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Society of Petroleum Engineers

SPE International
SPE Europe Region

2022 SPE EUROPE ENERGY GEOHACKATHON

13. Computer Vision Using Python

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#DatafyingEnergy

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Federico Ricciuti

Machine Learning Specialist

TRE ALTAMIRA

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Summary

- Motivation: Problem definition and workflows
- Segmentation
- Unsupervised Segmentation
  - Feature based: SLIC, QuickShift
  - Deep Learning: ISB, DFC, W-Net
- Supervised Segmentation
  - Deep Learning: U-Net
- Example

Problem

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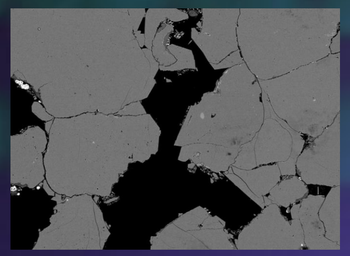
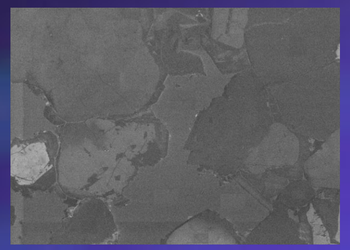
BSE



CL

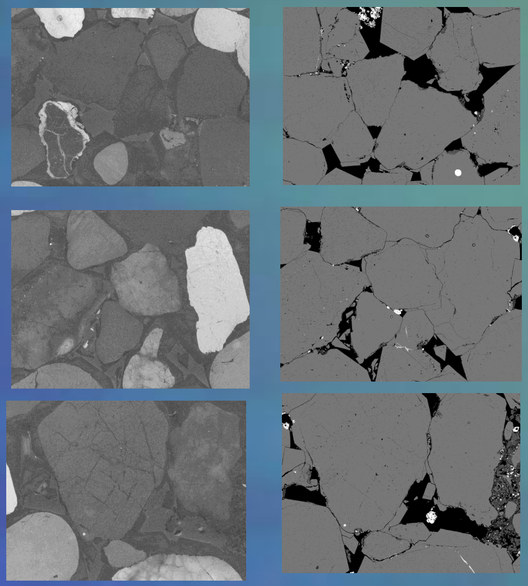


Model

Pixelwise Classification Map

Training

Partially labeled dataset



Expected classification map

~~Expected classification map~~

Expected classification map

...

...

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Problem

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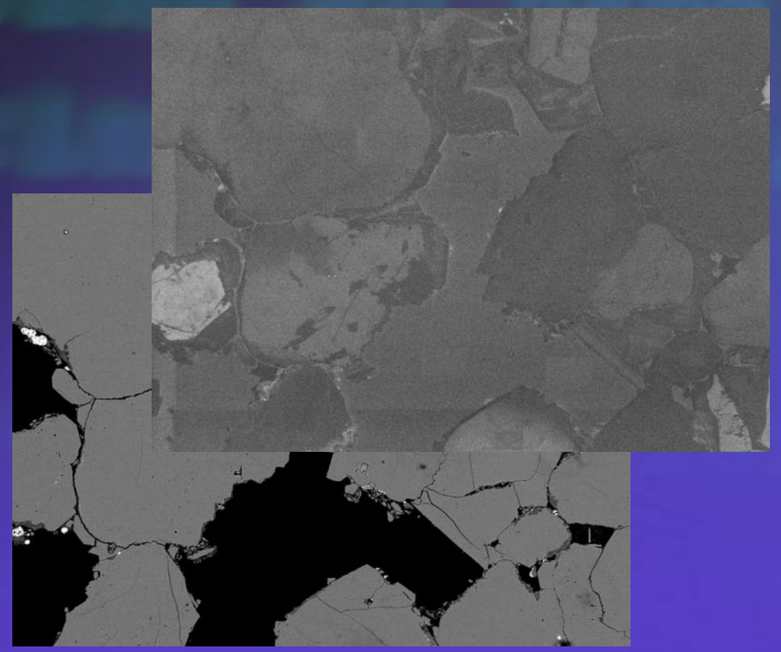
2-Channel input



Pixelwise Classification Map

1: Pore spaces

2: Quartz

3: Quartz overgrowth

4: Others

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Problem

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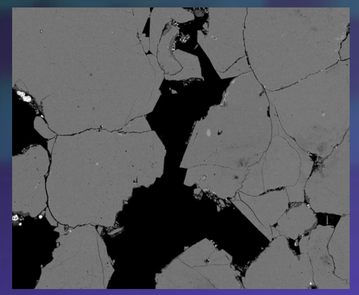
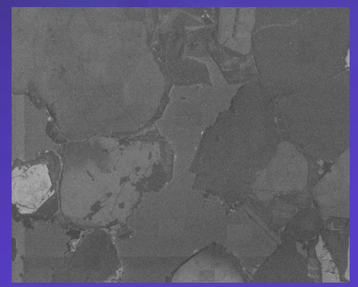


Detection of Pore Spaces

Detection of Quartz and Quartz overgrowth

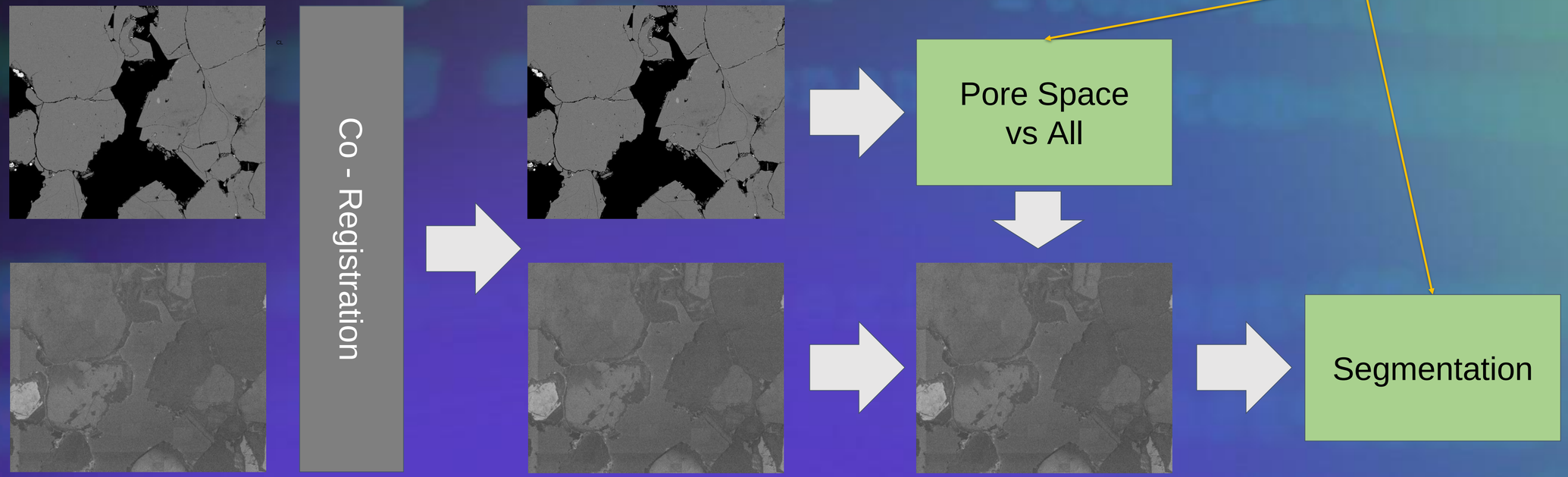
CL



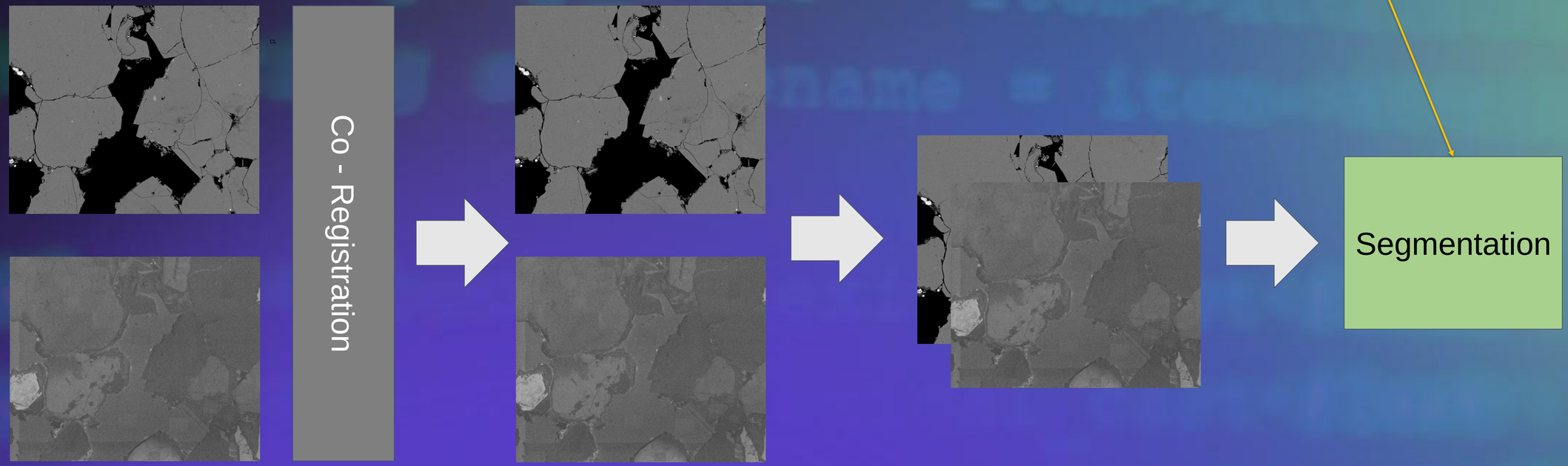
Detection of Pore Spaces

Detection of Quartz and Quartz overgrowth

Workflow 1


Semantic Segmentation
Co - Registration
Pore Space vs All
Segmentation

Workflow 2

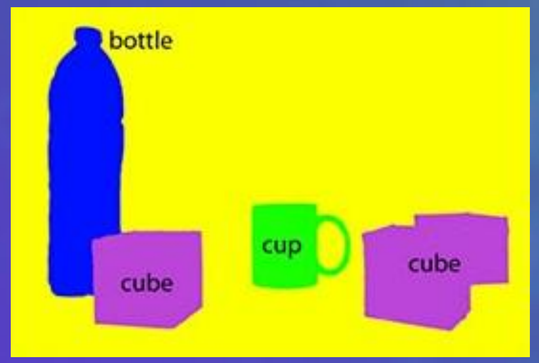


...and many others

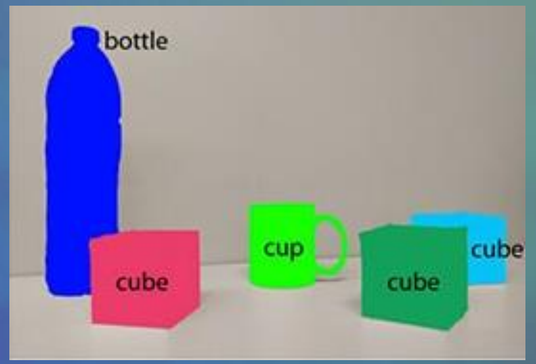
Segmentation

The two main types of Segmentation tasks are:

- **Semantic segmentation** is the task of clustering parts of an image together which belong to the same object class
- **Instance segmentation** is the task of detecting and delineating each distinct object of interest appearing in an image



Semantic segmentation

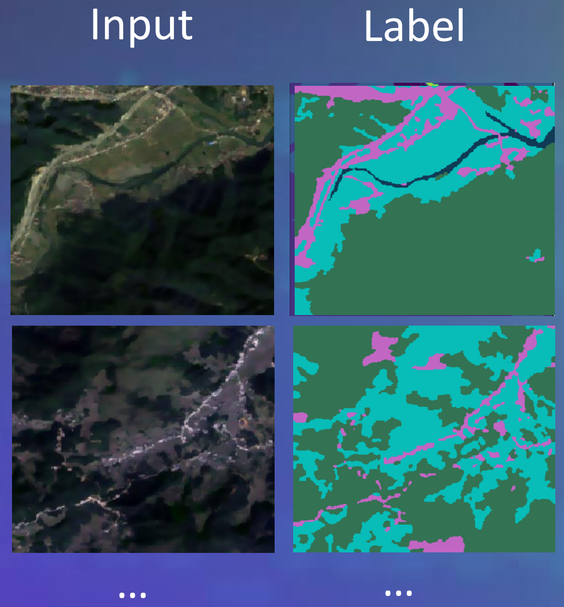


Instance segmentation

Use Case: Hunan (S2 True Color Subset)

500 Satellite images 256x256

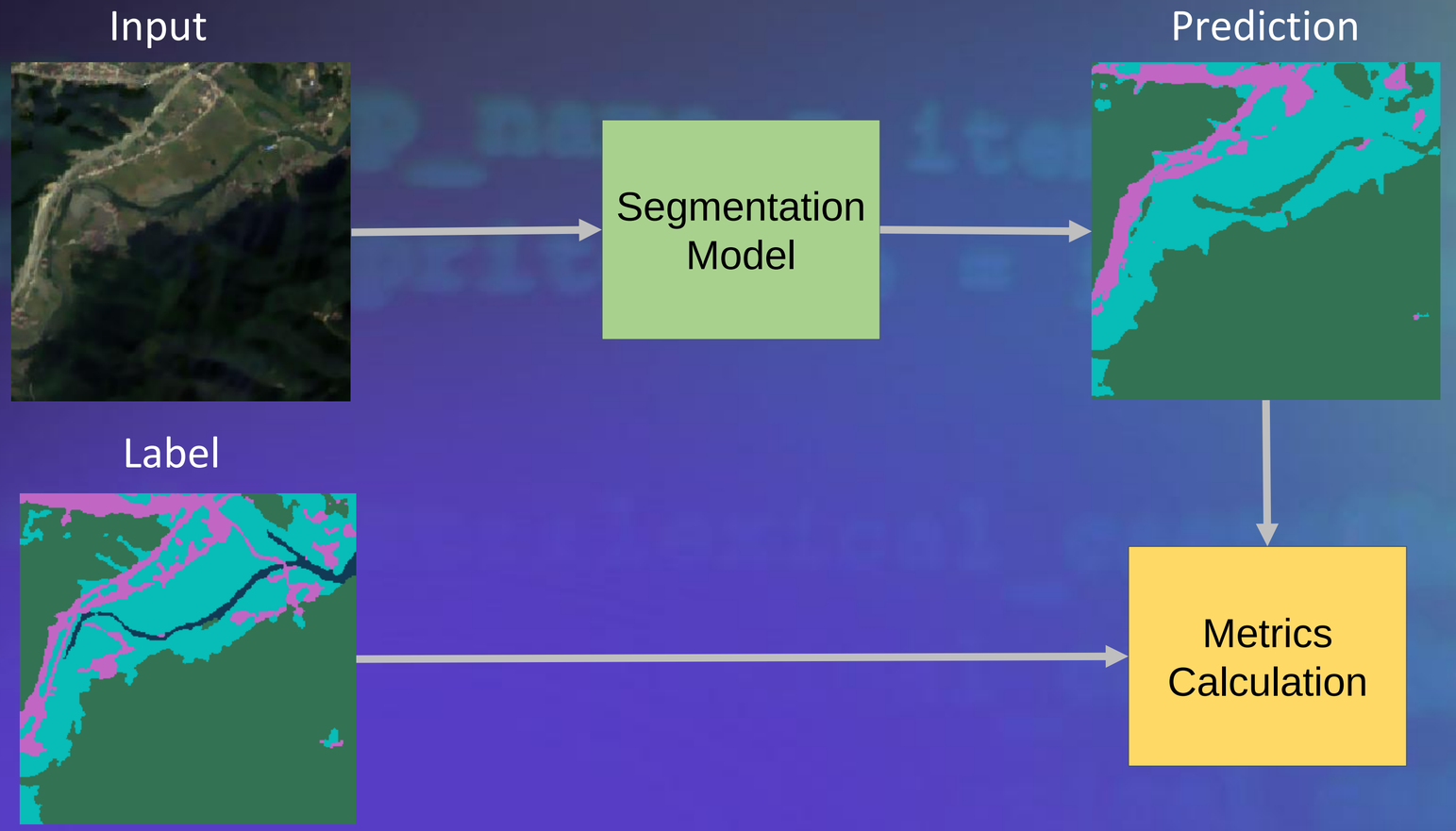
400	-	training
50	-	validation
50	-	test



0 – cropland
1 – forest
2 – grassland
3 – wetland
4 – water
5 – bare land
6 – others
255 – unclassified

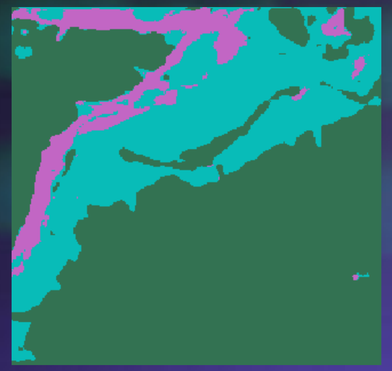
Why this dataset as an example? The size of the training/validation/test sets could be like those that you will have

Metrics

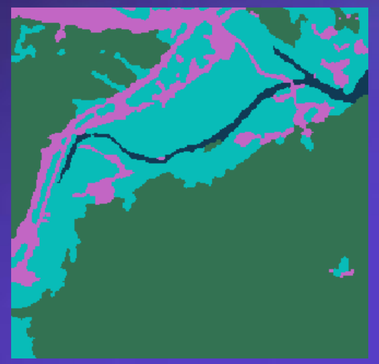

Input
Segmentation Model
Prediction
Label
Metrics Calculation
Recall
Precision
F1
...

Metrics - Recall, Precision, F1, Accuracy

Prediction



Label



Confusion Matrix

		Ground Truth		
		c1	c2	c3
Prediction	c1	8	10	1
	c2	5	60	50
	c3	3	30	83

Precision		
c1	c2	c3
8/(8+10+1)	60/(5+60+50)	83/(3+30+83)
Recall		
c1	c2	c3
8/(8+5+3)	60/(10+60+30)	83/(1+50+83)
F1 Score		
2*(Recall*Precision)/(Recall+Precision)		
Accuracy		
(8+60+83)/(8+10+1+5+60+50+3+30+83)		

Semantic Segmentation

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Unsupervised

Models that learn to segment each image (i.e. cluster the pixels into their ground truth classes) without seeing the ground truth labels

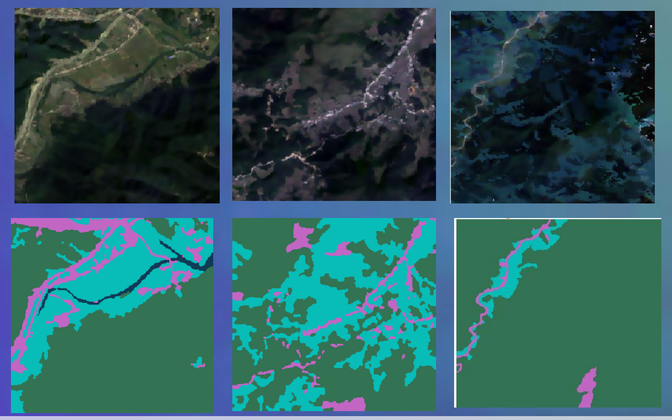
- **Labelling not required for training**
- **Generally worst accuracy with respect to supervised methods**

Training Set

Supervised

In the case of fully supervised setting, the dataset consists of images and their corresponding pixel-level class-specific annotations (expensive pixel-level annotations)

Training Set



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Semantic Segmentation

Unsupervised

- SLIC
- QuickShift
- Felsenszwalb
- …

Semantic Segmentation

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Unsupervised – Deep Learning

- **ISB:** Unsupervised Image Segmentation by Backpropagation
- **DFC:** Unsupervised Learning of Image Segmentation Based on Differentiable Feature Clustering
- **W-Net:** A Deep Model for Fully Unsupervised Image Segmentation
- …

Supervised – Deep Learning

- **U-Net**: Convolutional networks for biomedical image segmentation
- …

Libraries and Tools

- https://www.python.org/
- https://conda.io/

Python

Conda

- https://code.visualstudio.com/

Visual Studio Code

- https://www.pytorchlightning.ai/
- https://scikit-image.org/
- https://pytorch.org/
- https://github.com/qubvel/segmentation_models.pytorch

PyTorch

PyTorch Lightning

scikit-image

Segmentation Models

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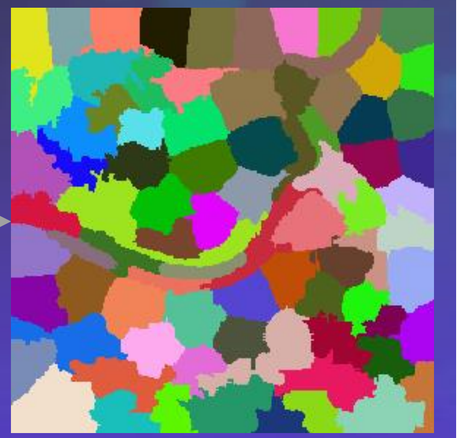
Unsupervised Segmentation
Classic methods

SLIC

Input

Output



Algorithm 1 SLIC superpixel segmentation

/ Initialization */*

Initialize cluster centers $C_k = [l_k, a_k, b_k, x_k, y_k]^T$ by sampling pixels at regular grid steps S.

Move cluster centers to the lowest gradient position in a 3×3 neighborhood.

Set label $l(i) = -1$ for each pixel i.

Set distance $d(i) = \infty$ for each pixel i.

repeat

  / Assignment */*

  for each cluster center C_k **do**

    for each pixel i in a $2S \times 2S$ region around C_k **do**

      Compute the distance D between C_k and i.

      if $D < d(i)$ **then**

        set $d(i) = D$

        set $l(i) = k$

      end if

    end for

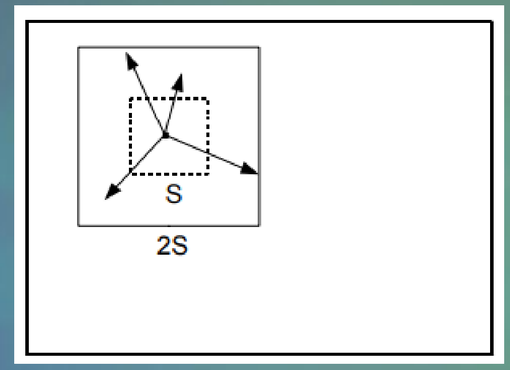
  end for

  / Update */*

  Compute new cluster centers.

  Compute residual error E.

until $E \leq$ threshold



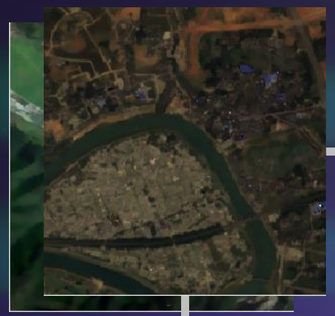
Limited search space

The distance between the new and the old cluster centers

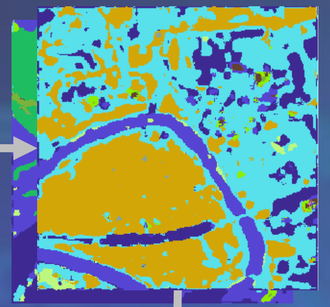
Unsupervised Segmentation
Deep Learning

ISB

Unsupervised Image Segmentation by Backpropagation



Neural Network



Network prediction

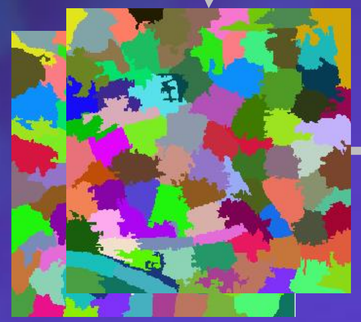
Weights Update

e.g. SLIC

Pre-Segmentation

Loss calculation

Refinement



Refinement

Algorithm 1: Unsupervised image segmentation

Input: $\mathcal{I} = \{\boldsymbol{v}_n \in \mathbb{R}^3\}_{n=1}^N$ // RGB image

Output: $\mathcal{L} = \{c_n \in \mathbb{Z}\}_{n=1}^N$ // Label image

$\{W_m, \boldsymbol{b}_m\}_{m=1}^M \leftarrow$ Init() // Initialize

$\{W_c, \boldsymbol{b}_c\} \leftarrow$ Init() // Initialize

$\{\mathcal{S}_k\}_{k=1}^K \leftarrow$ GetSuperPixels($\{\boldsymbol{v}_n\}_{n=1}^N$)

for $t = 1$ **to** T **do**

- $\{\boldsymbol{x}_n\}_{n=1}^N \leftarrow$ GetFeats($\{\boldsymbol{v}_n\}_{n=1}^N, \{W_m, \boldsymbol{b}_m\}_{m=1}^M$)
- $\{\boldsymbol{y}_n\}_{n=1}^N \leftarrow \{W_c \boldsymbol{x}_n + \boldsymbol{b}_c\}_{n=1}^N$
- $\{\boldsymbol{y}'_n\}_{n=1}^N \leftarrow$ Norm($\{\boldsymbol{y}_n\}_{n=1}^N$) // Batch norm.
- $\{c_n\}_{n=1}^N \leftarrow \{\arg\max \boldsymbol{y}'_n\}_{n=1}^N$ // Assign labels

for $k = 1$ **to** K **do**

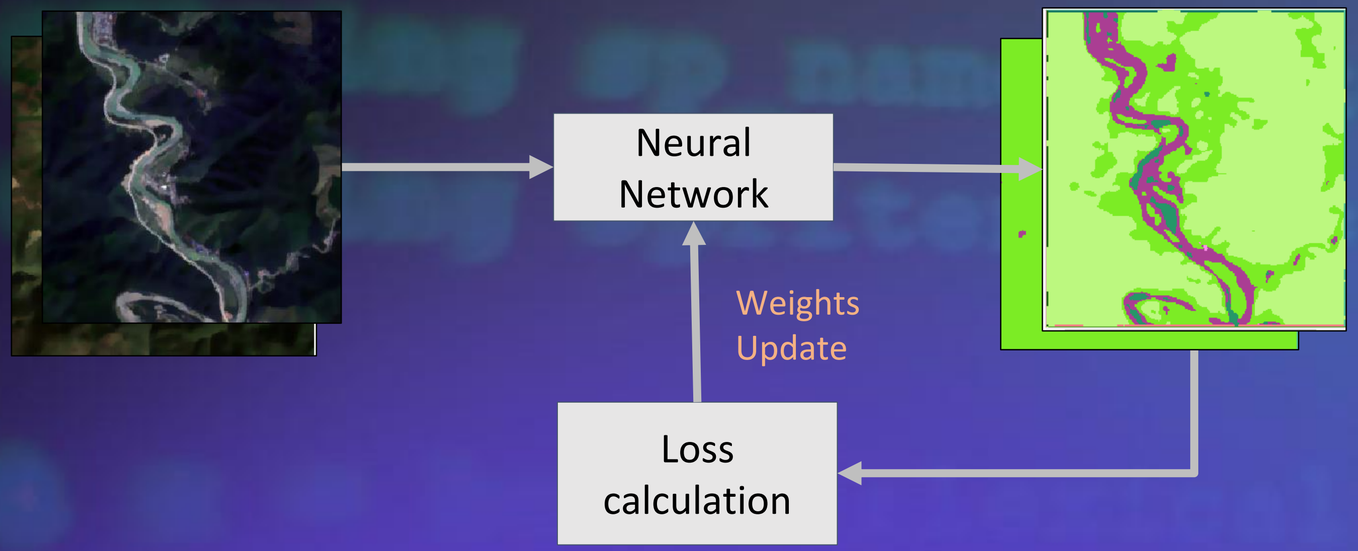
- $c_{\max} \leftarrow \arg\max |c_n|_{n \in \mathcal{S}_k}$
- $c'_n \leftarrow c_{\max}$ **for** $n \in \mathcal{S}_k$

$\mathcal{L} \leftarrow$ SoftmaxLoss($\{\boldsymbol{y}'_n, c'_n\}_{n=1}^N$)

$\{W_m, \boldsymbol{b}_m\}_{m=1}^M, \{W_c, \boldsymbol{b}_c\} \leftarrow$ Update($\mathcal{L}$)

DFC

Unsupervised Learning of Image Segmentation Based on Differentiable Feature Clustering



- Spatial continuity
- Feature similarity

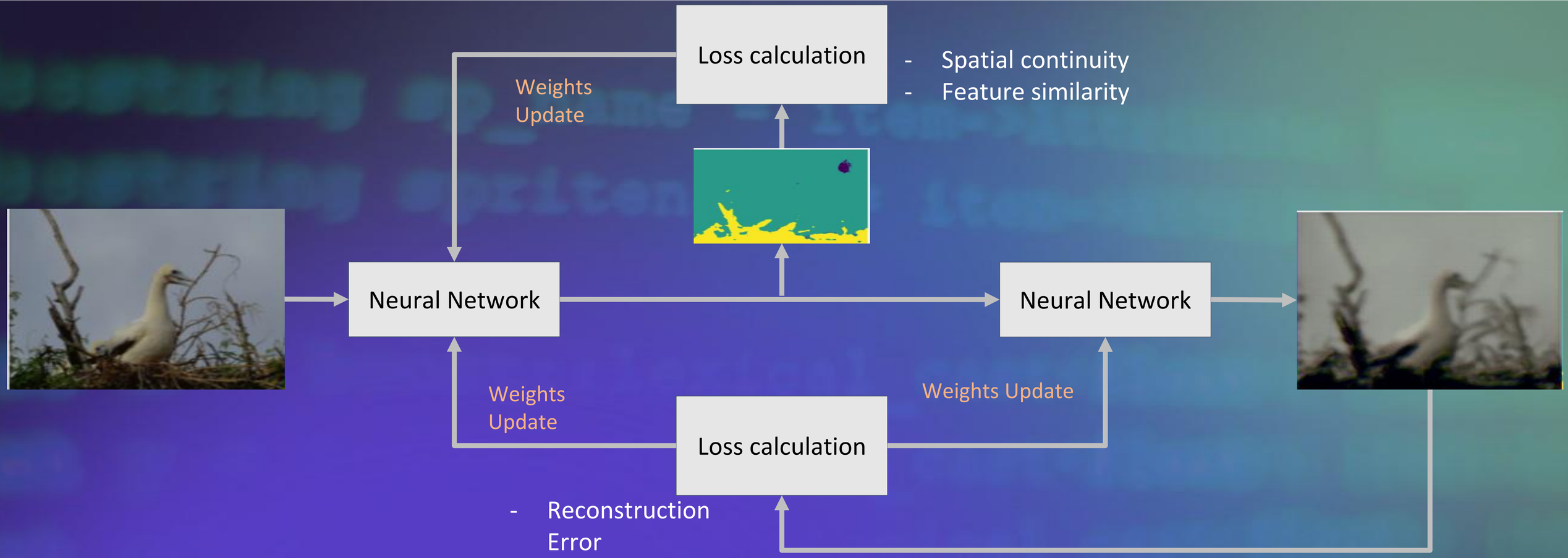
Network prediction

Algorithm 1: Unsupervised image segmentation

Input: $\mathcal{I} = \{\boldsymbol{v}_n \in \mathbb{R}^3\}$ // RGB image
μ // weight for L_{con}
Output: $\mathcal{L} = \{c_n \in \mathbb{Z}\}$ // Label image
$\{W_m, \boldsymbol{b}_m\}_{m=1}^{M} \leftarrow$ Init() // Initialize
$W_c \leftarrow$ Init() // Initialize
for $t = 1$ **to** T **do**
  $\{\boldsymbol{x}_n\} \leftarrow$ GetFeats($\{\boldsymbol{v}_n\}, \{W_m, \boldsymbol{b}_m\}_{m=1}^{M}$)
  $\{\boldsymbol{r}_n\} \leftarrow \{ W_c \boldsymbol{x}_n \}$
  $\{\boldsymbol{r}'_n\} \leftarrow$ Norm($\{\boldsymbol{r}_n\}$) // Batch norm.
  $\{c_n\} \leftarrow \{ \arg\max_i r'_{n,i} \}$ // Assign labels
  $L \leftarrow L_{\text{sim}}(\{\boldsymbol{r}'_n, c_n\}) + \mu L_{\text{con}}(\{\boldsymbol{r}'_n\})$
  $\{W_m, \boldsymbol{b}_m\}_{m=1}^{M}, W_c \leftarrow$ Update(L)

W-Net

A Deep Model for Fully Unsupervised Image Segmentation

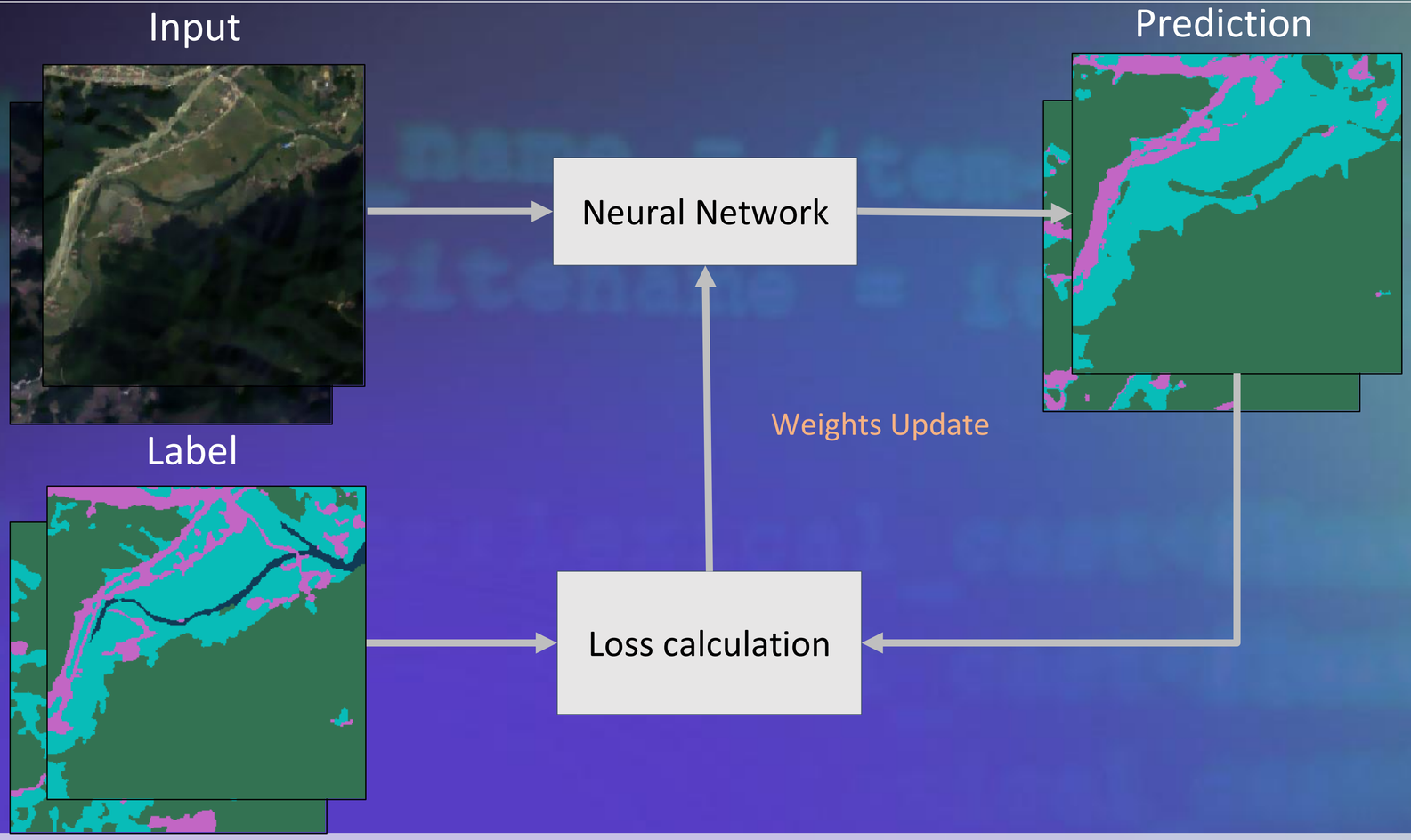


Rand Index

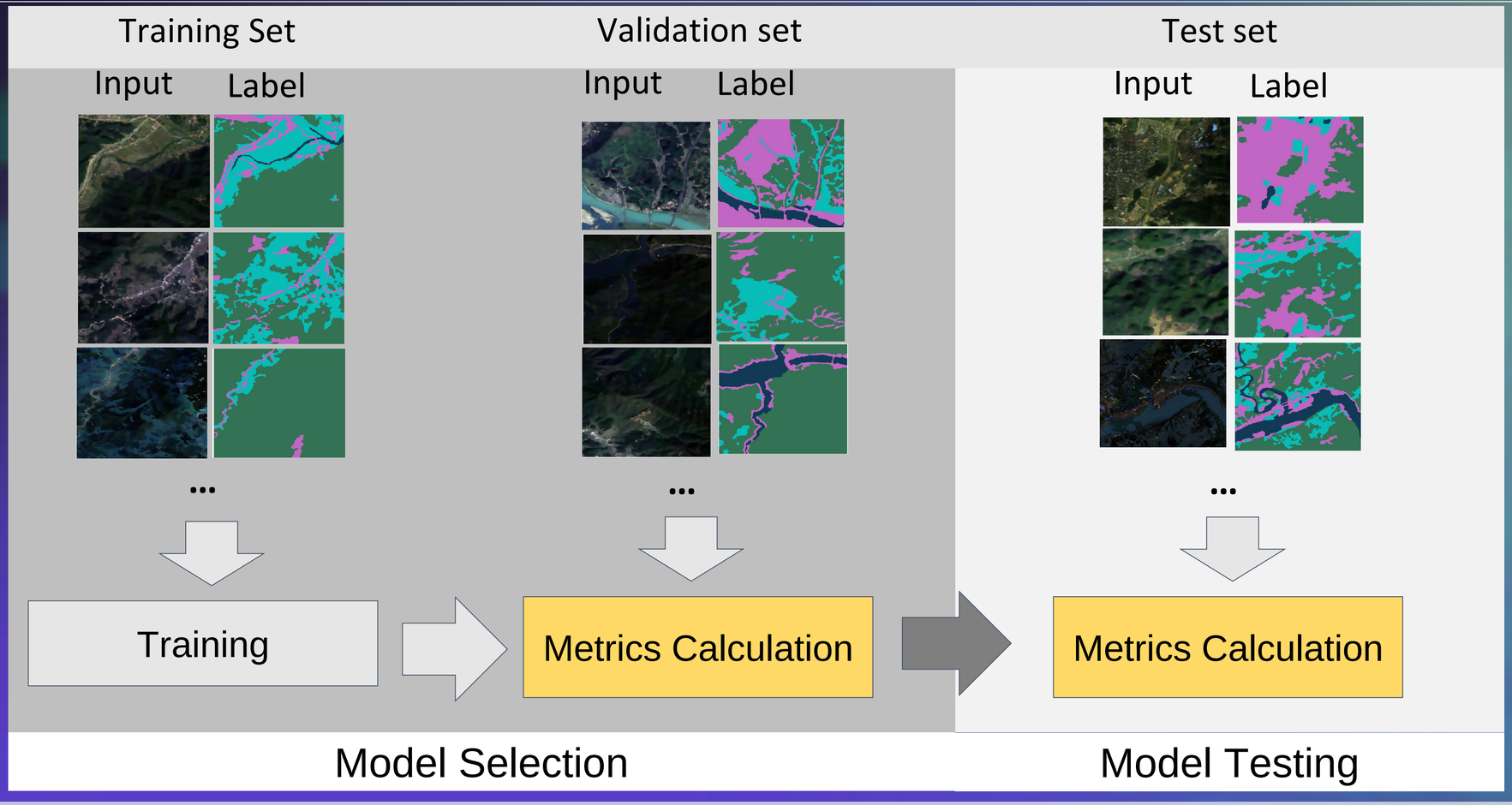
$$Rand\ Index = \frac{Correct\ pairs\ same\ clusters + Correct\ pairs\ different\ clusters}{Total\ number\ of\ pairs}$$

Supervised Segmentation
Deep Learning

Supervised Segmentation



Semantic Segmentation - Supervised



Example

Setup Environment

Implementation of ISB, DFC and W-Net

- https://github.com/fedric95/Unsupervised-Segmentation

ISB, DFC, W-Net applied to the Hunan Dataset and the creation of a Supervised baseline

- https://github.com/fedric95/Hunan-Baseline

Recap

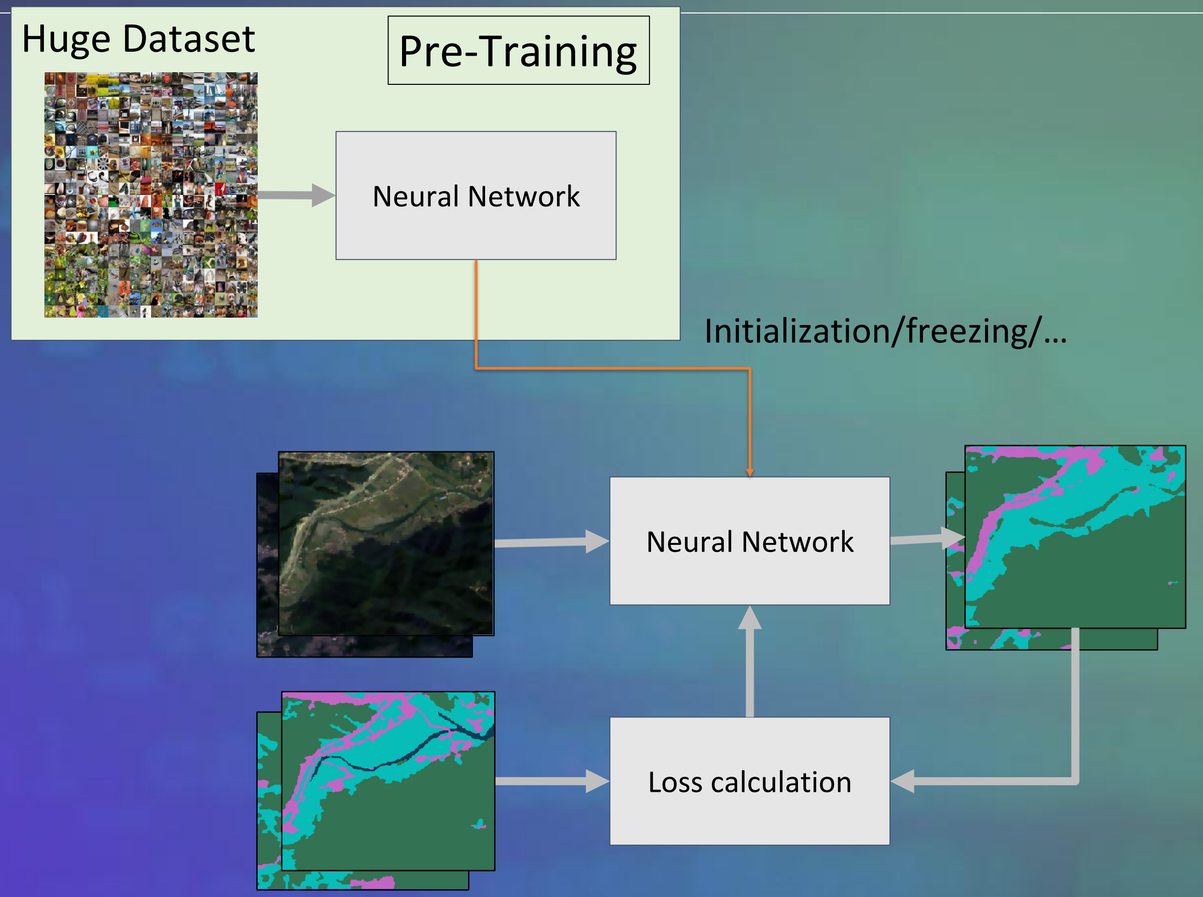
- Unsupervised Image Segmentation by Backpropagation
- Unsupervised Learning of Image Segmentation Based on Differentiable Feature Clustering
- W-Net: A Deep Model for Fully Unsupervised Image Segmentation

- U-Net: Convolutional Networks for Biomedical Image Segmentation

- QuickShift
- SLIC

More Advanced Concepts

- SOTA results on benchmark datasets (ADE20K, CityScapes, Pascal VOC, COCO-Stuff, iSAID, …) are generally obtained finetuning pre-trained models
- Particularly important if the number of samples in the training set is small
- Pretraining and target domain can be “quite” different
- It doesn't always work



Other topics

- **Ensemble of models**
- **Data augmentation**
- **Self-Supervised**
- **…**

Problem: mapping between a cluster result and a set of classes:
https://sparse-plex.readthedocs.io/en/latest/book/clustering/comparing_clusterings.html#label-mapping-using-hungarian-method

References

[1] Asako Kanezaki. “**Unsupervised Image Segmentation by Backpropagation”**. IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), 2018.

[2] Wonjik Kim*, Asako Kanezaki*, and Masayuki Tanaka. “**Unsupervised Learning of Image Segmentation Based on Differentiable Feature Clustering”**. IEEE Transactions on Image Processing, *W. Kim and A. Kanezaki contributed equally to this work, 2020

[3] Xia, Xide, and Brian Kulis. "**W-Net: A Deep Model for Fully Unsupervised Image Segmentation.**" arXiv preprint arXiv:1711.08506, 2017.

[4] Ronneberger, Olaf, Philipp Fischer, and Thomas Brox. "**U-Net: Convolutional Networks for Biomedical Image Segmentation**." International Conference on Medical image computing and computer-assisted intervention. Springer, Cham, 2015.

References

[5] Li, Yansheng, Yuhan Zhou, Yongjun Zhang, Liheng Zhong, Jian Wang, and Jingdong Chen. "**DKDFN: Domain Knowledge-Guided deep collaborative fusion network for multimodal unitemporal remote sensing land cover classification.**" ISPRS Journal of Photogrammetry and Remote Sensing 186, 2022: 170-189

[6] Achanta, Radhakrishna, Appu Shaji, Kevin Smith, Aurelien Lucchi, Pascal Fua, and Sabine Süsstrunk. "**SLIC Superpixels Compared to State-of-the-Art Superpixel Methods.**" *IEEE transactions on pattern analysis and machine intelligence* 34, no. 11 (2012): 2274-2282.

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Q&A

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