Technische Universität Braunschweig

Institut für Geodäsie und Photogrammetrie

Tutorial: Error Theory and Adjustment of Networks
Part: LASERTRACKER

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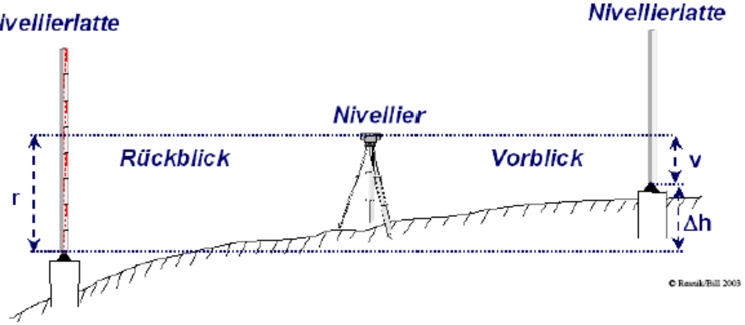
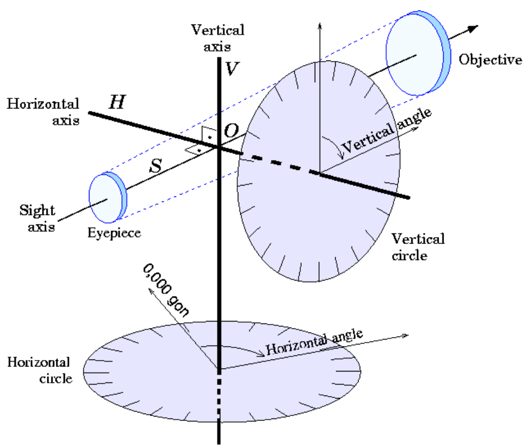
Typical Measuring Instrumentes

Typical Measuring Instruments

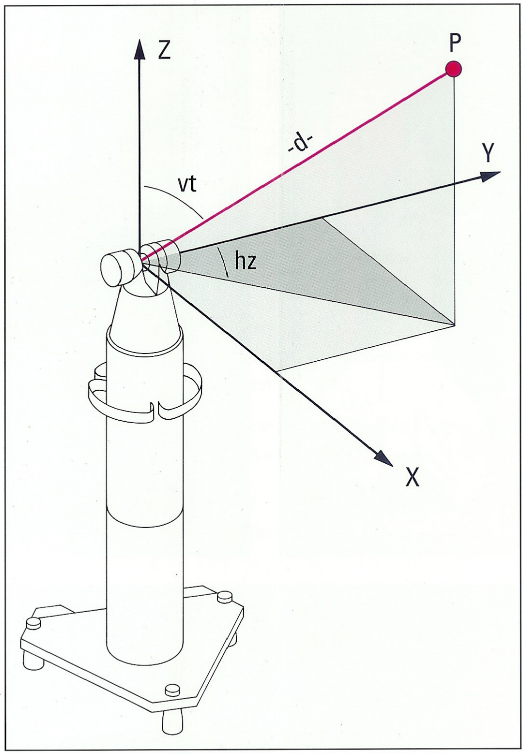
Levelling:



Total Station



Lasertracker



3D Cartesian Coordinate System

Principle: 3D-Cartesian Space
Often separated (Due to orientation to normal gravity vector)
- Horizontal xy-plane
- Vertical direction: z-component

Measurements:

- Horizontal directions / bearings $r_1, r_2, \ldots$
  Angles are differences betweer

- Slope distances d_i

- Zenithal angles z_i
  Elevation angles 100gon - z_i

Validity of 3D-Cartesian Coordinate System

A local cartesian coordinate system neglects the curvature of the earth. This effect can be computed for deviation in heights and for distances:

Distance [m]	Deviation in Height [mm]	Deviation for Distance in horizontal plane [mm]
50	-0.19	0.000
100	-0.78	0.000
250	-4.90	0.000
500	-19.62	0.001
1000	-78.48	0.008
2000	-313.92	0.066
5000	-1962.05	1.026

Typical observations and their pre-processing

Typical observations in local 3D networks

- **Leveling**
  - Height differences
- **Total Station**
  - Distances
  - Directions/Bearings
  - Zenith angels
- **Laser tracker (horizontation ?, see last chapter)**
  - Distances
  - Directions/Bearings
  - Zenith angels

Functional relation between observations and coordinates

Observations between point P_i and P_j. X, Y, Z are point coordinates.

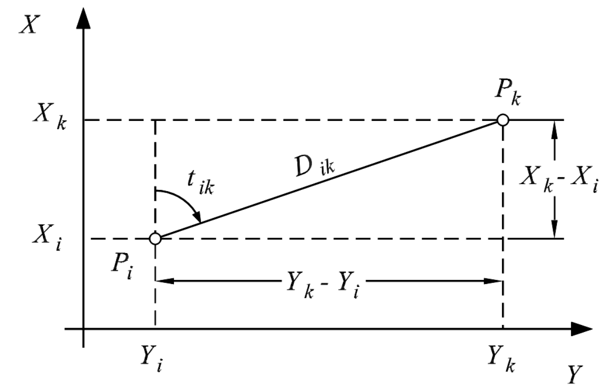
$$\Delta h_{ij} = Z_j - Z_i$$

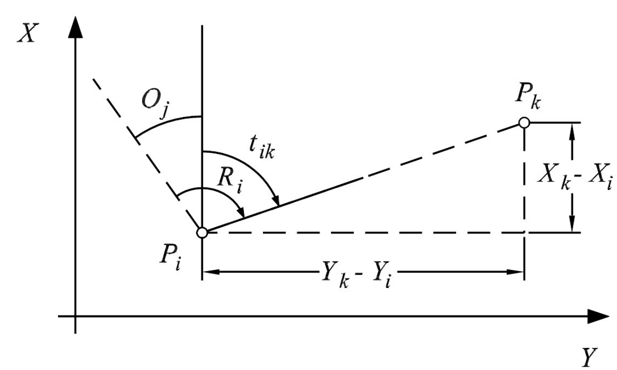
$$d_{ij} = \sqrt{(X_j - X_i)^2 + (Y_j - Y_i)^2 + (Z_j - Z_i)^2}$$

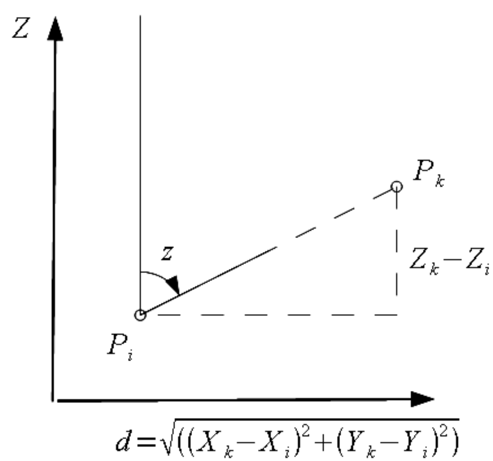
$$r_{ij} = \operatorname{atan}\left(\frac{(Y_j - Y_i)}{(X_j - X_i)}\right) + o$$

Parameter o: orientation unknown

$$z_{ij} = \operatorname{acos}\left(\frac{Z_j - Z_i}{d_{ij}}\right)$$







Additional Parameters:

- Calibration is not perfect, add:

  -**Additional constant** for distances

  -**Scale factor** for distances

- **Refraction unknown** for zenith angles
  to account for atmospheric effects, e.g. in tunnels

- **Deviations of the vertical**
  affects directions and zenith angles;
  important to account for gravity field variations

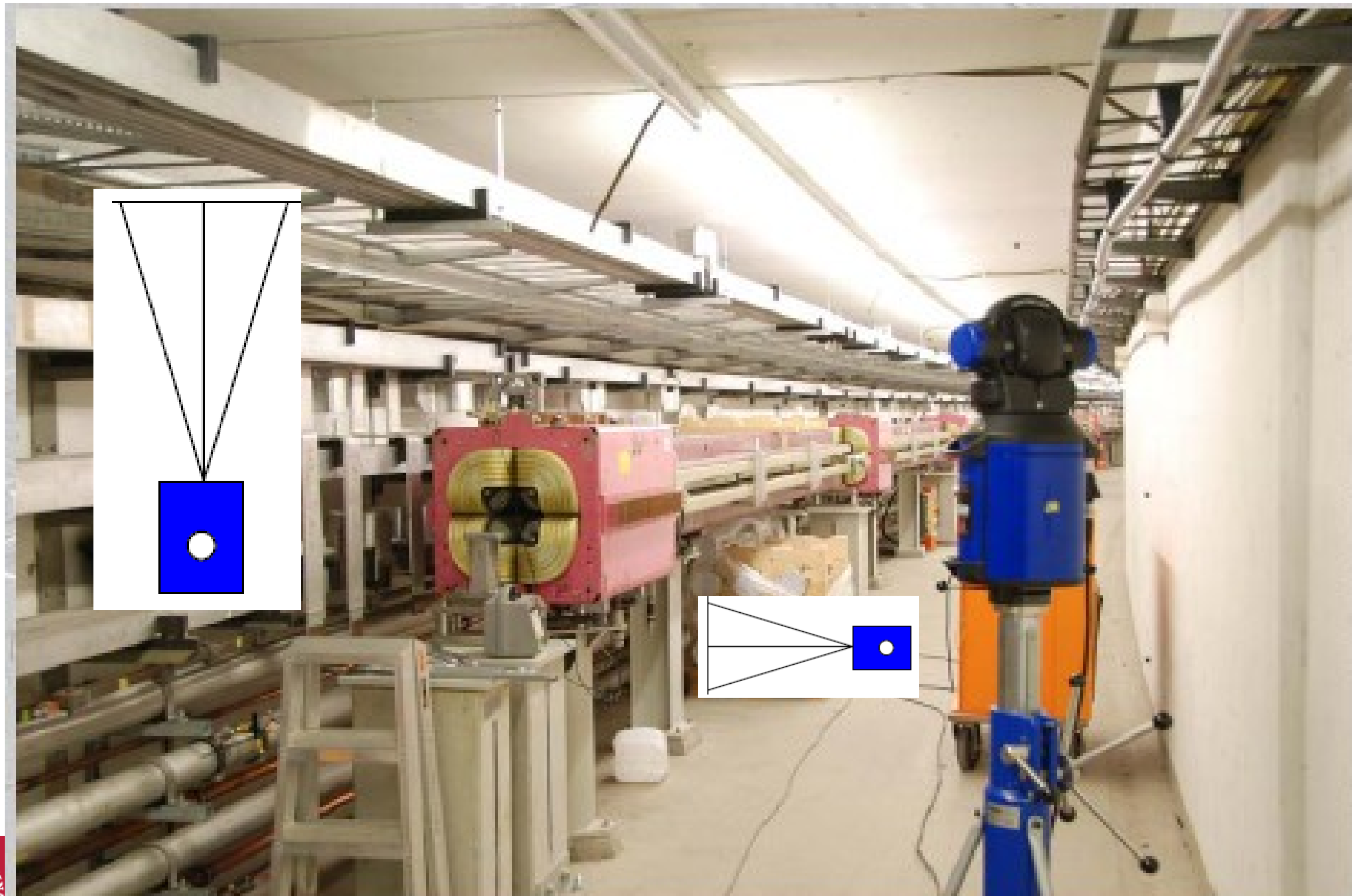
Combination of Lasertracker with other instruments

Characteristics of a Lasertracker

- **Absolute** and **relative** **distances**, **horizontal** and **vertical** **angles/directions**
- **Not** automatically **oriented to earth gravity field** (only by external levels)
- **Calibration** is given by manufacturer, can be controlled by user
- **Precision of Distance Measurements**
  - Interferometric: Continuous with **nm** precision : 10^{-9}
  - Absolute: 0.025 mm + 0.001 ppm
- **Precision of Angles Observations** (automatic readings)
  - Horizontal : 0,6 mgon
  - Vertical : 0,6 mgon

  i.e. less precise than total stations with e.g. $\sigma_H = \sigma_V = 0.15$ mgon

Use of Lasertracker with arbitrary orientation : Rotation up to 180°



Treatment of extrmely rotated Lasertracker :

Include for each set-up (position) of lasertracker data a complete set of three orientation angles

φ ω κ

i.e. use **full 3D-rotation matrix** for observations

To be introduced for each instrumental set up

Requires : Approximate values for these rotation angles.
(Their determination is without the scope of this tutorial)

Rigorous hybrid adjustment is possible: Lasertracker, Total Station and levelling

Use **lasertracker measurements**,
i.e. horizontal directions, vertical angles and distances
with their adequate covariance-matrix
as **additional group of observations** in **adjustment model.**

$$
\begin{vmatrix} L_{hz} \\ L_{vz} \\ L_{dist} \\ L_{lev} \\ L_{az} \\ L_{hz'LT} \\ L_{v'LT} \\ L_{dist'LT} \\ . \\ . \end{vmatrix}
+
\begin{vmatrix} v_{h} \\ v_{z} \\ v_{dist} \\ v_{lev} \\ v_{az} \\ v_{hz'LT} \\ v_{v'LT} \\ v_{dist'LT} \\ . \\ . \end{vmatrix}
=
\begin{vmatrix} A \end{vmatrix}
*
\begin{vmatrix} x_{x} \\ x_{y} \\ x_{z} \\ x_{add} \\ x_{trans} \end{vmatrix}
$$

Software Package PANDA

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Package for Adjustment of Networks and Deformation- Analysis

Interactive processing of **1D-, 2D- and 3D**-geodetic networks out of all areas of surveying and geodesy

Preprocessing of **raw total station and leveling data**, including plausibility control and computation of approximate coordinates

Combined rigorous adjustment of lasertracker. total station, leveling and azimuth observations together with GPS-coordinate sets and existing/given coordinates

Deformation analysis for 1D-, 2D- and 3D-networks (e.g. rigorous congruency tests)

Interactive **simulation** and network **optimization**

Software Package PANDA

Package for Adjustment of Networks and Deformation- Analysis

Independant development **for PC** under WINDOWS

Local cartesian, local spherical, **ellipsoidal and global cartesian** coordinate systems; different mapping systems

Different **transformation** concepts are included

All common **datum definitions**: Fixed datum, minimum constraint and weak datum; hierarchical concept

All common **quality measures** for **precision** and **reliability**

Can process **large networks** (e.g. 20.000 stations) in acceptable time