Fully-automated Occlusion-insensitive Norway Spruce Tree Reconstructions from 3D Point Cloud Data

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1. Introduction and Motivation

- Trees play an important role in various ecosystem **simulations** and analyses
  - results strongly depend on the correctness and precision of the **input parameters**
  - extensive (and destructive) field-work measuring often required to obtain the data
  - certain applications specifically require **3D models** of the trees
- **LiDAR** (Light Detection And Ranging) technology captures only **individual points**
- New method for **automatic reconstruction** of 3D models of trees from given point clouds
  - aimed at Norway spruce trees
  - exceptionally difficult—frequent **trunk occlusions** caused by a high leaf density
  - results in **large gaps** in the scanned data (existing methods fail in such reconstructions)

2. Proposed Algorithm

- Three phases of the reconstruction:
  - **Component identification:** Spatially-related clusters of the points are identified
  - **Component analysis:** Branch structure is reconstructed in each identified component
  - **Component connecting:** All the components are interconnected to form the final tree branch structure

2.1 Component identification

- The input data consist only of the **isolated points**
- The algorithm constructs a **neighborhood graph** to introduce basic spatial relationships
  - close points connected, but no edges between different branches
- Results in a set of components, each consisting of spatially related points
  - points in one component belong to the **same branch** or trunk part

2.2 Component analysis

- Branch structure in each component has to be reconstructed
- The algorithm constructs a **geodesic graph**
  - characterizes how the lengths of **shortest paths** from the designated source point gradually increase throughout the component (Figure 1 (right; warm colors))

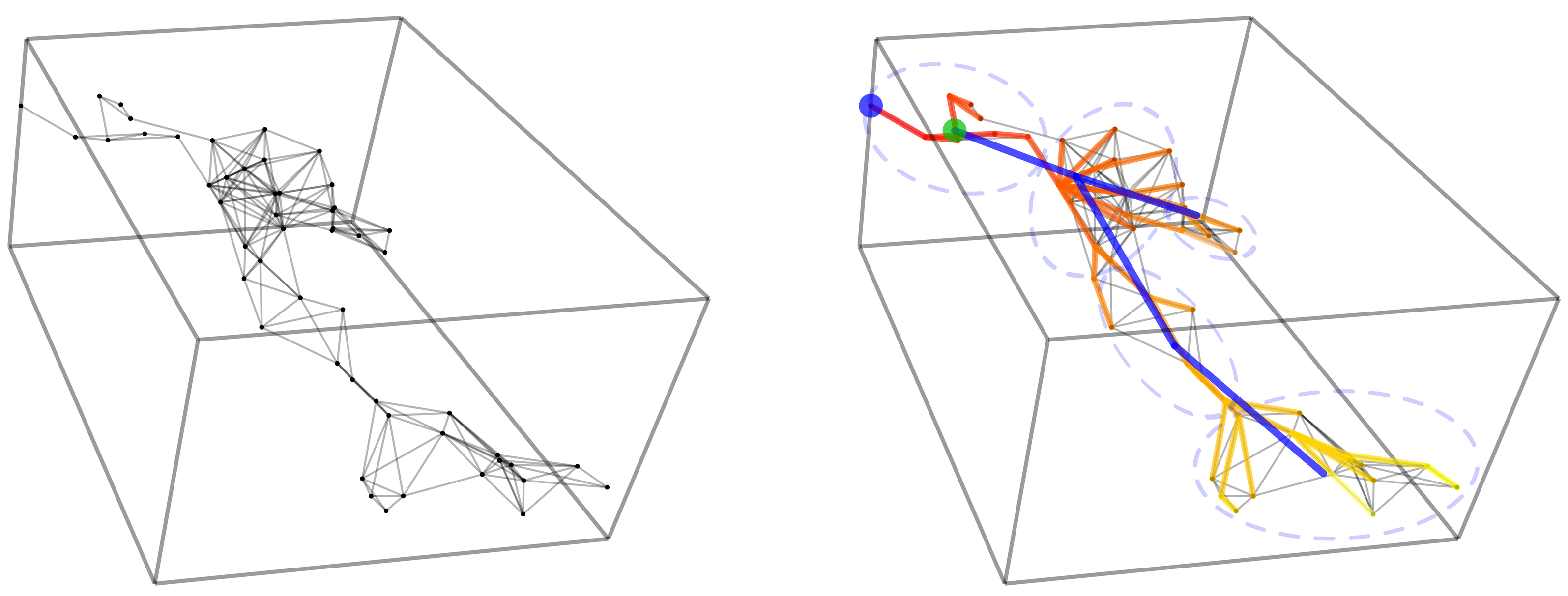

Figure 1: *Illustration of the component analysis phase*

- Extraction of a clean and **reduced skeleton** of every component is desirable
  - the algorithm "**collapses**" points with similar distances from the source point, unless they clearly belong to different subbranches (Figure 1 (right; blue lines))

2.3 Component connecting

- In order to connect all the components, information about the **trunk's position** is needed
  - the algorithm fits a **segmented conical model** to the automatically selected components
  - **iteratively refined** by fitting it to more selected components
- The algorithm then iteratively selects a component to be **connected** to any other component while minimizing a certain **cost function**
- The cost function describes the **probability** of the connection of two endpoints from different components based on:
  1. **euclidean distance** of the endpoints
  2. **outgoing vectors** describing directions and probabilities of branch continuations
  3. **slope function** roughly estimating expected slopes of the main branches
- Results in the **fully-interconnected** skeleton representing the tree branch structure

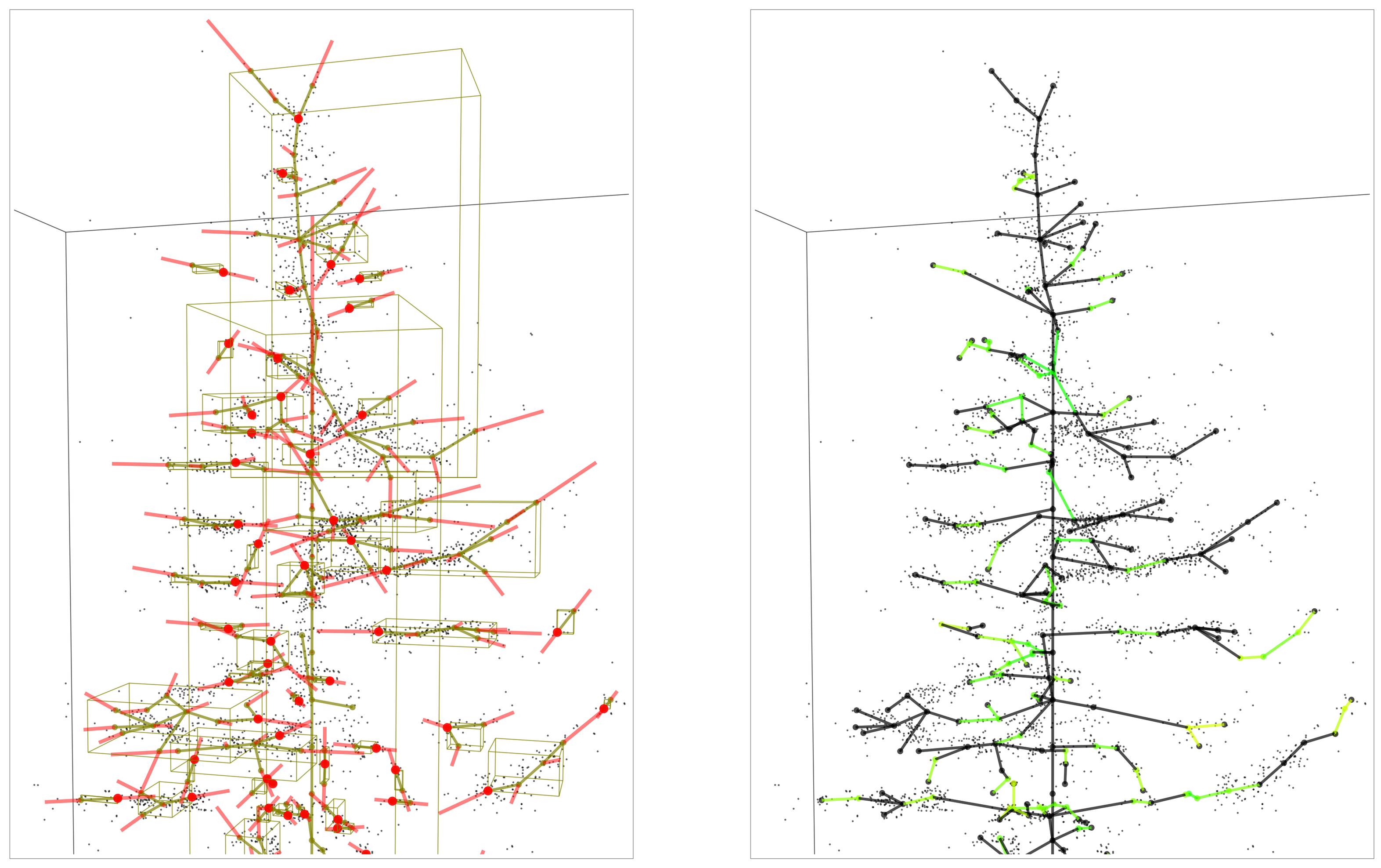

Figure 2: *Outgoing vectors (left) and the skeleton after the connecting (right)*

- An estimation of the **branches' thicknesses** is also often required
  - estimation possible from the amount of **tree structure** grown from this branch
- After basic structure **cleaning** and **smoothing**, the final tree branch structure is obtained

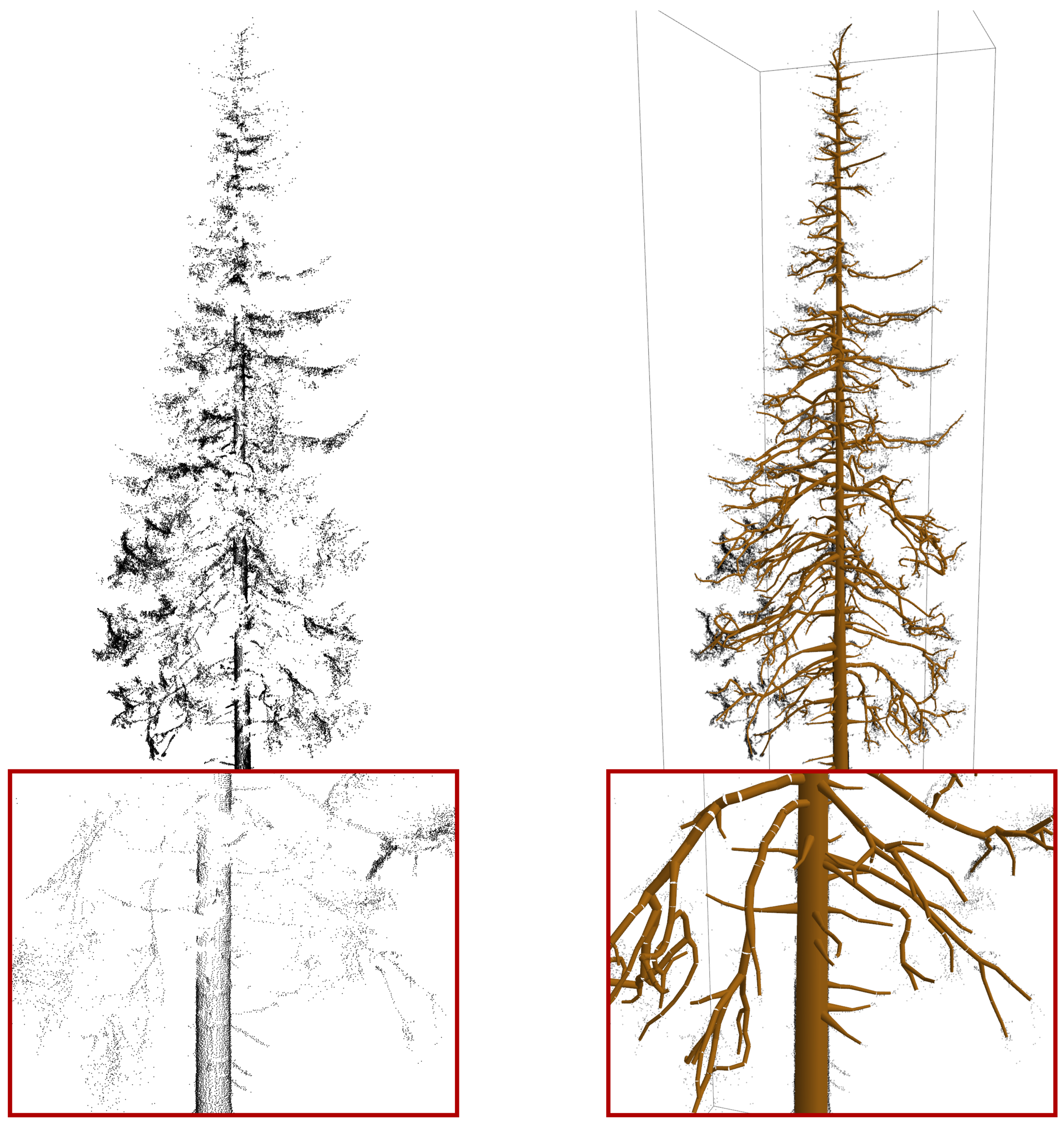

Figure 3: *Example of the input data (left) and final reconstructed skeleton (right)*

3. Conclusions and subsequent work

- Existing methods fail on **sparse** and **non-uniform** 3D point clouds
- We have proposed a novel, **fully automated** method for tree reconstructions
  - does not require high-resolution data
  - fairly insensitive to occlusion-induced artifacts in the point clouds
- Reconstructed models were used to **derive branch statistics**
  - **branch counts** for different branch orders
  - **biomass volume** estimations for individual branches

References

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