Affordable air-ground mobile mapping system for precise forestry applications

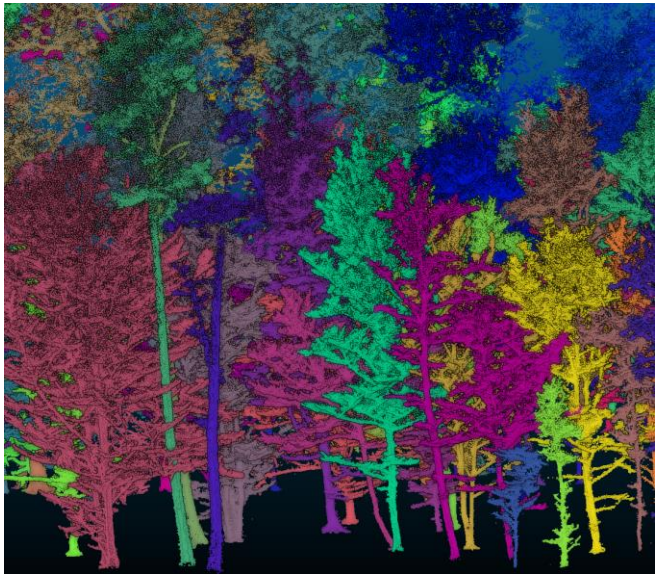
J. Będkowski[1], **M. Kulicki[1,2]**, K. Stereńczak[3], M. Matecki[1]

1. IPPT PAN, 2. IDEAS NCBR, 3. Forest Research Institute

EuroCOW, Warsaw 16-18.06.2025

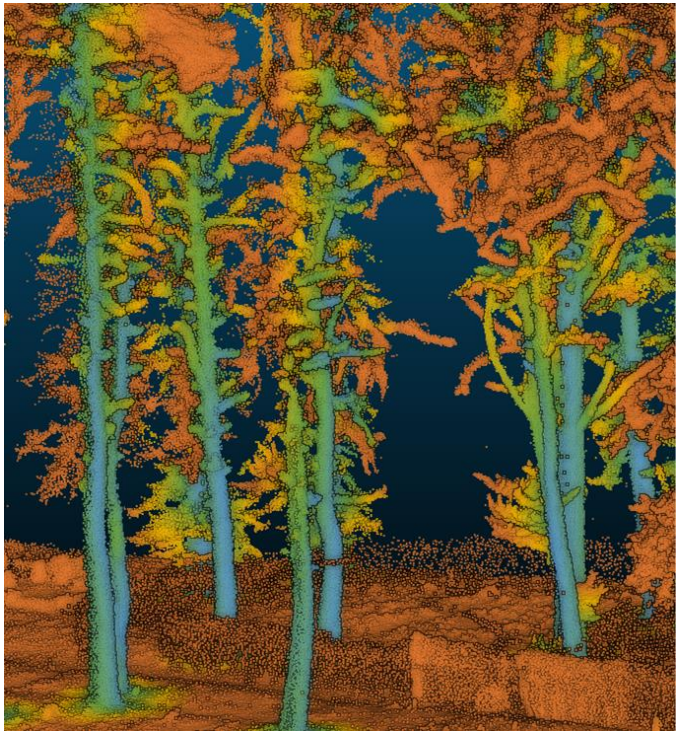
Precision forestry using close-range LiDAR

- Traditional forest inventory: labor-intensive, basic variables only, sampling-based
- Our solution: high detail scans of individual trees using close-range LiDAR
- Affordable air and ground mapping system
- Fast, precise, many attributes can be derived
  - Tree species
  - Biomass
  - Timber volume
  - Stem shape
  - Health assessment



Our forest mapping solution

- Low-cost LiDAR hardware
- Shoulder-mounted and UAV-based platforms
- Open-source mapping software: https://github.com/MapsHD/HDMapping
- Open-source tree detection software: https://github.com/3DFin/3DFin



Device: Mandeye MLS

- LiDAR: LiVOX MID 360
- Compute module: Raspberry Pi 4
- DJI Battery BG70
- Custom chassis
- Original design: handheld (with optional TLS)

LiDAR parameters: LiVOX MID 360

- laser Wavelength: 905 nm,
- detection Range: 40 m at 10% reflectivity, 70 m at 80% re
- close proximity blind zone: 0.1m
- field of view: horizontal: 360°, vertical: -7° 52°,
- range precision: 2 cm (at 10m),
- point rate: 200,000 points/s (first return),
- weight: 265g,
- scanning pattern: non repetitive.

Mapping software: HDMapping

- Open source (MiT licence): https://github.com/MapsHD/HDMapping

Main tools:

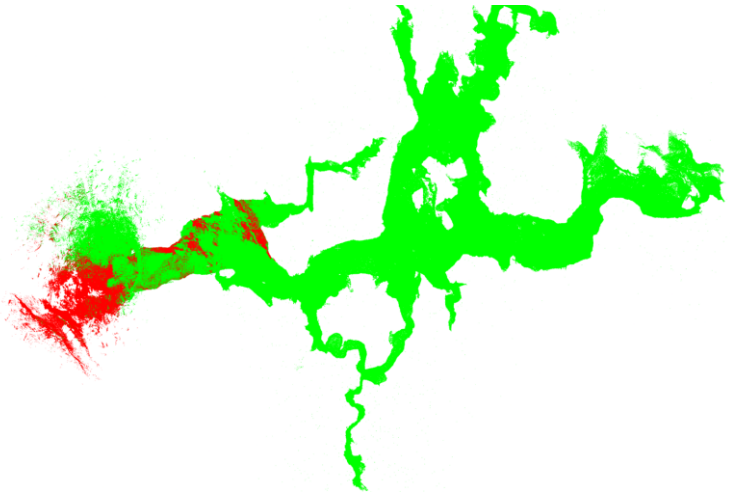
- Initial trajectory estimation (LiDAR odometry)
- Single trajectory refinement (minimizing drift, pose graph SLAM)
- Multiple trajectory refinement (fusion of different sessions)
- Georeferencing (trajectory refinement using GNSS fixed points)

Novel setup: Double Shoulder-mounted LiDAR

Multi-scanner Calibration (Shoulder mount)

- Rigid base
- Initial Calibration using ICP
- Single IMU source
- Synchronised scanning based on timestamps
- Unified wide angle data stream

Novelty: high mobility for extreme environment mapping



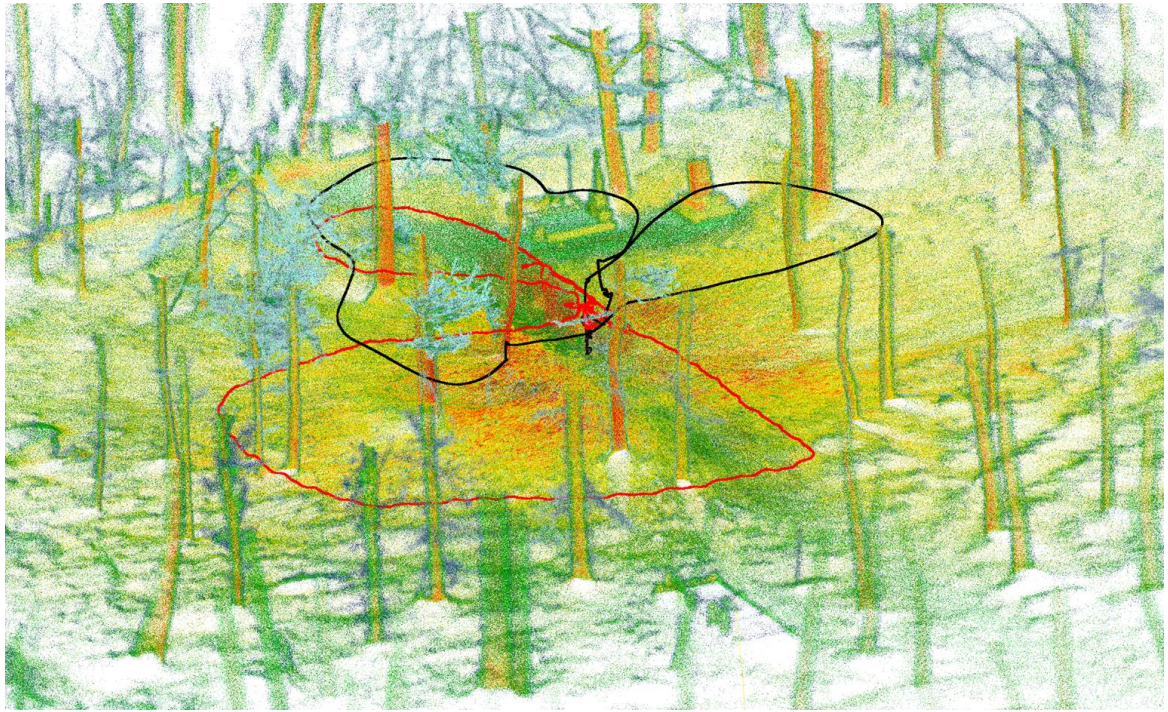
UAV LiDAR setup

- DJI Avata 2 (250g + 350g payload)
- Consumer-grade
- FPV controlled
- up to 5 minutes flight with payload

Possibility of over and under canopy fusion

Figure: Fekry et al., 2022 – Ground-based/UAV-LiDAR fusion for tree modeling in subtropical forests, *Forest Ecosystems*, 9, 100065. https://doi.org/10.1016/j.fecs.2022.100065

Early field trial: shoulder-mount + UAV



Red line: shoulder-mounted trajectory, black line: trajectory obtained from UAV

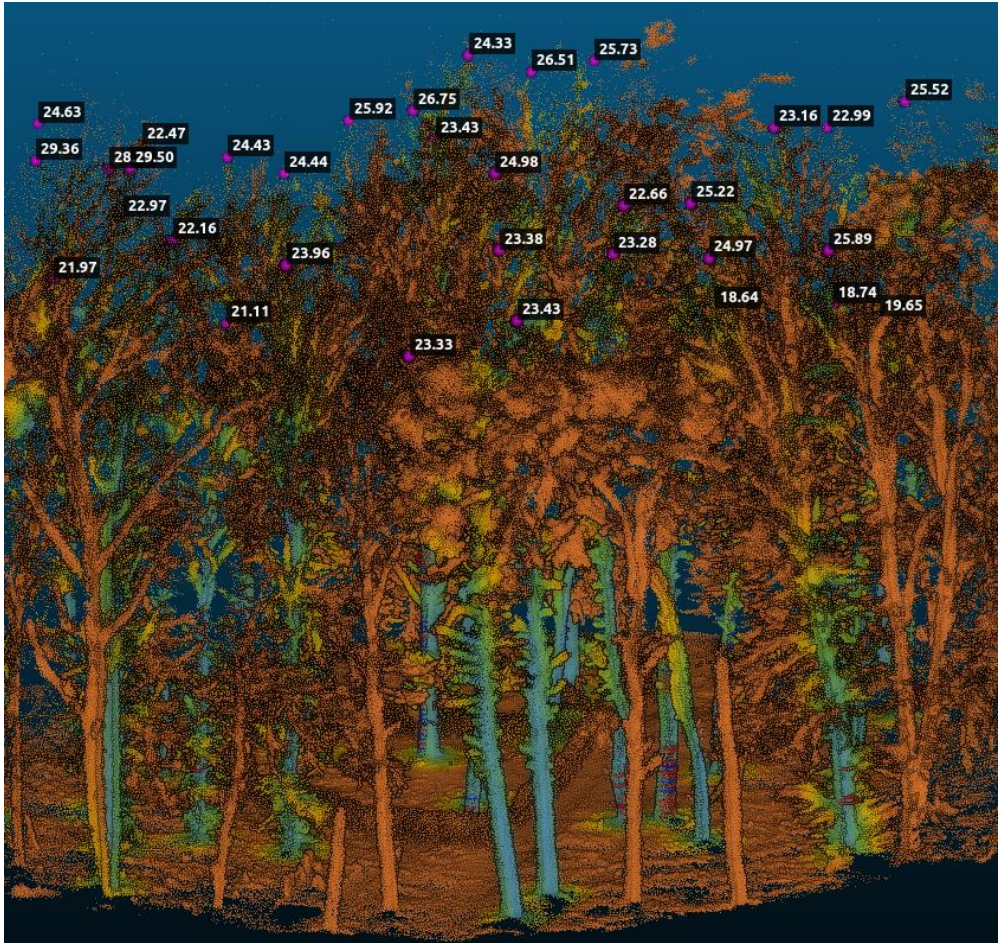
3D view of the scanned plot

3DFin - automated tree detection

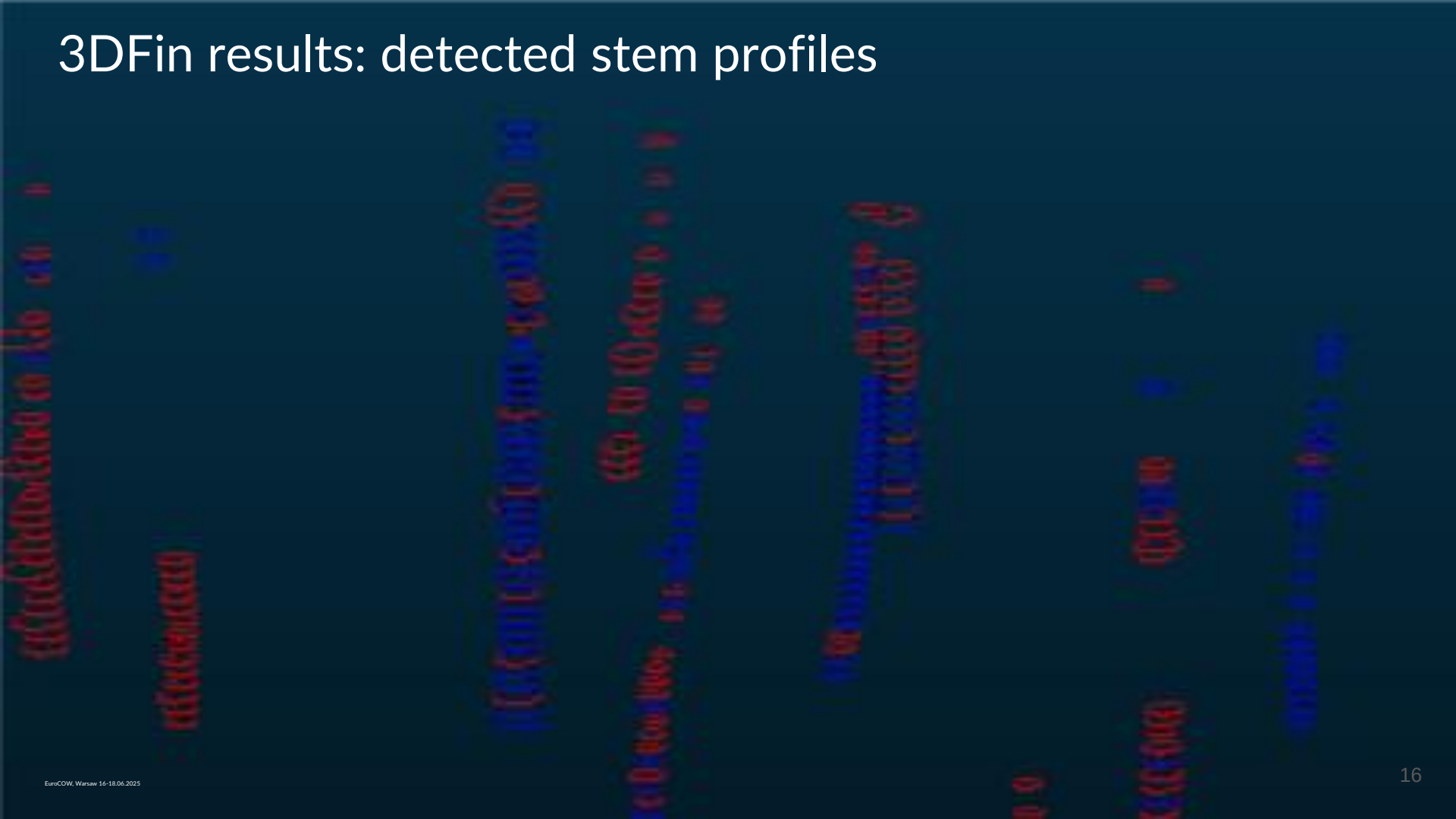
- CloudCompare plugin and python library
- Ground normalization
- Tree stem detection
- Estimates diameter, stem angle, tree height

Laino, D. et al. (2024). 3DFin: a software for automated 3D forest inventories from terrestrial point clouds. Forestry: An International Journal of Forest Research. https://doi.org/10.1093/forestry/cpae020

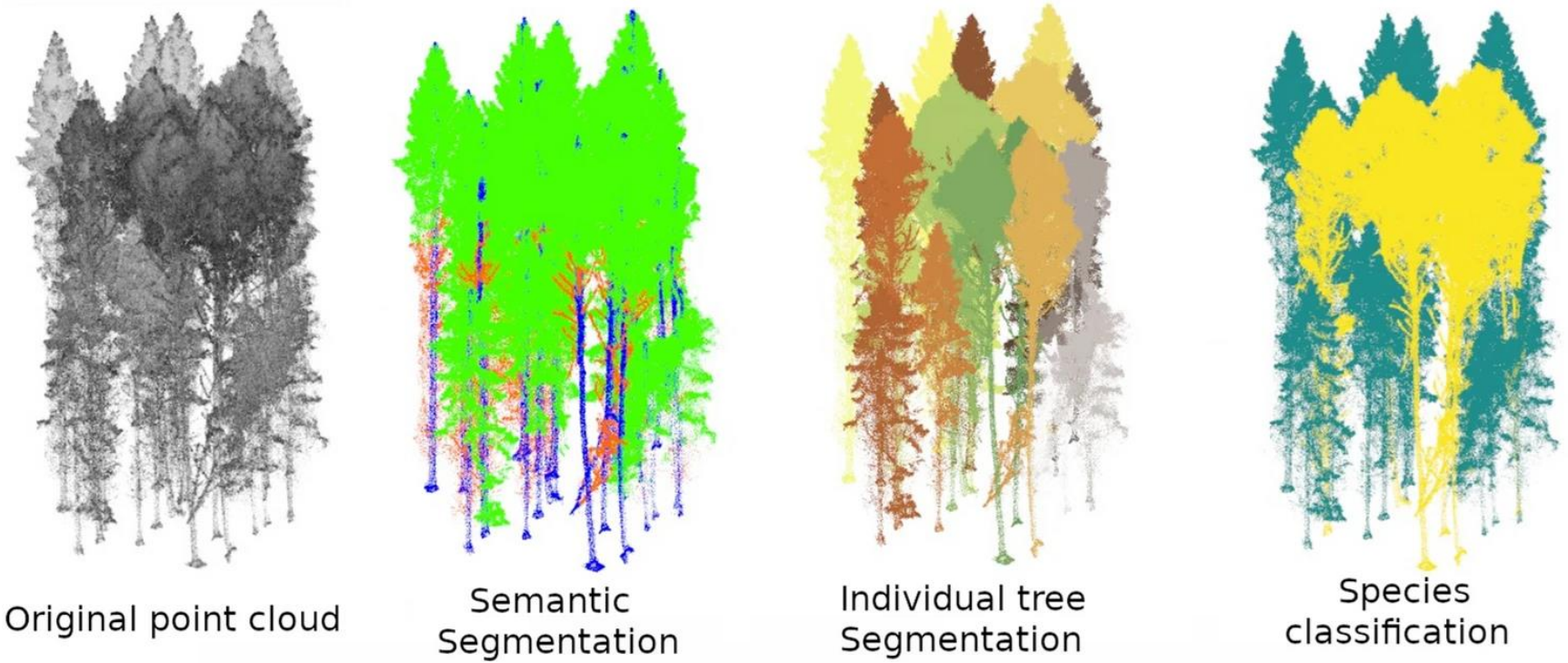
3DFin results: tree detection & height



3DFin results: detected stem profiles



Concurrent work: Deep Learning data processing



Kulicki, M., Cabo, C., Trzciński, T. *et al.* Artificial Intelligence and Terrestrial Point Clouds for Forest Monitoring. *Curr. For. Rep.* 11, 5 (2025).

Summary

- Novel affordable air-ground forest mapping solution
  - Double LiDAR shoulder-mounted
  - Lightweight consumer grade UAV
- Based on open-source mapping software:
- Integrated with 3DFin tree detection


Thank you for attention!
Contact: maksymilian.kulicki@ideas-ncbr.pl
EuroCOW, Warsaw 16-18.06.2025