FIG WORKING WEEK 2017

Helsinki Finland

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Towards the influence of the angle of incidence and the surface roughness on distances in terrestrial laser scanning

M. Zámečníková and H. Neuner

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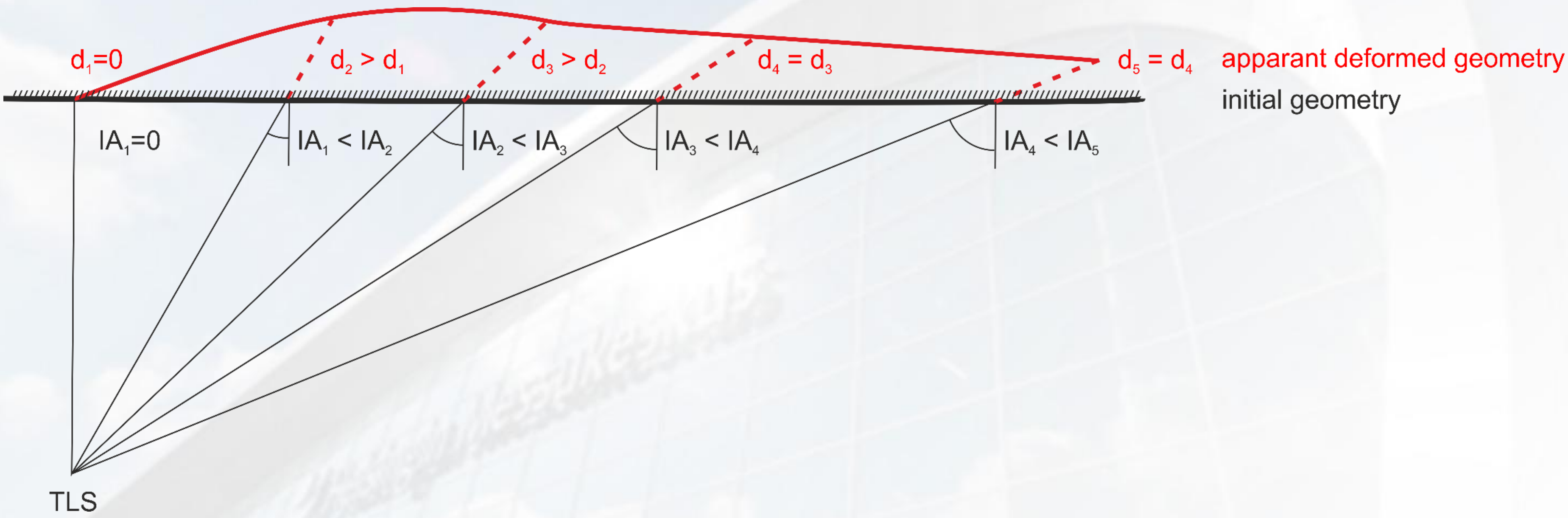
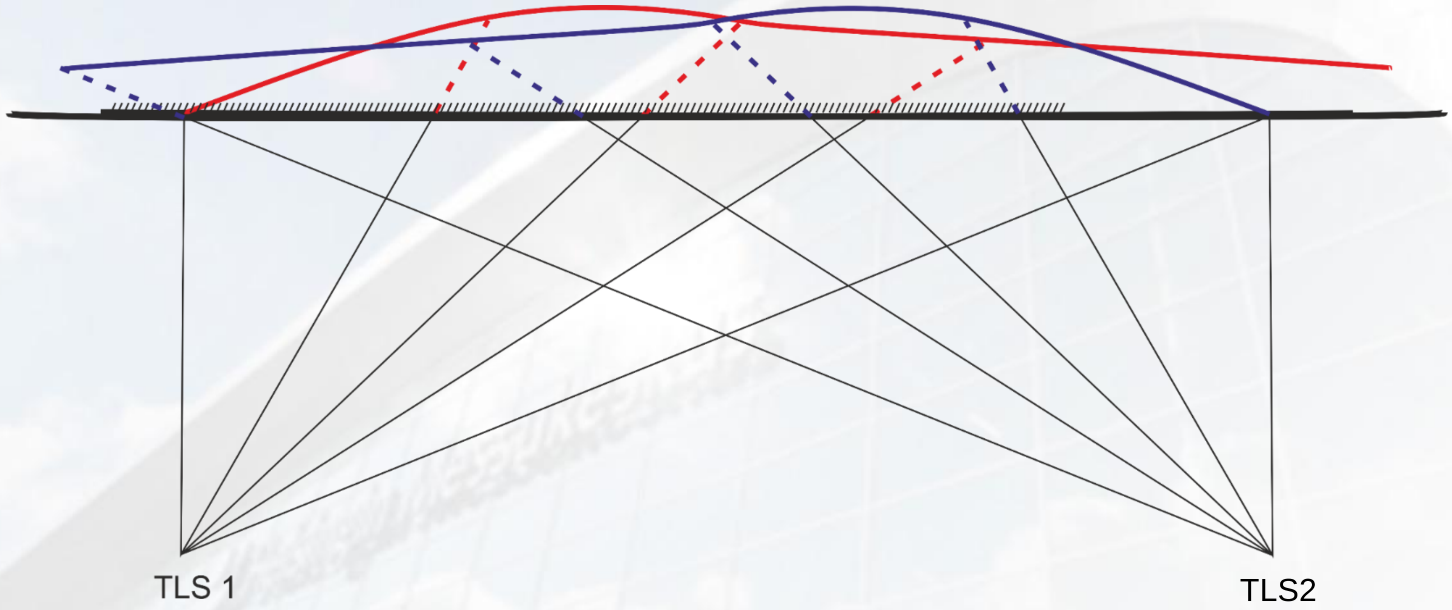
Motivation and relation to deformation monitoring

- Separation of real object deformations from apparent deformations caused by variating systematic influences.

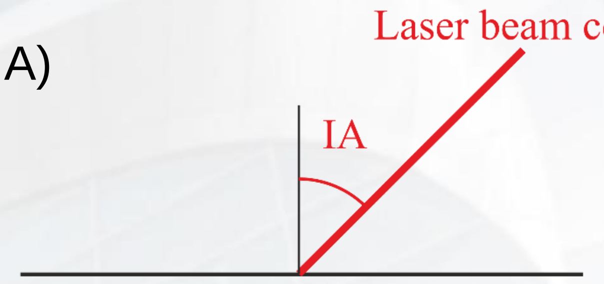


Motivation and relation to deformation monitoring

- Scanning from a second station causes a different impact of the systematics on the determined geometry.



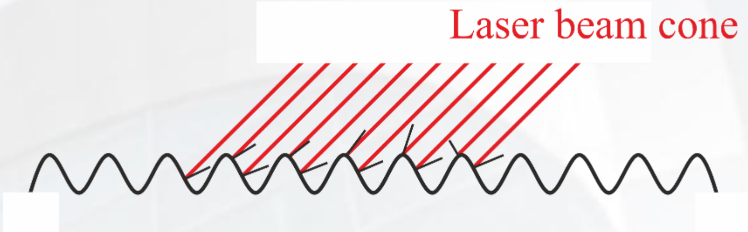
- TLS: The beam reflected on the object surface ⇨ obtaining distance measurement ⇨ results are influenced by measurement configuration and surface properties
- Measurement configuration: Incidence angle (IA)
- Traditional definition



Reference	Nature	Measure
Linstaedt et al., 2009	systematic	Variation of displacement of a scanned surface from reference points
Gordon, B., 2008	systematic stochastic	3D-accuracy – point standard deviation
Soudarissanane, S. et al., 2011	stochastic	Standard deviation of the residuals of an approximated plane in the distance direction

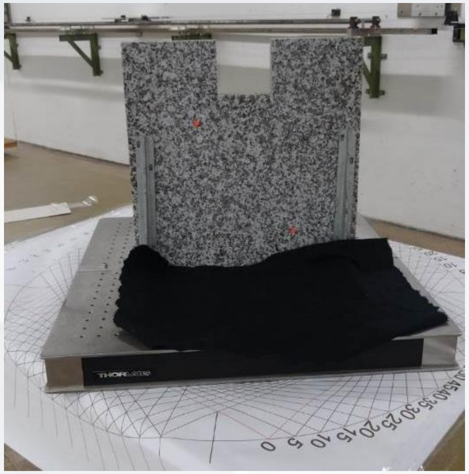
- Surface properties: Roughness

- Alternative perspective: combined influence of IA and roughness



- Aim of the research:
  a) Identification of a possible joint influence of the incidence angle and of the surface roughness on the resulting distance measurement.
  b) Specification of the nature of the combined influence (systematic/stochastic)

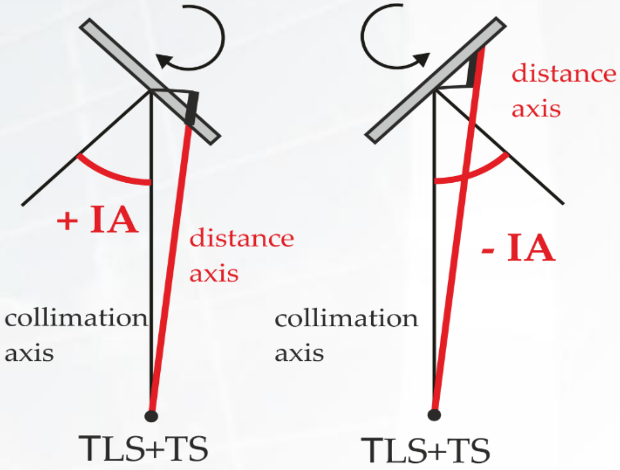
Measurement instrument
Leica MS50 (TLS+TS)
σ_{RL}=2 mm+2 ppm



Measured object
3 plates
Material – granite
Dimension - 40x40 cm
Roughness levels: smooth (s), rough (r), very rough (vr)
IA setting - angle scale; rotation w.r.t. the vertical axes

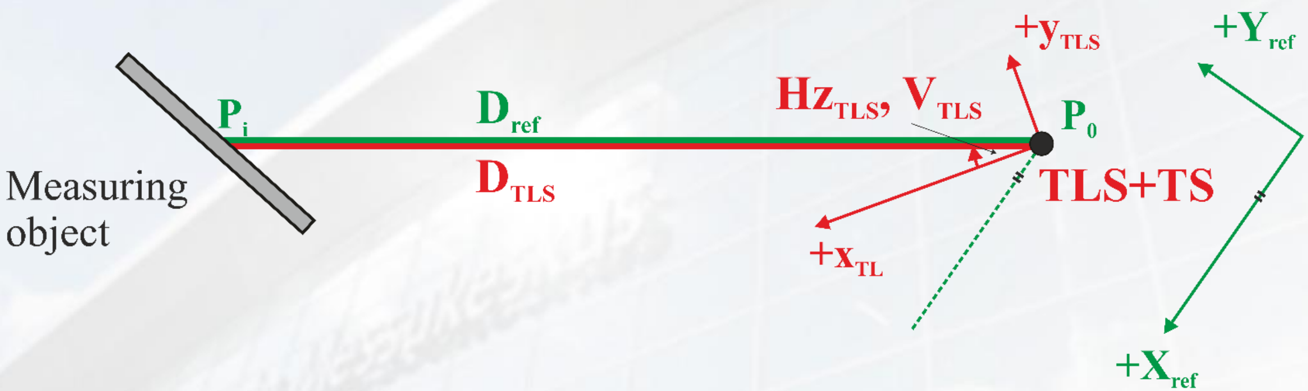
Measuring room
Laboratory

Parameters:
IA – (19) →0, ±(10,20,30,35,40,45,50,55,60) gon
Roughness – smooth, rough, very rough



Key feature of the developed methodology

- Investigation of directly measured single distances D_{TLS}
- Principle - Comparison of reference distance D_{ref} and D_{TLS}

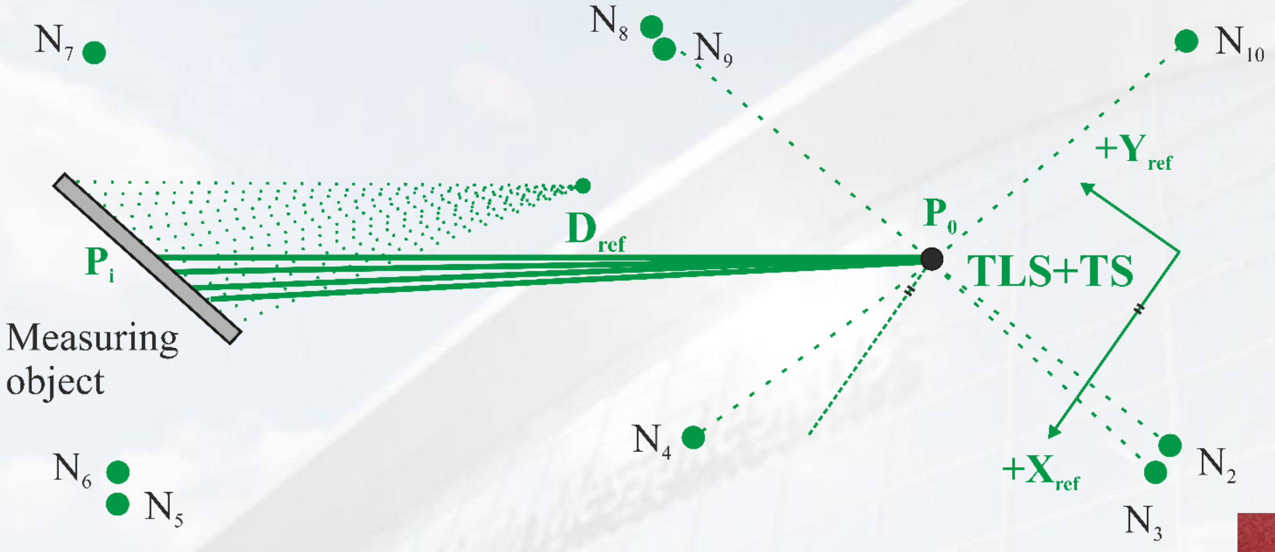


$$\Delta D = D_{ref} - D_{TLS}$$

Determination of the reference distance

Step1: Establishment of a reference frame:

- Leica Absolute Tracker AT960 (MPE=±15µm+6µm/m)
- Levelling provides orientation to gravity



- Determination of the network points:
  Free network adjustment ⇨ σ_X, σ_Y, σ_Z max. 0.06 mm

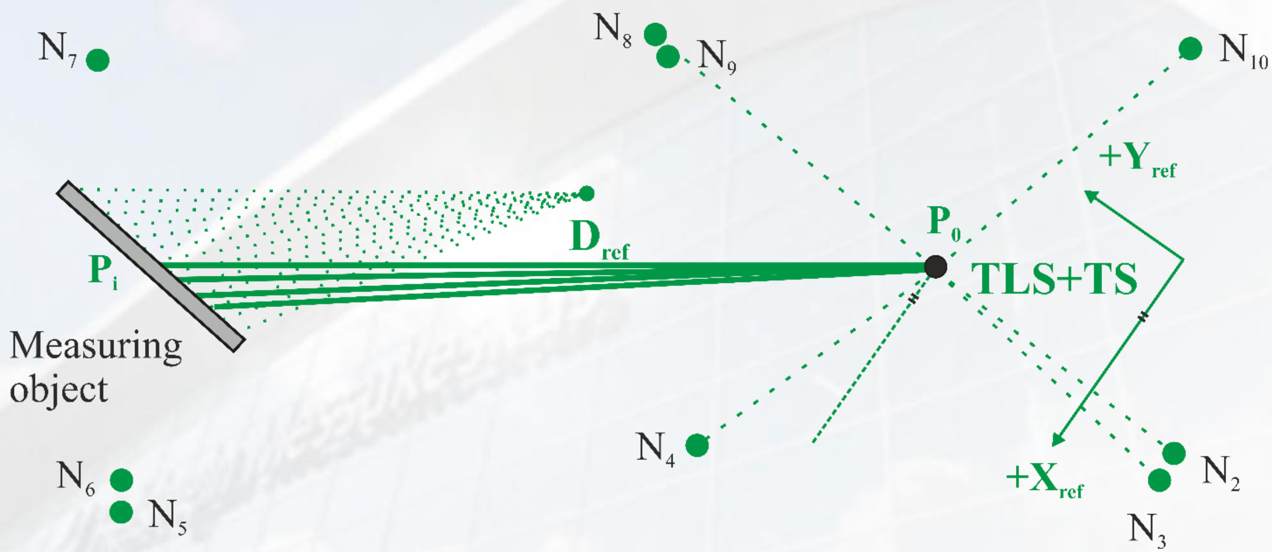
Determination of the reference distance

Step2: Determination of the station coordinates of the MS50

⇨ Starting point common to all reference distances

- Hz, V- measurements to the six nearest network points (CCR-Reflector)

⇨ backward resection and trigonometric levelling



- Precision: σ_x, σ_y, σ_z max. 0.02 mm

Determination of the reference distance

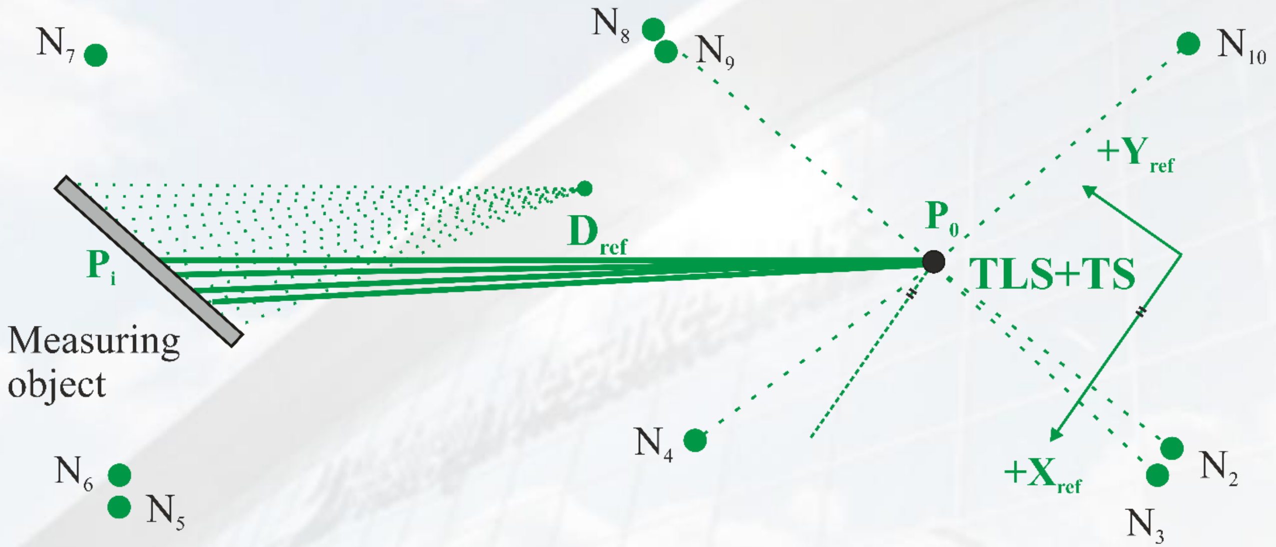
Step3: Determination of the reference point cloud

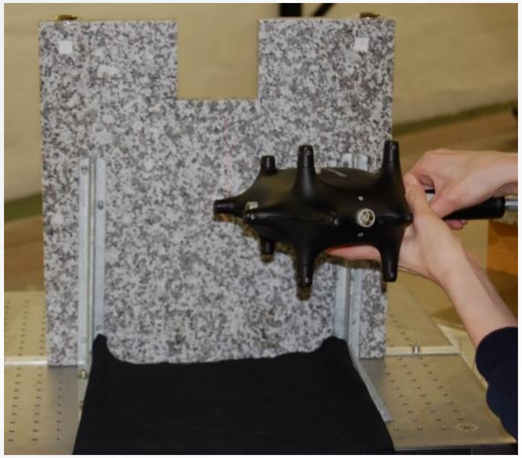
⇨ Endpoint of the reference distances

- Leica Absolute Scanner LAS-20-8:

  Uncertainty – spatial length (2 sigma) UL : 26 µm +4 µm /m

  Connected to the Laser Tracker ⇨ reference point cloud results in the reference frame





- Point spacing 0.05 mm (20 millions points)

Determination of the scanned distance

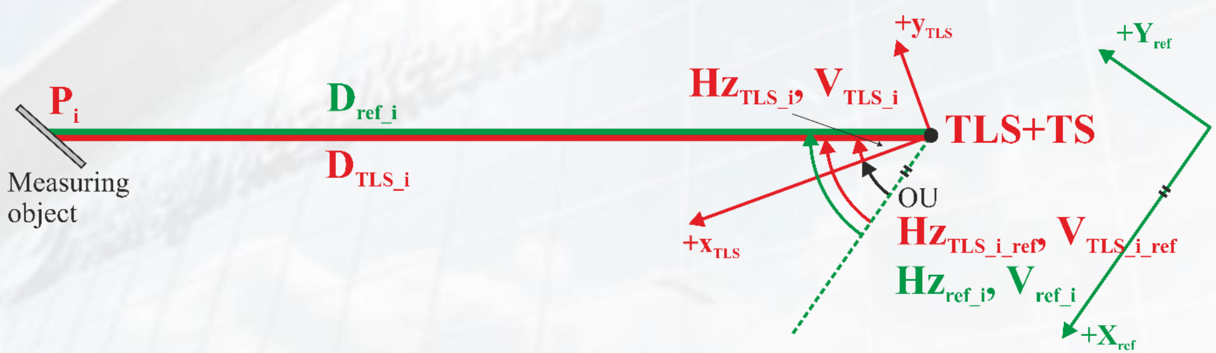
- Cartesian coordinates ⇨ D_{TLS} (Hz_{TLS}, V_{TLS})
- Scanning in local coordinate system (LCS)
- Measurement frequency 62Hz
- Distance 10 m
- Point sampling at 1 cm
- Repeated determination of the reference point cloud and the scanned distances for every IA and roughness level

Allocating the reference distance to the scanned distance

- Based on commonly referenced horizontal direction and vertical angle
  D_{TLS} (Hz_{TLS}, V_{TLS}) ⇔ D_{ref} (Hz_{ref}, V_{ref})

- V_{TLS} and V_{ref} are directly comparable as both the Laser Tracker and the TLS+TS are oriented to gravity

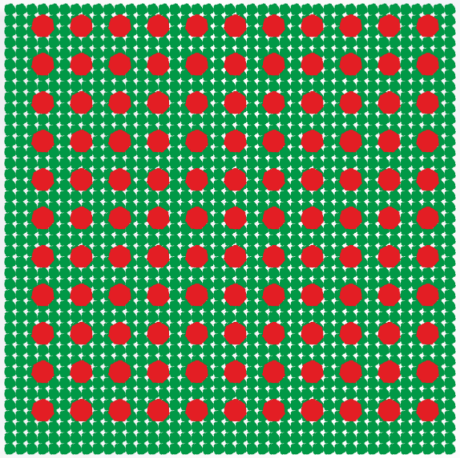
- Comparison of Hz_{TLS} with Hz_{ref} requires the estimation of the unknown station orientation OU ⇨ results from backward resection as well



Allocating the reference distance to the scanned distance

- Identification of corresponding D_{TLS} (Hz_{TLS_ref}, V_{TLS_ref}) and D_{ref} (Hz_{ref}, V_{ref})

- Search domain: $$Hz_{ref} - \Delta \leq Hz_{TLS\_ref} \leq Hz_{ref} + \Delta$$ $$V_{ref} - \Delta \leq V_{TLS\_ref} \leq V_{ref} + \Delta$$



- At 10 m - $\Delta = 3^{cc}$
  ⇨ max. impact on the distance under 60 gon = 0.06 mm

- Ca. 140 - 290 correspondences between D_{TLS} and D_{ref} were found for each IA

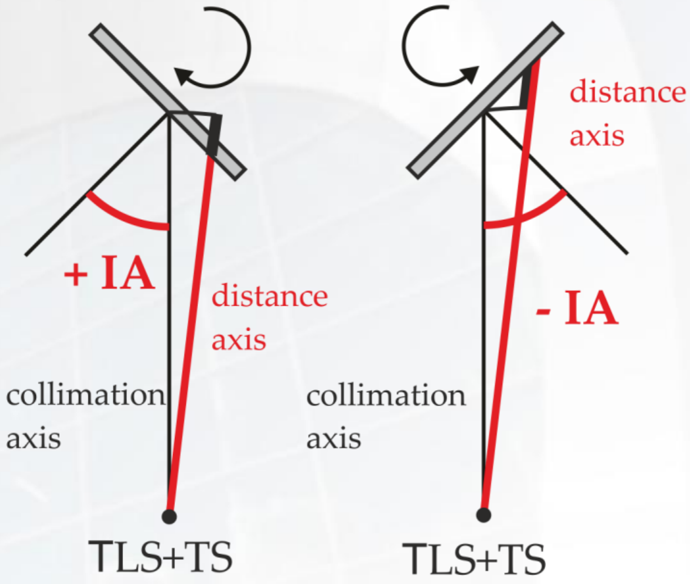
- Calculate the mean value and standard deviation of the differences $\Delta D_i = D_{ref,\,i} - D_{TLS,\,i}$ for each IA and roughness level

Quality assessment

- Quantification of the uncertainty of the reference distance according to the Guide to the Expression of Uncertainty in Measurement (GUM): $\sigma_{D\_ref} < 0.1$ mm

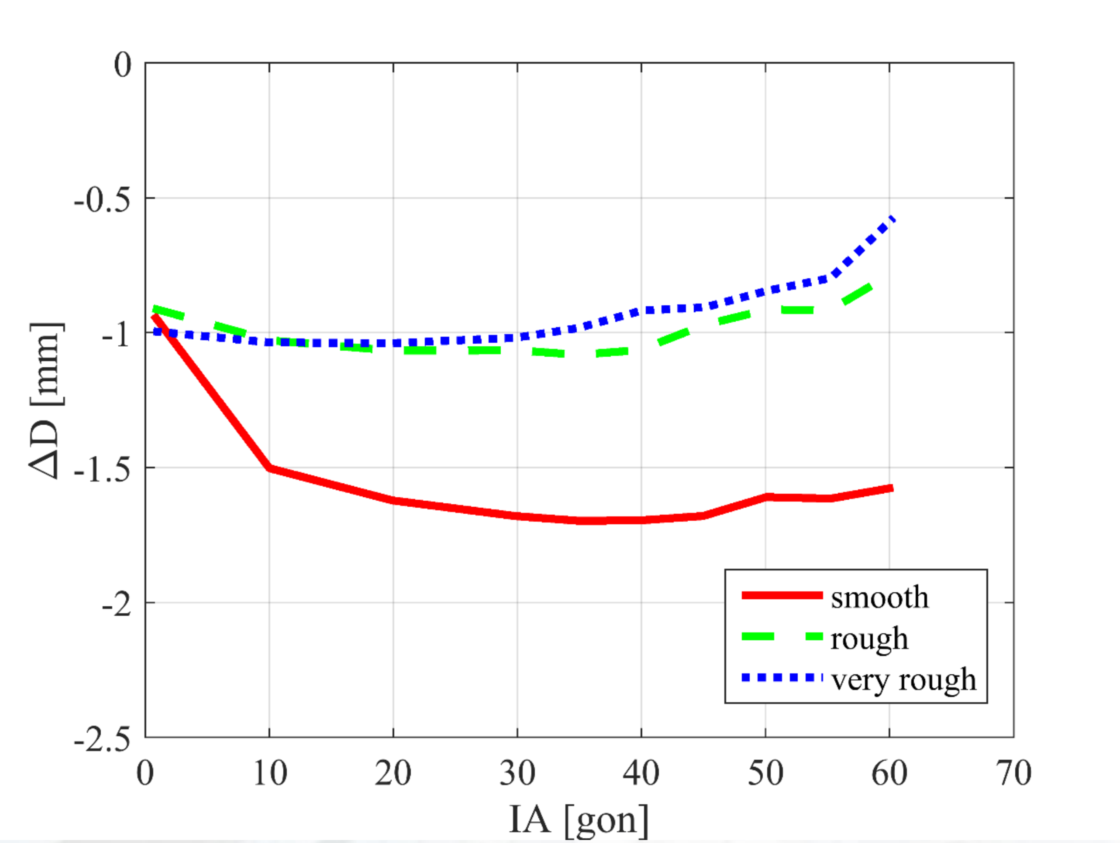
- Periodic measurements to check:
  - stability of TLS-specimen
  - stability of the Laser Tracker
  - stability of the reference frame

- Measuring configurations that reduce other influences causing similar effects,
  e.g. eccentricity between collimation and distance axis.



– Reproducibility: Second campaign with completely new set-up

Obtained results



- ΔD: mean values
- Max. discrepancy between curves determined in the two campaigns 0.09 mm
- Effect of traditional IA: smooth curve ⇨ 0.8 mm
- Joint effect of IA and roughness: differences between curves ⇨ < 1.0 mm
- Systematic nature of the combined influence
- Statistical significance of the joint effect

Thank you for your attention!