A Concept for the Calibration of Terrestrial Laser Scanners

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Overview

- Problem and previous calibration methods
- Test field TU Berlin
- Functional Model
- Measurement and analysis
- Conclusions




Problem

- Instrumental errors influences the result of the survey
  - Coordinates of the point cloud
  - Derived surfaces
- No option to use common calibration methods
  - Fix direction increments →
  - A direction can not be reproduced in two faces

Project Objectives

- Determination of calibration parameters, estimation of accuracy
  - Simultaneous in one step
  - No control points
  - Quick and dependable
  - Low effort (personal, equipment)
  - Reproducibility

Test Object

Technical specifications:
2 stepping motors
1 stepping motor interface
2 toothed belts
1 Leica „Disto Pro“

Measuring velocity:	1 point/s
σ_d:	± 1 mm
σ_{hz}:	± 0.01 gon
σ_v:	± 0.01 gon
Price:	750,- €

Calibration Field

Installation of a calibration field: 15 planes, evenly distributed

Detail of the calibration field

Planarity of the Plates

- Usage of common, coated chipboards (ca. 1,00 m x 1,30 m)

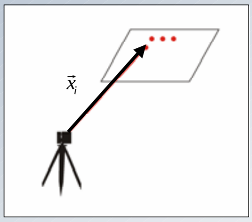
→ The functional model requires the planarity of the plates

Picture: Rollei 6006

Contour lines, distance 0,5 mm

Functional Model

- Determination of : $\vec{x}_i$
- Observables:
  - Horizontal direction Hz_i,
  - Vertical direction V_i,
  - Slope distance S_i
- Unknowns:
  - Plane parameter **n** and d
  - Translation t and orientation q
  - Addition constant k
  - Horizontal collimation error c
  - Trunnion axis error i
  - Vertical index error h
  - Eccentricities of axis a_x, a_y, a_z



Principle of Measure

Functional Model

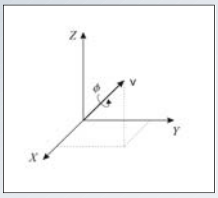
- Formulation of a condition equation for each point
  - consideration of original observations and the relevant instrumental errors

$$\vec{x} = f(Hz_i, V_i, S_i, c, i, h, k, m, a_x, a_y, a_z, \quad q, \vec{t})$$

- Plane equation

$$\vec{n} \cdot \vec{x} - d = 0$$

→ Parameterization of gyratory errors by quaternions



Functional Model

- Usage of Quaternions:
  - Bilinear adjustment problem
  - just one constraint for each rotation
- Sequence of transformations, as quaternion rotations around the three main axis
- Gauß-Helmert-Model

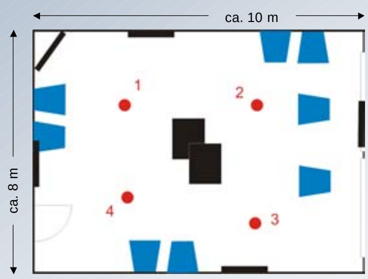
$$n_x^2 \cdot n_y^2 \cdot n_z^2 - 1 = 0 \qquad q_0^2 \cdot q_x^2 \cdot q_y^2 \cdot q_z^2 - 1 = 0$$

$$\begin{bmatrix} -N & C \\ C^T & 0 \end{bmatrix} \cdot \begin{bmatrix} \vec{x} \\ \vec{k}_2 \end{bmatrix} + \begin{bmatrix} -A^T \cdot M^{-1} \cdot \vec{w}_1 \\ \vec{w}_2 \end{bmatrix} = 0$$

reduced normal equation system

Calibration Procedure

- Scanning of calibration plates from different stations (Recommended: 4 equally distributed stations)

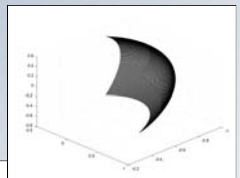


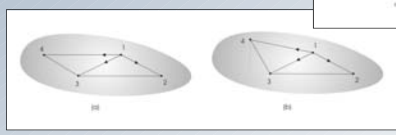
Ground plan

calibration room

Calibration Process

- Transfer of original measured values
- Station wise segmentation of planes
  - Triangulation
  - Detection (assignment point-plane)
- Adjustment of planes

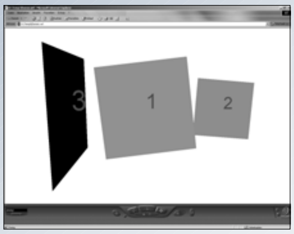




→ Parameters of planes i for each station j: (nx, ny, nz)i,j, di,j

Calibration Process

- Detection of identical planes:
  - Manually assignment: representation in a viewer (VRML-Plugin)

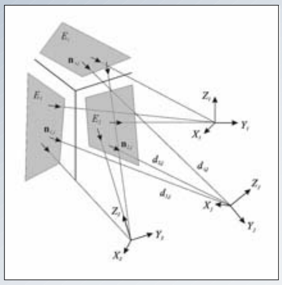


  - automatically assignment: usage of projective geometry and robust Monte-Carlo-methods, e.g. GASAC [Rodehorst 2004]

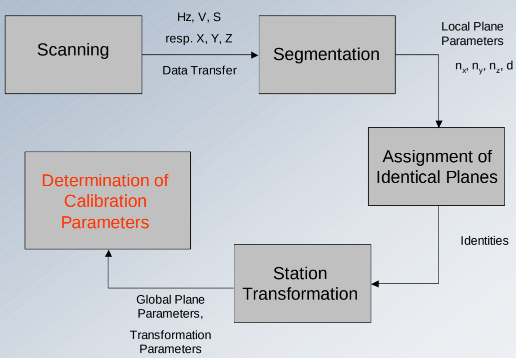
Calibration Process

- Simultaneous referencing of different stations by interconnected transformation by means of identical planes

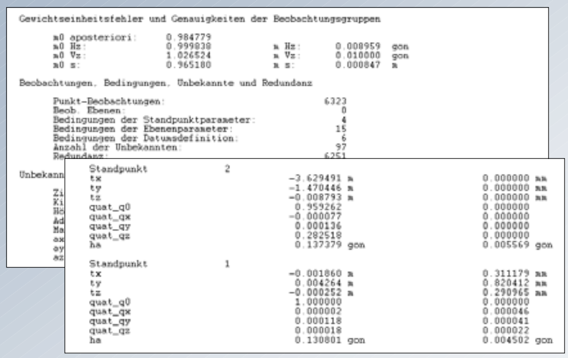
→ Proximity values for transformation parameters needed in the calibration process



Calibration Process - Overview



Results



Gewichtseinheitsfehler und Genauigkeiten der Beobachtungsgruppen

m0 aposteriori:	0.984779			
m0 Hz:	0.999838	m Hz:	0.008959	gon
m0 Vz:	1.026524	m Vz:	0.010000	gon
m0 s:	0.965180	m s:	0.000847	m

Beobachtungen, Bedingungen, Unbekannte und Redundanz

Punkt-Beobachtungen:	6323
Beob. Ebenen:	0
Bedingungen der Standpunktparameter:	4
Bedingungen der Ebenenparameter:	15
Bedingungen der Datumsdefinition:	6
Anzahl der Unbekannten:	97
Redundanz:	6251

Unbekann

Standpunkt 2		
tx	-3.629491 m	0.000000 mm
ty	-1.470446 m	0.000000 mm
tz	-0.008793 m	0.000000 mm
quat_q0	0.959262	0.000000
quat_qx	-0.000077	0.000000
quat_qy	0.000136	0.000000
quat_qz	0.282518	0.000000
ha	0.137379 gon	0.005569 gon
Standpunkt 1		
tx	-0.001860 m	0.311179 mm
ty	0.004264 m	0.820412 mm
tz	-0.000252 m	0.290965 mm
quat_q0	1.000000	0.000000
quat_qx	0.000002	0.000046
quat_qy	0.000118	0.000041
quat_qz	0.000018	0.000022
ha	0.130801 gon	0.004502 gon

Conclusions

- Calibration strategy for polar measuring instruments (scanners) acting by tacheometer principle
- Using of reference planes instead of reference points
- Simultaneous determination of relevant instrumental errors without wasteful reference measurements
- No determination of resolution, spot size, reflection behavior on different surfaces, effects at the measure to edges etc.

End

Thank you for your attention!

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