Towards General Deep-Learning-Based Tree Instance Segmentation Models

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Motivation

The segmentation of individual trees from forest point clouds is crucial for downstream analyses such as carbon stock estimation. Segmentation methods based on deep learning have large potential because complex segmentation rules can be learned in a data-driven way. Since such methods are trained in a supervised manner, the question arises how they perform under domain-shift, that is when the test data differs from the training data. Knowledge in this regard is important to determine what is needed to develop general, broadly applicable tree segmentation models.

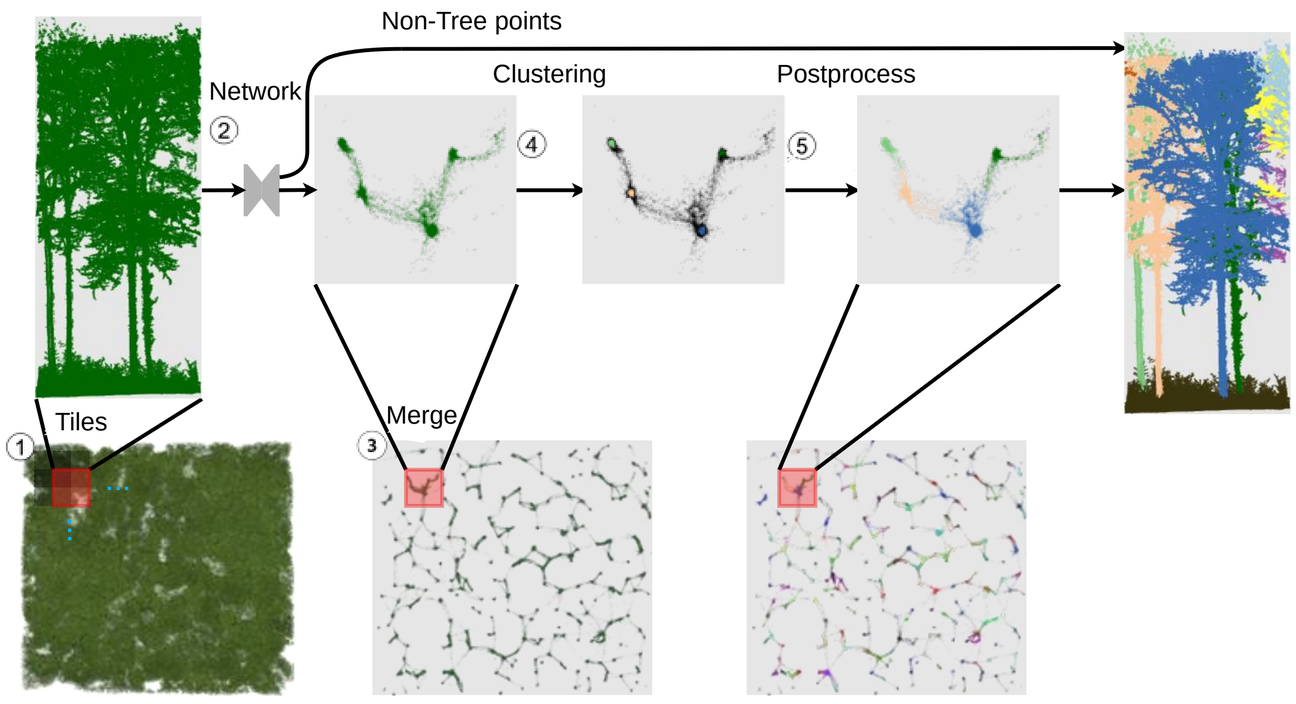
Research questions

1. Coniferous UAV → Deciduous MLS
Does training on coniferous-dominated UAV point clouds improve the performance on deciduous-dominated MLS point clouds?

2. MLS/TLS → low-resolution UAV
Does training on MLS/TLS point clouds generalize to sparser UAV point clouds?

Method

Network: We employed TreeLearn [4], which projects points towards the tree base and then clusters them to get tree instances.



Training conditions:

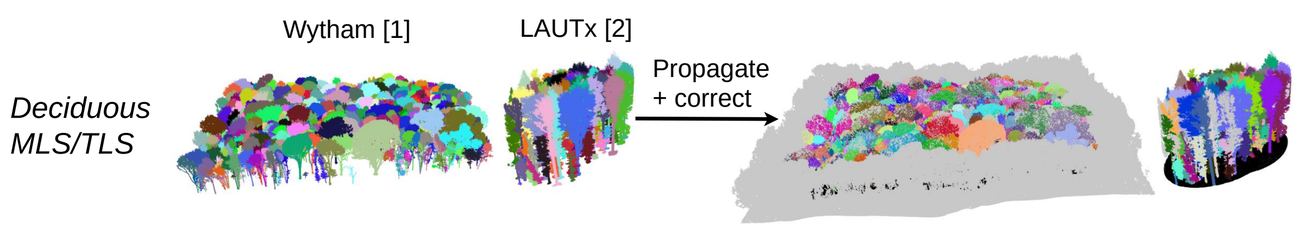
- Obtain baseline by training with automatically segmented data
- Fine-tune baseline model with *(i) deciduous MLS/TLS* data, *(ii) coniferous UAV* data and *(iii) all data* from the first two conditions.
- Compare performance of the models on *(1) deciduous MLS* data and *(2) low-resolution eucalypt UAV* data to assess performance under domain-shift.

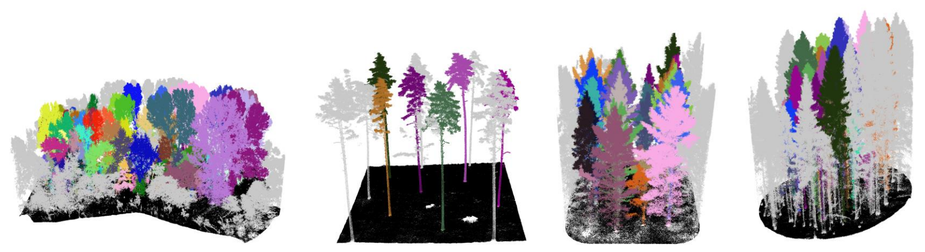
Conclusion

- Generalization from sparse to more dense point clouds with different tree composition is in principle possible, while generalization from dense to sparse poses a problem.
- In future research, a more quantifiable characterization of different forest point clouds should be established to enable a more thorough and systematic comparison between domains.

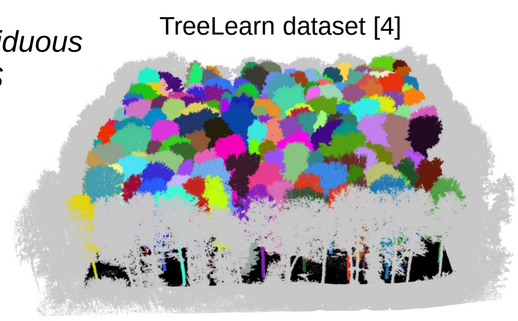
Data

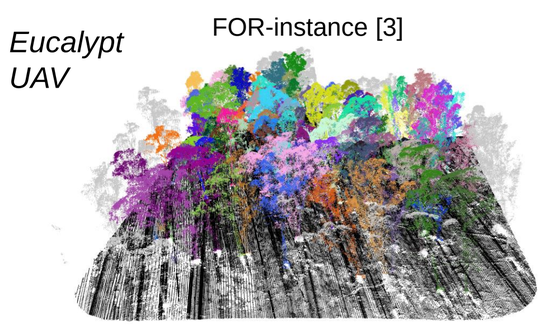
Training data consists of previously published datasets that have been partly modified to enable processing of the complete point cloud. The modified datasets are made publicly available.





Test data consists of two previously published datasets from different domains.





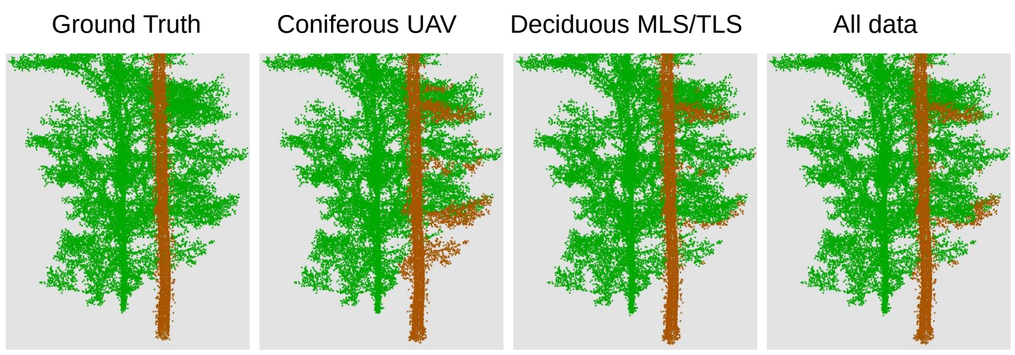
Results

1. Coniferous UAV → Deciduous MLS

Training on coniferous UAV data substantially improves performance on out-of-domain MLS data compared to the baseline!

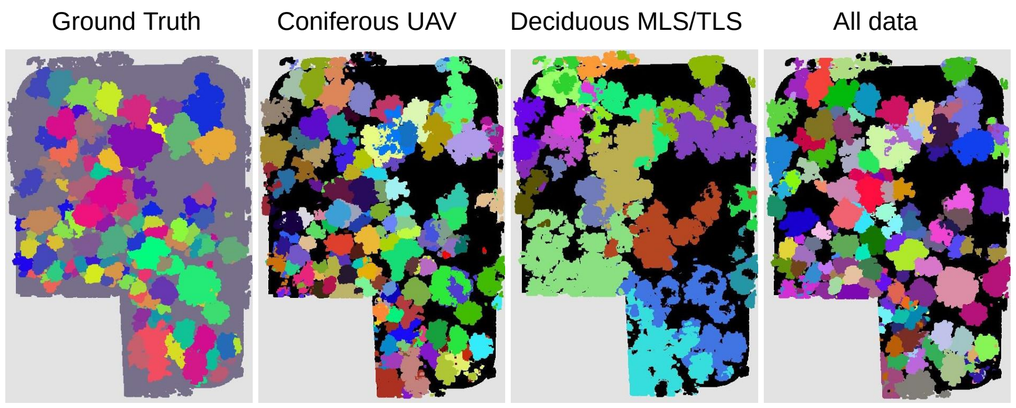
Training Data	F1-Score on deciduous MLS
baseline	93.98
+ coniferous UAV	**96.25**
+ deciduous MLS/TLS	97.31
+ all data	96.88

While an even better performance can be achieved when only training with in-domain data, such a specialized model performs poorly on low-resolution data (see second result).



2. MLS/TLS → low resolution UAV

When only training with high-resolution MLS/TLS data, performance on low resolution data decreases drastically due to severe cases of merged trees.



Try out TreeLearn:

References

[1] Calders et al. (2022). Laser scanning reveals potential underestimation of biomass carbon in temperate forest. Ecological Solutions and Evidence, 3(4), e12197.
[2] Tockner et al. (2022). Automatic tree crown segmentation using dense forest point clouds from Personal Laser Scanning (PLS). International Journal of Applied Earth Observation and Geoinformation, 114, 103025.
[3] Puliti et al. (2023). FOR-instance: a UAV laser scanning benchmark dataset for semantic and instance segmentation of individual trees. arXiv preprint arXiv:2309.01279.
[4] Henrich et al. (2023). TreeLearn: A Comprehensive Deep Learning Method for Segmenting Individual Trees from Forest Point Clouds. arXiv preprint arXiv:2309.08471.

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