Pushing the boundaries for drone-based blade imaging
- measuring from an airborne platform

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Disclaimer: work in progress

Everything is relative,…
but relative to what?

Overview of presentation

- Who am I?
- The LER Blades research project
- The equipment
- Image-based 3D reconstruction (photogrammetry, structure-from-motion,…)
- Sub-millimeter precision 3D reconstruction of leading edge segments
- Determining absolute scale
- Fusing LiDAR data to a common coordinate frame
- Outro

Who am I?

- Associate professor at Aalborg University
- Does research in Computer Vision and Computer Graphics
- Absolutely no real experience with wind turbines
- Drone “research” is a rapidly growing thing in our department
- … but what is drone research, really? We use drones as a vehicle for getting the sensors to places where it could not otherwise go

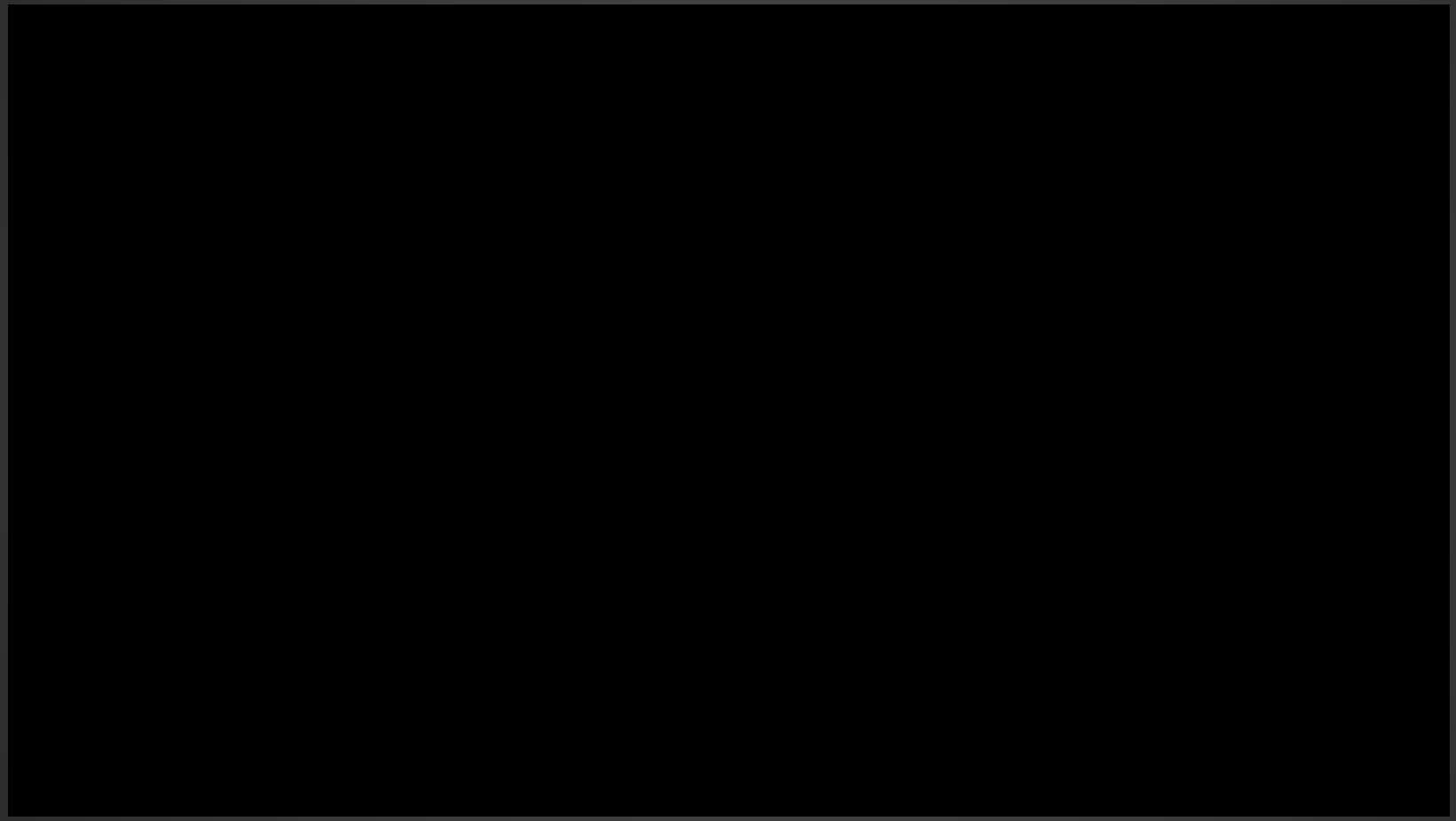
The LER Blades project

- Leading Edge Roughness on wind turbine blades
- Funded by EUDP, approx. 16 MDKK
- Partners:
  - Power Curve Aps
  - DTU Wind
  - Aalborg University
  - Danish National Metrology Institute
- Project period: October 1, 2015 to March 31, 2019

Project vision

- Inspect parked turbine using camera mounted on drone
- Perform high-resolution 3D reconstruction of leading edge patches
- Compute roughness parameters/descriptors
- Map roughness descriptors to loss in Annual Energy Production

Video demonstrating the concept



Equipment

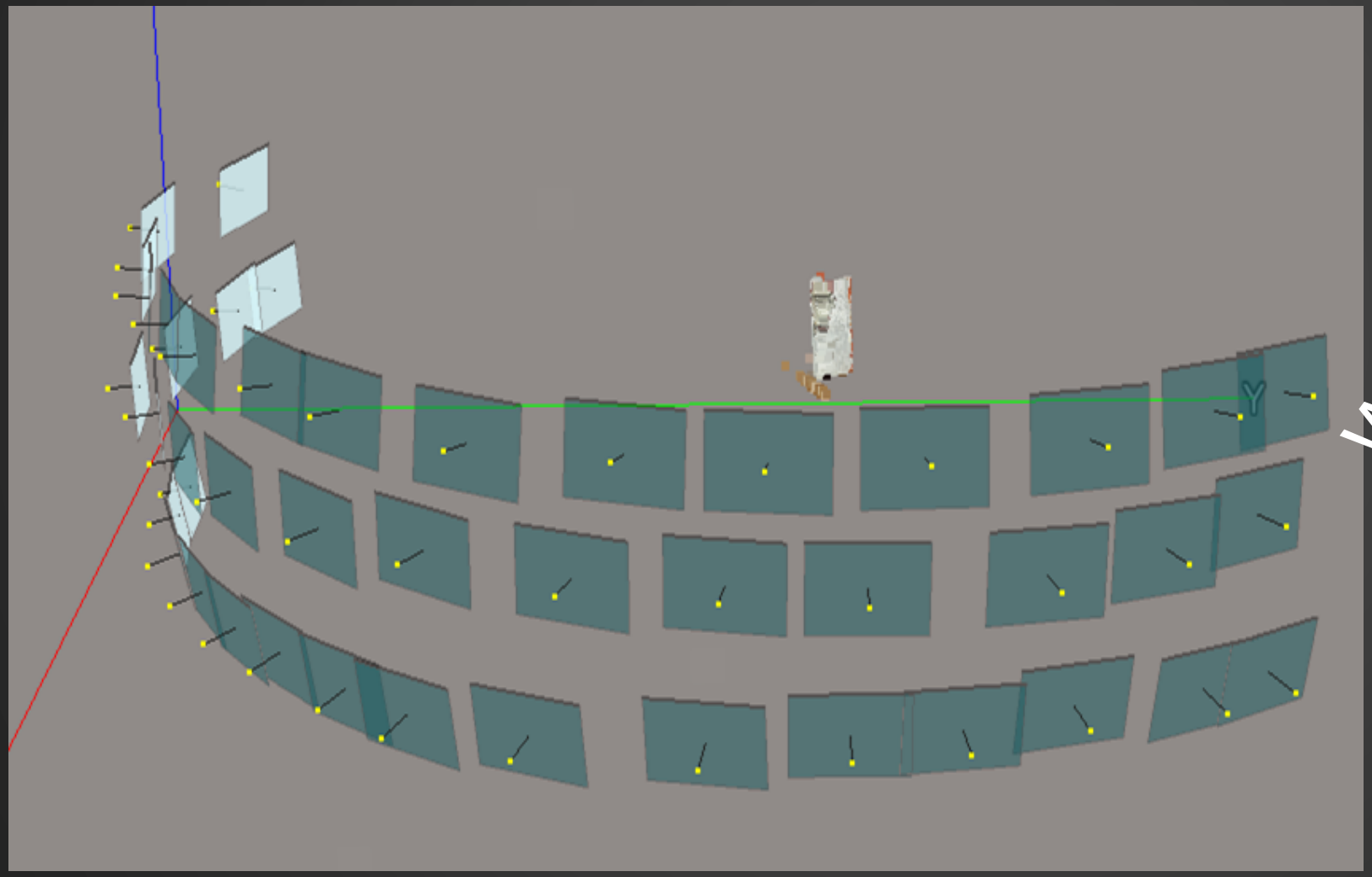
- Drone: DJI Matrice 600 Pro airframe, 6 rotor, A3 controller
- LIDAR: Hokuyo UTM-30LX
  - Range = 100 mm to 30000 mm
  - Scanning area = 270 degrees
  - Angular resolution = 0.25 degrees
  - Speed = 25 milliseconds per scan (40 revolutions per second)
  - Accuracy = +/- 30mm

Camera: Canon 5Ds, 50 Mpixel, 70-300 mm zoom lens, set at 260 mm

Drone flight controller: GPS based with an RTK module addition, resulting in approximately 10 mm accuracy in all three dimensions

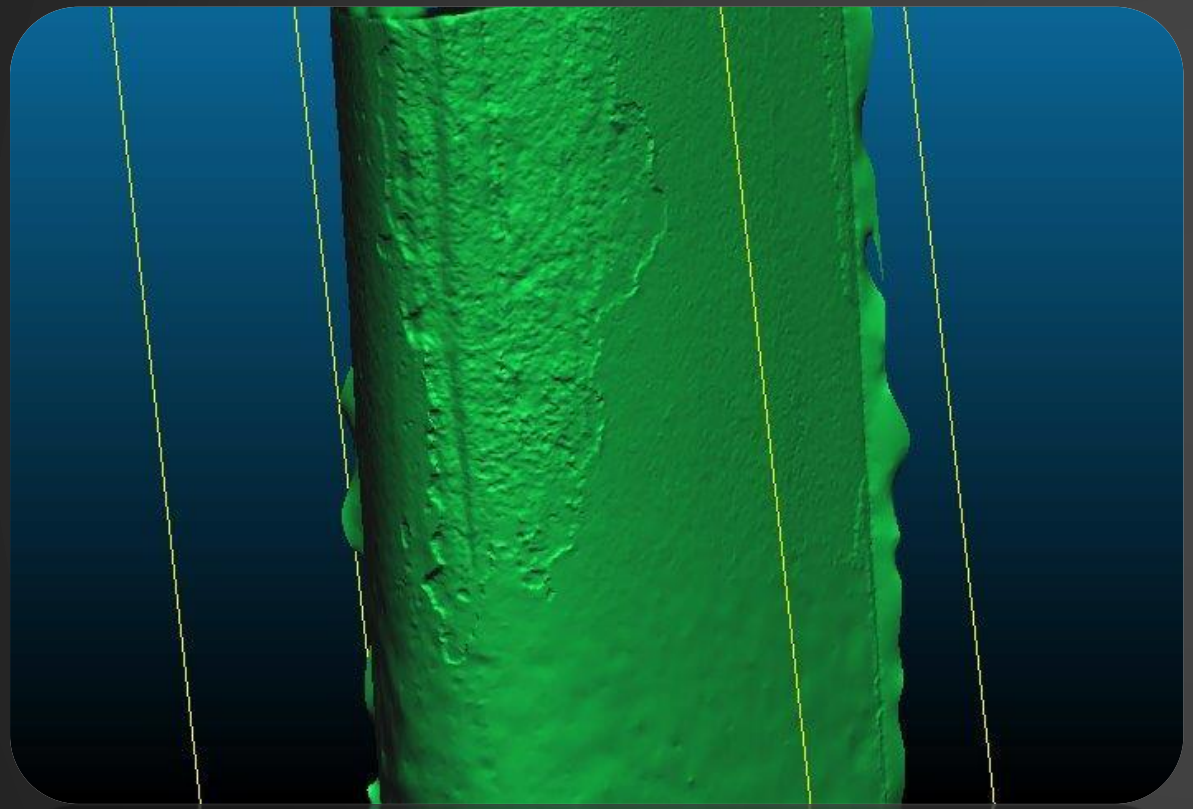
Target acquisition distance to blade: 2 m (effective pixel size is about 25 micrometer on the blade with these settings)

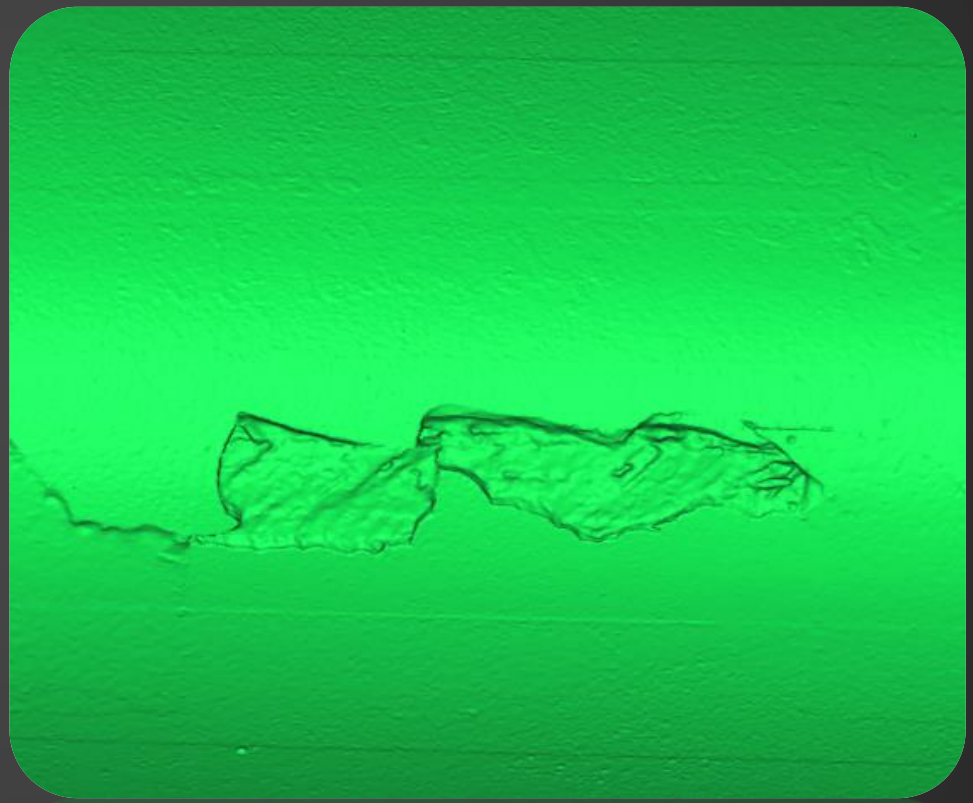
Multi-view 3D reconstruction
Photogrammetry
Structure-from-Motion (SfM)



We use ContextCapture or PhotoScan

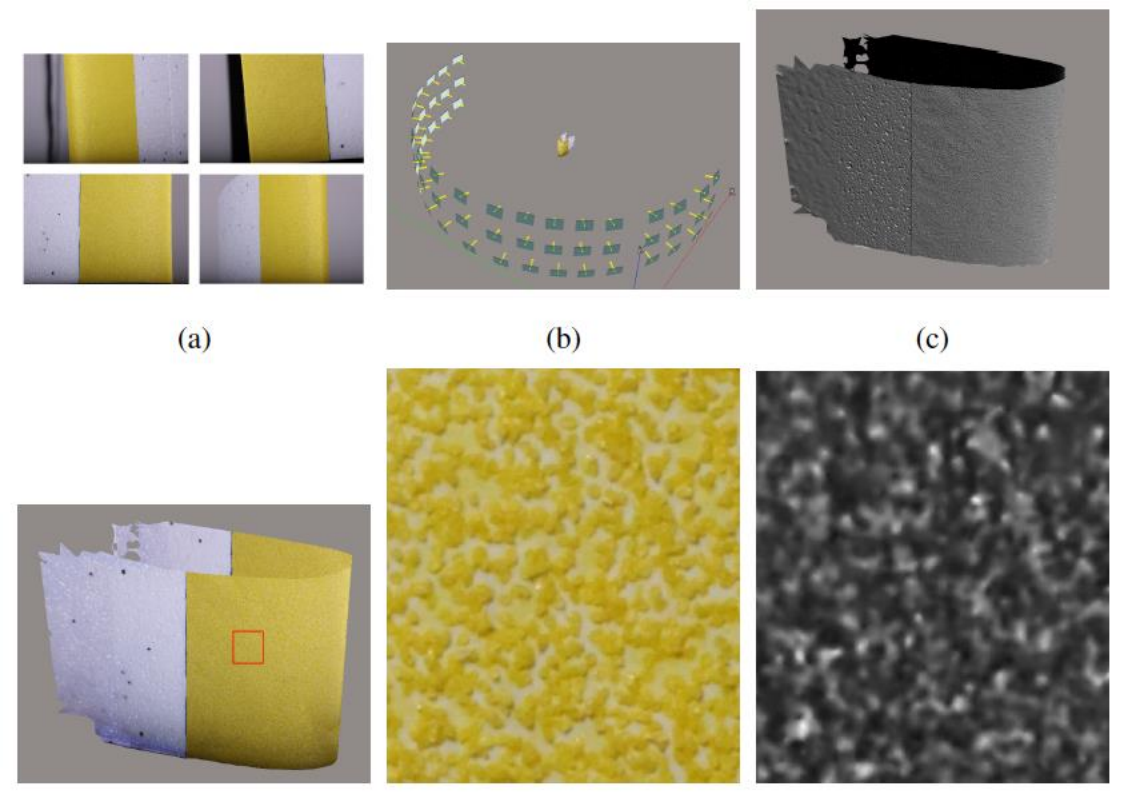
Examples of result





”limit” for SfM…

Validation of measurements?



Grit size	Nom. av. diam. (μm)
P40	425
P60	269
P80	201
P100	162
P120	125
P180	82
P240	58.5

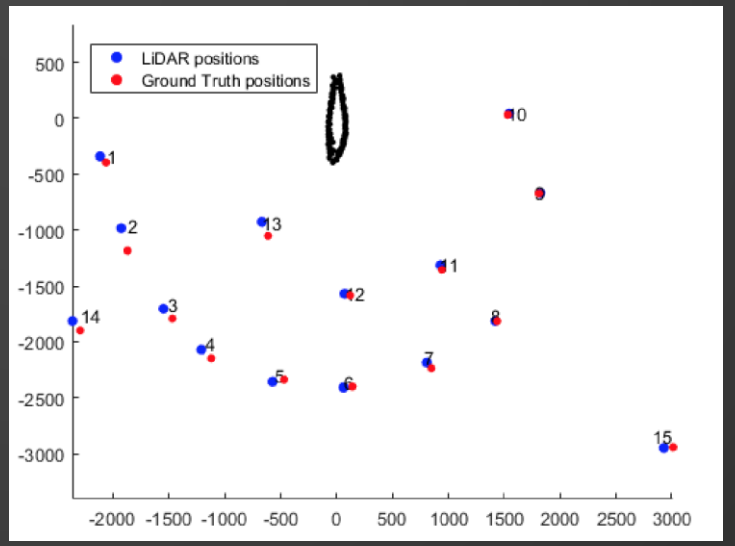
Paper being submitted with Mikkel Schou Nielsen and Jørgen Garnæs from DfM, and Ivan Nikolov from AAU

P60 sandpaper reconstruction

25mm by 50mm patch

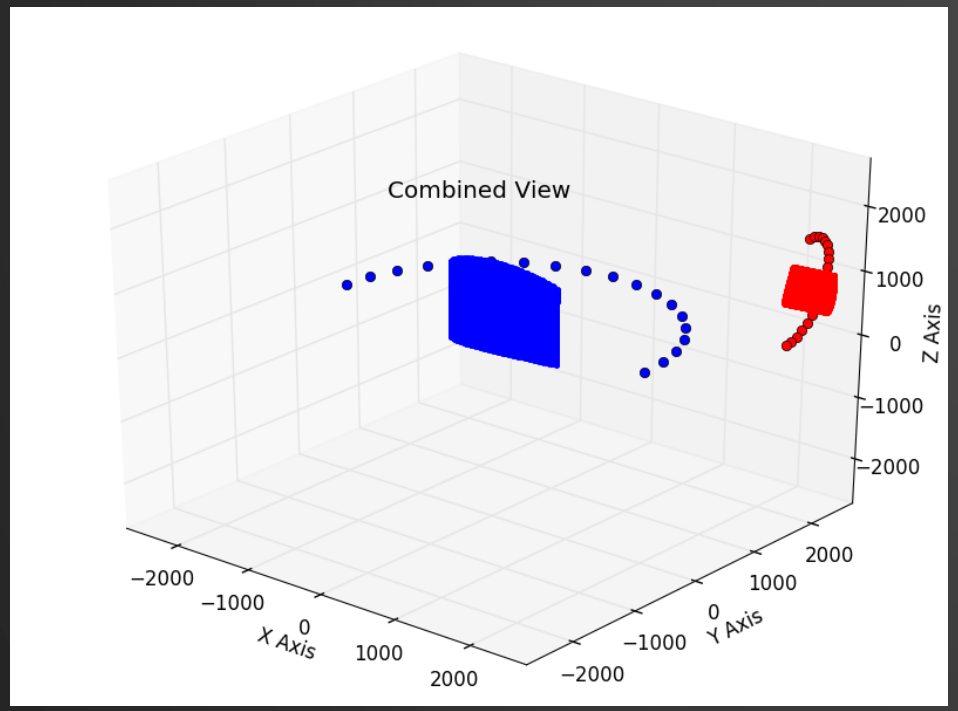
How to avoid bumping into blade?

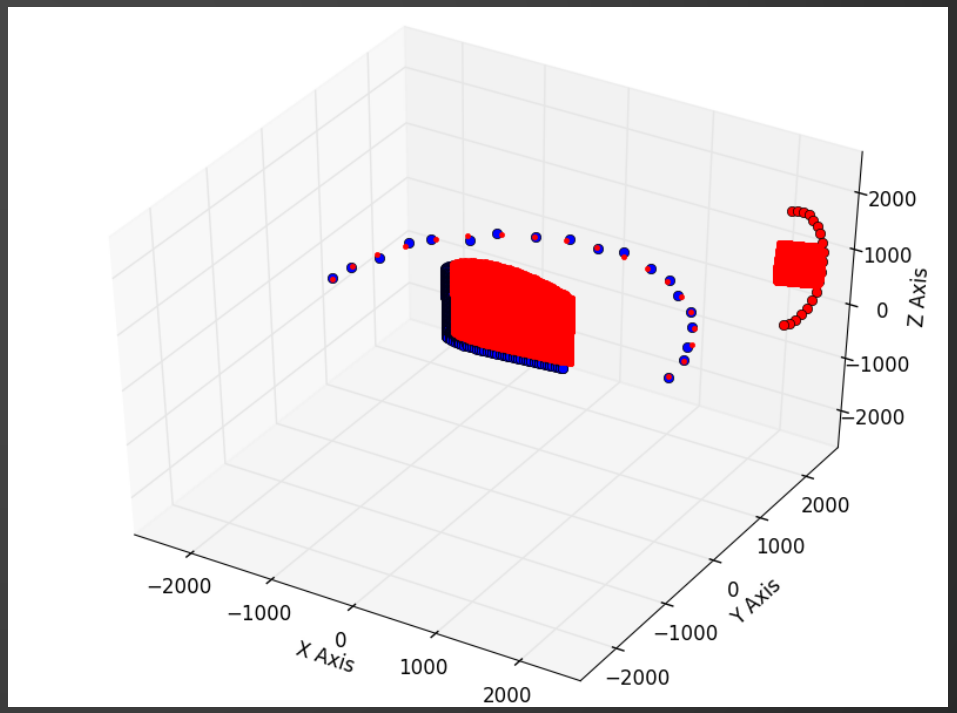
- Manual control of drone is not realistic
- RTK GPS module has high accuracy, but low update rate and the blade is moving in the wind
- Solution: use LIDAR data for localizing drone position in coordinate



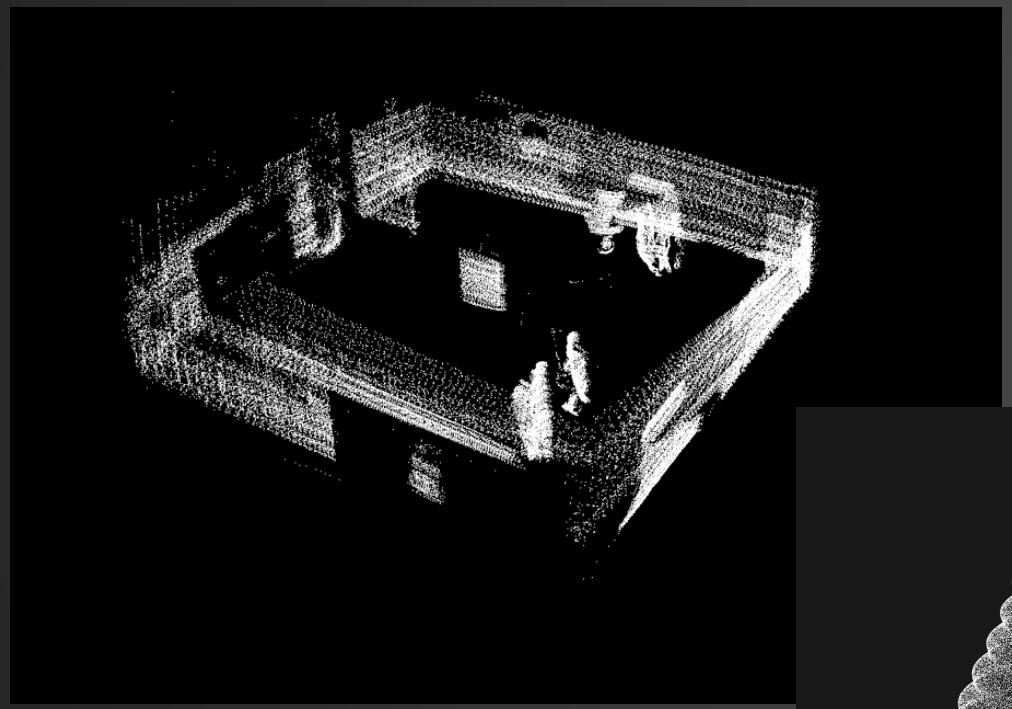
Fixing the scale of the 3D reconstruction

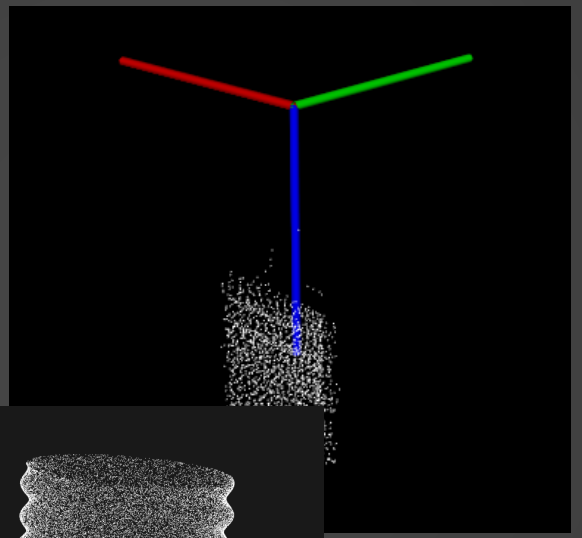
- 3D reconstruction from Structure-from-Motion is accurate but only up to scale
- Estimate 7 DOF transformation from SfM model camera location point cloud to LIDAR camera location point cloud (translation, rotation, and one scale)

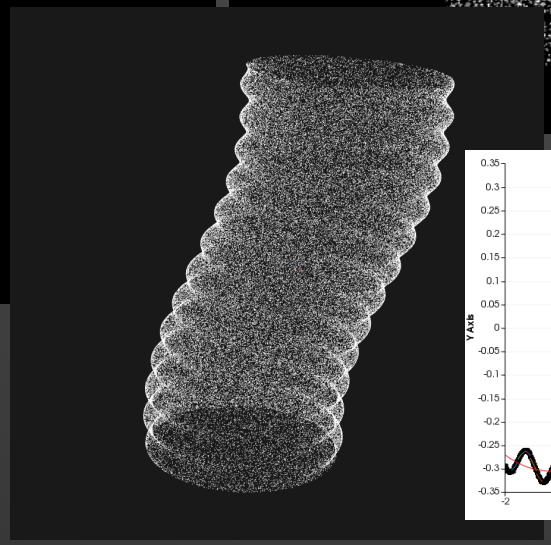


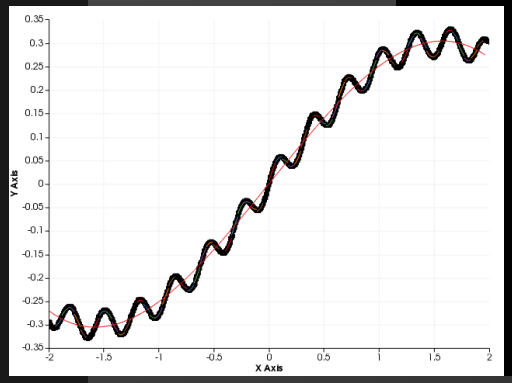


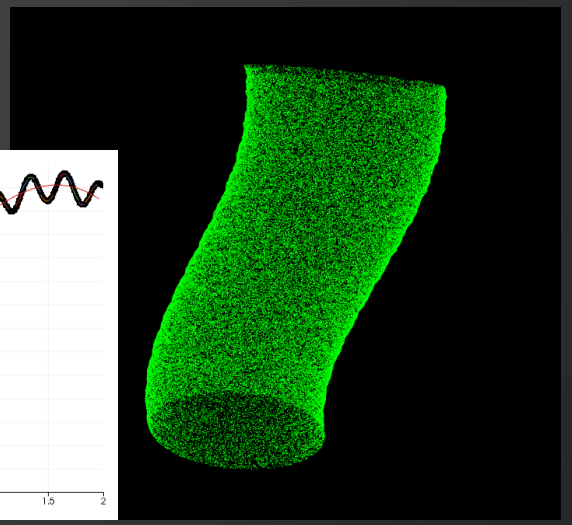
Combining layers of LIDAR scans











Outro

- Pushing the boundaries for drone-based inspection
- Extreme high resolution images (1600 pixels per square millimeter blade surface)
- Extreme high resolution 3D reconstruction (millimeter and below)
- Requires auto-pilot for holding the drone at the right location relative to blade
- Everything is relative (as they say)…
- Structure-from-Motion anchors 3D reconstruction and camera positions to blade-centric coordinates, but not in real-time, and only up to scale
- LIDAR “simultaneous localization and mapping (SLAM)” anchors drone positions to blade-centric coordinate system in real-time, and to scale
- Blade-centric drone positions allow solving for the absolute scale of 3D SfM reconstructions
- Model-based filtering on combination point clouds allow for removing blade swaying artifacts

- Thank you for your attention