TreeGPT - Generative pre-trained transformer for forestry applications with 3D point clouds

Degree programme: Master of Science in Engineering
Specialisation: Data Science
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As of today, we still rely on largely incomplete manual forest inventories to manage the wooden third of Switzerland's land area. Advancements in 3D computer vision applied to LiDAR point clouds can improve that. TreeGPT leverages self-supervised training on unlabeled and synthetic point clouds of single trees and contributes to the creation of a foundation model for forestry vision tasks.

Context

Advances in 3D computer vision with point clouds offer opportunities in forestry, where forest inventories are important for sustainable management. LiDAR scanners from various platforms (ground, mobile, aerial) are already used for this purpose, but challenges remain. The large amount of raw data available makes self-supervised learning approaches, not yet used in this field, particularly interesting.

Methodology

We adapted PointGPT for forest point clouds using two stages: pre-training a task-agnostic network with generative objectives, then fine-tuning with and without spectral adapter layers for tasks like species classification.

For robust pre-training, we created an additional dataset combining real single-tree point clouds from aerial laser scanning, synthetic tree models, and hybrid synthetic clouds from different simulated LiDAR platforms.

Results and outlook

The generative pre-training enables the transformer to learn robust representations, achieving performance comparable to other point- or graph-based networks while operating directly on mostly unlabeled 3D data. The spectral adapter layers enable efficient fine-tuning on new tasks while freezing the main model and training less than 1% of parameters. This foundation model approach contributes to advances in precision forestry and scalable monitoring systems, improving forest ecosystem management.

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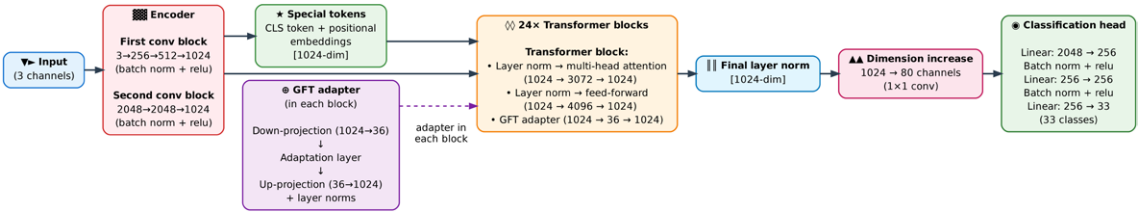
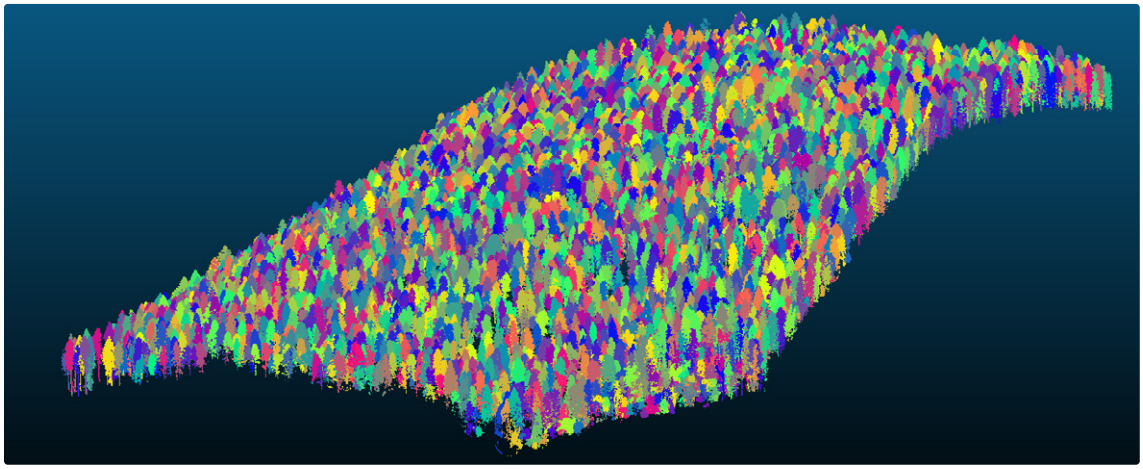


Overview of the model architecture TreeGPT-Large with 312 million total parameters.



A LiDAR forest plot used in the study.