

Universität Stuttgart



Deriving Semantics from Textured Meshes

2nd International Workshop on Point Cloud Processing
Stuttgart, December 04-05, 2019

Dominik Laupheimer



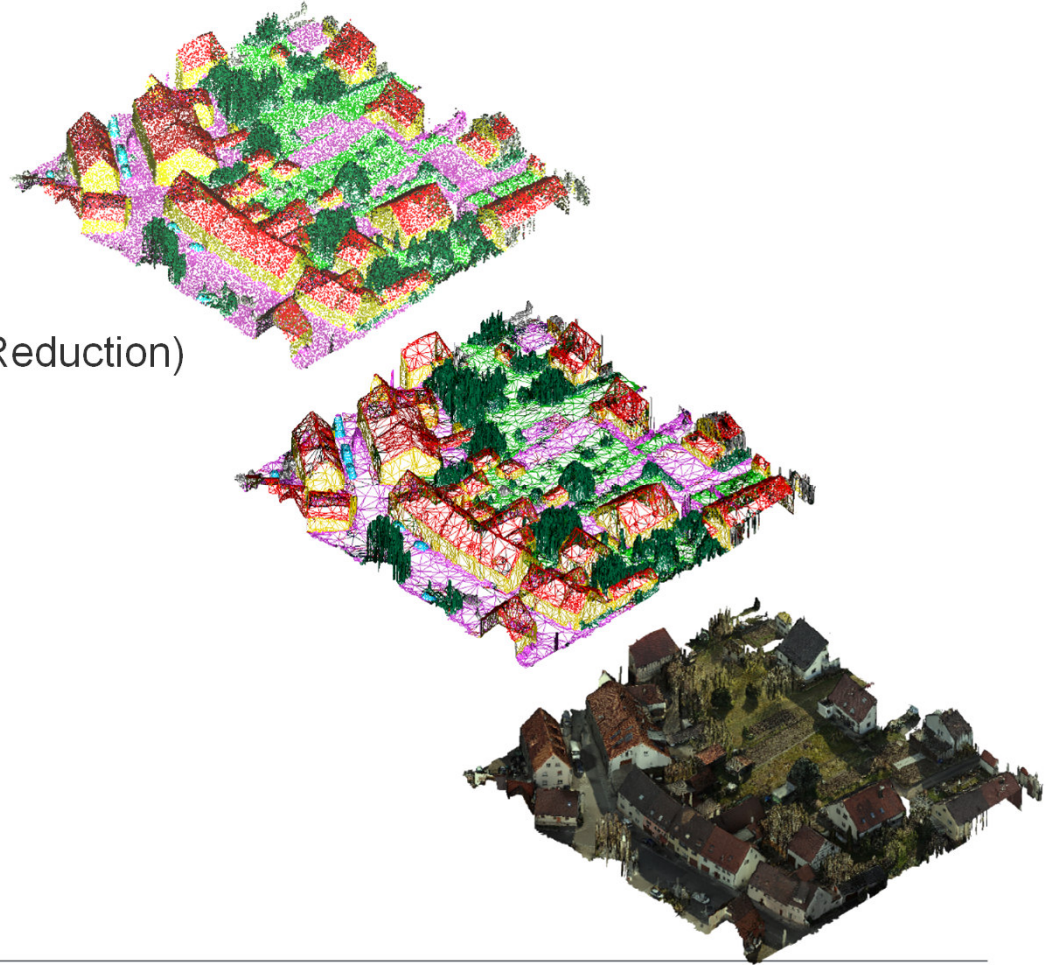
Textured Meshes



A mesh is a wired point cloud.

Motivation: Why Meshes?

- Reduced Memory Consumption
- Good Compression Behavior (Noise Reduction)
- Waterproof Surface Representation
 - Explicit Topology
 - Texture
- Unambiguous Normal Calculation



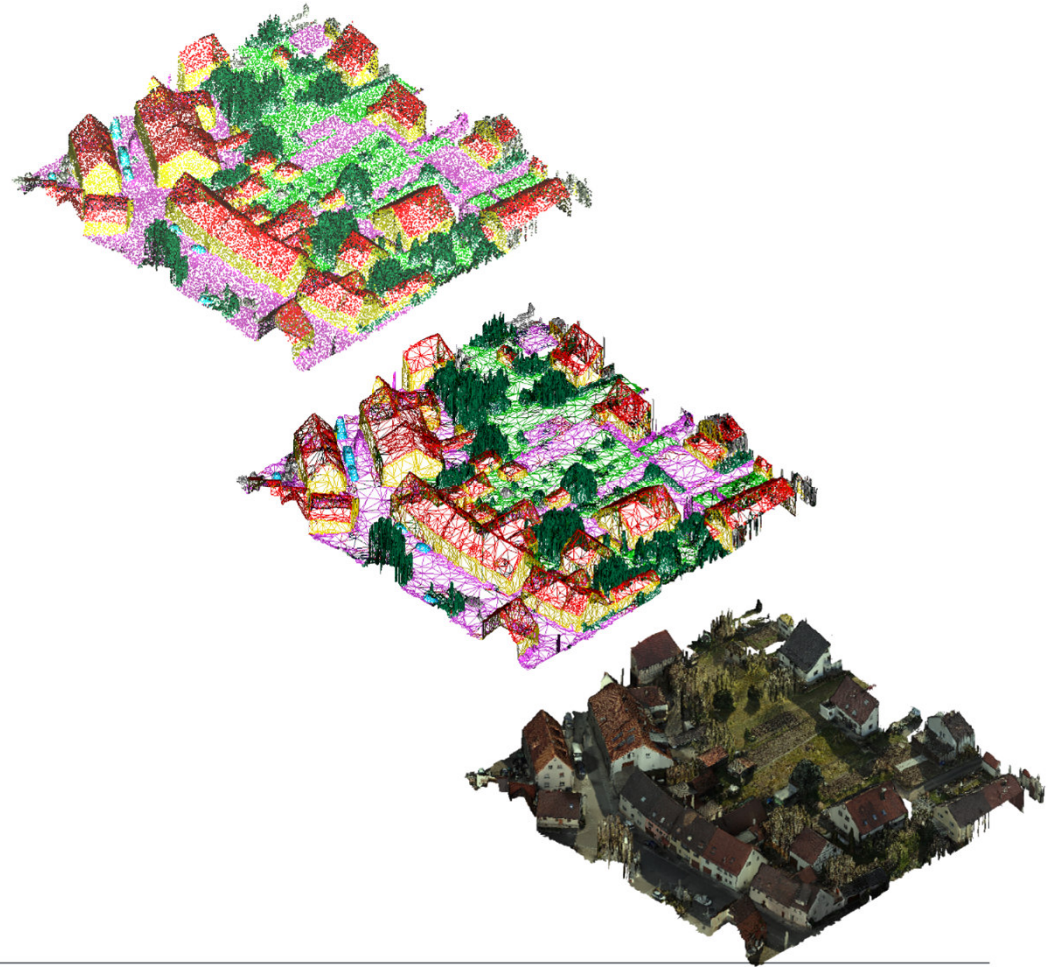
Motivation: Why Meshes?

- “Fusing” Data Representation

- Imagery
- Point Clouds

- Use-cases

- Viewshed and Flood Analysis
- City Models
- Visualization + VR



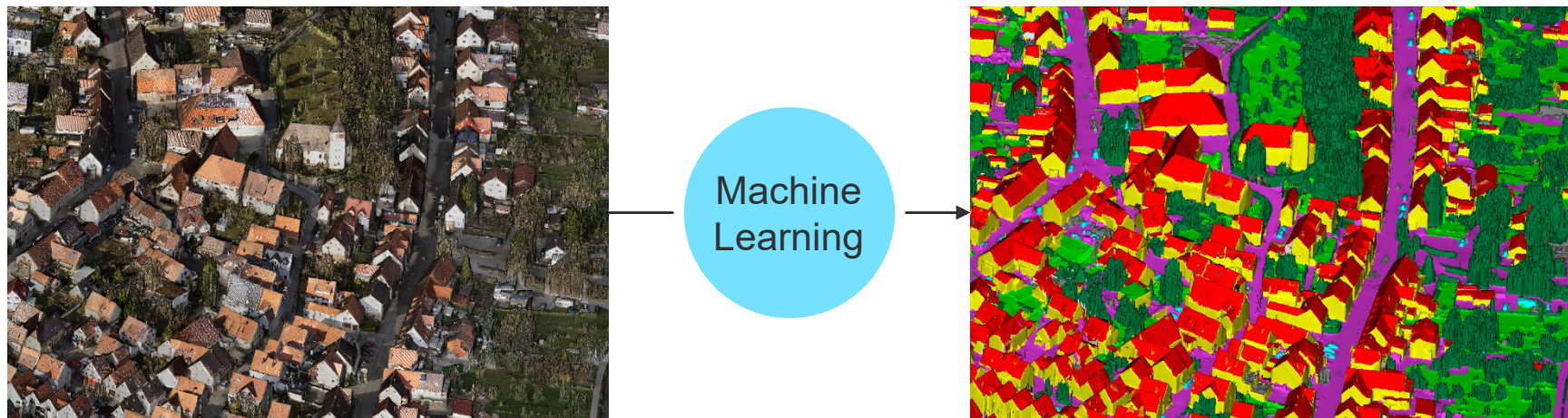
Motivation: Why Meshes?

“Meshes are comprehensive maps for literally the whole world!”



Snapshot of Google's 3D representation (mesh).

Aim: Semantic Segmentation of Meshes



Availability of Ground Truth Data

ALS Point Cloud Benchmarks / Public Data Sets	Mesh Benchmarks / Public Data Sets
ISPRS 3D Semantic Labeling (Vaihingen, V3D) RoofN3D (TU Berlin) AHN3 (the Netherlands) GRSS Data Fusion Contest (Track 4: 3D Point Cloud Classification)	?

Availability of Ground Truth Data

ALS Point Cloud Benchmarks / Public Data Sets	Mesh Benchmarks / Public Data Sets
ISPRS 3D Semantic Labeling (Vaihingen, V3D) RoofN3D (TU Berlin) AHN3 (the Netherlands) GRSS Data Fusion Contest (Track 4: 3D Point Cloud Classification)	Only Indoor Scenes

Ground Truth Generation

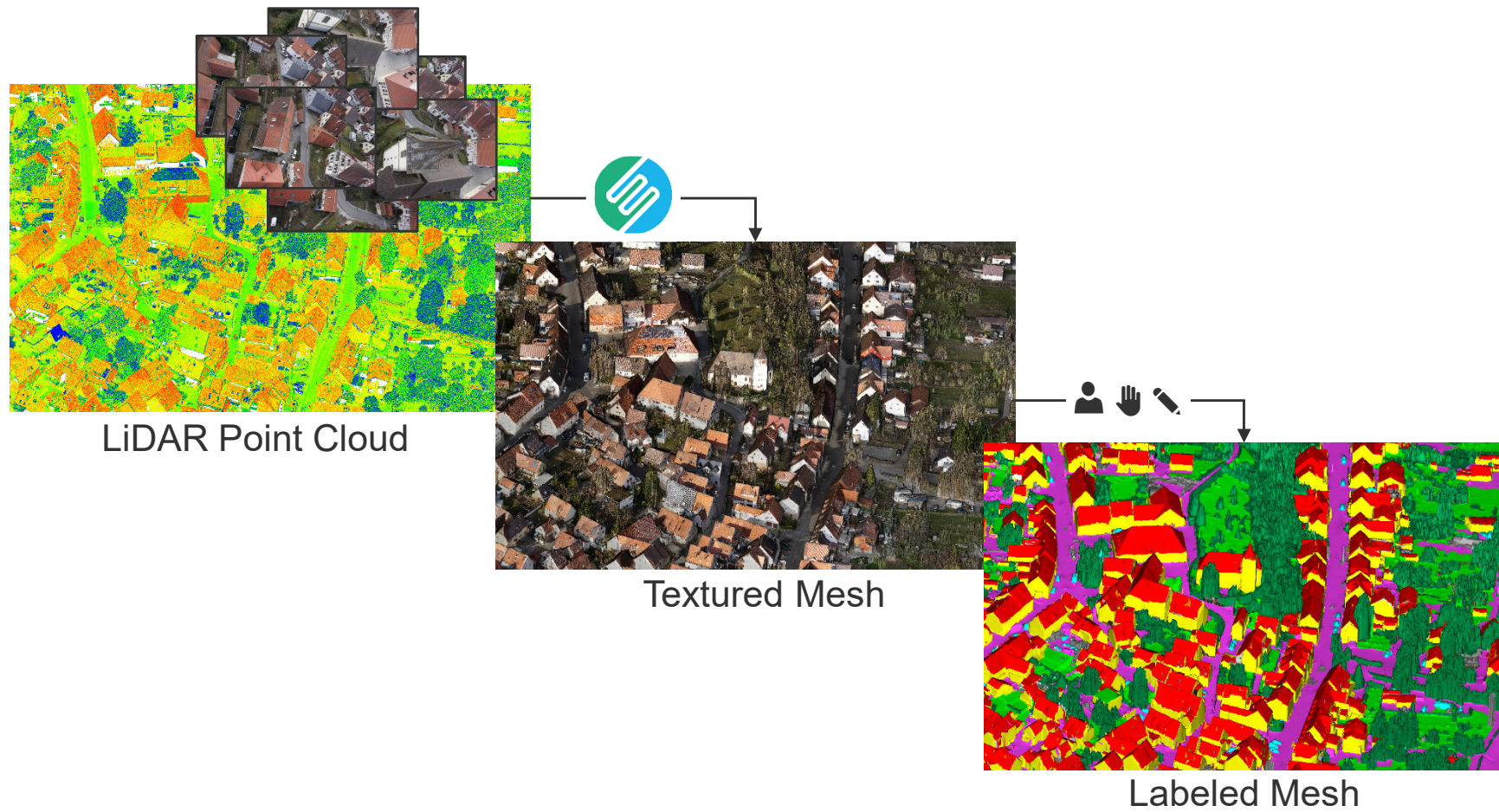
Data Acquisition



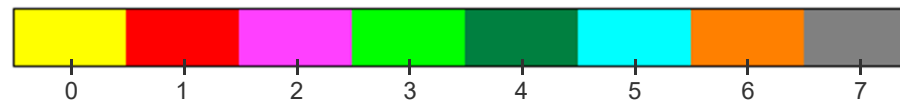
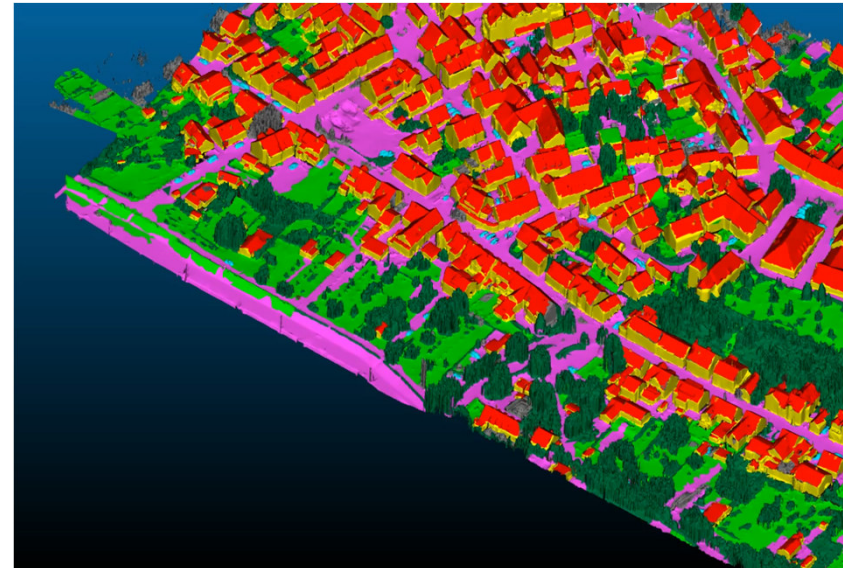
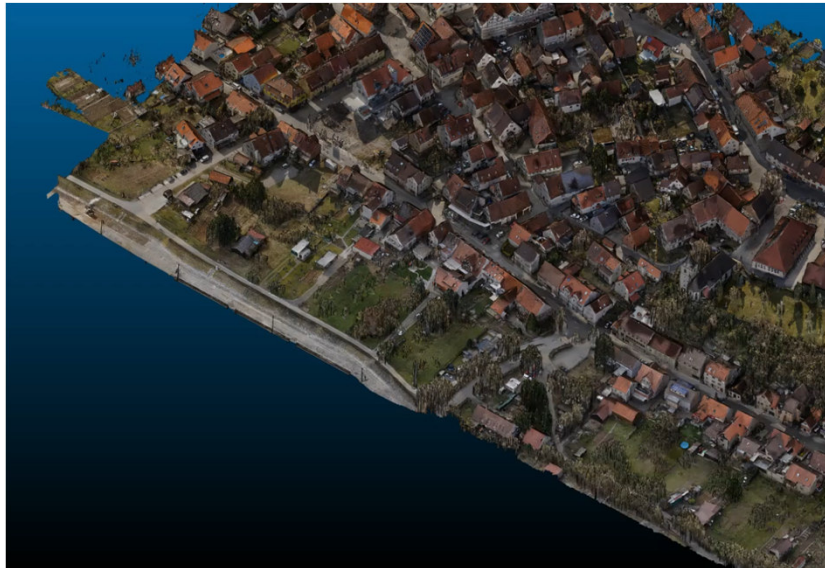
LiDAR: 800 pts/m², footprint Ø < 3 cm
Photogrammetry: GSD @ 3.7 mm (nadir), 2.3 cm (oblique)

Cramer, M.; Haala, N.; Laupheimer, D.; Mandlbauer, G. & Havel, P., 2018:
Ultra-high precision UAV-based LiDAR and Dense Image Matching. Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-1, 115-120.
DOI: [10.5194/isprs-archives-XLII-1-115-2018](https://doi.org/10.5194/isprs-archives-XLII-1-115-2018)

Ground Truth Generation



Labeled Ground Truth



0. building mass/facade

1. roof

2. impervious surface

3. green space

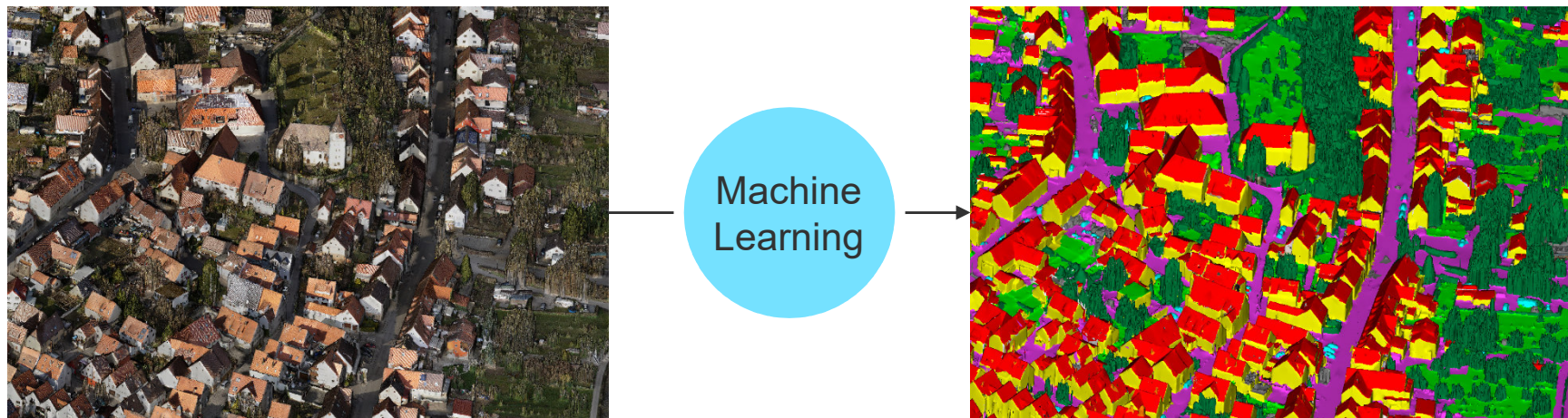
4. mid and high vegetation

5. vehicle

6. chimney/antenna

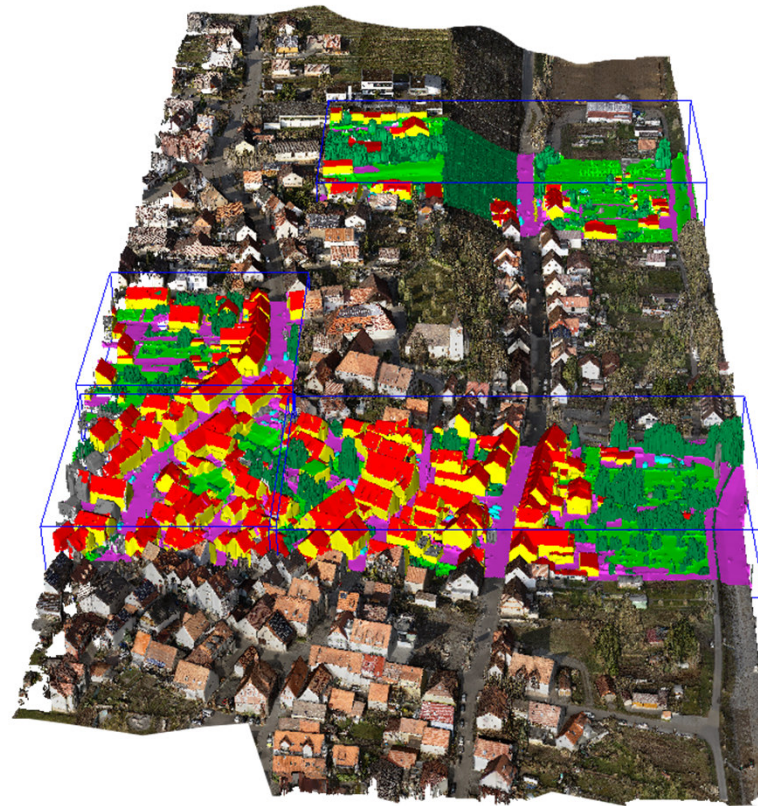
7. clutter

Aim: Semantic Segmentation of Meshes



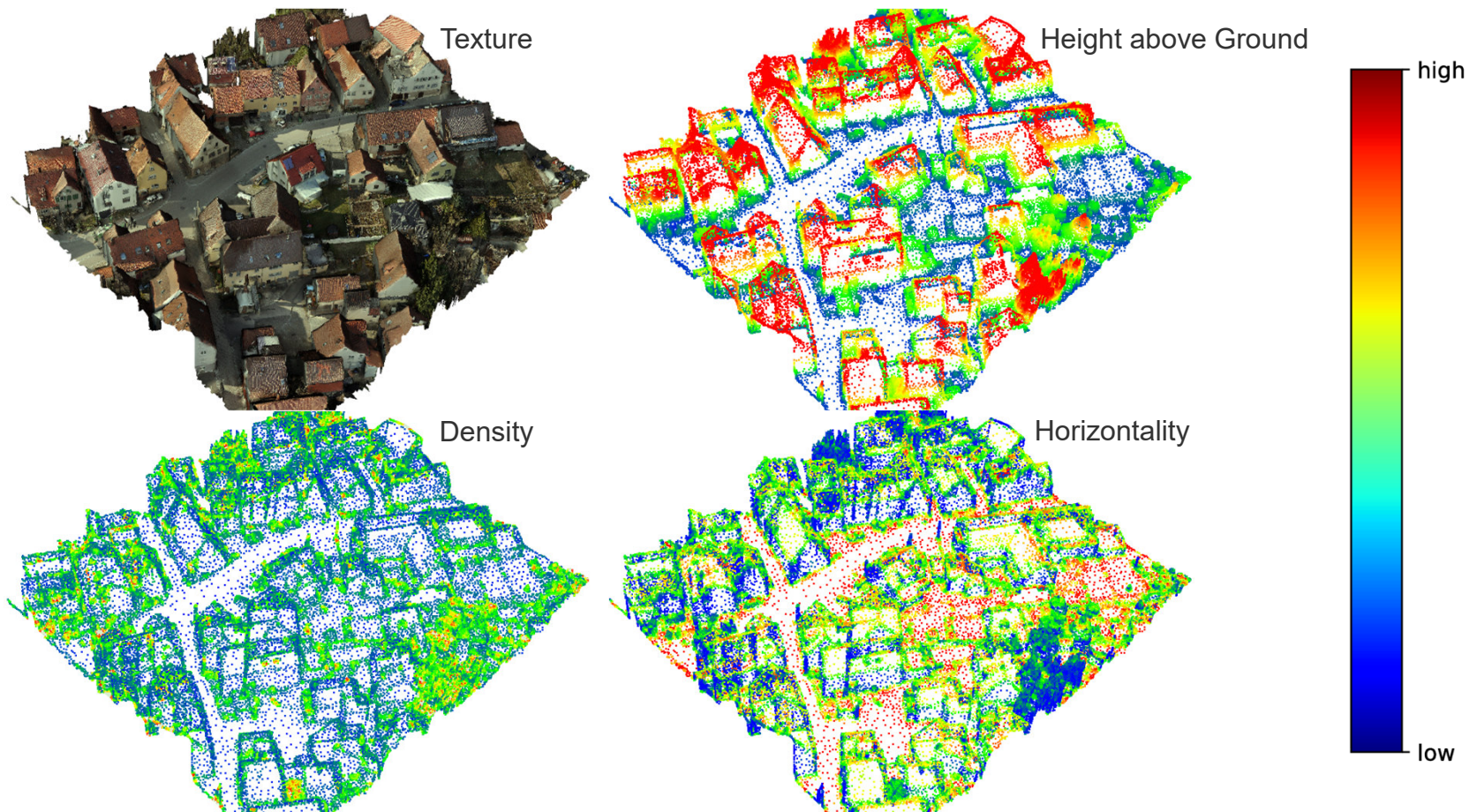
Methodology

- Ground Truth Generation
- Feature Calculation
 - Geometric & radiometric
 - Multi-scale contextual features
- Train Classifier
 - Multi-Branch 1D CNN*
 - RF
- Inference/Evaluation



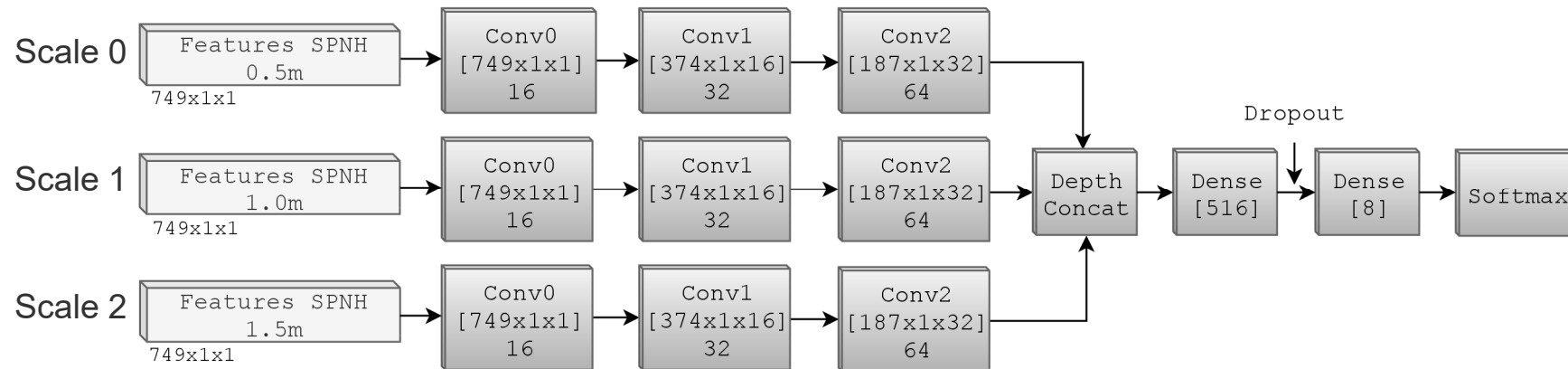
* George, D., Xie, X. & Tam, G., 2018:
3D Mesh Segmentation via Multi-branch 1D Convolutional Neural Networks. Graphical Models, 96, 1-10.

Feature Calculation



Feature-Based Multi-Branched 1D CNN

Network Architecture



George, D., Xie, X. & Tam, G., 2018:

3D Mesh Segmentation via Multi-branch 1D Convolutional Neural Networks. Graphical Models, 96, 1-10.



Results

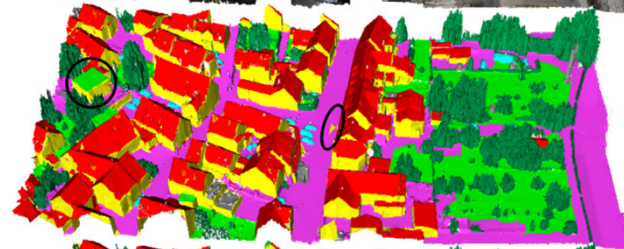
Textured Mesh

~300.000 faces



Ground Truth

Label Noise



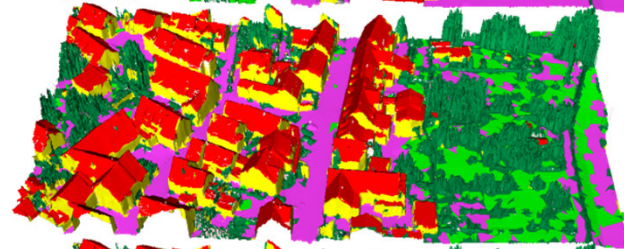
RF Prediction

250 trees, depth: 25

Training Time: 6.6h

Accuracy: 79.01%

Inference Time: 45.83s



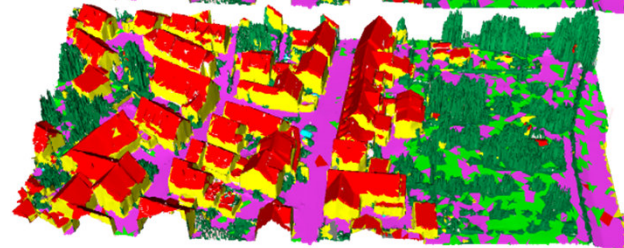
1D CNN Prediction

9.3 million parameters

Training Time: < 15min

Accuracy: 79.87%

Inference Time: 14.69s

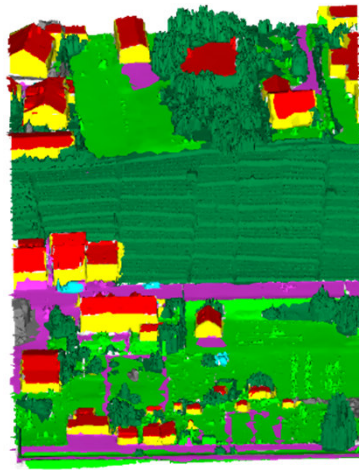


Comparison of Feature Influence

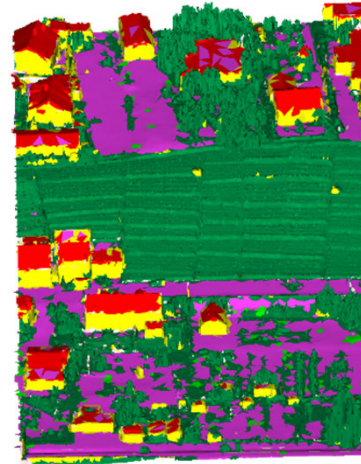
Feature-Based Multi-Branch 1D CNN



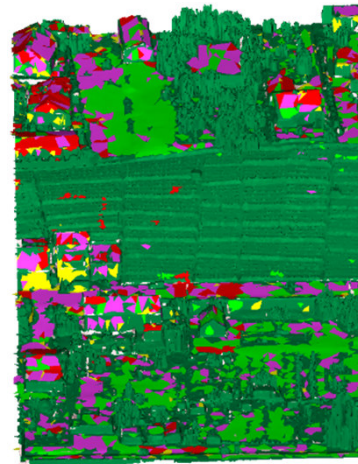
Textured Mesh



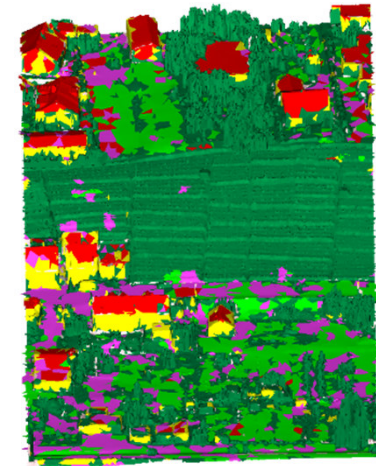
Ground Truth



Prediction
(geometry only)



Prediction
(texture only)

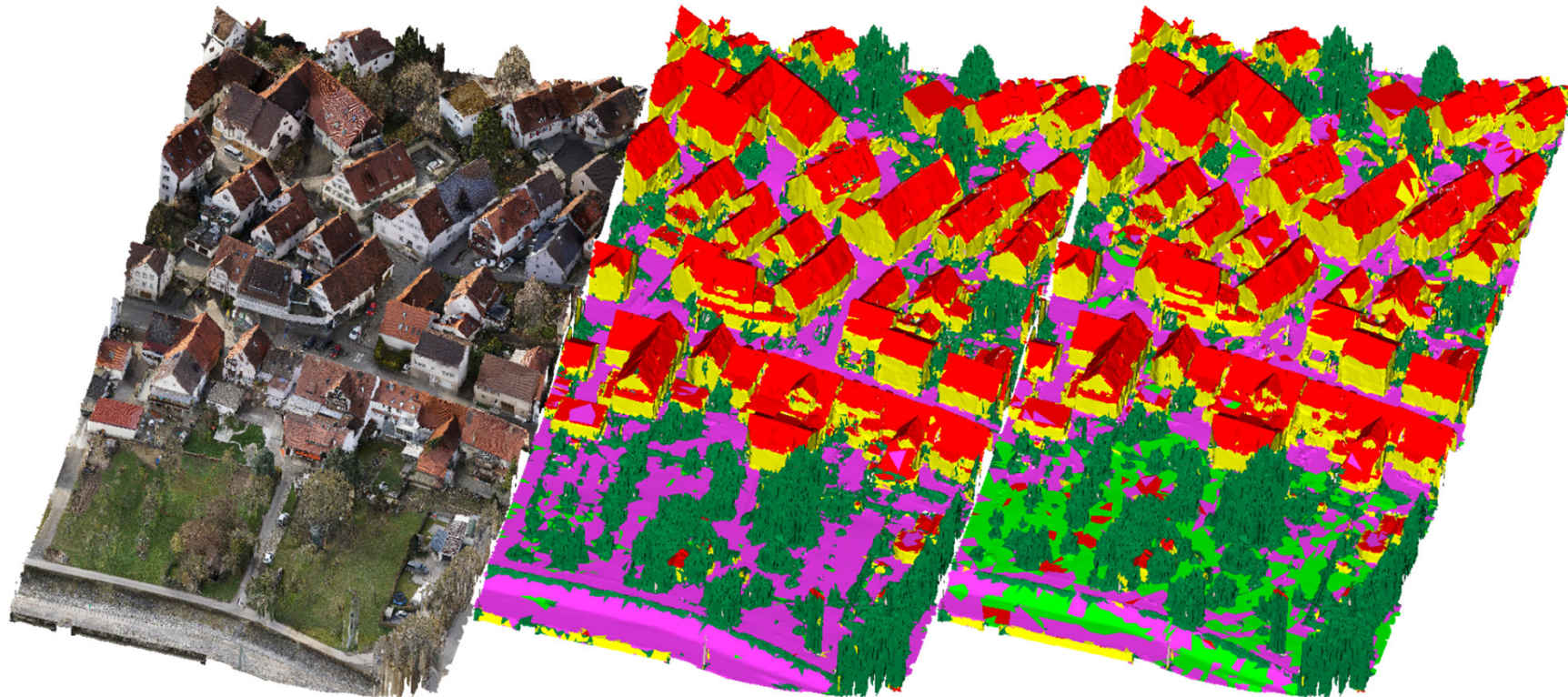


Prediction
(all features)



Comparison of Feature Influence

Feature-Based Multi-Branch 1D CNN



Textured Mesh

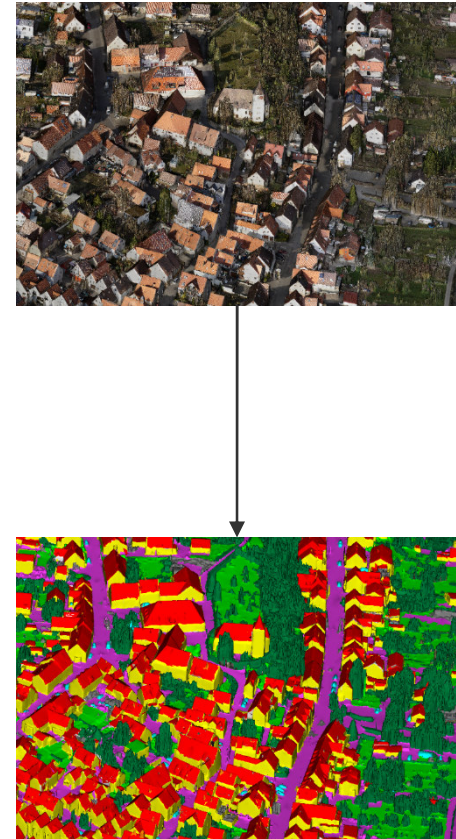
Prediction Using
Geometric Features Only

Prediction Using
Geometric & Radiometric
Features



Conclusion

- Alternative 3D Data Representation: Meshes
 - Data fusion
 - Good georeferencing/relative orientation of LiDAR and imagery necessary
- Ground Truth Generation
- Pipeline for Mesh Generation and Semantic Segmentation
 - Overall accuracy: ~80 %
 - Detection of buildings and mid/high vegetation works well
- Features
 - Geometry > Radiometry
 - Radiometry matters!



Future Work

- Ground Truth Generation

- [Avoid label noise](#)
- [Crowdsourcing](#)

- Georeferencing

- [Hybrid georeferencing](#)

Glira, P.; Pfeifer, N.; Mandlbauer, G., 2019:
Hybrid Orientation of Airborne LIDAR Point Clouds and Aerial Images.
ISPRS Annals of Photogrammetry, Remote Sensing and
Spatial Information Sciences, Volume IV-2/W5, 2019, pp.567-574.
DOI: 10.5194/isprs-annals-IV-2-W5-567-2019

- Features

- [Incorporate LiDAR features](#)
- [Incorporate texture explicitly](#)

