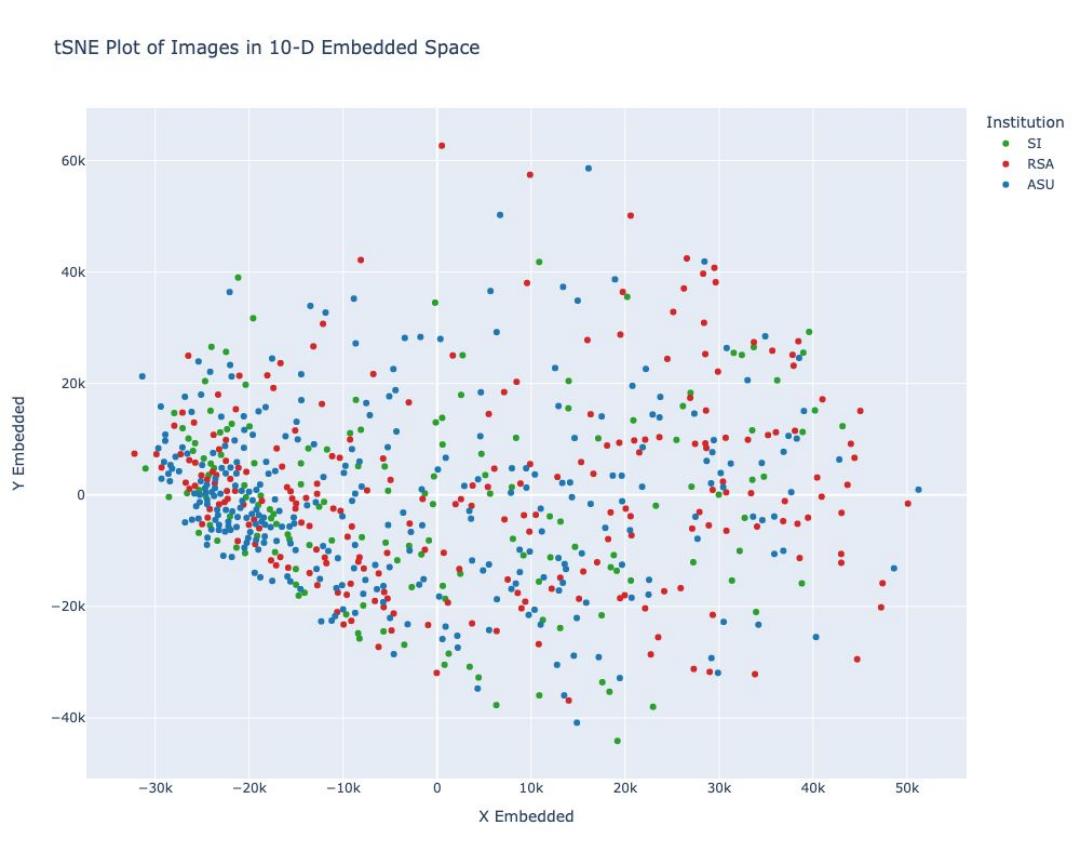

tSNE Plot of Images in 10-D Embedded Space
Cluster Assignment
0
1
2
Y Embedded
60k
40k
20k
0
−20k
−40k
−30k
−20k
−10k
0
10k
20k
30k
40k
50k
X Embedded

Results


tSNE Plot of Images in 10-D Embedded Space
Plant Species
Vitus arizonica Engelm
Vitus girdiana Munson
Vitus californica Benth
Y Embedded
X Embedded
60k
40k
20k
0
−20k
−40k
−30k
−20k
−10k
0
10k
20k
30k
40k
50k

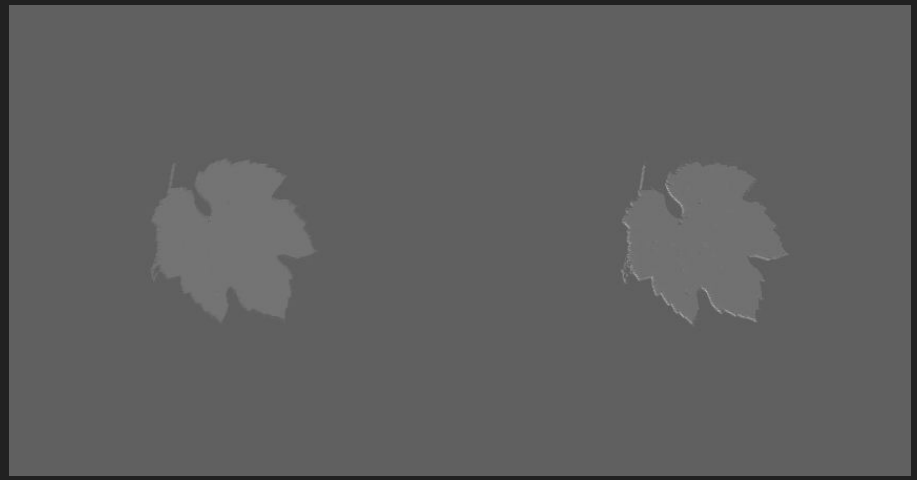

333
70
121
20
29
17
21
32
25
True label
Predicted label
0
1
2
300
250
200
150
100
50

Results


tSNE Plot of Images in 10-D Embedded Space
Institution
SI
RSA
ASU
Y Embedded
60k
40k
20k
0
−20k
−40k
−30k
−20k
−10k
0
10k
20k
30k
40k
50k
X Embedded

Results: Feature Maps

- Feature maps show promise
  - Extracting edge morphology
  - Extracting size, area, and texture

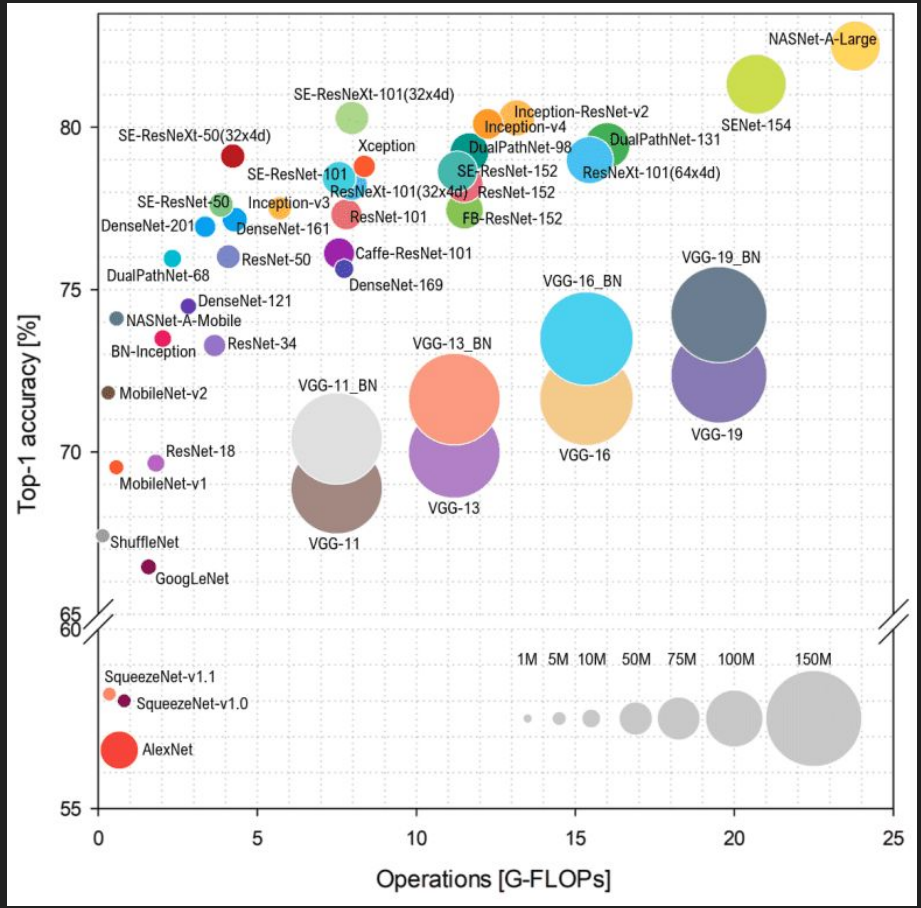


Further Work

More robust network architecture.

- Used poor performing traditional CNN architecture.
- ResNet/VGG are used in segmentation software like LeafMachine.

Transfer Learning opportunity



Bianco et al. 2018
Benchmark Analysis of Representative Deep Neural Network Architectures

Further Work

Alternative clustering methodology.

- ClusterGAN
- DAIC (Deep Adaptive Image Clustering)
- ASPC-DA (Adaptive Self-Paced Deep Clustering with Data Augmentation)

Morphology retaining data augmentation for pretraining step.

- Rotations
- Translations

Plug for OSS Project

No high level library for DL Image Clustering.

Current Implementation Workflow

- Read paper
- Hope and pray for author's github link works 🙏
- Refactor (often times) depreciated code/Integration Hell

Goal Workflow

- Read paper
- Scikit-learn esque implementation

Example: Segmentation Models

Acknowledgments

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Jun Wen

Questions?