Fast automatic method for constructing topologically and geometrically precise tree models from TLS Data

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The method

The method recreates the architecture of a tree by fitting a set of cylinders on Cartesian (x, y, z) coordinates collected by a terrestrial laser scanner (TLS). We use a **local-to-global** approach, where the point cloud is first partitioned into small surface patches giving the local details of the woody surface (Fig. 1.). From this network of patches, the following processes are then applied automatically:

- exclusion of ground and non-tree points,
- segmentation into stem and branches,
- fitting a set of cylinders to each segment,
- cylinder model post-processing
  - filling possible gaps
  - error correction with, e.g., botanical rules

The reconstruction method is fully **automatic** and **fast**; from tens of seconds to upto ten minutes per tree in this study. For more details, see [1].

Fig. 1. TLS-point cloud partitioned into surface patches.

Validation with real TLS data

The quality of the method was assessed on real TLS data captured from two 5-year-old Eucalyptus nitens using a Leica Geosystems HDS-6100 TLS device. Parameter extraction results are listed in Table 1 and one of the trees is illustrated in Fig. 2. Scans were acquired indoor with the following measurement setup:

- top and bottom separately,
- scanned from 3 positions,
- distance to scanner 5 m,
- 3 sampling resolutions:

M $0.036°$
H $0.018°$
U $0.009°$

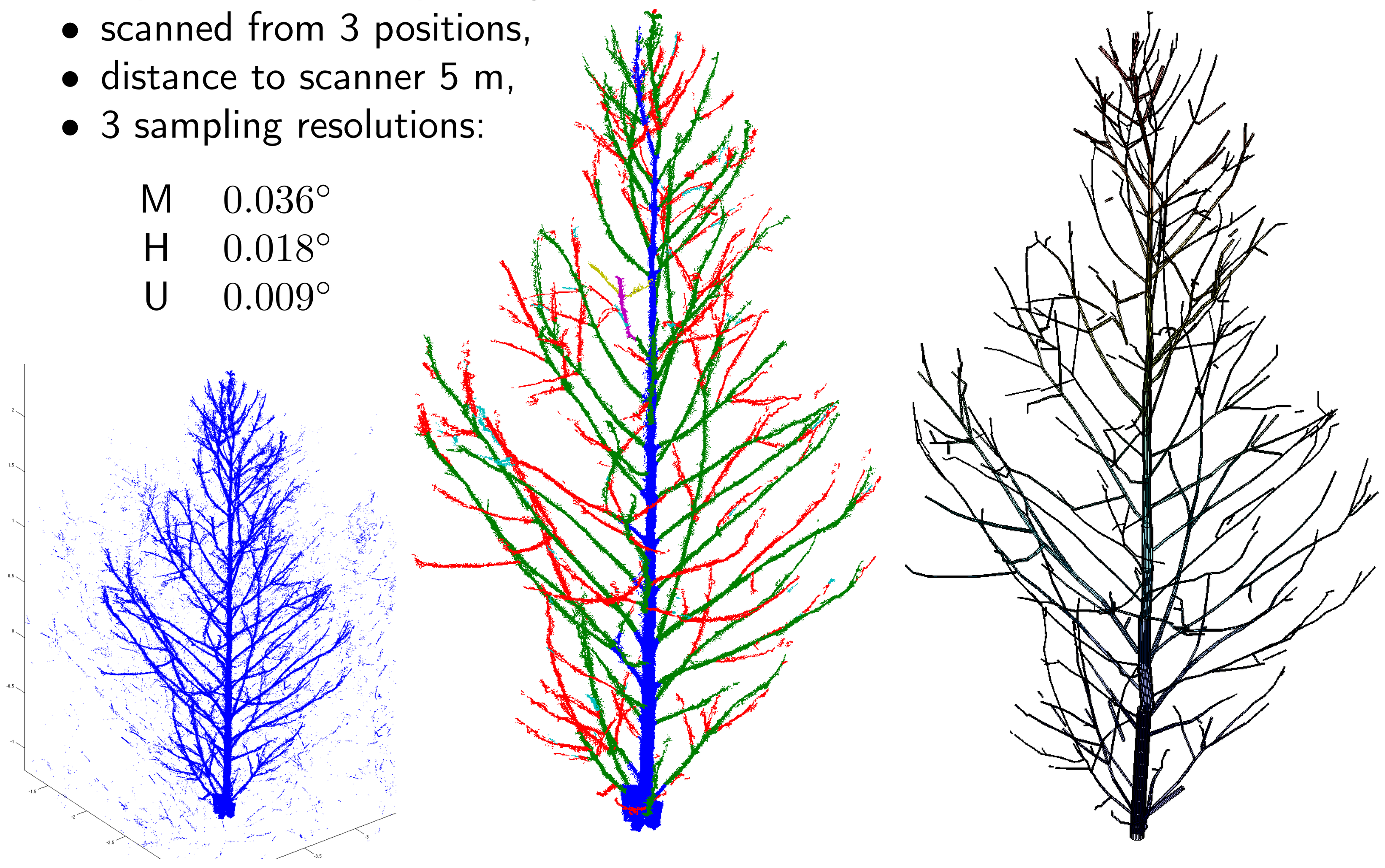

Fig. 2. Example of the 3D architecture of the top part of an Eucalyptus tree. Left, raw point cloud; middle, segmented point cloud; and right, reconstructed cylinder model.

Table. 1. Comparisons between measured and modelled tree parameters for the Eucalyptus trees (T=trunk and B=Branch).

	pos. #	res.	Tot Vol (dm^3)	T Vol (dm^3)	B Vol (dm^3)	T Len (m)	B Len (m)	B (#)
Measured Tree #1			11.5	8.7	2.7	6.3		
Measured Bottom				5.8		1.8		
Measured Top				2.9		4.5		
Model Top	1	U	4.5	2.4	2.1	4.5	67	150
Model Top	2	U	5.7	3.1	2.6	4.6	74	176
Model Top	3	U	6.5	3.6	3.0	4.5	79	227
Model Top	3	H	6.7	3.5	3.2	4.5	61	145
Model Top	3	M	5.6	3.2	2.4	4.4	26	46
Model Bot	3	U	7.1	5.4	1.7	1.8	22	72
Model Bot+Top	3	U	13.6	9.0	4.7	6.3	101	299
Measured Tree #2			18.3	12.2	6.0	5.8		
Measured Bottom				8.7		1.8		
Measured Top				3.5		4.0		
Model Bot	1	U	11.9	9.5	2.5	1.6	43	80
Model Bot	2	U	9.8	6.2	3.5	1.6	53	126
Model Bot	3	U	10.6	6.3	4.3	1.6	56	147
Model Top	3	U	10.2	4.8	5.4	3.9	93	280
Model Bot+Top	3	U	20.8	11.3	9.7	5.5	149	427

Parameter and empirical function extraction

From the reconstructed tree architecture models, topological and geometrical information can be estimated. For example:

- stem structure (dbh, length, taper, volume,...)
- branch structure (length, taper, volume, curvature...)
- branching patterns (orders, parent–child-relations,...)

Furthermore, see Mikko Kaasalainen's presentation[2] on how statistical distributions determined from the models can be used to generate virtual trees.

Validation with artificial data

The quality of the method was assessed using an artificial tree model (30-year-old Scots Pine) and simulated laser scanning [3]. The measurement simulation setup is:

- scanned from 3 positions,
- distance to scanner 20 m,
- sampling resolution $0.01°$.

The tree is illustrated in Fig. 3 and parameter extraction results are shown in Table 2 for reconstructions from all possible combinations of the scanning positions.

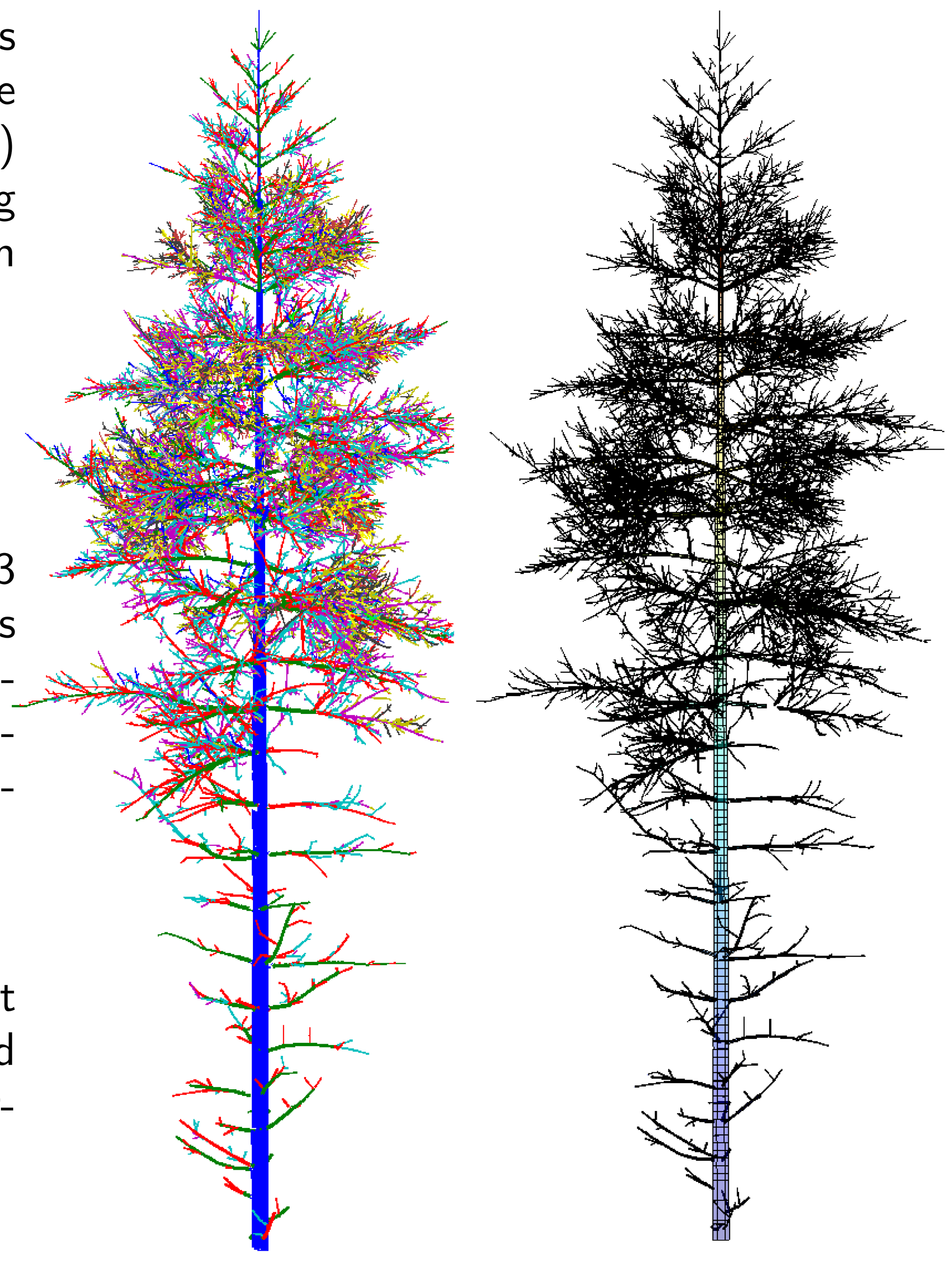

Fig. 3. The segmented point cloud (left) and reconstructed cylinder model (right) of the artificial scots pine.

Table. 2. Comparison between actual and modelled results for the Scots pine.

Scan positions	T Vol (dm^3)	B Vol (dm^3)	T Len (m)	B Len (m)	B (#)	1st-ord. B (#)	2nd-ord. B (#)
1	347	232	17.7	1468	5145	90	365
2	351	224	17.6	1690	6153	93	419
3	351	198	17.7	1449	4824	86	341
1, 2	351	285	17.7	2260	8808	105	592
1, 3	348	294	17.7	2101	7938	107	611
2, 3	350	287	17.7	2272	8735	109	592
1, 2, 3	350	325	17.7	2529	10055	120	829
Actual	348	303	17.7	3327	13659	110	1053

Conclusion

The results show that the proposed method is able to **successfully reconstruct** the visible architecture from both **artificial and real TLS** measurements. The branching structure, stem length and volume, and tree volume agreed with the control data.

For branches with a radius smaller or comparable to the size of the laser footprint and to the registration error of multiple scans, the radius cannot be accurately reconstructed. However, the length of the branches and the branching structure are still reconstructed quite well.

The results show that the resolving power of this method was gradually improved by increasing the number of **scanning positions** around the tree and/or by decreasing the **sampling angle** of the TLS.

References

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