

Deep Learning-based Point Cloud Classification on Multiple Airborne LiDAR Datasets

Yuxing Xie (yuxing.xie@dlr.de)

PhD Student

The Remote Sensing Technology Institute (IMF)
German Aerospace Center (DLR)

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Wissen für Morgen



Guideline

- Introduction
- Public ALS Datasets
- How to Use Multiple Datasets
- The First Experiment
- Conclusion & Open Questions

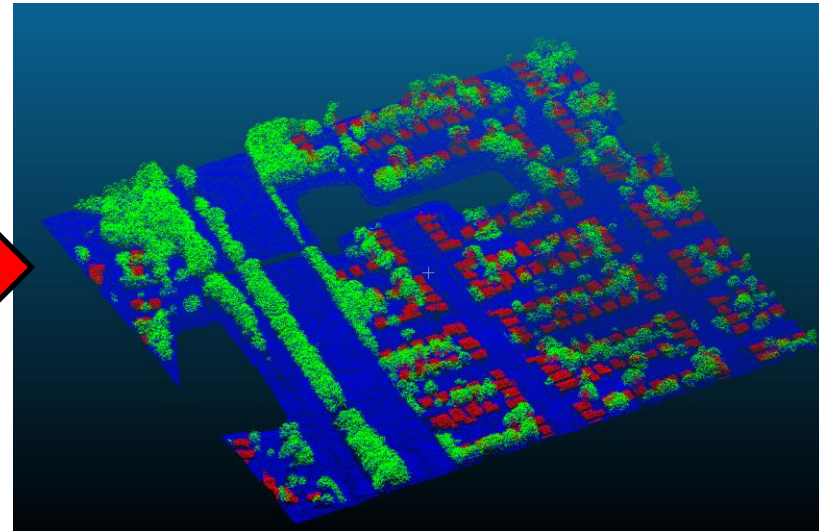
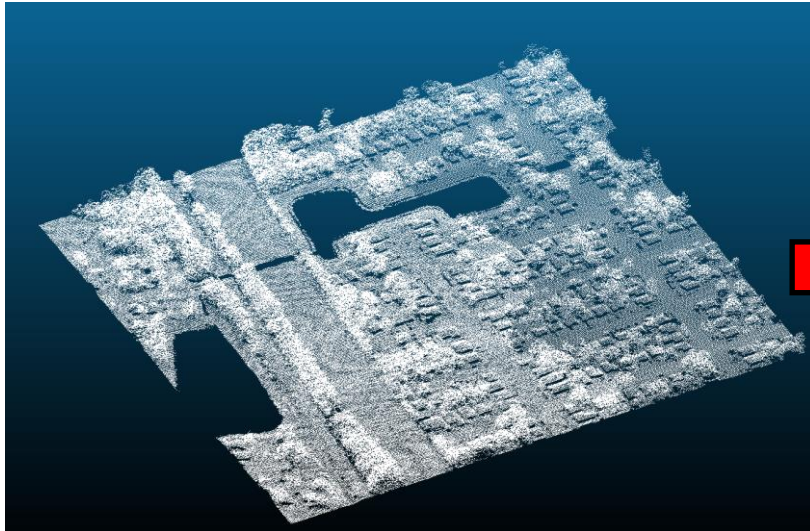


Introduction



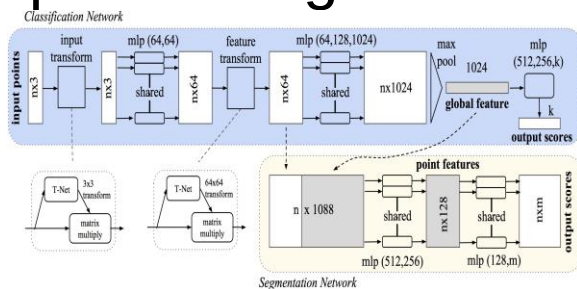
Introduction

- The task of **point cloud classification (semantic segmentation)** is to associate each point with a semantic label.

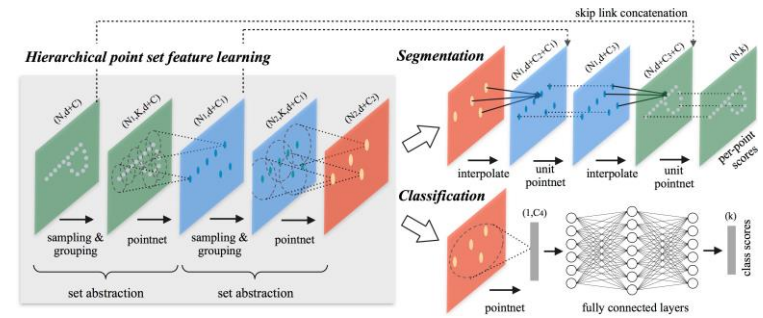


Introduction

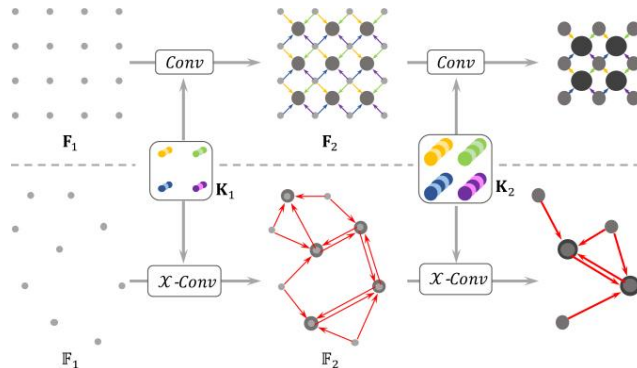
- Deep learning brings new possibilities in point cloud processing.



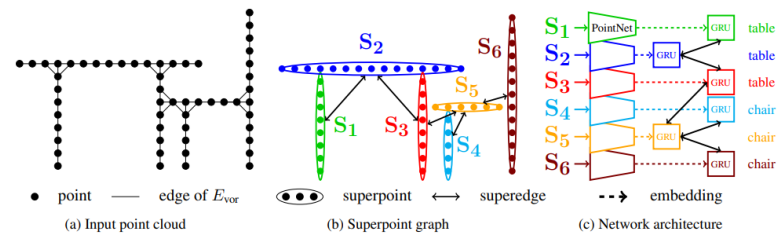
PointNet



PointNet++



PointCNN



SuperPoint Graph



Introduction

- Deep learning brings new possibilities in point cloud processing.

Qi, C. R., Su, H., Mo, K., & Guibas, L. J. (2017). *Pointnet: Deep learning on point sets for 3d classification and segmentation*. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition* (pp. 652-660).

Qi, C. R., Yi, L., Su, H., & Guibas, L. J. (2017). *Pointnet++: Deep hierarchical feature learning on point sets in a metric space*. In *Advances in neural information processing systems* (pp. 5099-5108).

Li, Y., Bu, R., Sun, M., Wu, W., Di, X., & Chen, B. (2018). *Pointcnn: Convolution on x-transformed points*. In *Advances in Neural Information Processing Systems* (pp. 820-830).

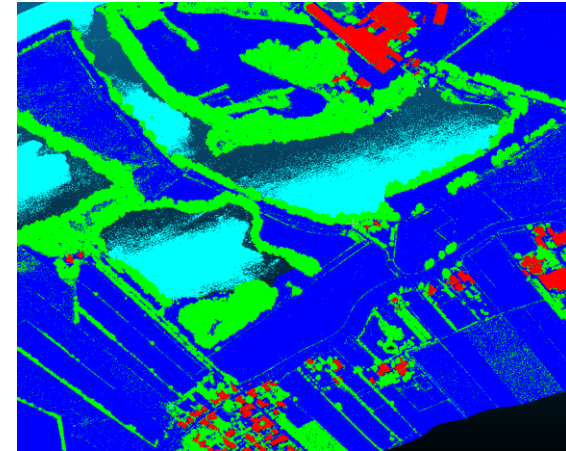
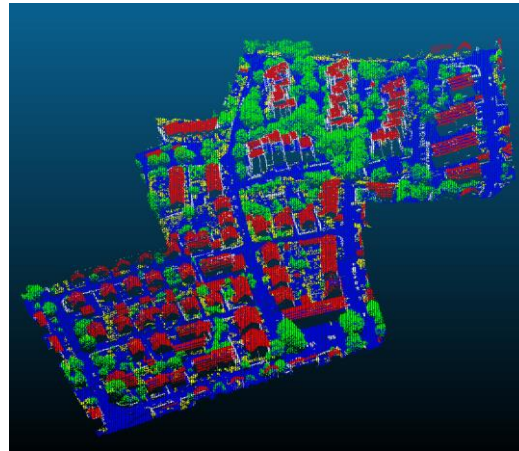
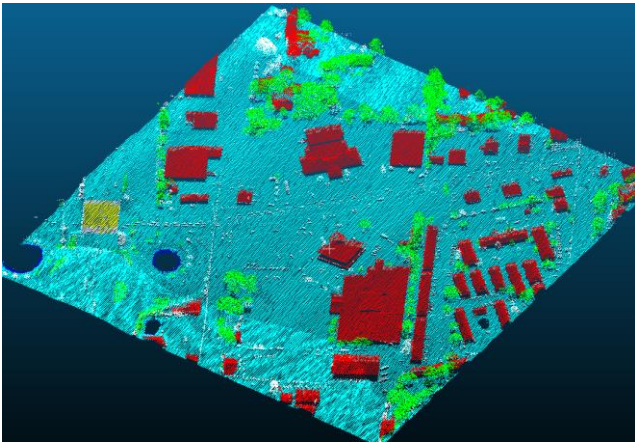
Landrieu, L., & Simonovsky, M. (2018). *Large-scale point cloud semantic segmentation with superpoint graphs*. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition* (pp. 4558-4567).

Xie, Y., Tian, J., & Zhu, X. X. (2020). A **Review** of Point Cloud Semantic Segmentation. *IEEE Geoscience and Remote Sensing Magazine*(In Press)



Introduction

- More public point cloud datasets than ever provide available research materials to test “data-hungry” algorithms.



Public ALS Datasets



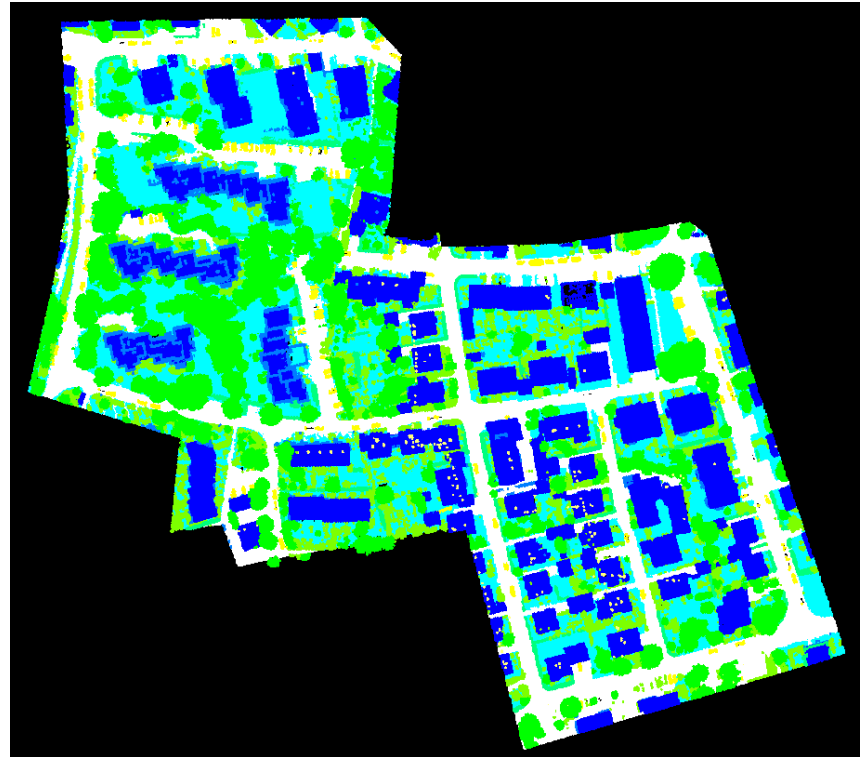
Public ALS Datasets

- ISPRS Vaihingen Dataset
- Data Fusion Contest 2018 (DFC2018)
- Data Fusion Contest 2019 (DFC2019)
- Actueel Hoogtebestand Nederland 3 (AHN3)



Datasets *ISPRS Vaihingen*

- Only 1.1 million points in total:
 - ✓ Ca. 700, 000 as the training data
 - ✓ Ca. 400, 000 as the test data
- **9 classes**: powerline, low vegetation, impervious surfaces, car, fence/hedge, roof, façade, shrub and tree.
- Density: ca. 6 points / m²

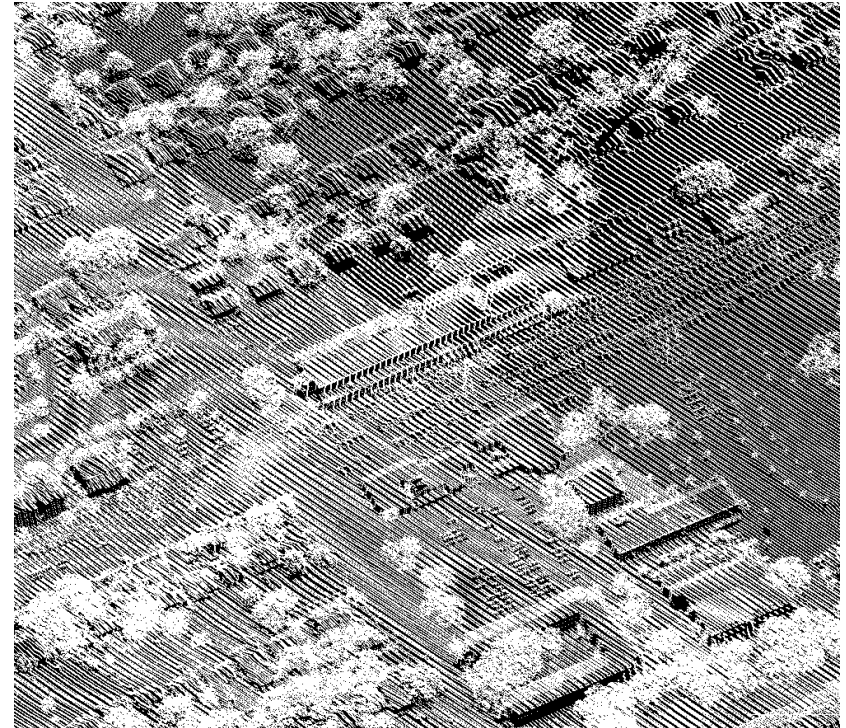


<http://www2.isprs.org/commissions/comm3/wg4/3d-semantic-labeling.html>



Datasets *DFC2018*

- **Multispectral** LiDAR point clouds (1550 nm, 1064 nm, and 532 nm)
- **20** urban land use and land cover classes
- However, no **direct** point-wise semantic labels

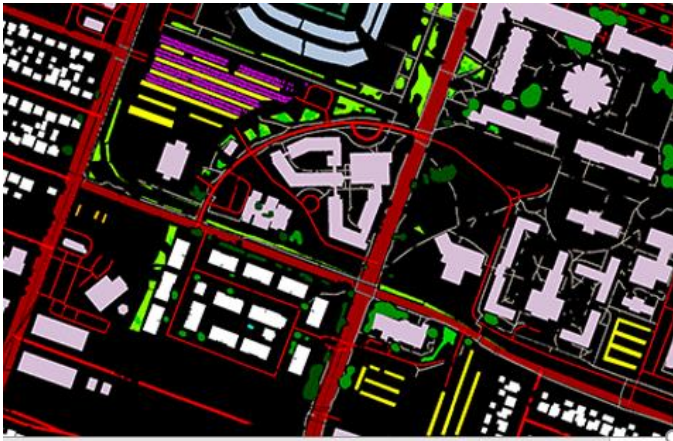


<http://www.grss-ieee.org/community/technical-committees/data-fusion/2018-ieee-grss-data-fusion-contest/>

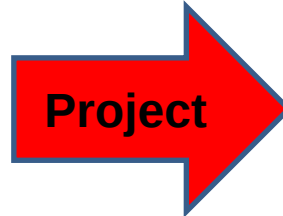


Datasets *DFC2018*

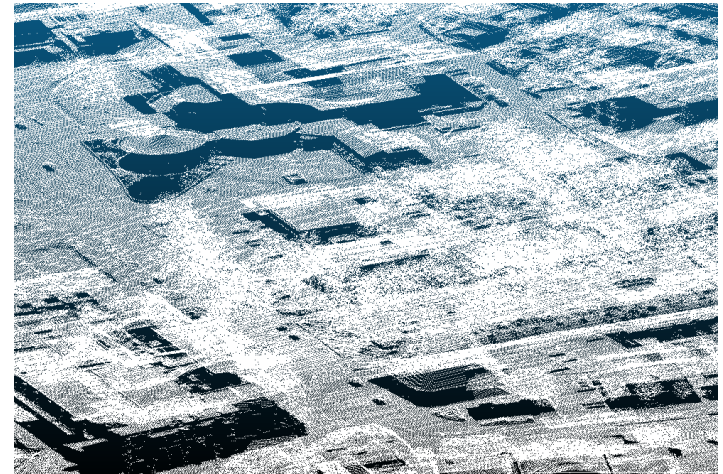
- A solution to create point-wise labels:



2D Ground Truth

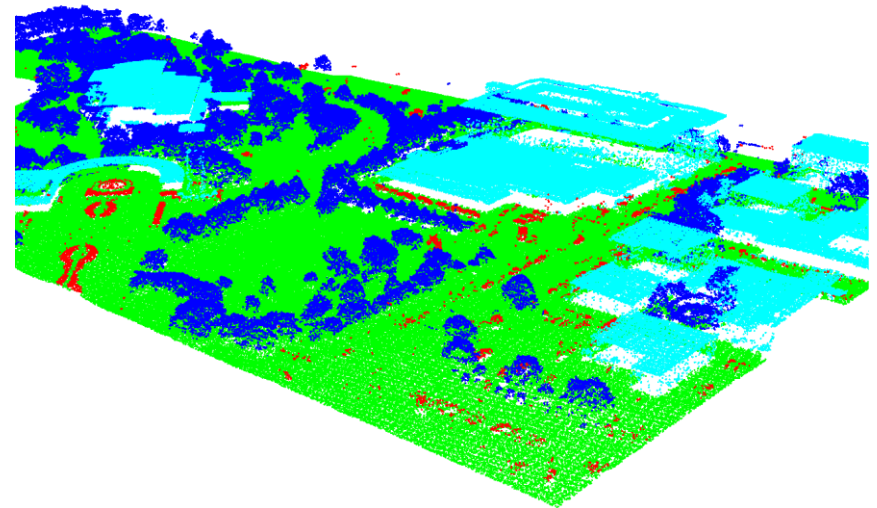


Point Clouds



Datasets *DFC2019*

- Tens of millions of points
- Captured in two American cities, Jacksonville and Omaha
- **5 classes**: ground, building, tree, water and bridge
- Density: 3-6 points / m²



<http://www.grss-ieee.org/community/technical-committees/data-fusion/2019-ieee-grss-data-fusion-contest-data/>



Datasets *AHN3*

- A very large ALS LiDAR point cloud project, covering almost the entire Netherlands
- **5 classes**: ground, building, water, artwork (including bridges and other man-made structures) and “others” (mostly vegetation)
- Density: 10-20 points / m²



<https://www.pdok.nl/nl/ahn3-downloads>



Limitations of Above Datasets

- ISPRS Vaihingen:
Limited amount of points over a small region
- DFC2018:
No direct point-wise labels
- DFC2019:
Only 5 classes in total
- AHN3:
Only 5 classes labeled roughly

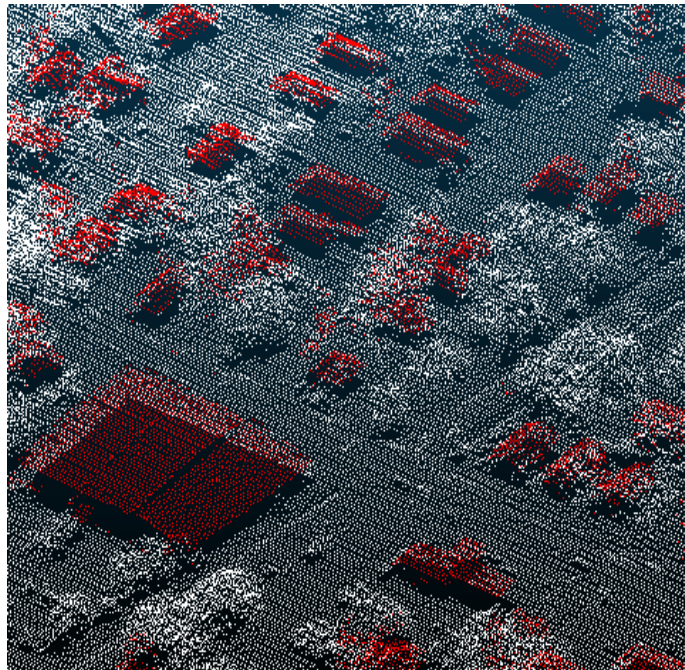


How to Use Multiple Datasets



How to Use Multiple Datasets

Relationship 1: a_i in $A = b_j$ in B



“Buildings” in DFC2019 Dataset

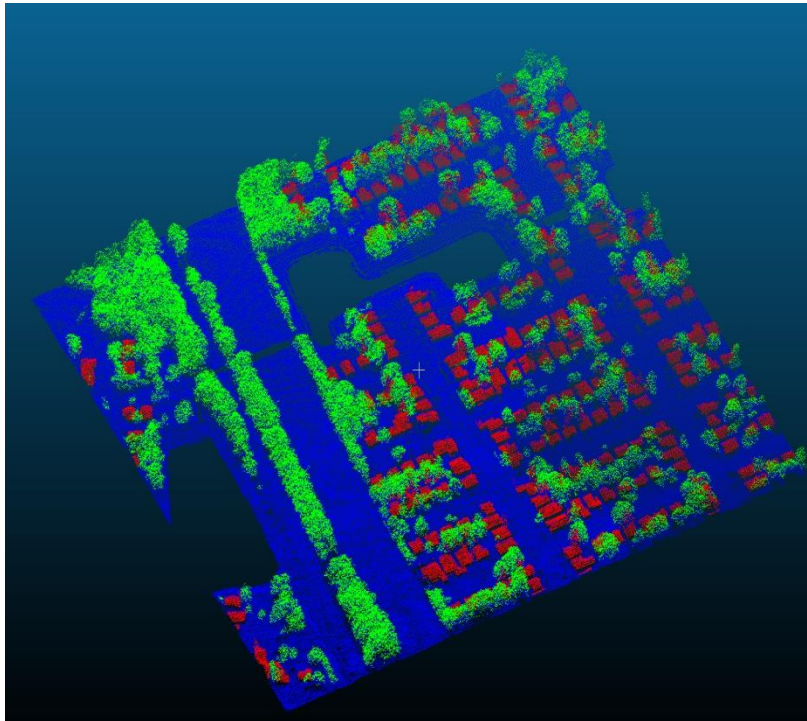


“Buildings” in AHN3 Dataset

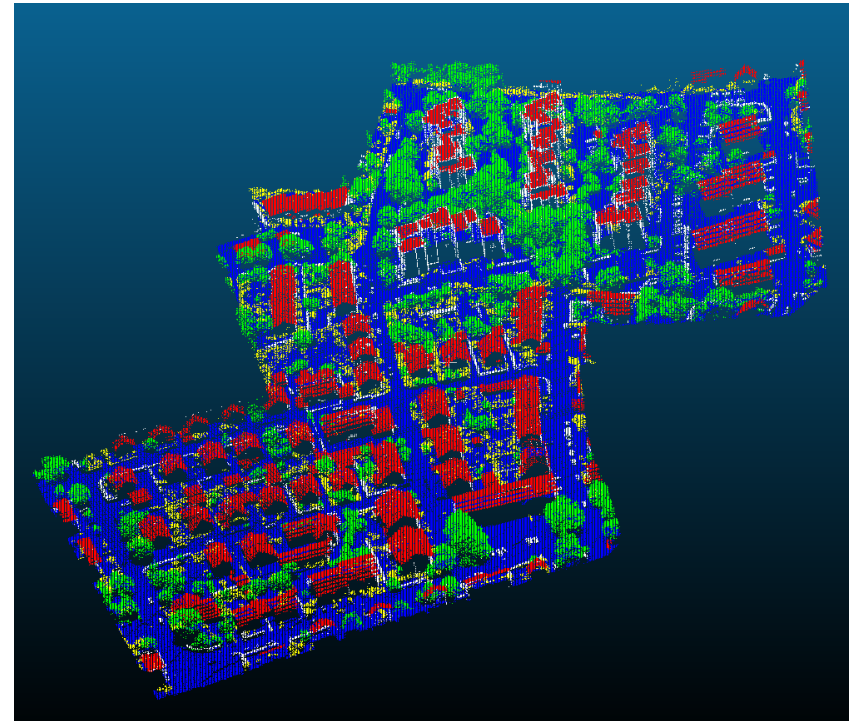


How to Use Multiple Datasets

Relationship 1: a_i in $A = b_j$ in B



“Ground” (blue) in *DFC2019 Dataset*

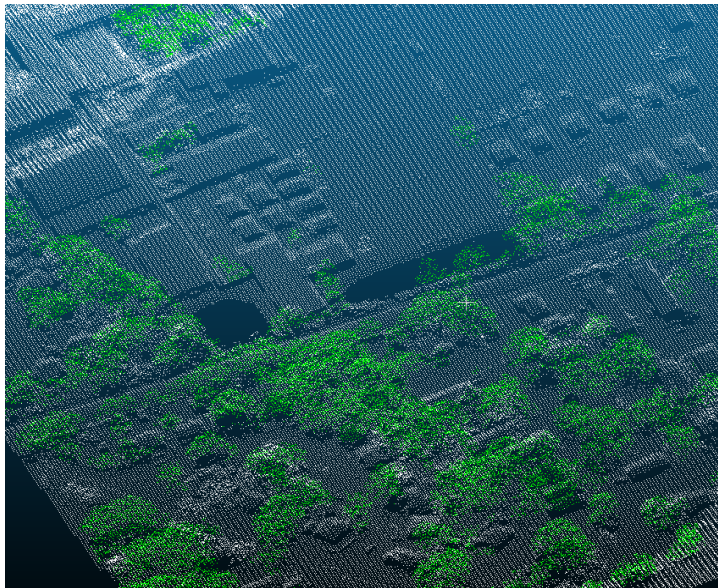


“Impervious Surfaces” (blue) in
ISPRS Vaihingen Dataset

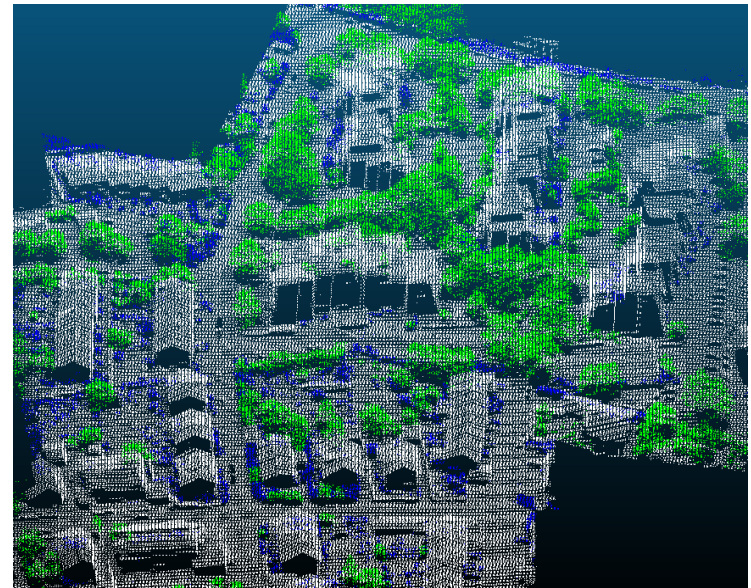


How to Use Multiple Datasets

Relationship 2: a_i in $A = (b_1 + b_2 + \dots + b_n)$ in B



“Trees” in DFC2019 Dataset



“Shrubs” (blue) and “Trees” (green) in ISPRS Vaihingen Dataset



The First Experiment



Data Preparation

- Data selection:
 - ✓ Training data: *ISPRS Vaihingen (training set)*
 - ✓ Validation data: *ISPRS Vaihingen (test set)*
 - ✓ Test data: 11 files from DFC2019 dataset



Data Preparation

- Modify original data:

- ✓ Delete unnecessary classes
- ✓ Renumber labels

0 Powerline

1 Low vegetation

2 **Impervious surfaces**

3 Car

4 Fence/Hedge

5 **Roof**

6 **Façade**

7 **Shrub**

8 **Tree**



1 Ground (**Impervious surfaces**)

2 Tree

3 Building (**Roof** + **Façade**)

4 Shrub

ISPRS Vaihingen Ground Truth Re-labeling



Data Preparation

- Modify original data:
 - ✓ Delete unnecessary classes
 - ✓ Renumber labels

0 Unlabeled

2 Ground

5 Tree

6 Building

9 Water

17 Bridge



1 Ground

2 Tree

3 Building

DFC2019 Ground Truth Re-labeling



Data Preparation

- Modify original data:
 - ✓ Delete unnecessary classes
 - ✓ Renumber labels

Training & Validation (ISPRS Vaihingen):

- 1 Ground
- 2 Tree
- 3 Building
- 4 Shrub

Test (DFC2019):

- 1 Ground
- 2 Tree
- 3 Building



Data Preparation

- Re-organize the data structure of points:

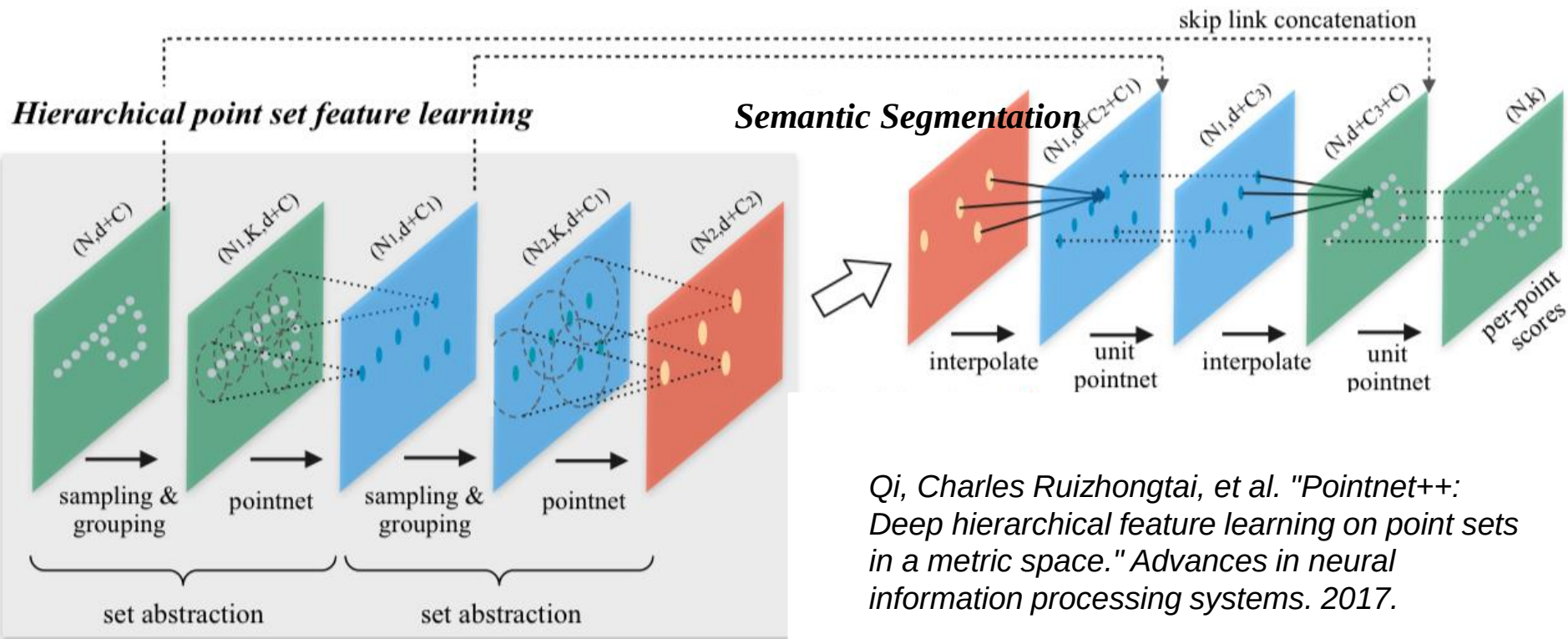
$\{x, y, z, i, \text{number of returns, return number...}\}$



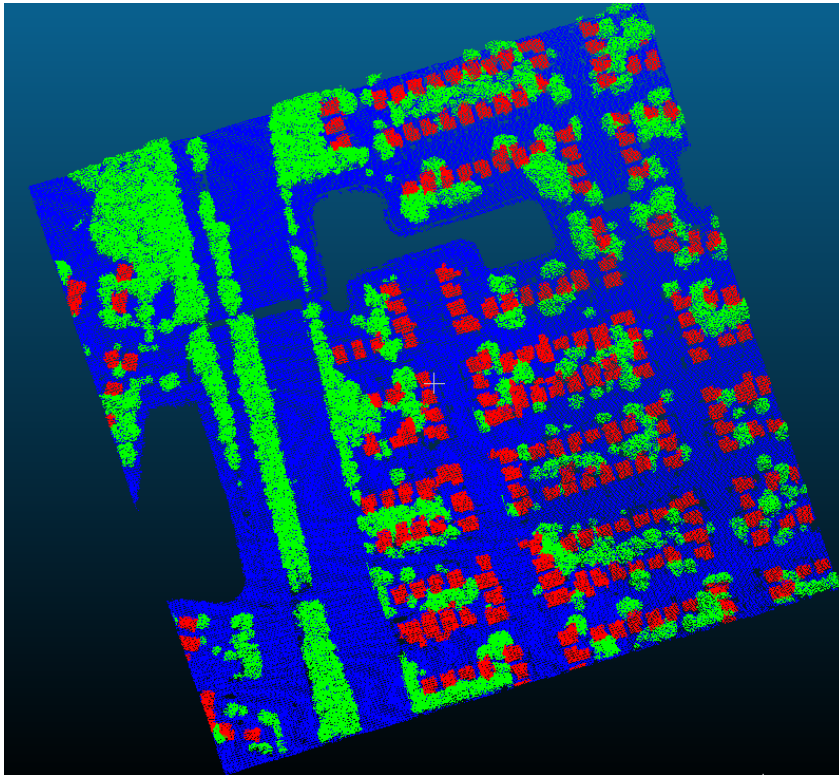
$\{x, \quad y, \quad z\}$



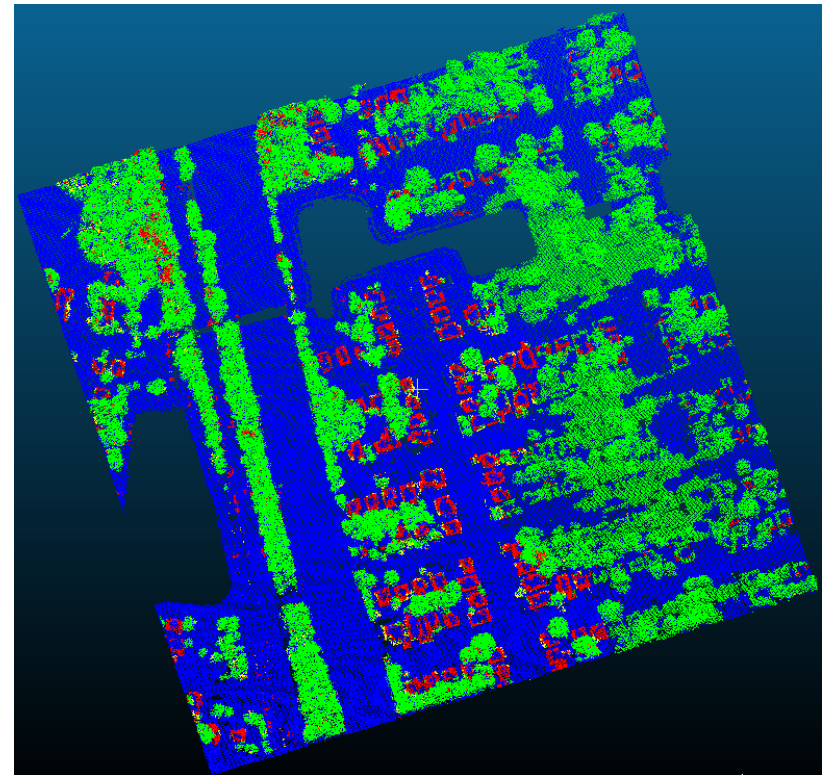
Methodology (PointNet++)



Results



Ground Truth



Prediction Results

Results

GT \ PR	Ground	Tree	Building	Shrub
Ground	3310099	132924	33527	8718
Tree	186347	1569767	65750	72057
Building	402201	234932	171117	38627
Shrub	?	?	?	?

Confusion Matrix



Results

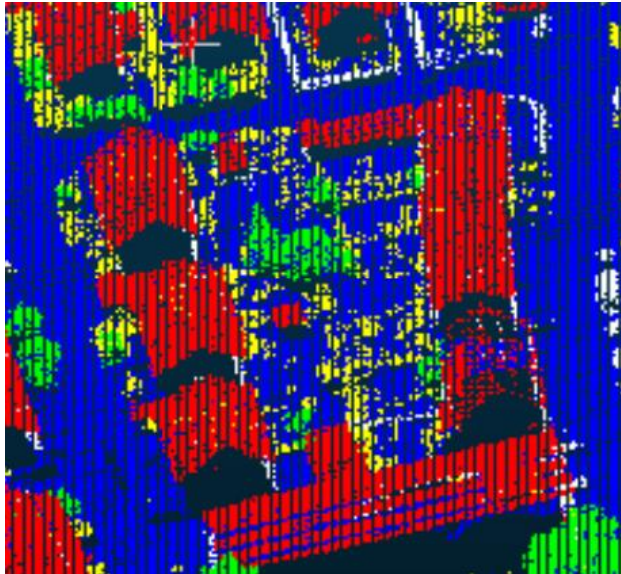
Overall Accuracy	IoU_Ground	IoU_Tree	IoU_Building
81.12%	81.25%	69.40%	18.09%

Accuracy and IoUs

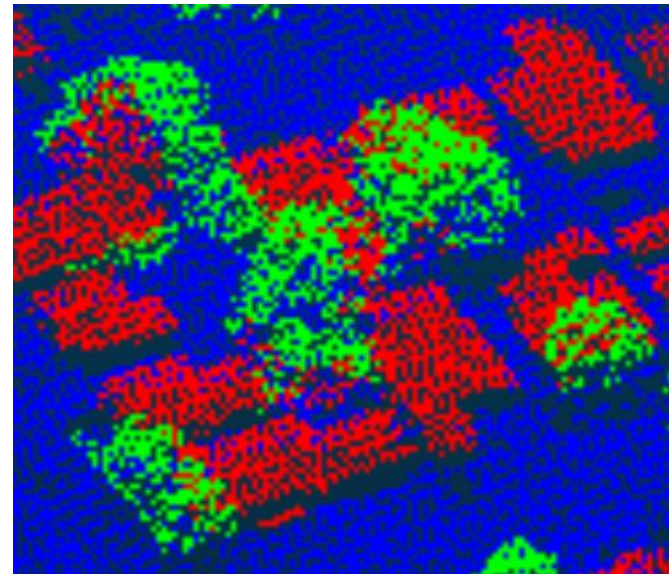


Discussion

- Roof type difference
- Different land cover distribution



Training Data (ISPRS Vaihingen)

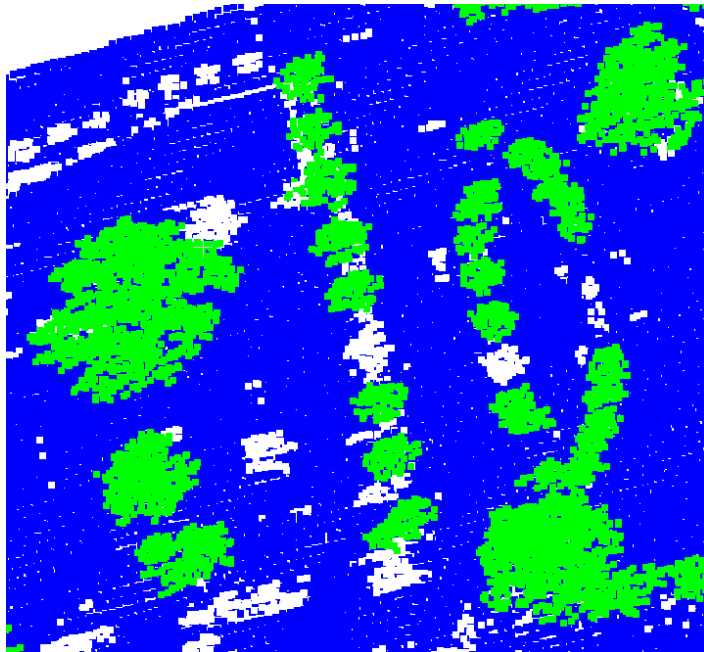


Test Data (DFC2019)

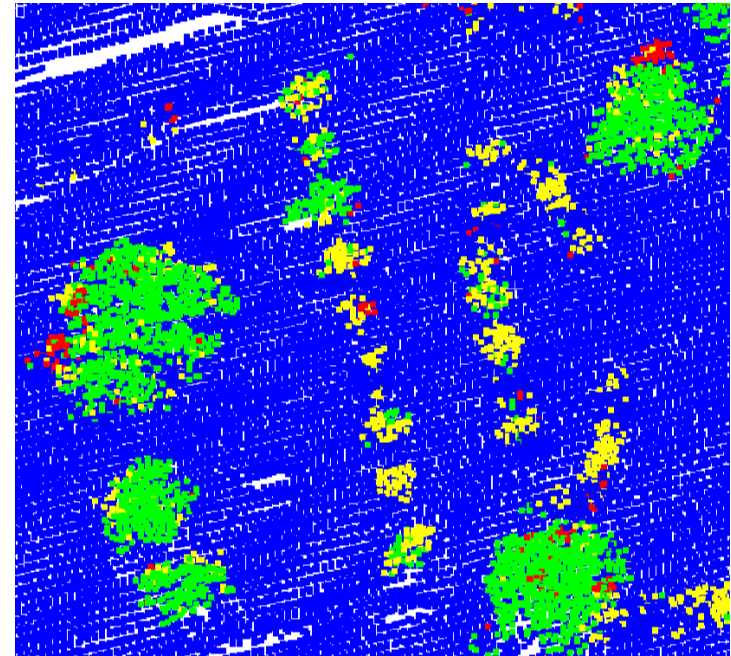


Discussion

- The subclass shrub can be recognized.
- A possible way to improve re-annotating efficiency



Trees (green) in the Ground Truth



Trees (green) and Shrubs (yellow) in Prediction Results

Conclusion & Open Questions



Conclusion

- A very initial work
- An idea to use multiple public datasets
- An example to test its feasibility



Q & A



Open Questions

- How many classes do we actually need?
- The difference between TLS (**small-area dense** point clouds) and ALS (**large-area sparse** point clouds) data when processed by deep learning techniques
- Are there other ways to utilize multisource semantic point clouds?

