



# A fast algorithm for estimation of stem dimensions, lean and sweep irrespective the position of the tree

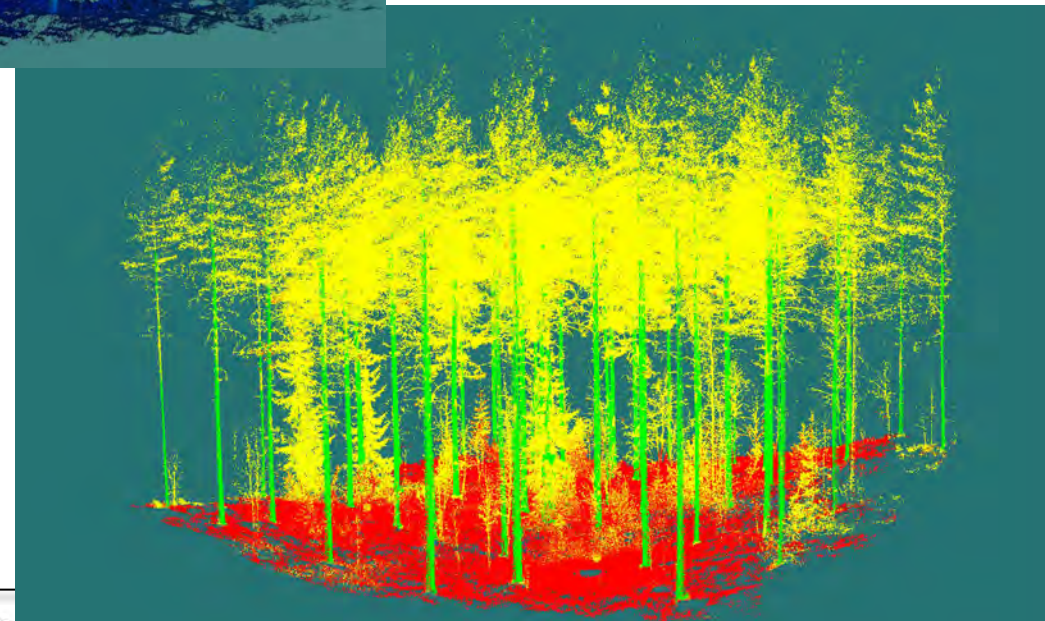
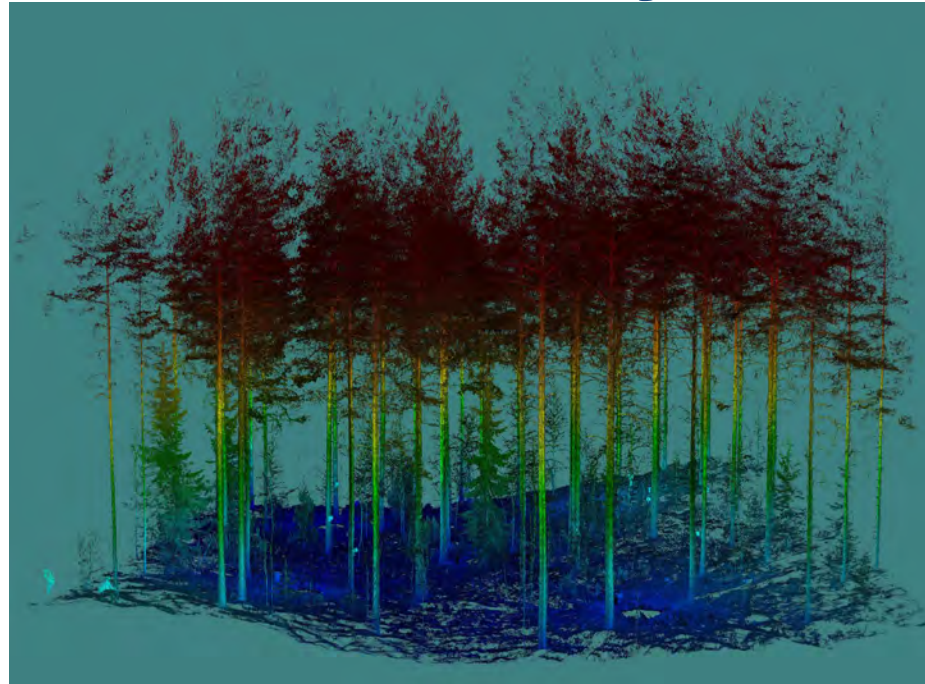
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# Forest inventory

- Measure MANY trees
- Two steps
  - Identify trees
  - Measure trees
- Point clouds
  - Stem detection: one step or two steps
  - Estimation of dimension





# Valuable Trees

- Value
  - Size or Form
  - Species
- Value Estimation
  - Incomplete measurements
    - DBH, height, defects assessment
  - Complete measurements
    - Scanning
    - Algorithms
- FEW Trees



# Terrestrial lidar

- Game changer
  - Accurate
  - Fast (some)
- Types
  - Stationary
  - Mobile
    - Vehicle
    - Handheld / backpack





# Photogrammetric Point Clouds



Trees: can be NON - vertical





# Stem Measurements

- Assuming circular cross section
  - Cylinder fitting:
    - RANSAC model: challenged by non-stem points
  - Circle fitting:
    1. Hough transform: required pre-knowledge of circle radius
    2. Least squares: influenced by outliers
    3. RANSAC: not the optimal solution



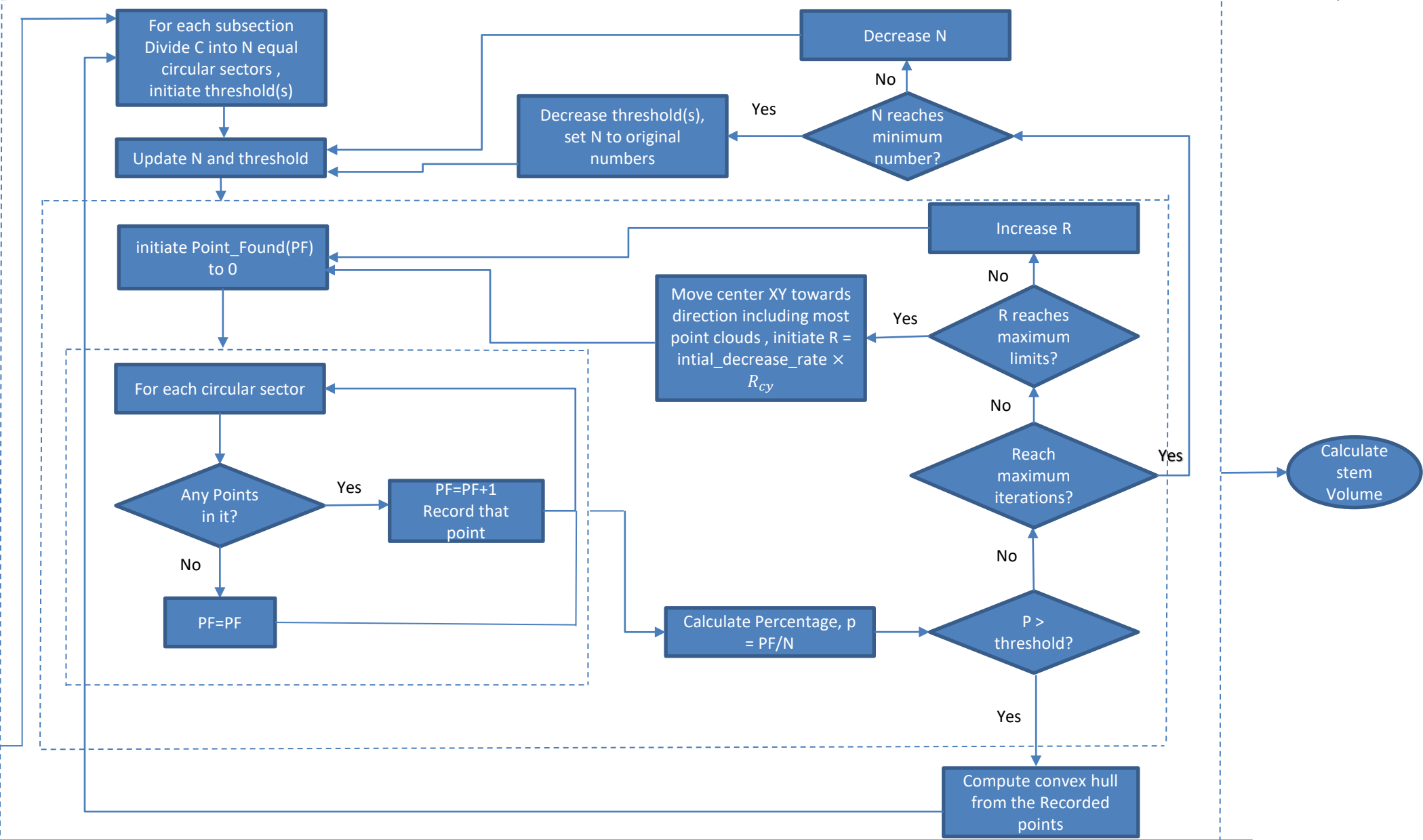
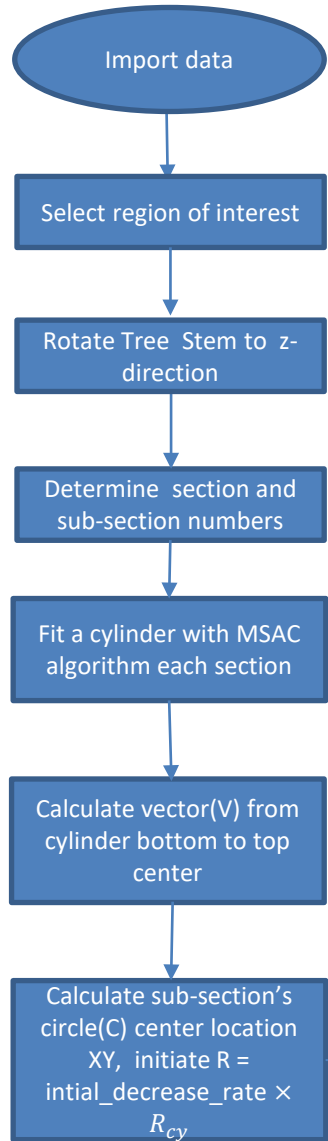
# Objective

Develop an algorithm that computes **accurately and precise**:

- Diameter along the stem
- Lean and sweep
- Volume



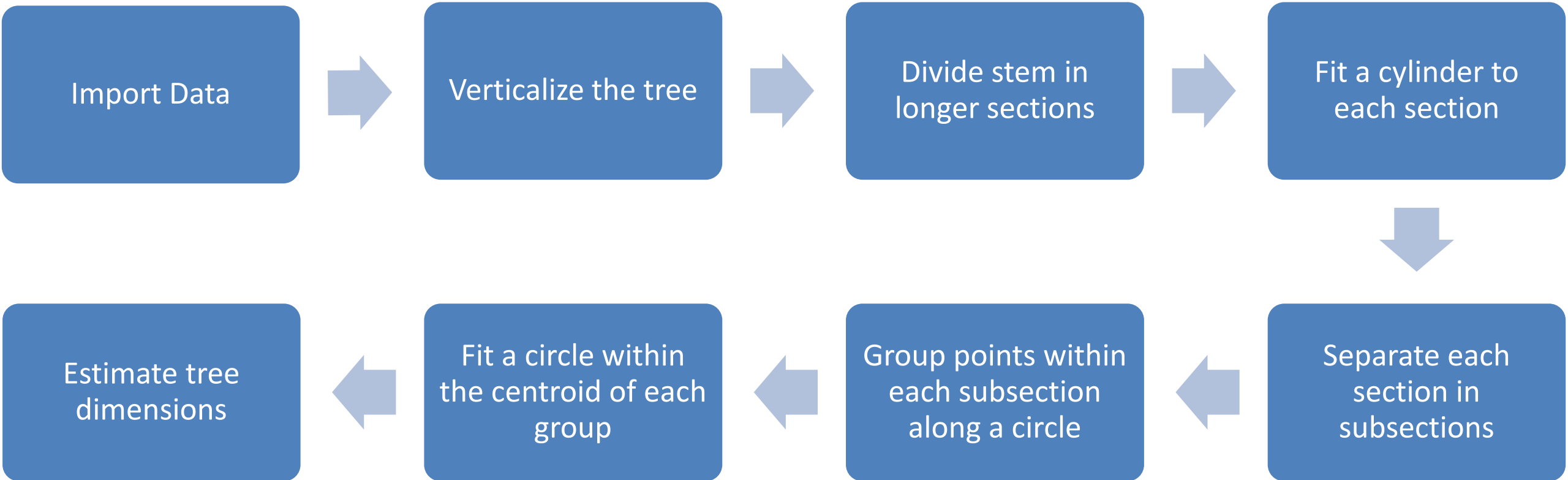
# Algorithm for estimation of tree dimensions







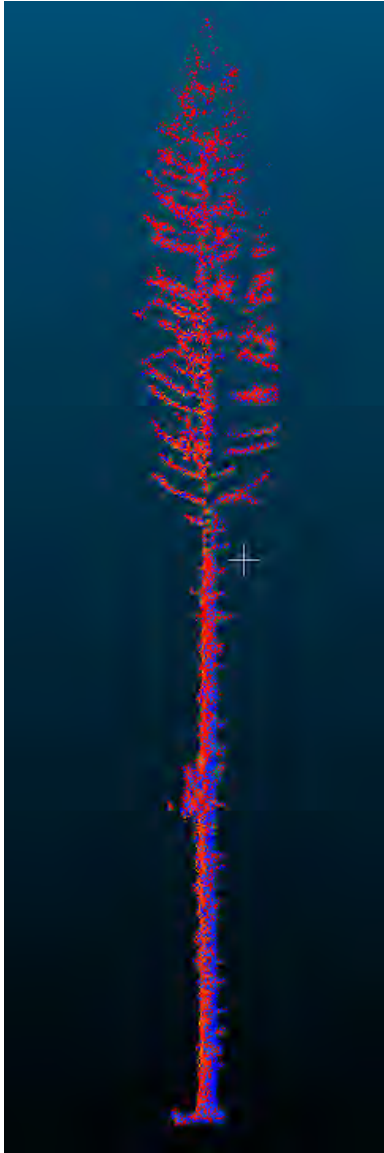
# Algorithm: Short Version



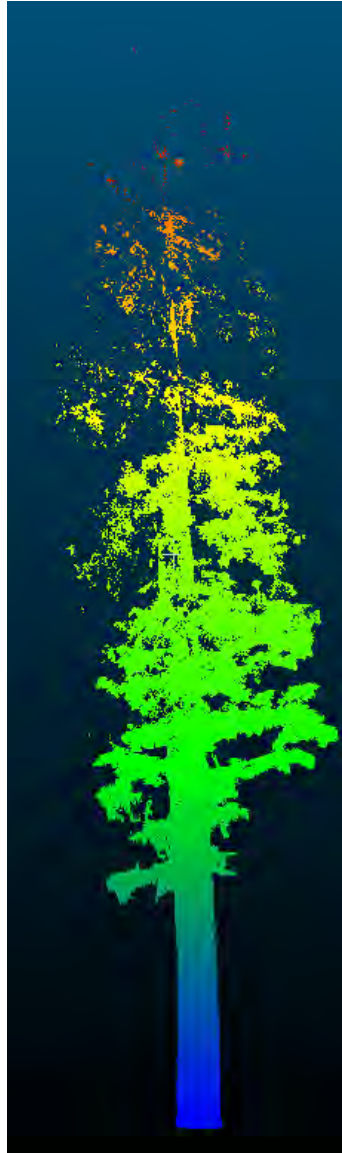


# Input data

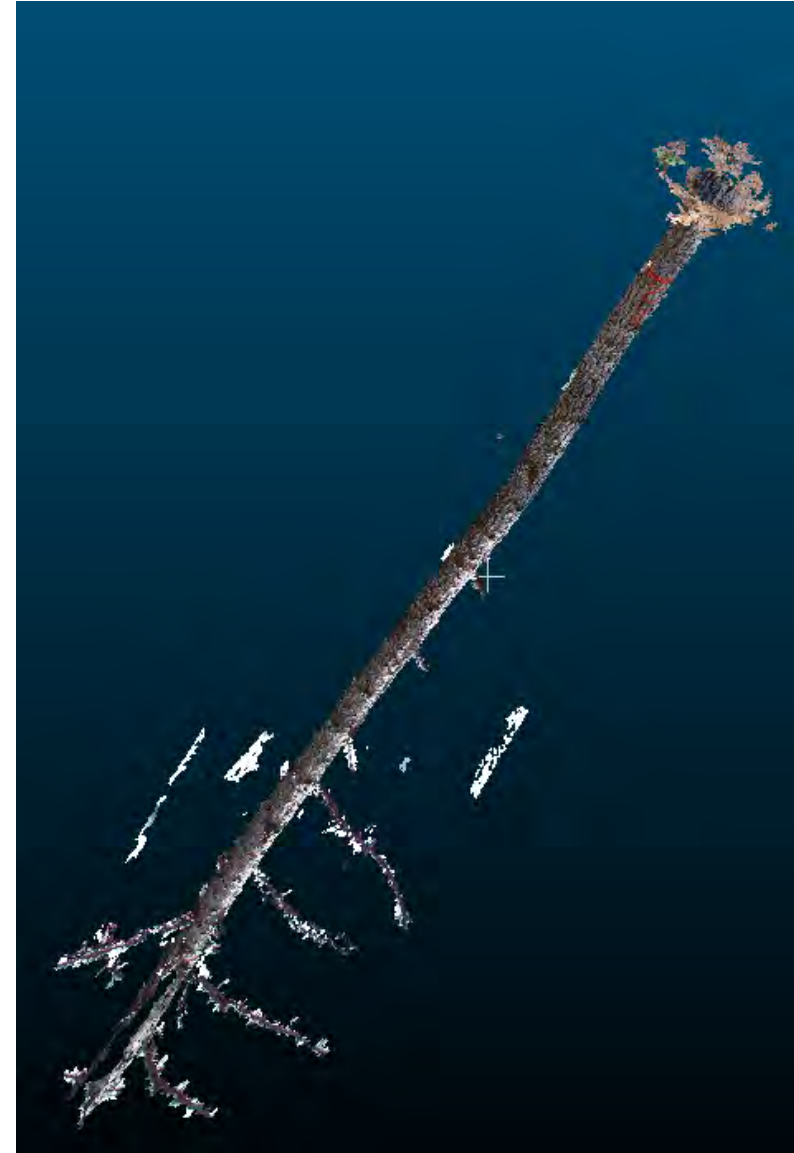
- Stationary Terrestrial Laser Scan
  - HJ Andrews LTER
  - Scanned in 2016
- Mobile Handheld Laser Scan
  - McDonald –Dunn Research Forest
  - Scanned in 2022
- Photogrammetric Point Cloud
  - Vernon Parish, LA
  - Pictures in 2012
- Diameters
  - Every meter: by hand from point cloud
  - DBH: in the field



HLS: McDonald-Dunn  
Height: 45.4 m  
# points: >245,000



TLS: HJ Andrews  
Height: 47.5 m  
#points: 2.40 mil

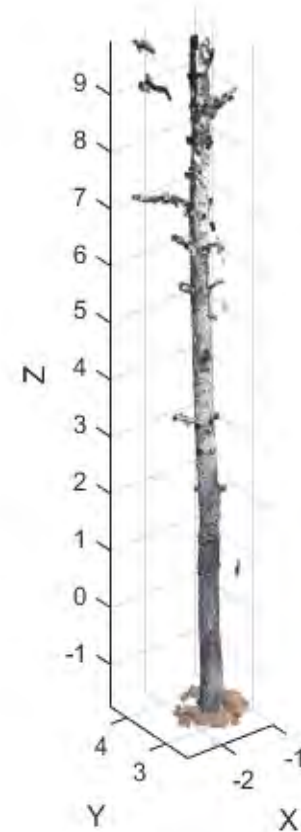
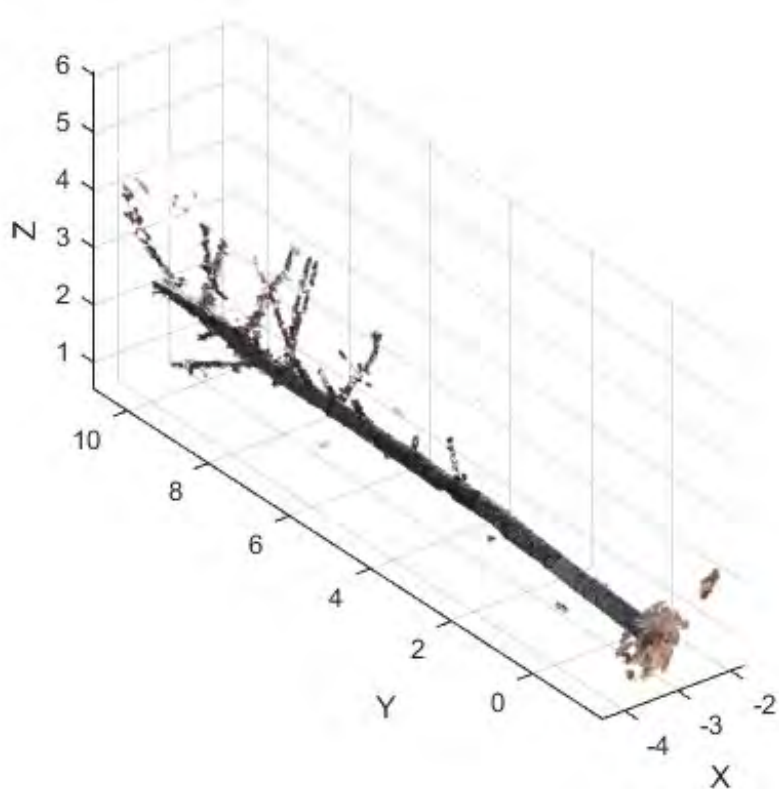


PPC: Vernon Parish  
Height: 15.1 m  
#points: 1.34 mil



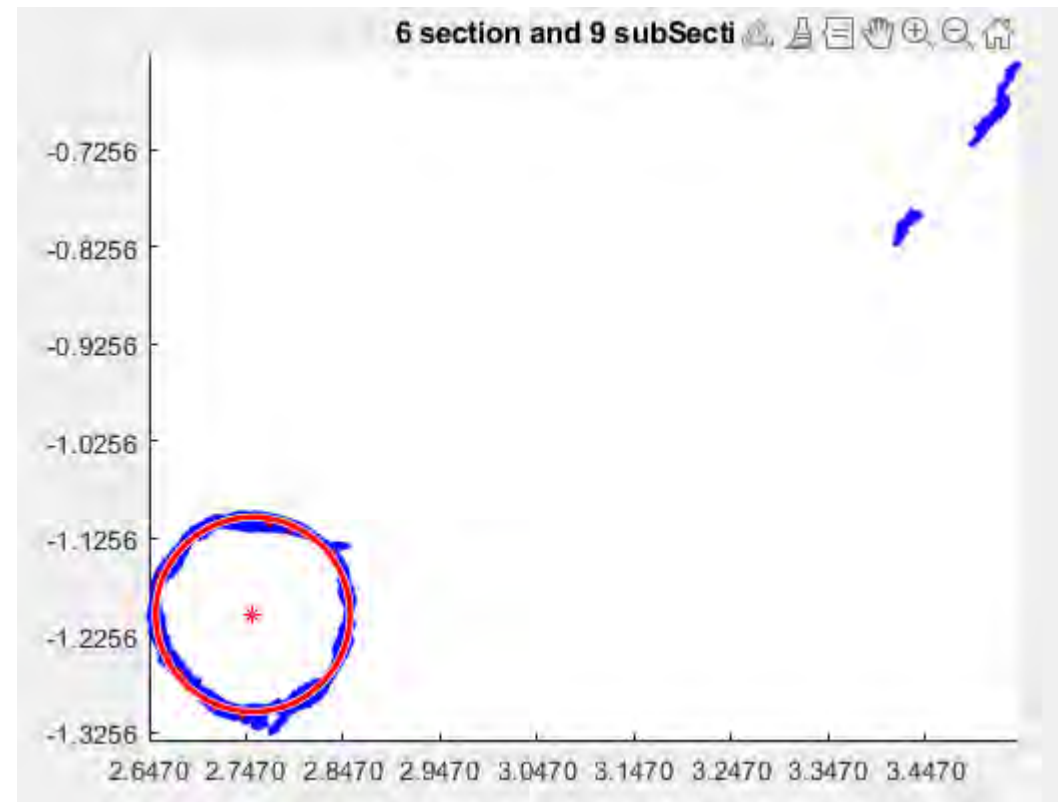
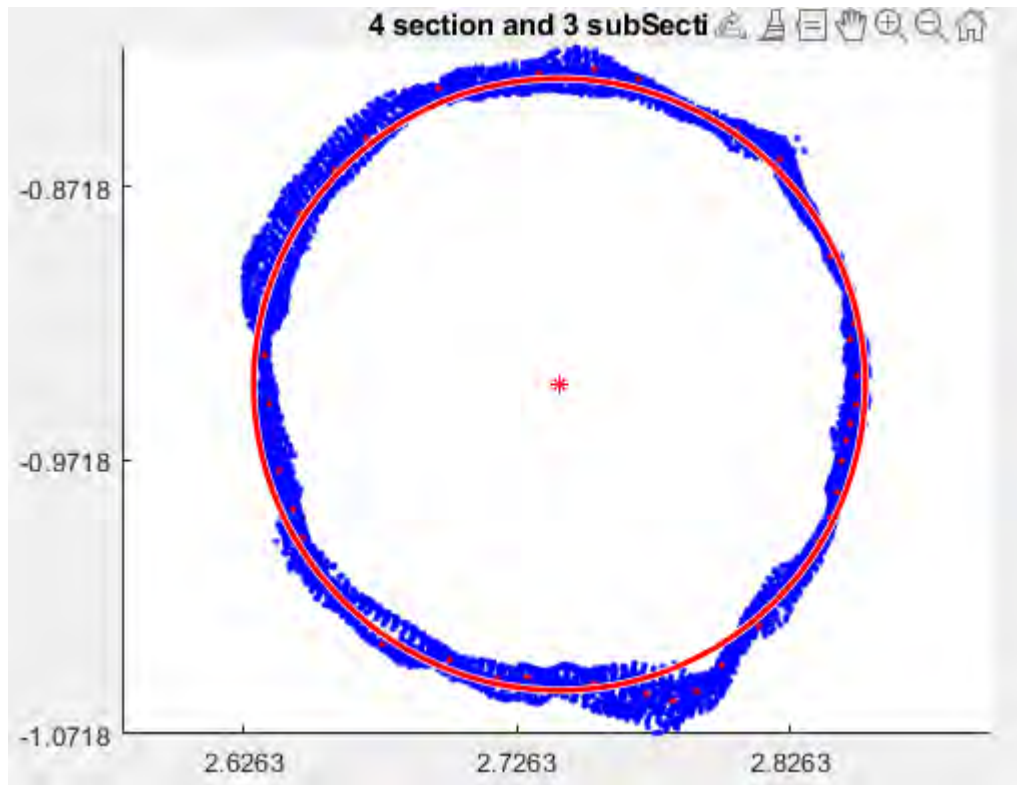
# Verticalize the tree

- Fit a cylinder with points on the lower portion of the stem
- PCA to identify main stem direction



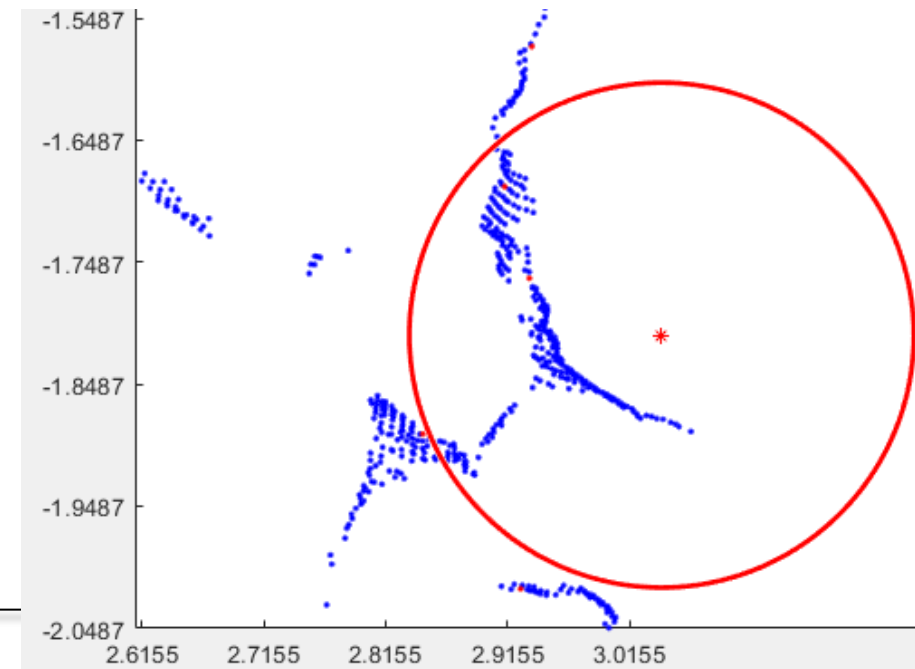
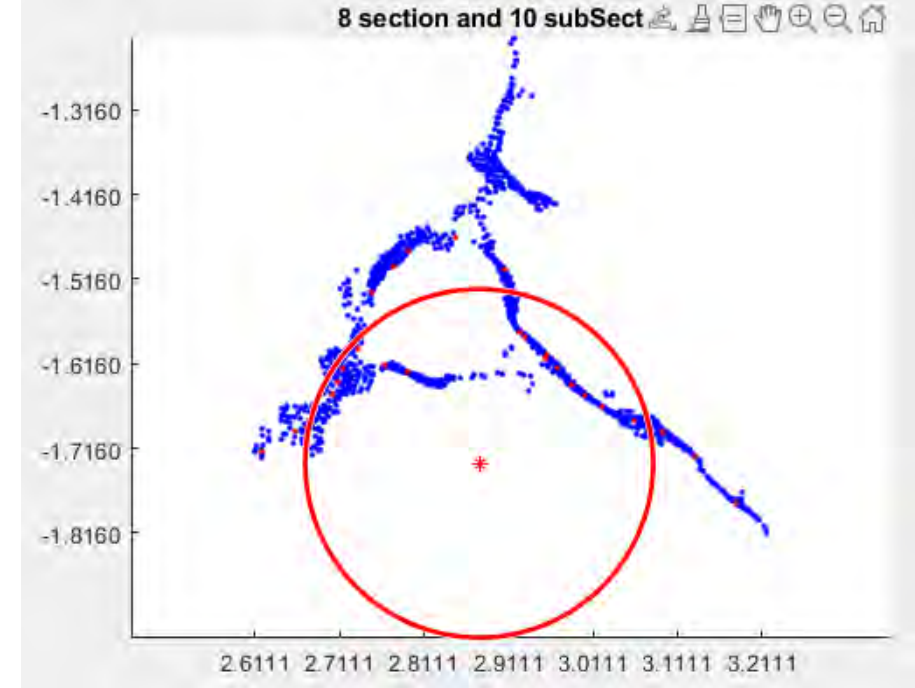
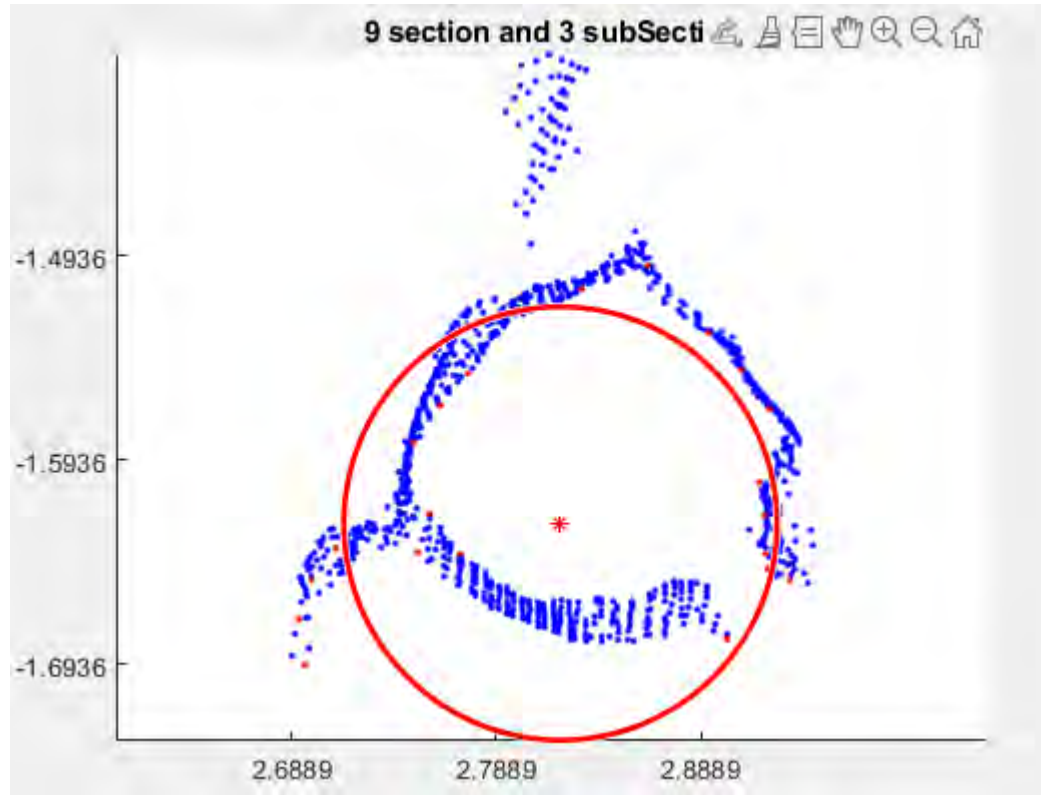


# Initial results





# Initial results (2)





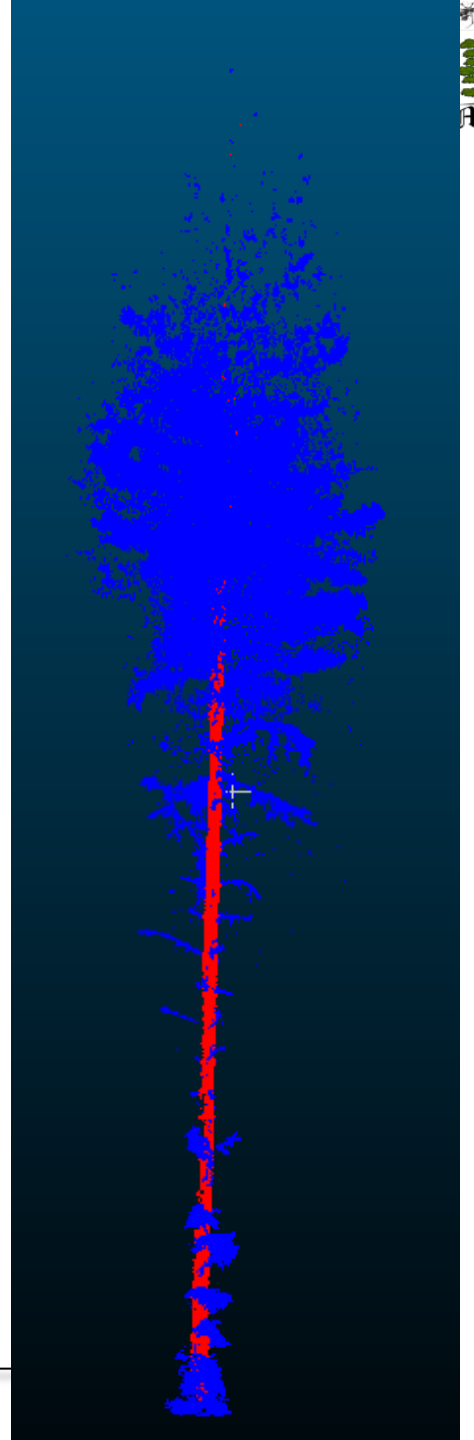
# Initial Results (3)

- Contradictory results
- Below main canopy: diameter bias
  - TLS: 2 mm
  - HLS: 4 mm
  - PPC: 2 mm
- Inside canopy: more than 25 cm
- **Issue: stem points not identified**



# Classify point cloud

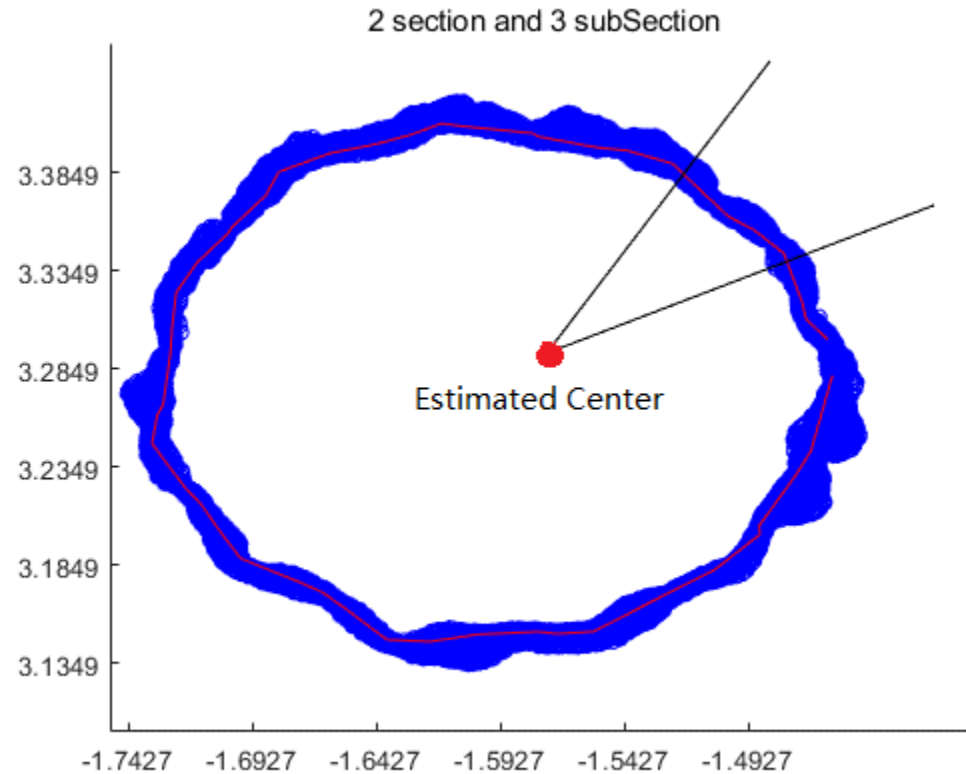
- Algorithm performs as expected IF stem identified
- Classify the points before measurements
- PointNet++
  - multilayer perceptron (MLP) artificial neural network
  - the information moves only forward
  - the connections between the nodes are not cyclic







# Improved algorithm



Classify points

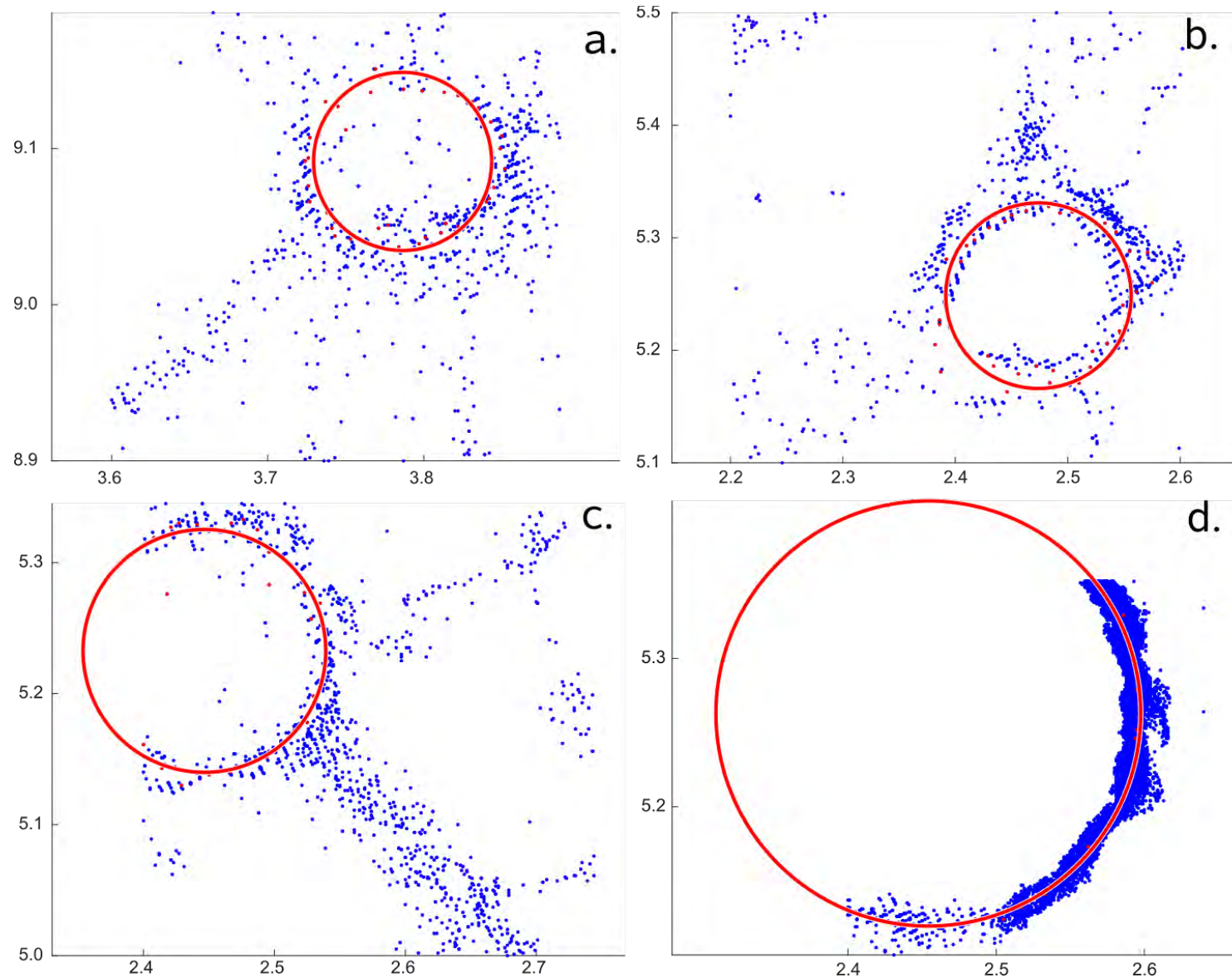
Section the stem

Select representative points

Fit Circle



# Final Results





# Results

Tree	Point cloud	DBH	Diam. Bias	Tree height	Height Bias	Lean / Sweep Bias	Volume Bias	# Points
		cm	mm	m	m	degree	m <sup>3</sup>	Million
1	TLS	51.0	1.7	47.3	-0.2	<1	-0.14	2.40
2	HLS	47.5	2.7	45.1	-0.3	<1	-0.22	1.34
3	PPC	16.4	1.8	12.4	-2.7	<1	-0.15	0.24



# Conclusion

- Accurate results
  - Diam: <2 mm
  - Volume: <0.25 m<sup>3</sup>
- Classification makes a difference
  - Trim branches to eliminate outliers - without classification
- Suitable for valuable trees (research)
- Code free at the end of May
- Not very fast

