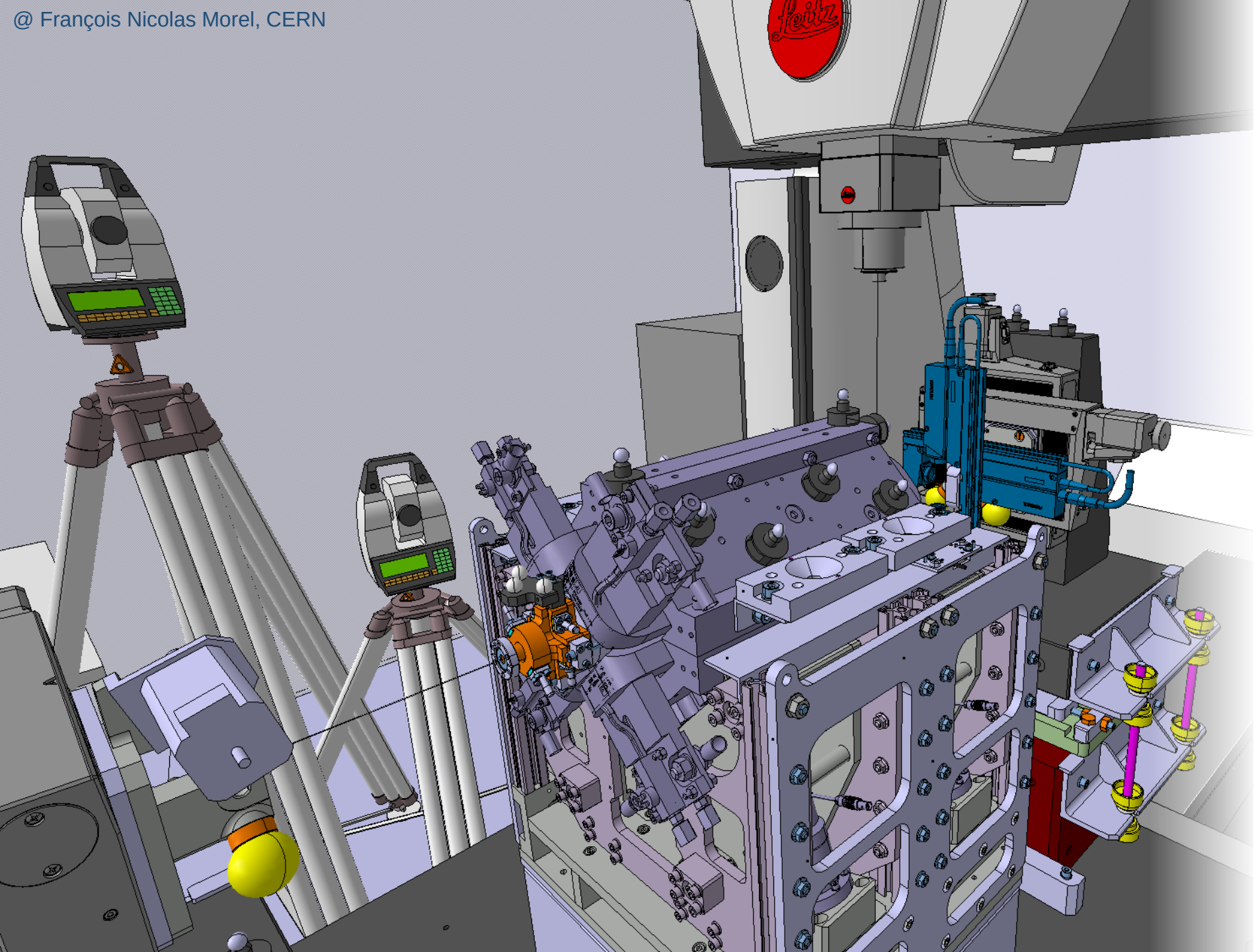
Recent developments on micro-triangulation for fiducial points and wires

Vasileios Vlachakis



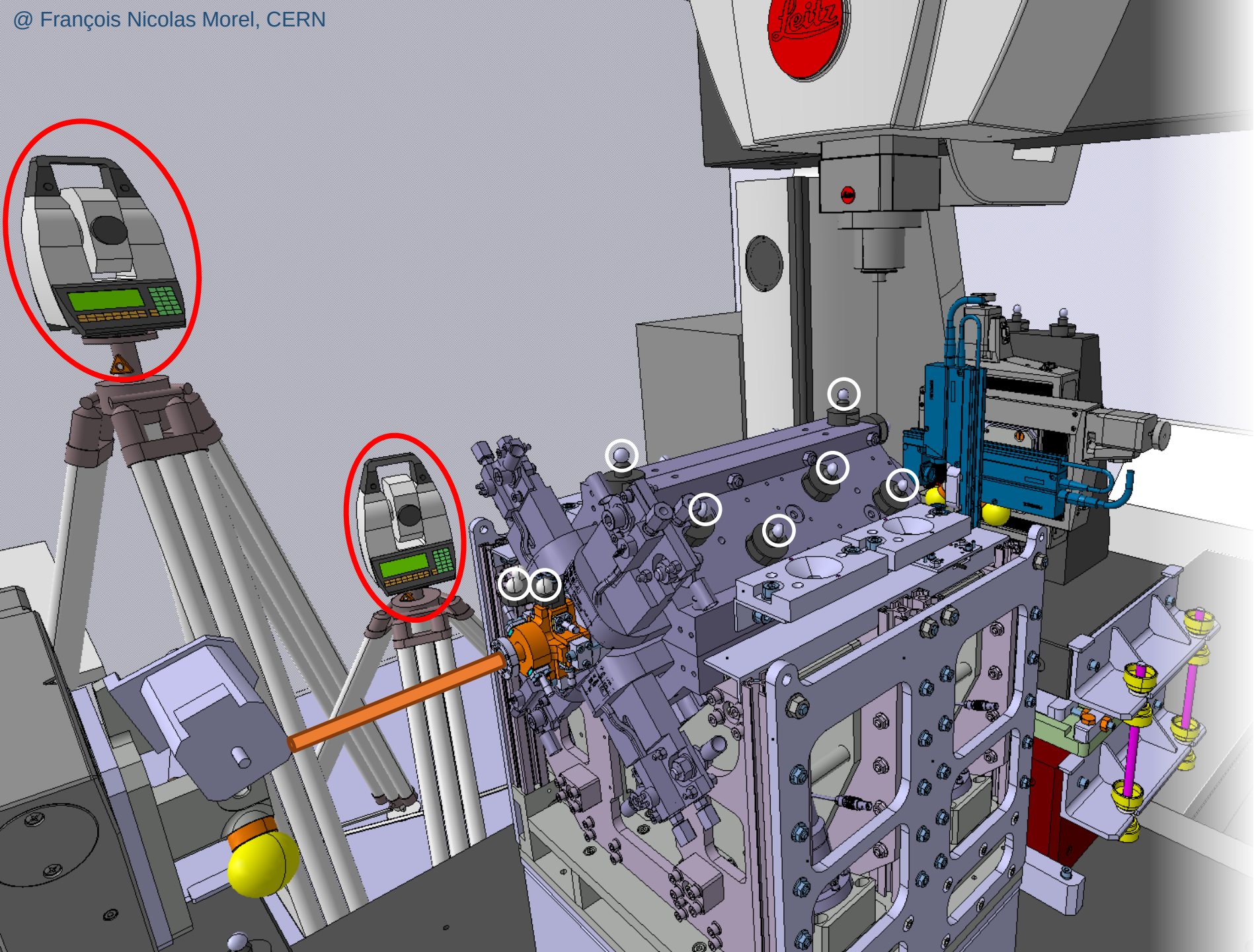
To link the fiducials with the wire, in geometric sense.

- Mechanical axis → fiducials
- Magnetic axis } stretched wire
- Electric axis } stretched wire

To measure the fiducials and the wire using theodolites.

- Observations → angles (horizontal, vertical)

- Leica TDA5005 theodolite.
- QDaedalus measuring system.
- Computer vision techniques.
- Least-squares analysis.



Leica TDA5005:

- Robotic theodolite.
- High accuracy:

$$0.5 \text{ arcsec} \;/\; 2.4 \; \frac{\mu m}{m}$$

Copper-Beryllium (CuBe) wire:

- Ø 100 µm.

Ceramic spheres:

- 0.5 inch
- Grade 40 (sphericity 1 µm)

Main features

☺ Advantages:

- Precise measurements – few micrometers
- Contactless measurements – ideal for stretched wire
- Automatic measurements – no need of observer
- Remote-controlled measurements – 7 m meters in cable, ∞ on-line
- Fast measurements – a series in <10 min (depending on the setup, conditions, etc.)
- Portable – few boxes…

♡ For fiducialization:

- Introduces the direct stretched wire observation (can lead to various applications related to alignment techniques).
- It is expected to have lower precision than a CMM.
- It is a low-cost, portable solution based on standard surveying-geodetic techniques.

☹ Disadvantage:

- The scale should be introduced using coordinates or distances as geodetic network constraints.

QDaedalus
Overview

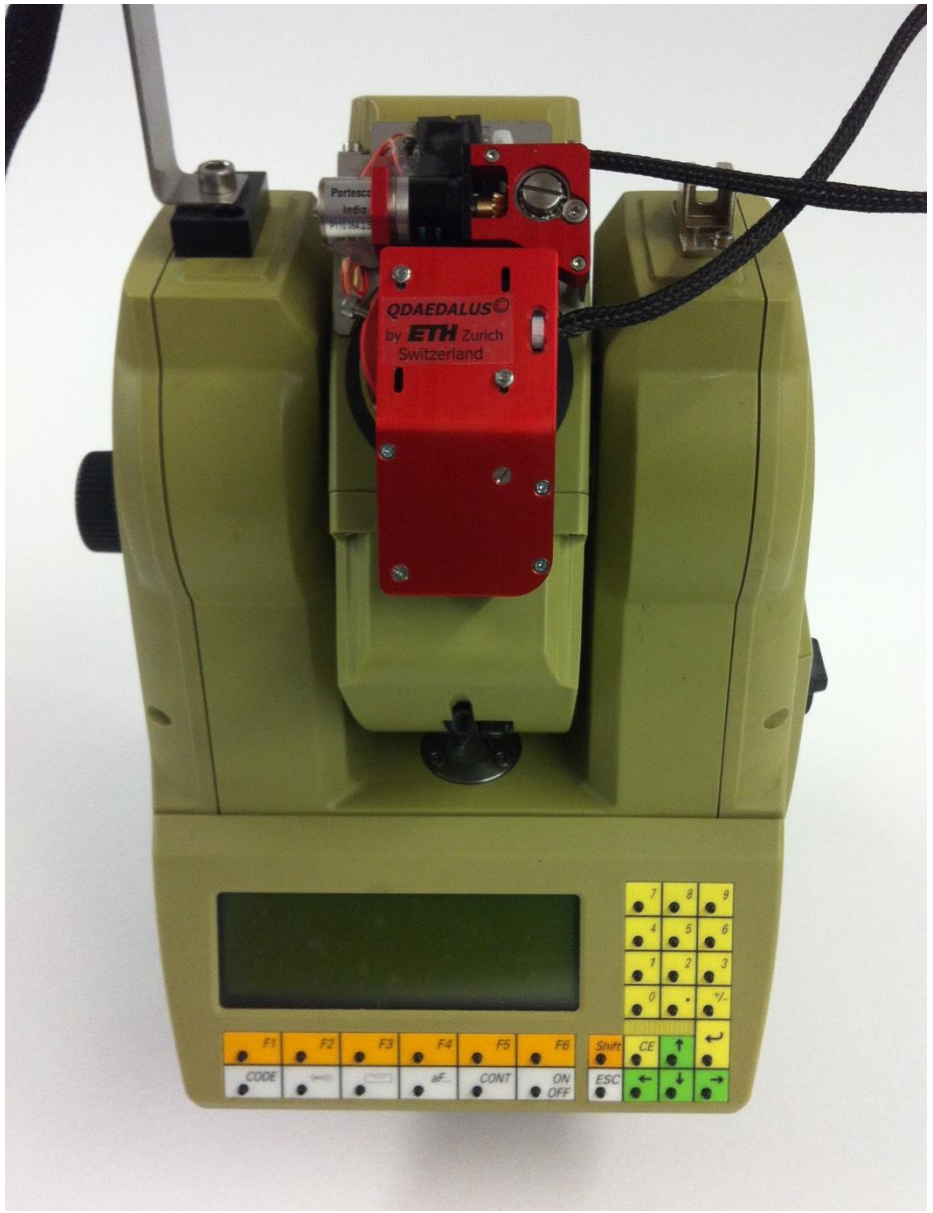
Developed at **ETH Zurich**

Consists of
hardware and software

Based on
industrial robotic theodolites

Reversible replacement
eye-piece ↔ CCD camera

Uses **Optical Target Recognition**

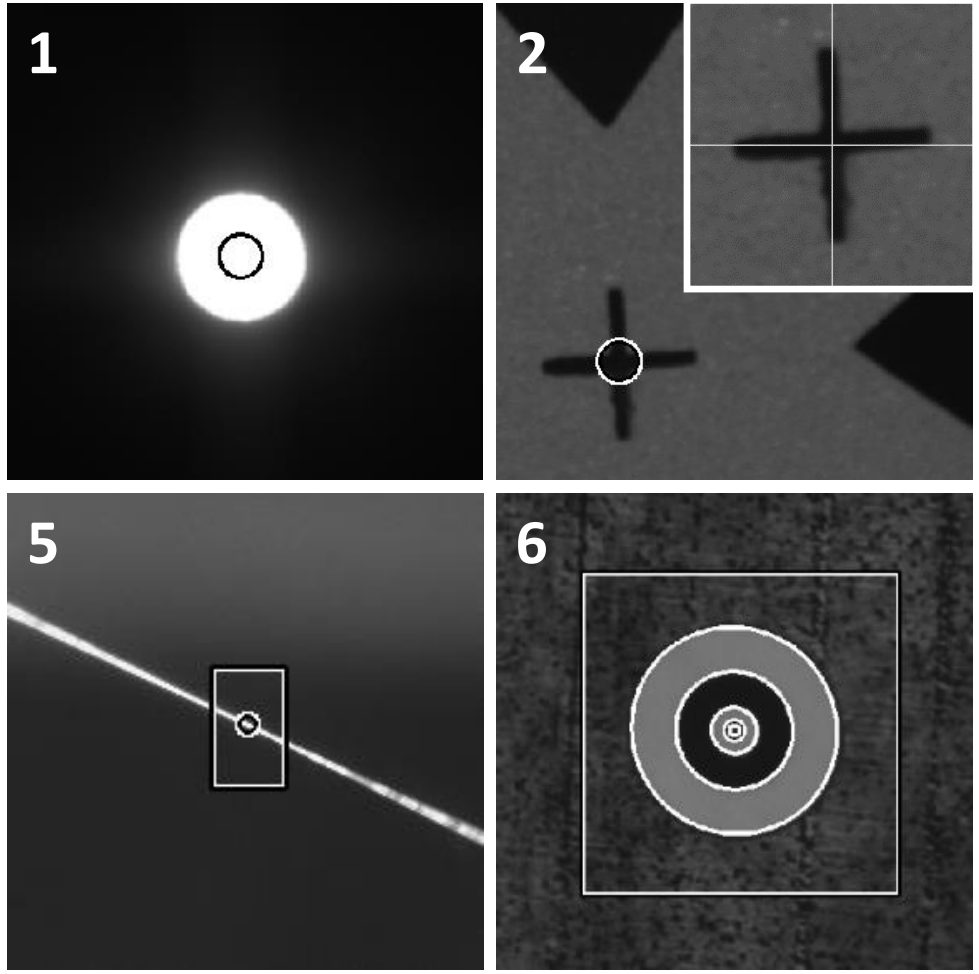


B. Bürki et al., "DAEDALUS: A versatile usable digital clip-on measuring system for Total Stations", in IPIN2010, Zurich, Switzerland, 2010.

QDaedalus
Optical Target Recognition

OTR Algorithms

1. Centre of mass
2. Template least-squares matching
3. Ellipse matching
4. Circle matching
5. Line matching
6. Multi-Ellipse matching



S. Guillaume et al., "QDaedalus: Augmentation of Total Stations by CCD Sensor for Automated Contactless High-Precision Metrology", in FIG Working Week 2012, Rome, Italy, 2012.

Tasks

Aim: To measure the targets (**fiducials**) and the **stretched wire** in a <u>common coordinate system.</u>

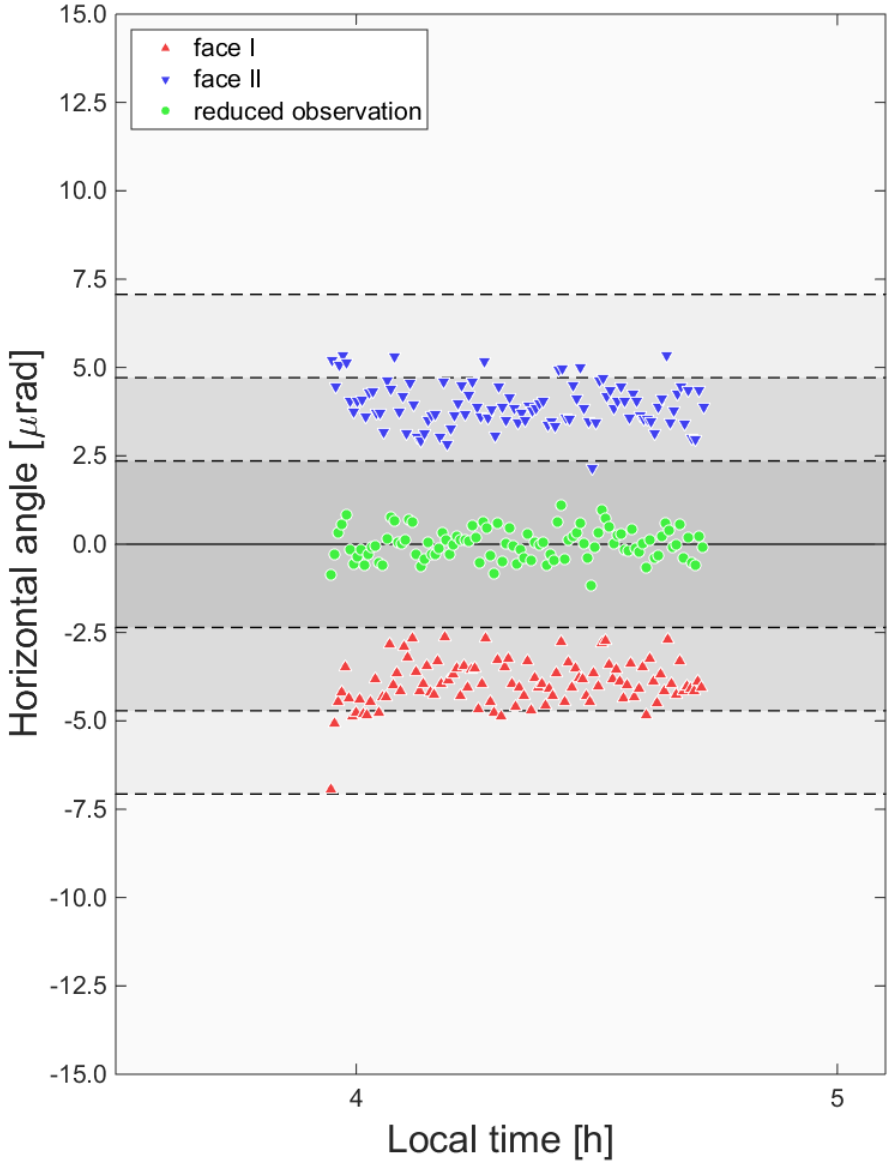
- ❑ To validate the measuring system.
- ❑ To develop and validate a wire detection and measurement algorithm.
- ❑ To develop an integrated geodetic network including spherical targets, stretched wire reconstruction, theodolite systematic errors.
- ❑ To simulate measurement configurations for precision and efficiency optimization.

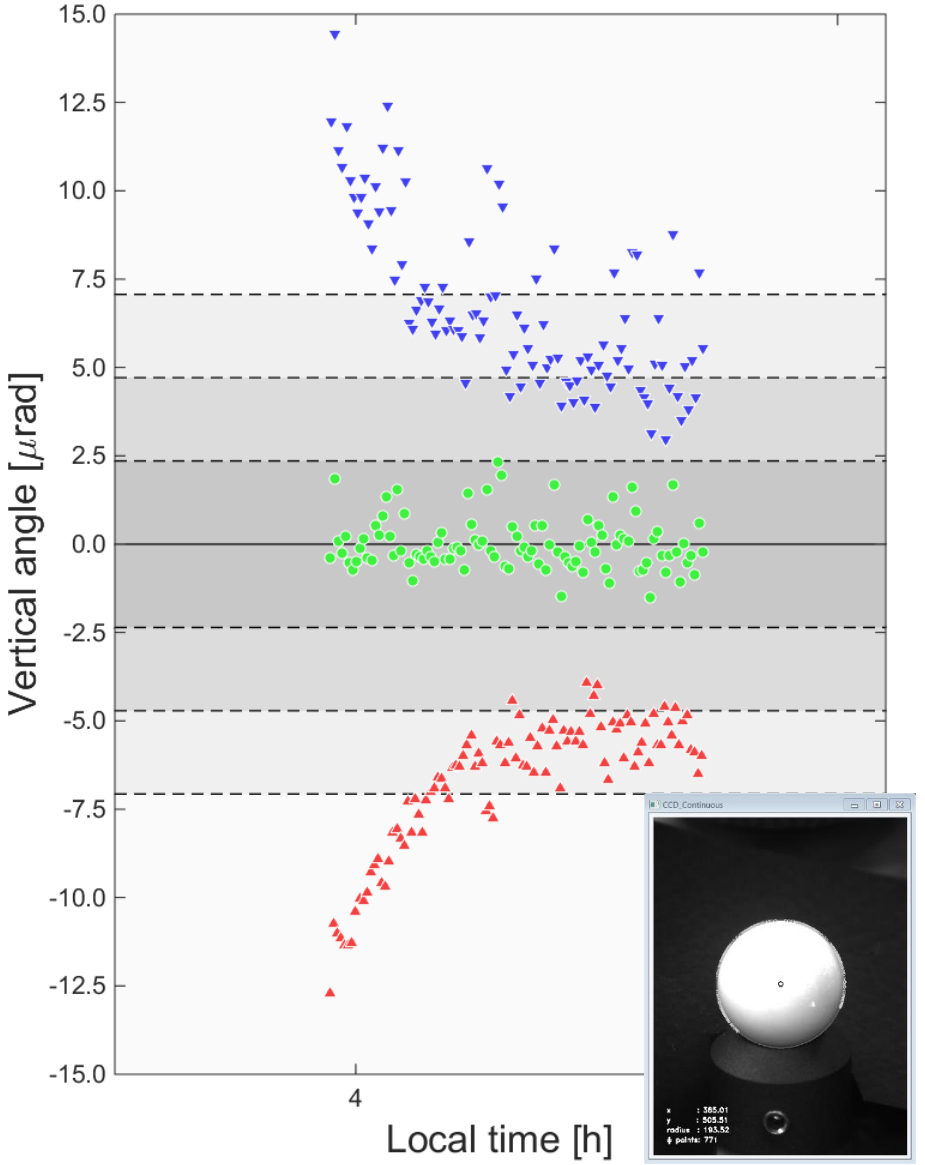
System validation

Factors that may affect the measurement

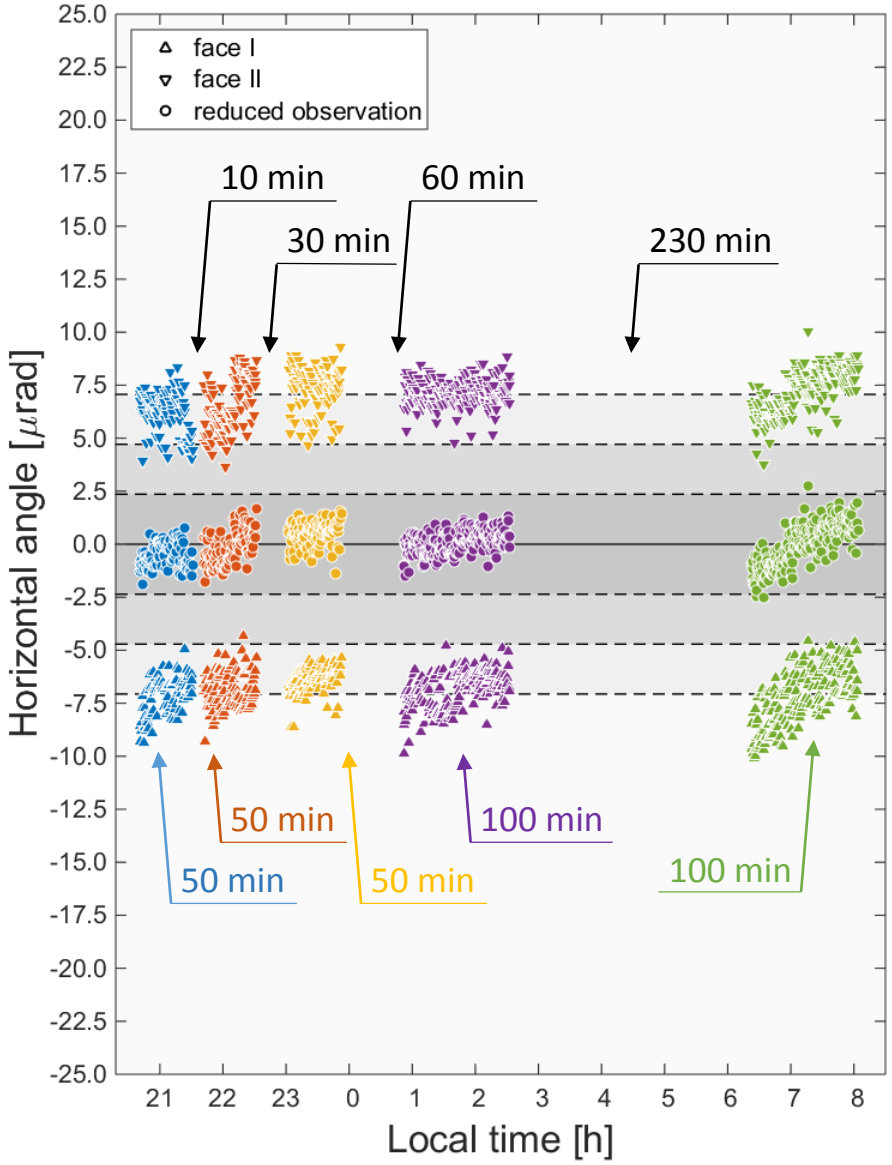
- Thermal effects
  - Camera, theodolite sensors, tripods

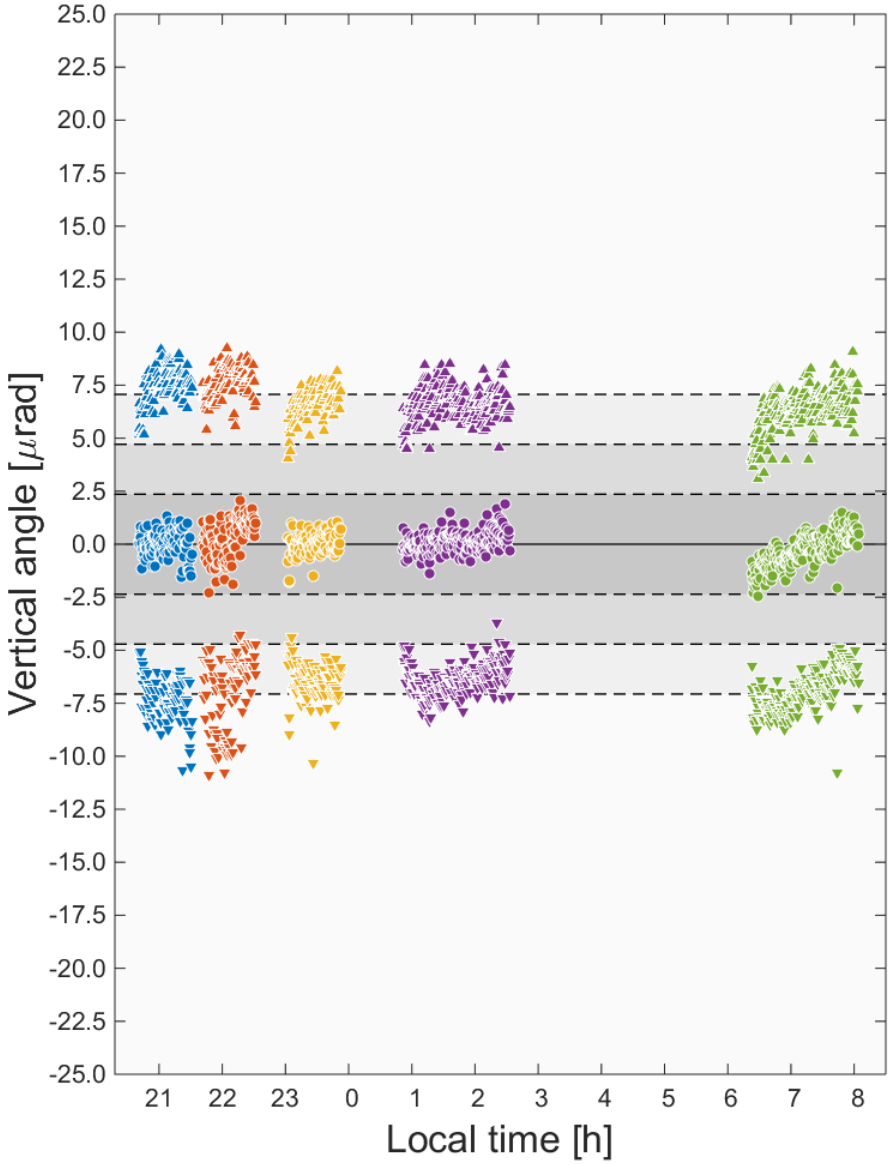
Measurement Stability





Measurement Stability

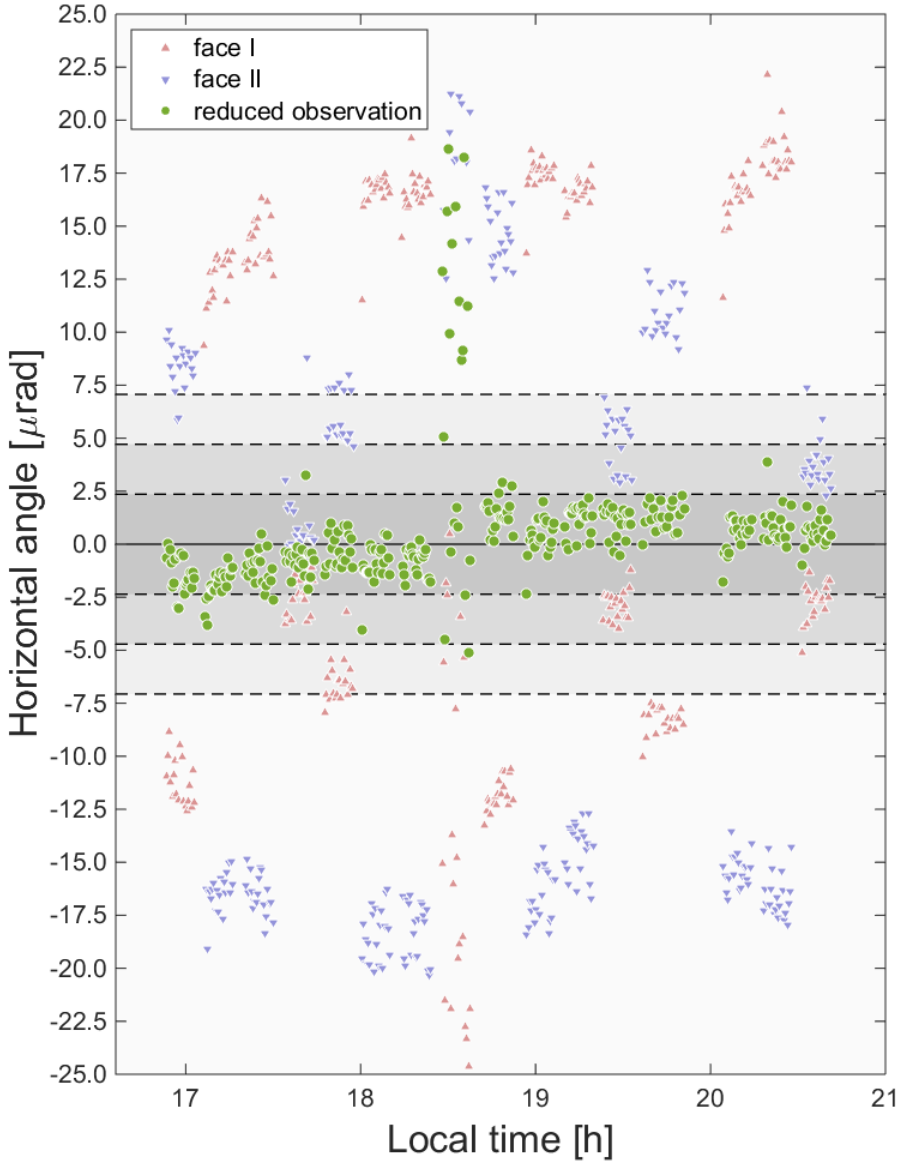


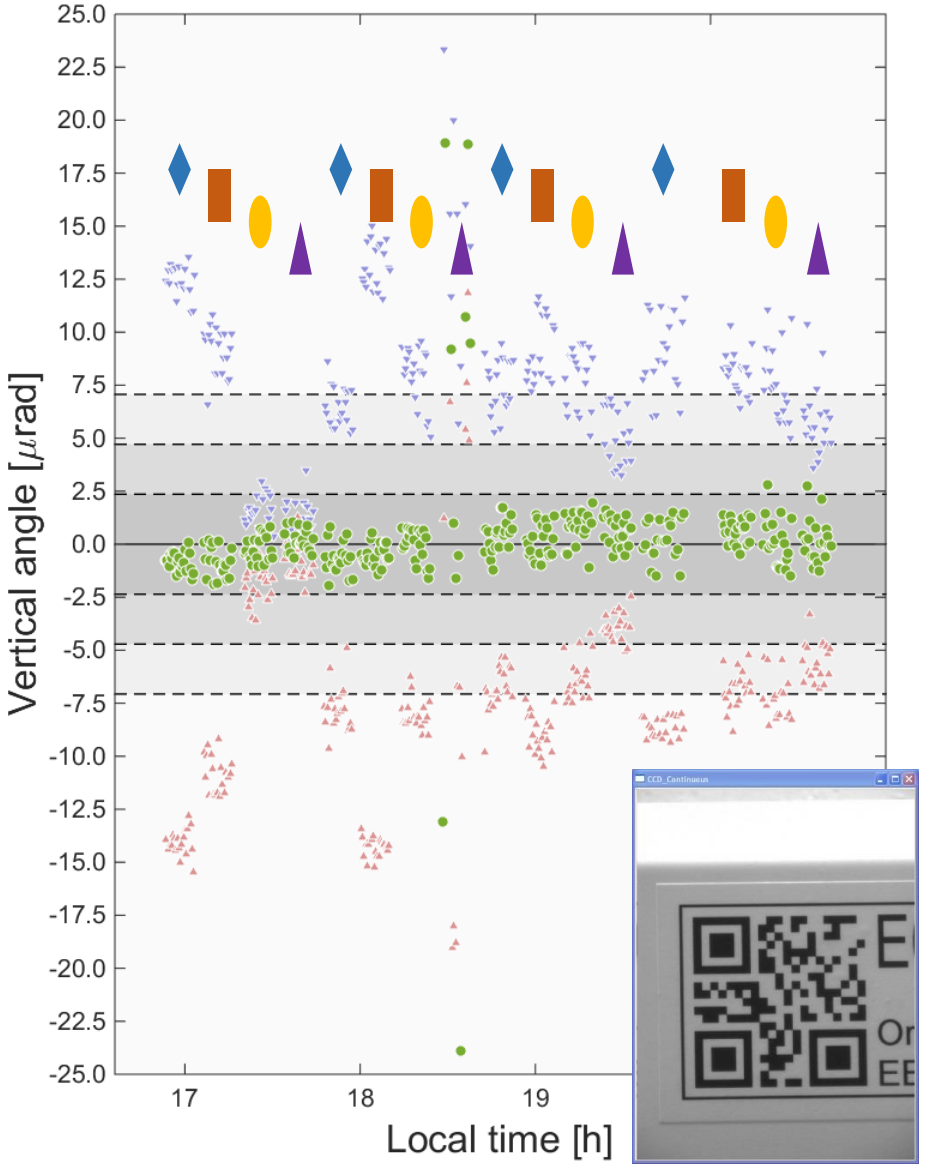


Factors that may affect the measurement

- Thermal effects
  - Camera, theodolite sensors, tripods
- Camera calibration
  - Distance: theodolite ↔ calibration target
  - Distance: calibration target ↔ target
  - Type of calibration target

Calibration

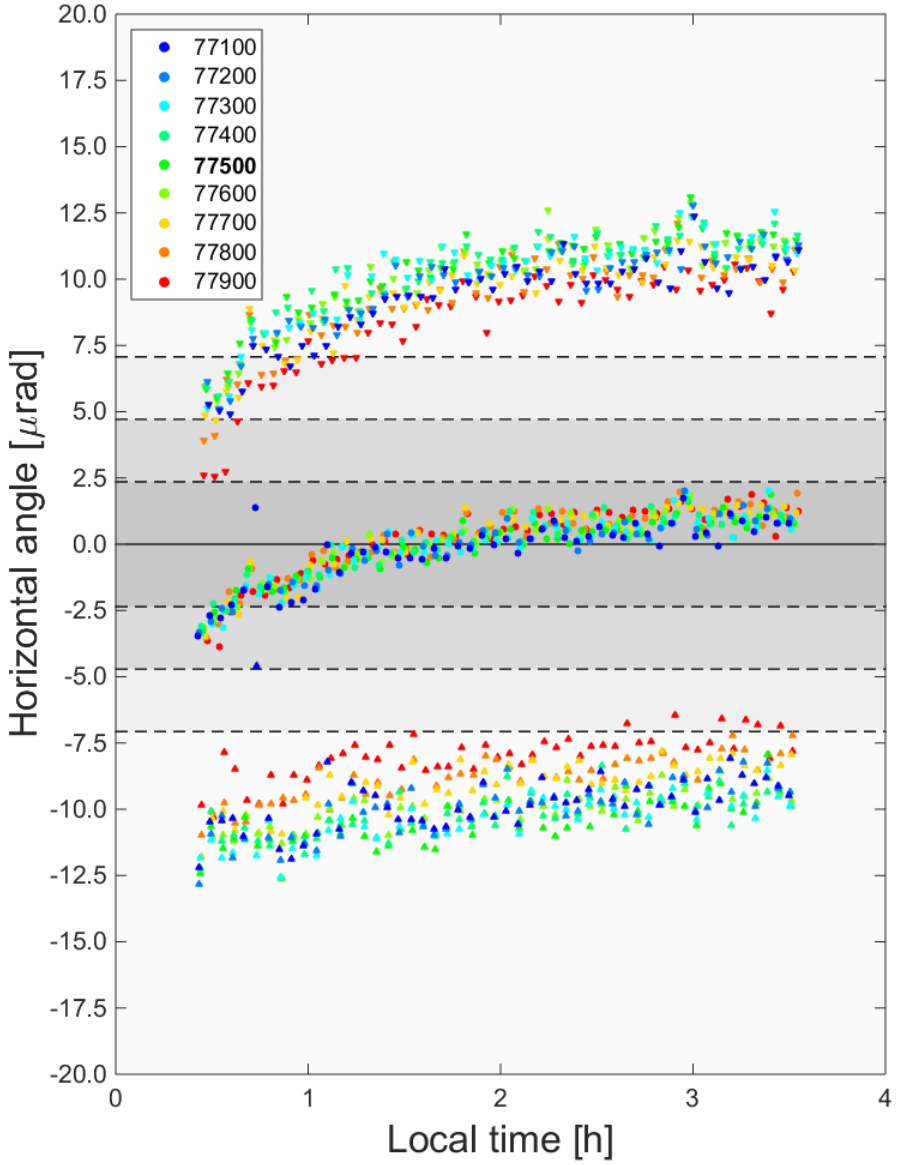


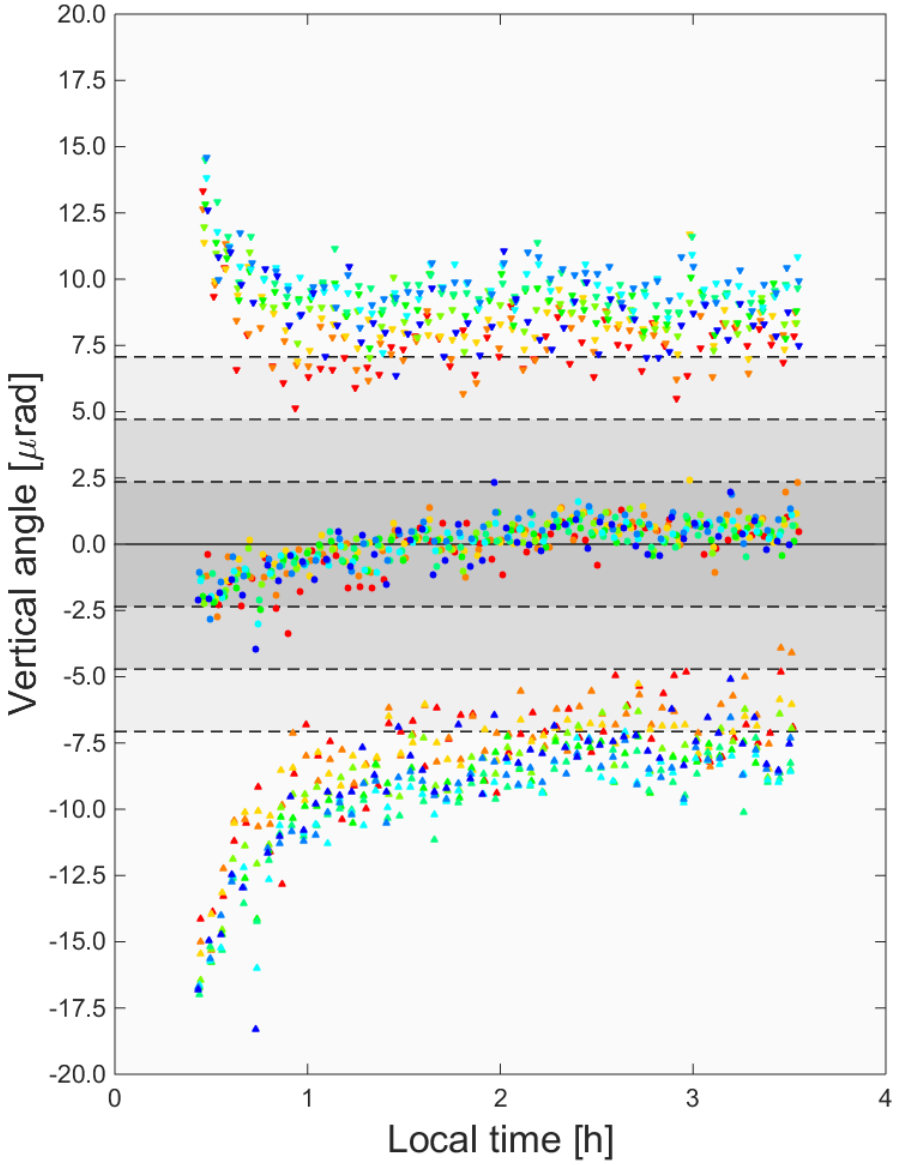


Factors that may affect the measurement

- Thermal effects
  - Camera, theodolite sensors, tripods
- Camera calibration
  - Distance: theodolite ↔ calibration target
  - Distance: calibration target ↔ target
  - Type of calibration target
- Focus on the target
  - Algorithm (circle, line)
  - Range of focus VS distance

Focus


77100
77200
77300
77400
77500
77600
77700
77800
77900
Horizontal angle [μrad]
Local time [h]

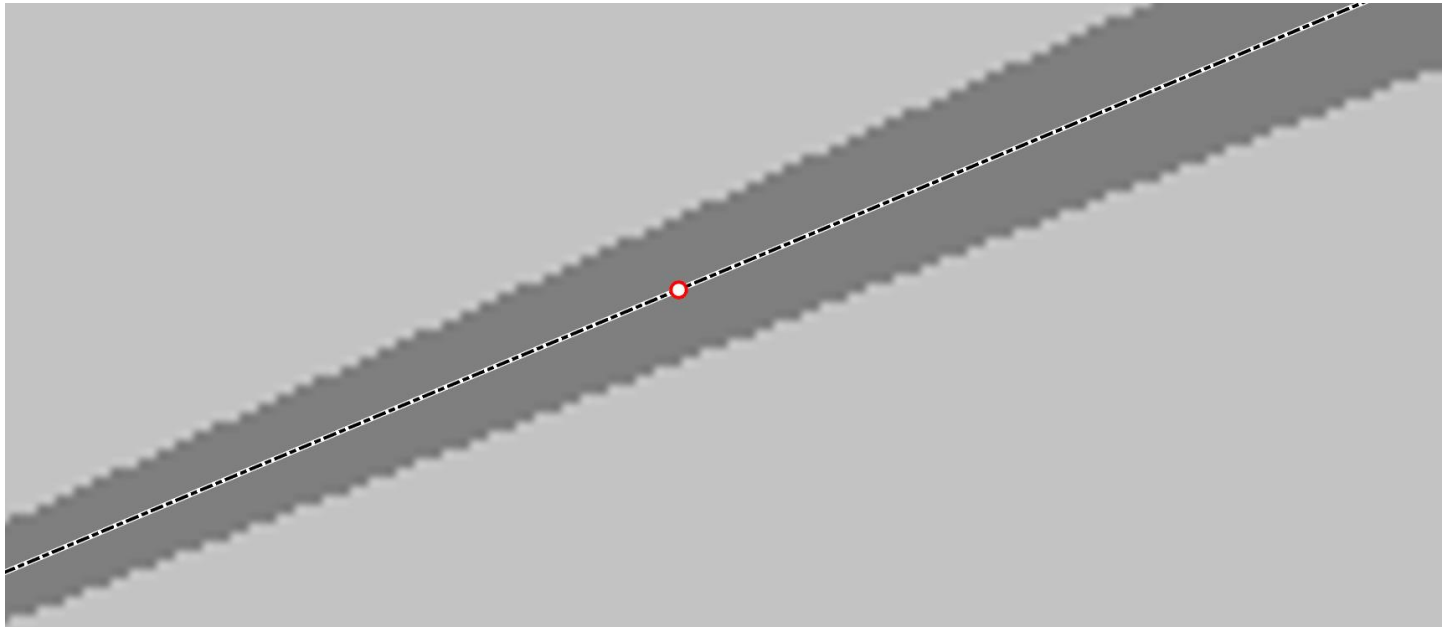

Vertical angle [μrad]
Local time [h]

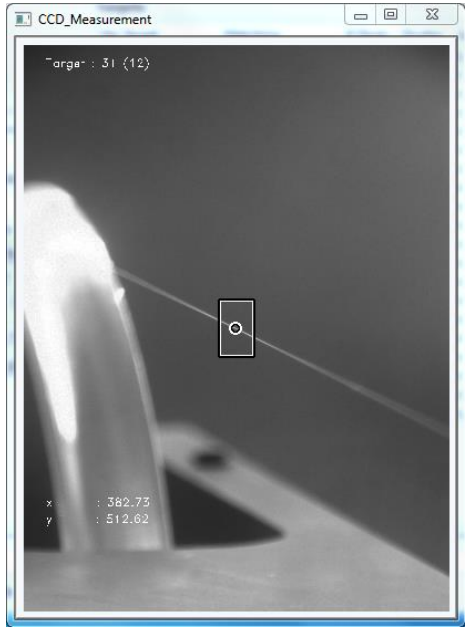
System validation

Factors that may affect the measurement

- Thermal effects
  - Camera, theodolite sensors, tripods
- Camera calibration
  - Distance: theodolite ↔ calibration target
  - Distance: calibration target ↔ target
  - Type of calibration target
- Focus on the target
  - Algorithm (circle, line)
  - Range of focus VS distance
- Light conditions
  - Ambient, external, internal
  - Algorithm (circle, line)
  - External light effect VS distance

Wire detection and measurement algorithm

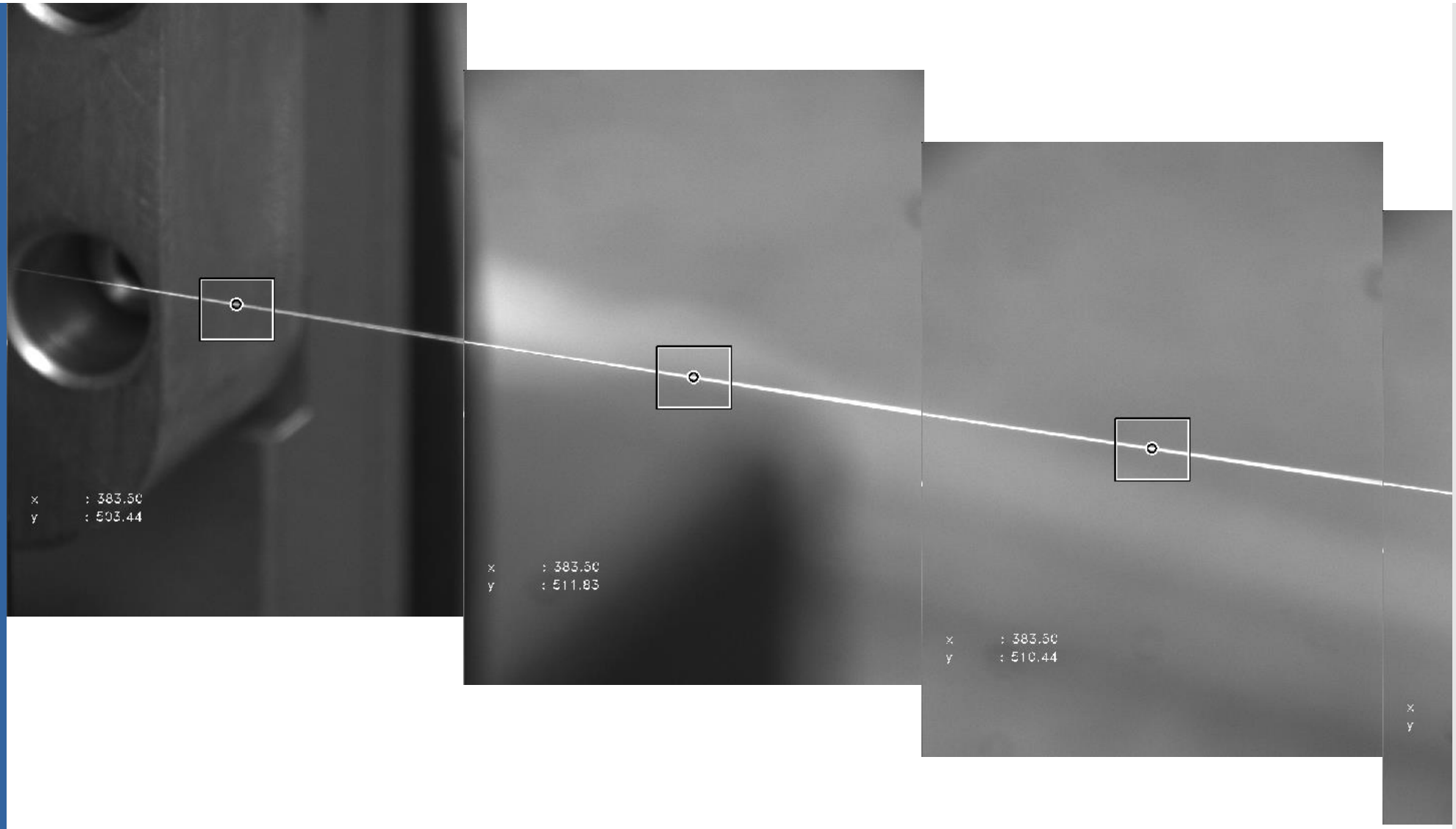




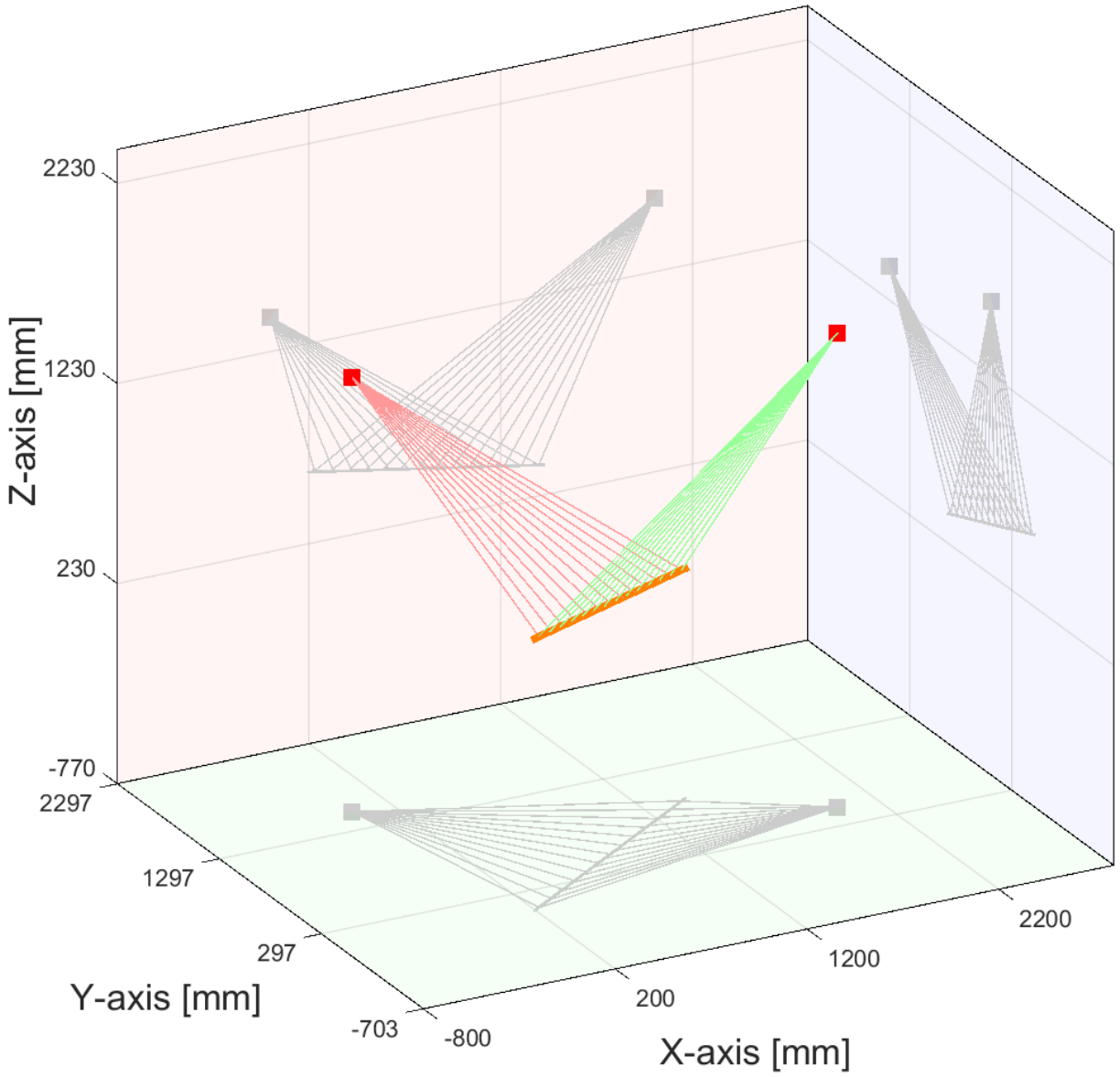
User defined parameters

1. **Minimum edge points (for each edge)**: increases the robustness.
2. **Width of Region Of Interest (ROI) window**: increases precision avoiding the out-of-focus area.
3. **Height of Region Of Interest (ROI) window**: helps when the wire is depicted inclined.
4. **Maximum residual**: increases precision discarding outlier pixels w.r.t. the fitting line.
5. **Canny threshold**: increases the robustness in case of noisy images.

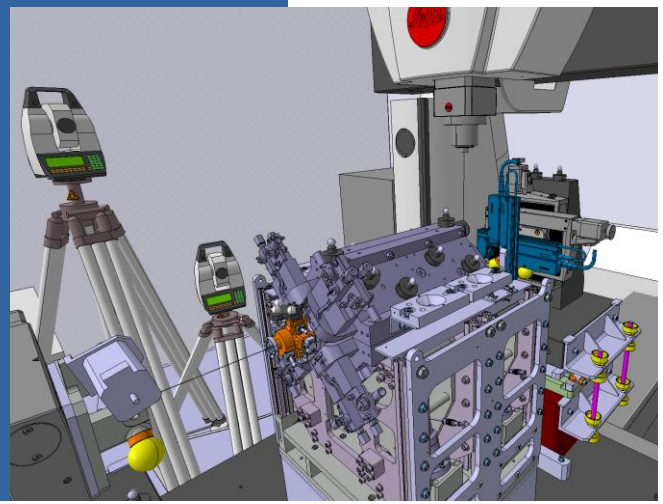
Wire detection and measurement algorithm

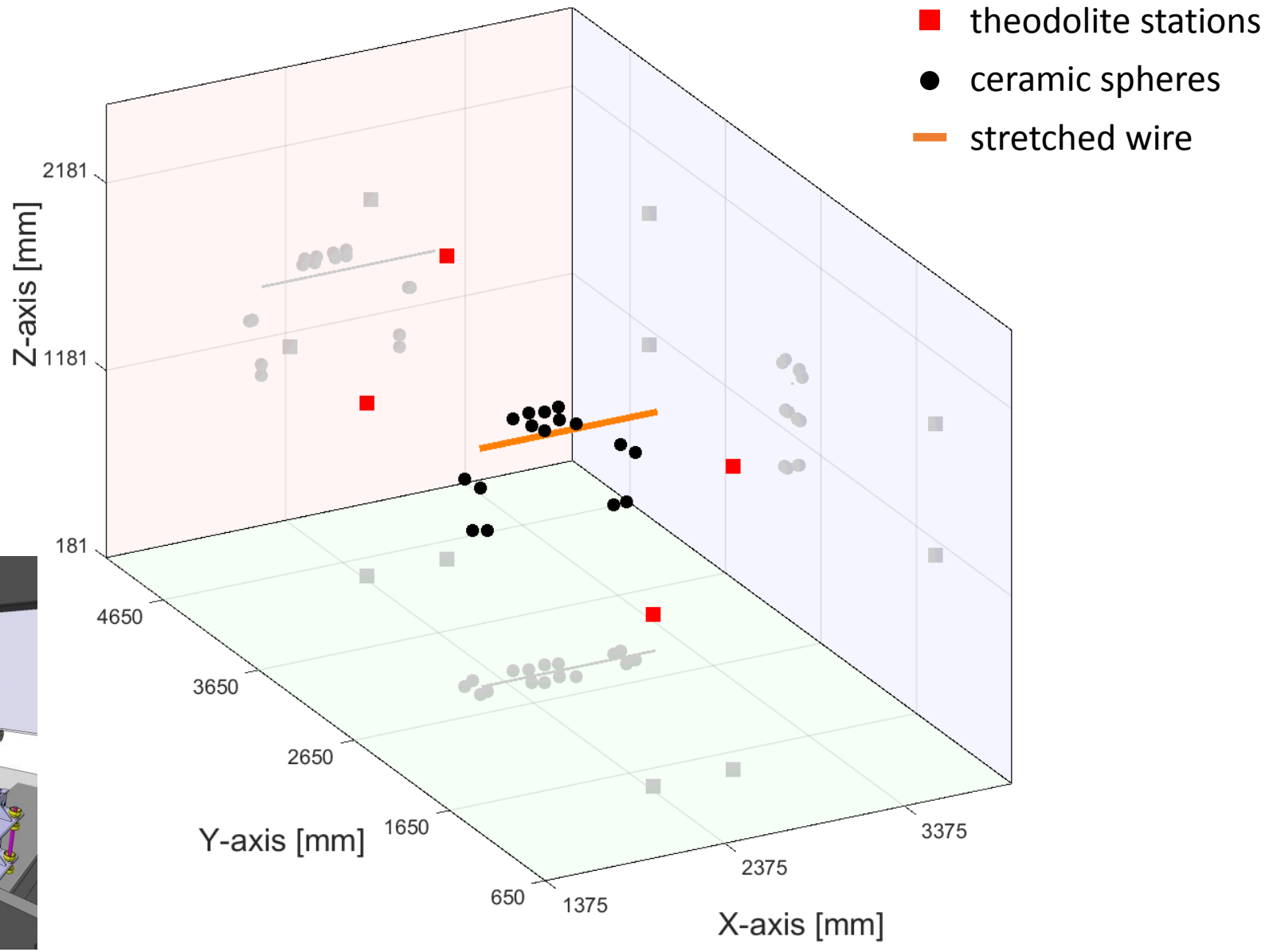


Angle observations' fan



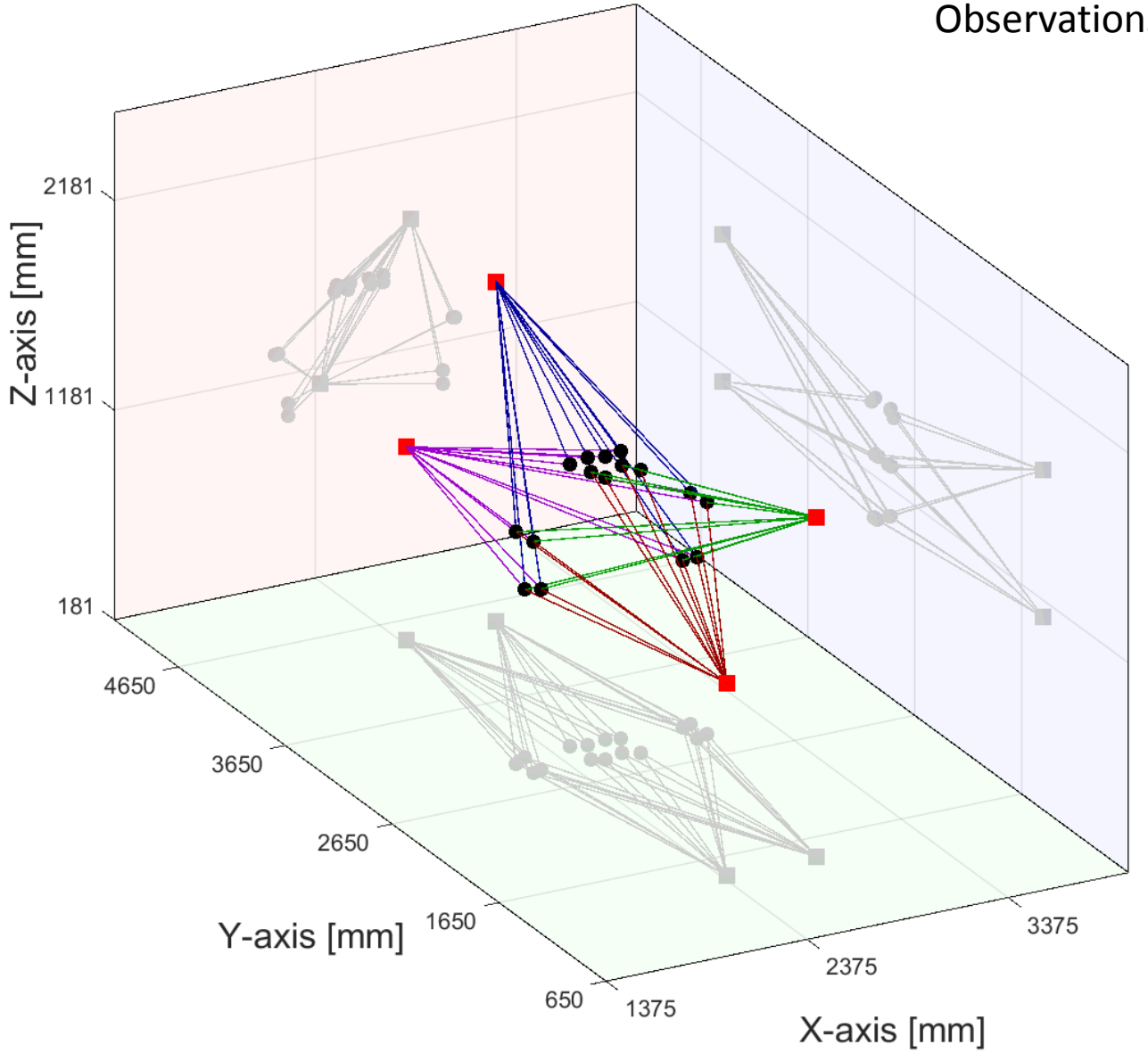
PACMAN bench configuration





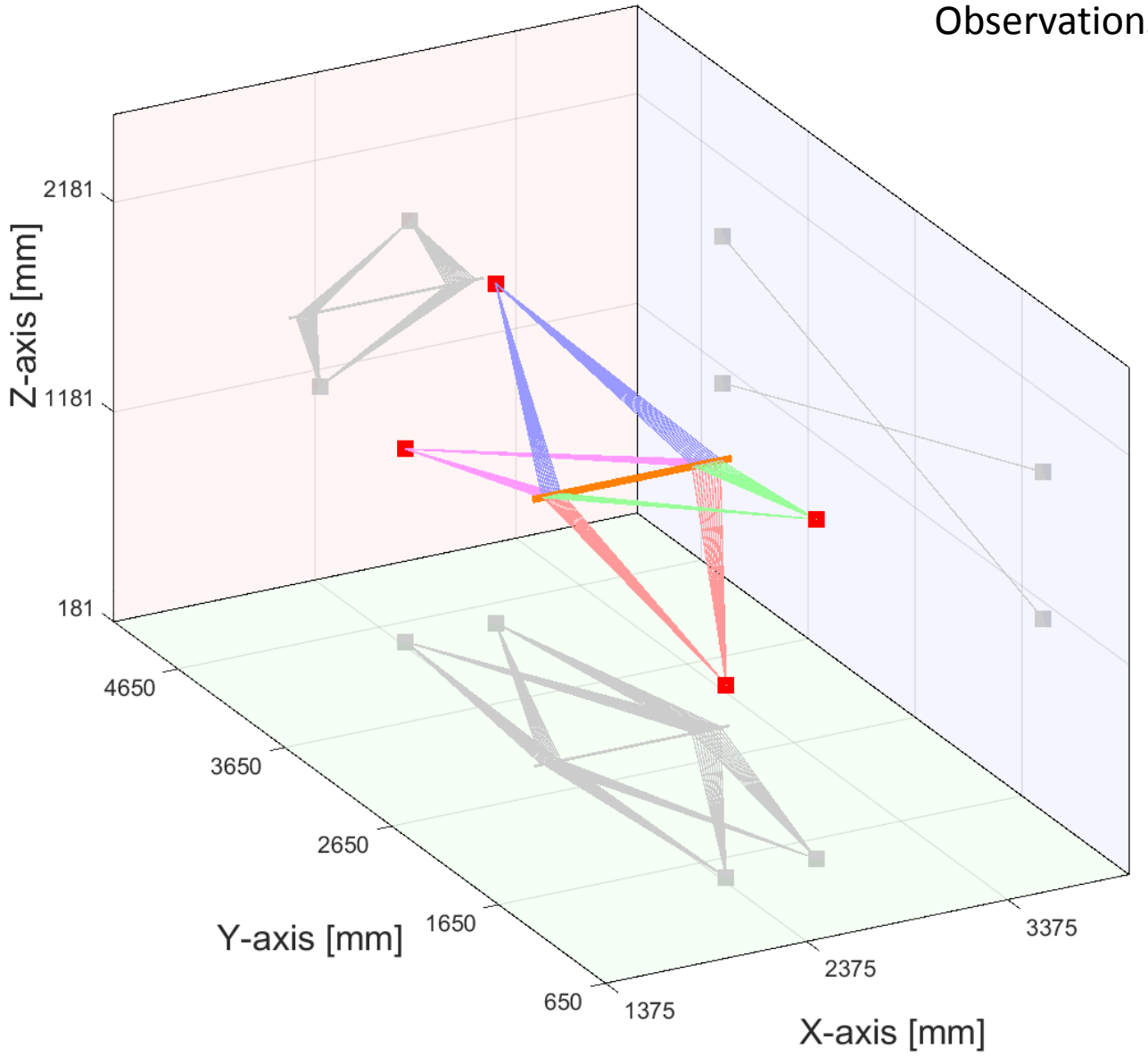
PACMAN bench configuration

Observations to the targets

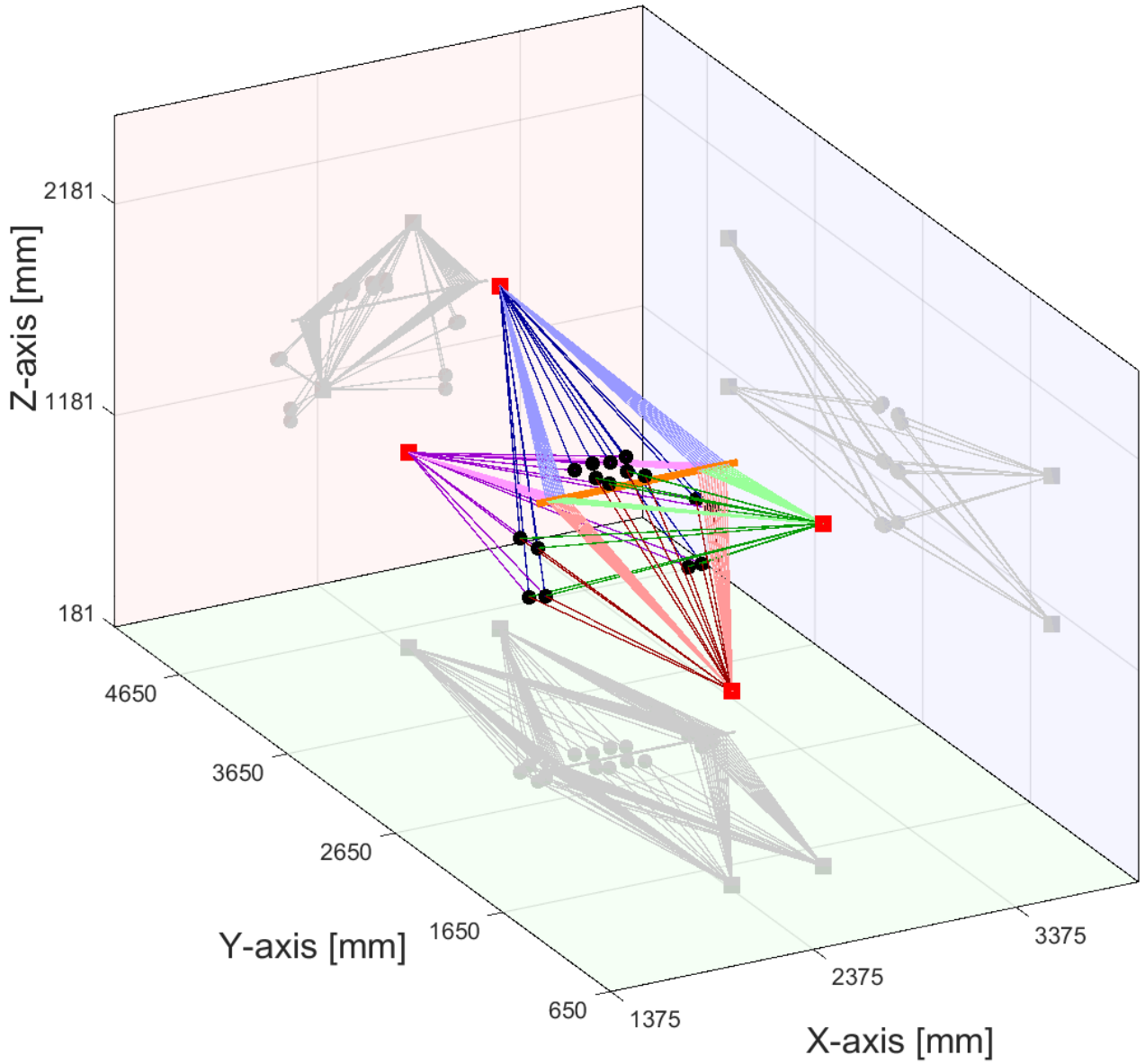


PACMAN bench configuration

Observations to the wire



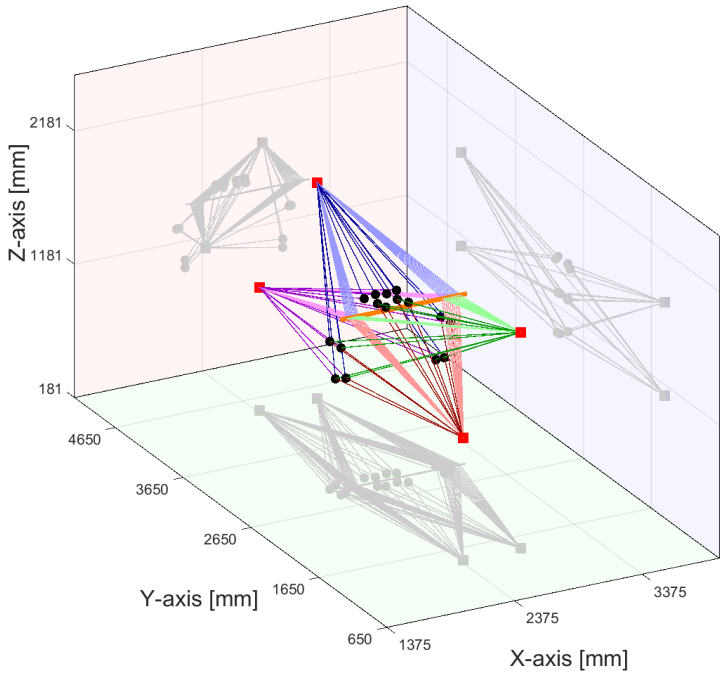
PACMAN bench configuration



Least-squares analysis software

Input:

- horizontal and vertical angles to targets and wires (with uncertainties).
- Approximate coordinates of the network (with uncertainties).
- datum constraints.
- user's parameters.



Output:

- stations: coordinates, orientations, and 3 systematic errors per instrument.
- targets: coordinates.
- wires: position, orientation and coordinates of the observed points.
- uncertainties.

Conclusion and outlook

Tasks:

- Validation of the measuring system.
- Development and validation of a wire detection and measurement algorithm.
- Development of an integrated geodetic network.
- Simulation of the measurement configurations.