Bulk density of wooden materials char determined by photogrammetry

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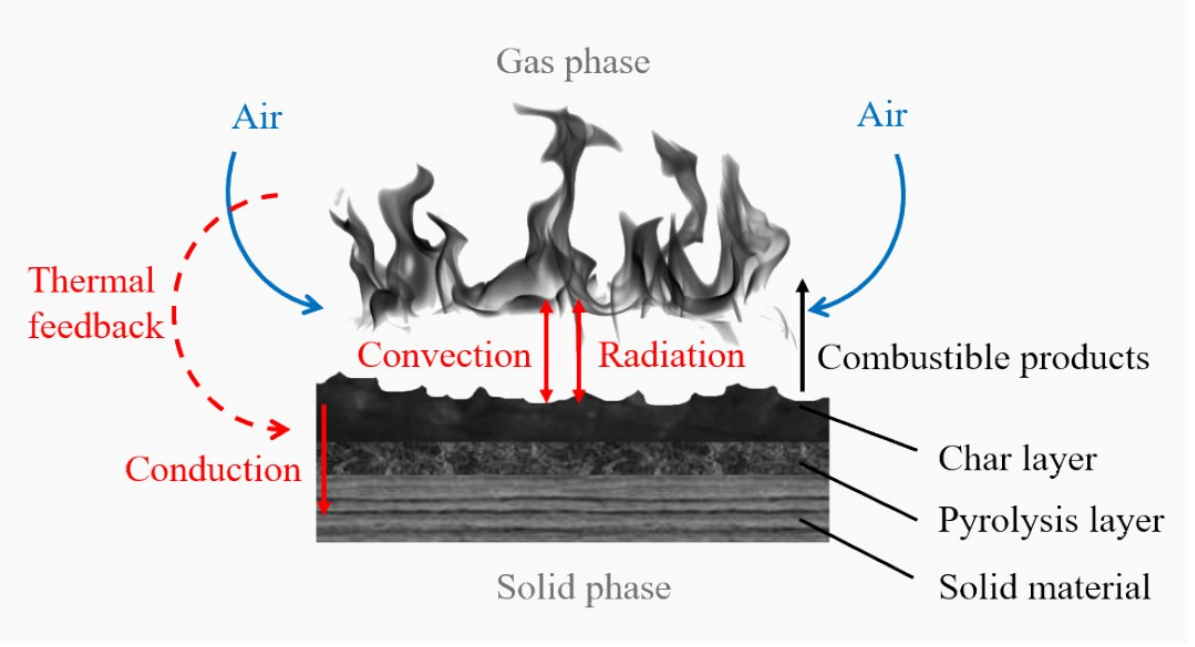
Char

- By product of various solid material pyrolysis
- Typical for pyrolysis of wood and wooden products
- Mainly consisted of carbon
- Causes difficulties in numerical simulations of pyrolysis



Why is char a problem?

- Each substance occuring in the model has different physicochemical properties
- Char behaves as pyrolysis inhibitor
- Physicochemical properties of char are poorly known
  - $a = \lambda/(\rho \cdot c_p)$

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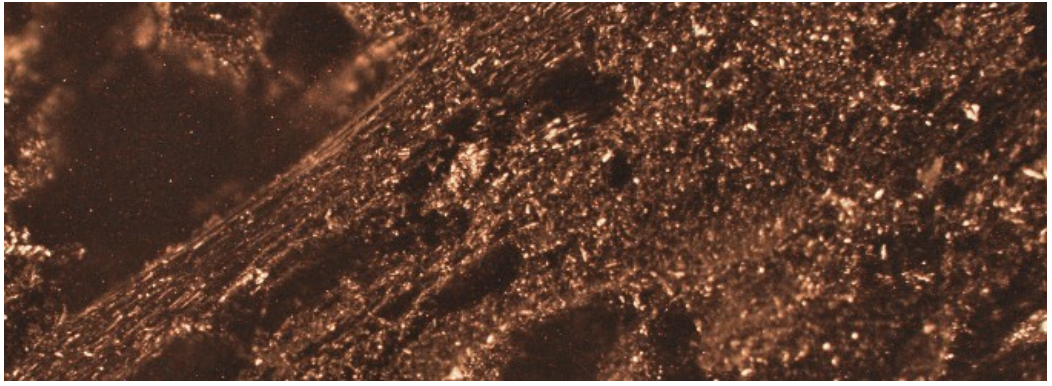
Density vs Bulk density

- Same units (kg/m^3)
- **Density** = mass over volume
- **Bulk density** = mass over volume defined by outer surface of sample including the volume of inner pores
- Char – highly porous and inhomogeneous
- Pores diameter < cells dimensions in the pyrolysis simulations
- **Main obstacle** – determination of sample volume

	Density (kg/m^3)	**Bulk density (kg/m^3)**
Amorphous carbon	1800 - 2100	-
Char	1400	150 - 500

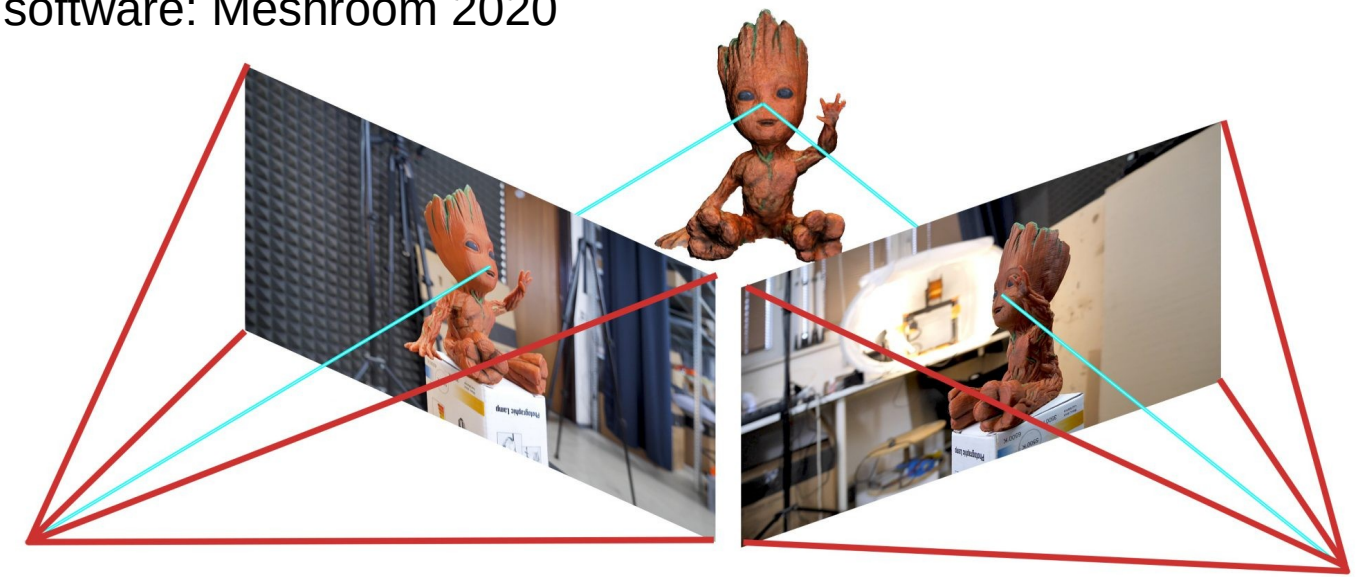


How can we measure the volume of char, respectively bulk density?

- **Methods in literature:**
  - gas/mercury porosimetry
  - pycnometry
  - immersion in liquids
- **Drawbacks**
  - time consuming
  - samples destruction
  - liquids flows into macropores

Photogrammetry

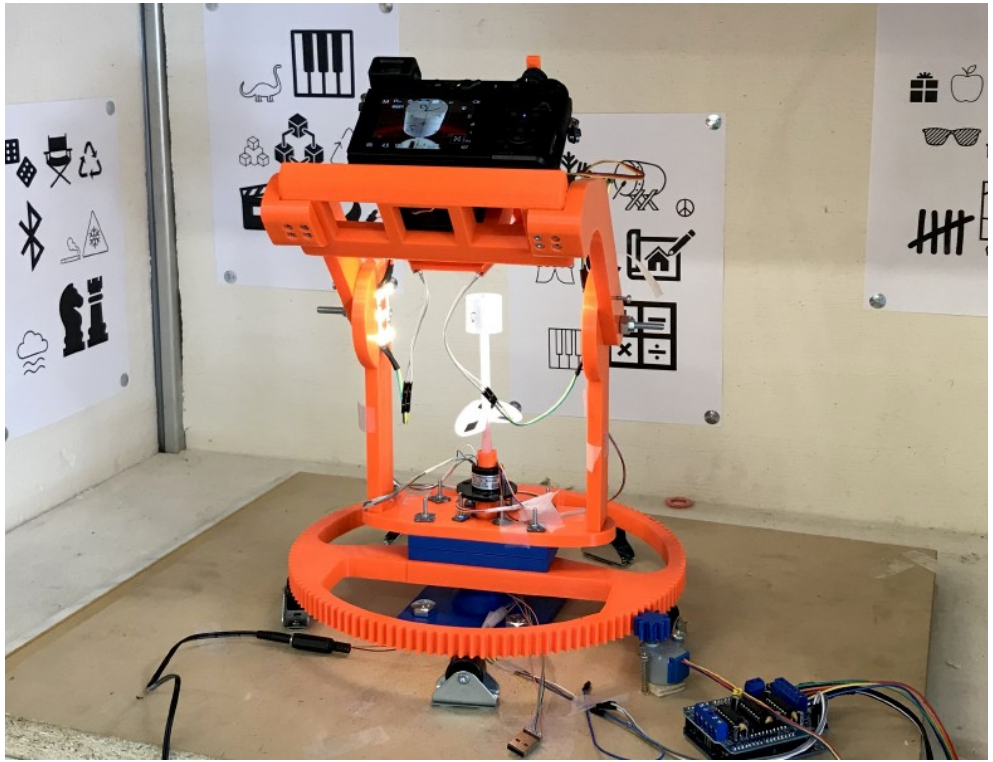
- Contactless method
- 3D reconstruction from multiple photographs of the measured object
- Essentials: Video card with CUDA (GTX and RTX series)
- Used software: Meshroom 2020

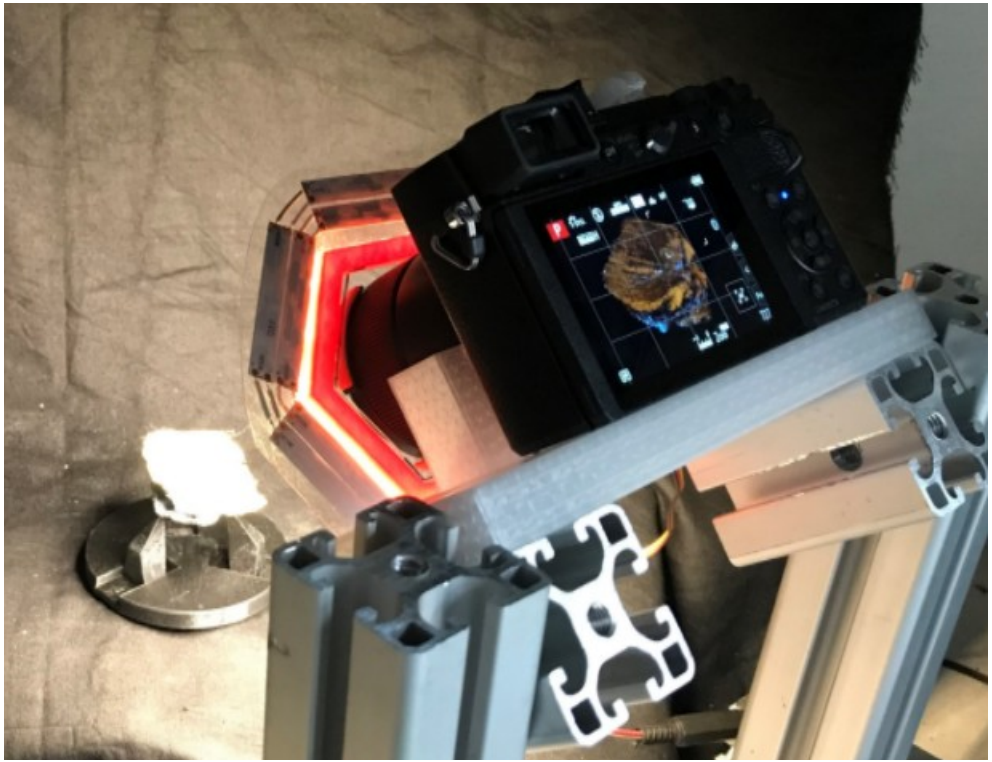


Photogrammetry – multiple photos

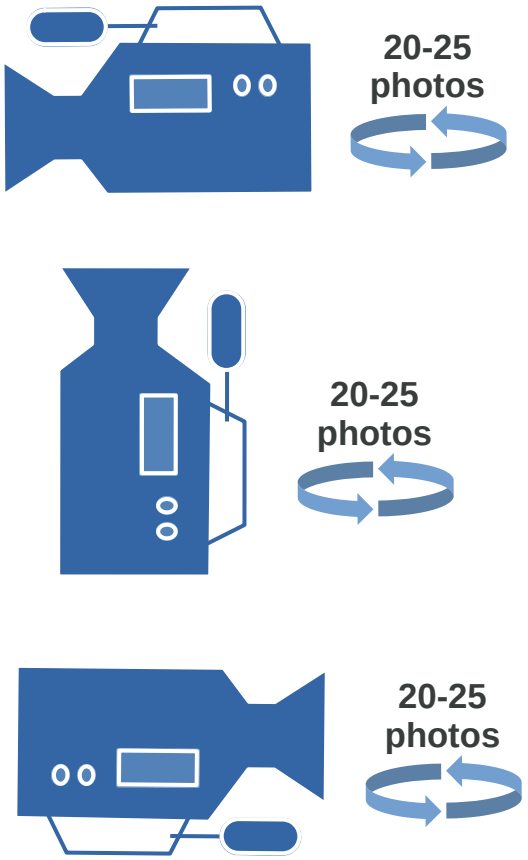
- ~ 60-70 photographs from various angles
- Photos must cover the whole surface of measured object
- Photos must overlap
- Automated rig was developed

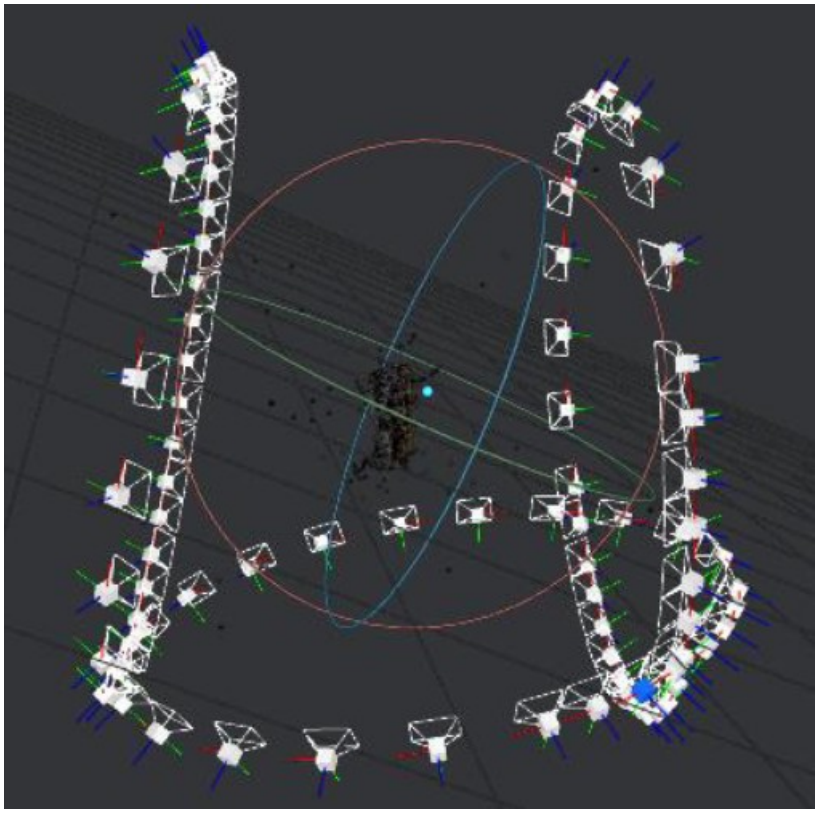
Former vs current rig





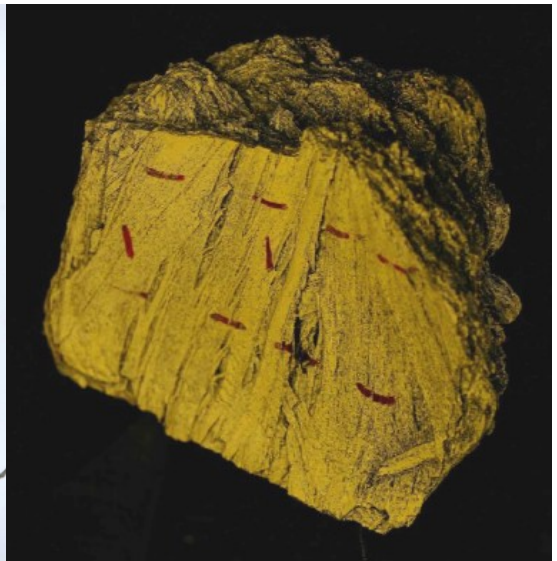
Sample positioning



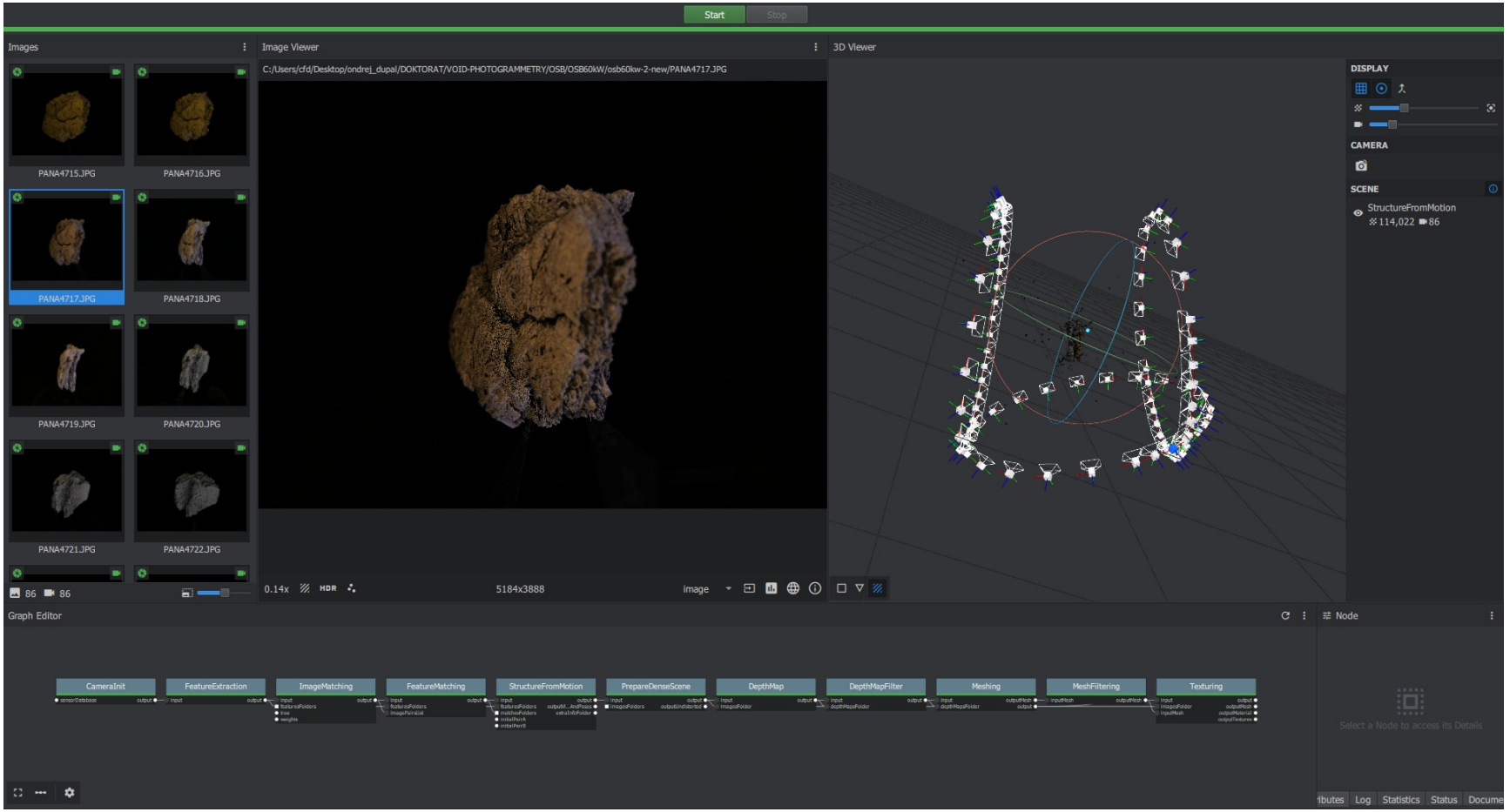


Sample preparation

- Cleaning of ash
- Dividing into smaller specimens
- Sandpapering (optional)
- Dying (essential) in chalk spray
- Reference marks
  - Distance 15 mm

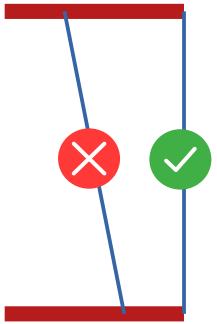


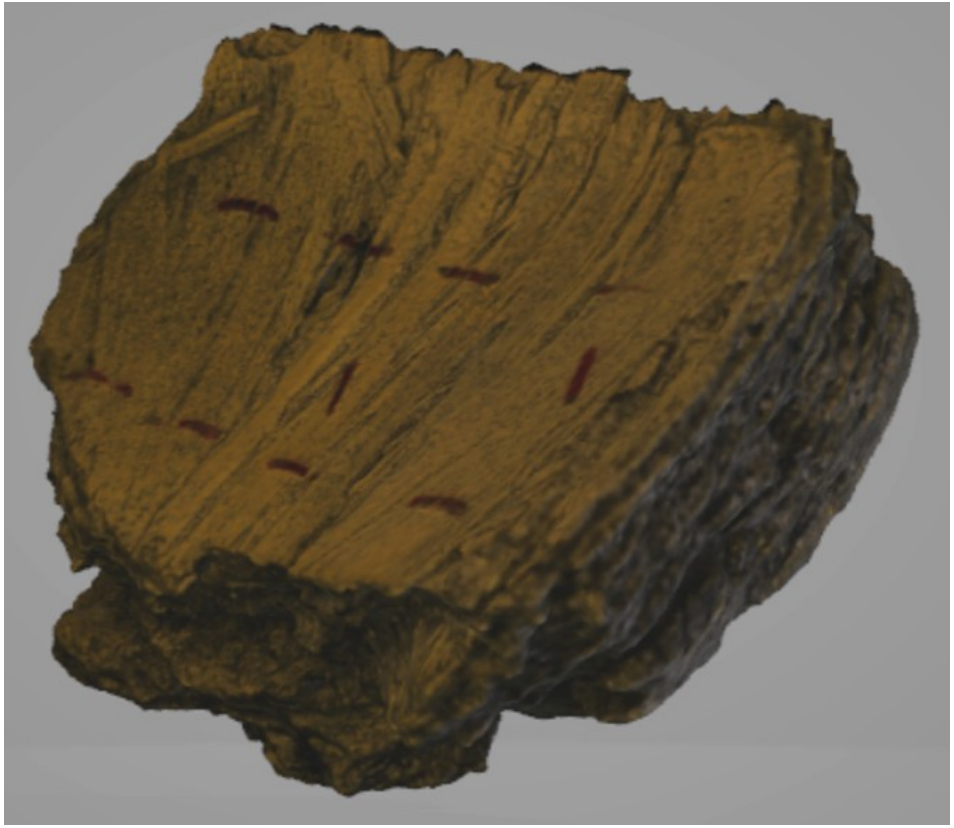
Software reconstruction



Scaling of 3D mesh

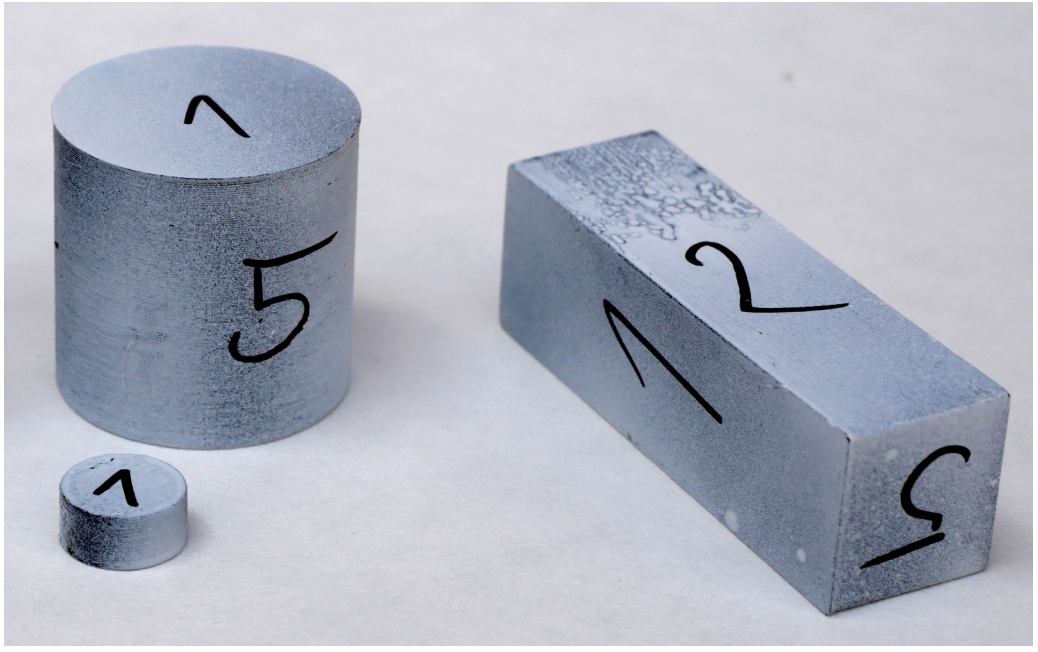
- In Meshlab
- Distance between red marks is always 15 mm
- Scaling ratio $\xi = x_0/15$
- Real volume $V = V_0 \cdot \xi^3$

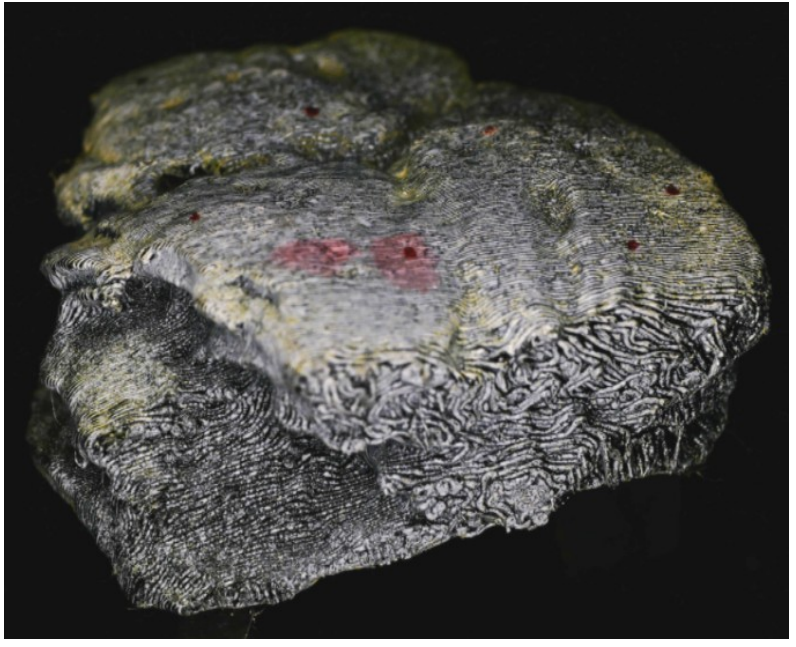




Measurement error estimation

- Simple shapes as prism, cube and cylinder
- Measurement of 3D printed char mesh





Impact of photos number on accuracy and time

- 3 rings ~ 70 photos
  - err < 3 %
  - 3 hours
- 4 rings ~ 100 photos
  - err < 2 %
  - **9 hours**

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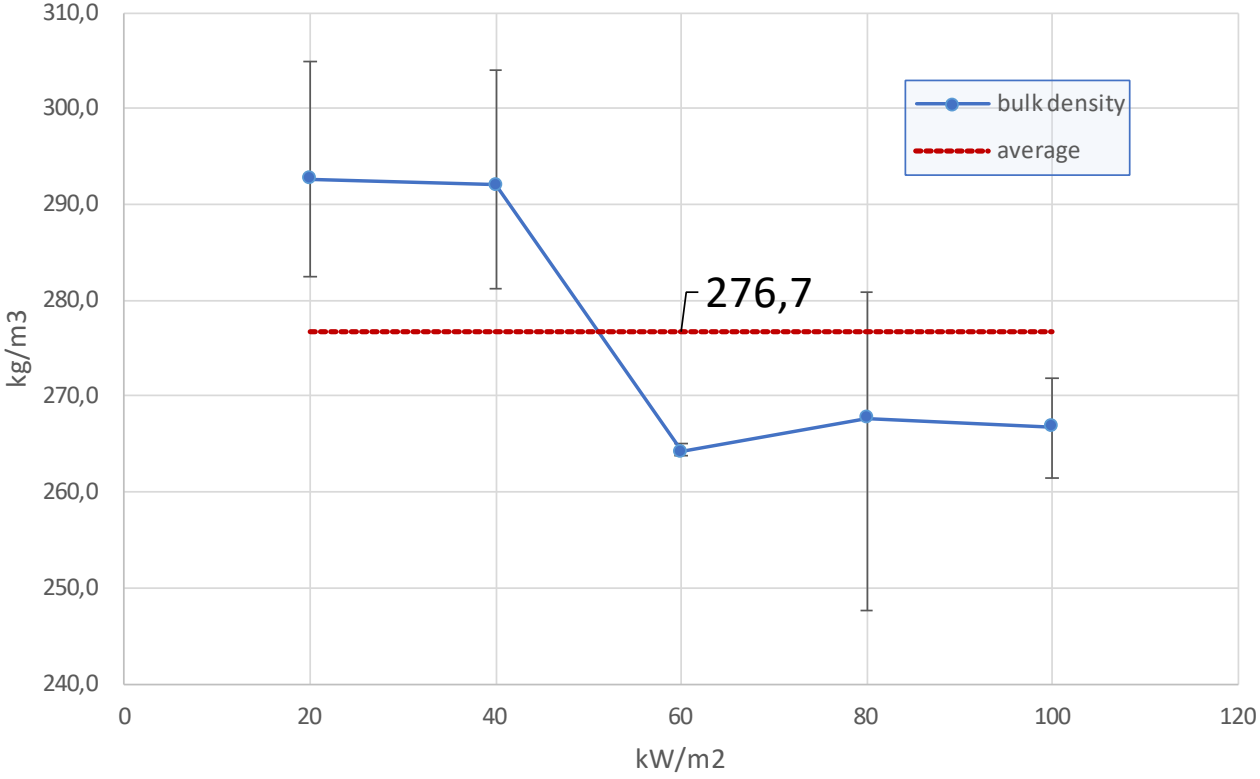
- Cylinder
  - err < 1 %

- Prism
  - err < 5 %
  - irregular mesh

Bulk density of OSB char

- Density of raw OSB ~ 600 – 680 kg/m3
- Density on surface > density inside the board
- OSB samples burnt in a cone calorimeter

Bulk density of OSB char



Conclusion

- Robust contactless method for volume, resp. bulk density determination
- Method not sufficient for
  - large flat surfaces
  - thin objects
- Future goals
  - Measure char bulk density of spruce, MDF and other wooden materials

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