The Open Source Software Package UNlTƐD

Controlling, Measuring and Analysing

Laboratory for Industrial Metrology

Metrology…

- Interdisciplinary area of expertise e.g. physicists, mechanical or surveying engineers
- Different approaches and principles of operation

- Collaboration and exchange of knowledge required
  - Consistent terminology
  - Established working practice

- Guide to the expression of uncertainty in measurement
  - Supplement 1: Propagation of distributions using Monte Carlo method
  - Supplement 2: Extension to any number of output quantities

Software…

- Most of (commercial) software packages do not support GUM
- Implemented algorithms are black-boxes and often undocumented
- Key parameters are missing
- Uncertainties are derived in a non-traceable way

- Conclusion of external comparisons of metrology software packages
  - Radomi & Schlösser (2010): *"There are significant differences in the results."*
  - Hermann et al. (2015): *"The reason for the differences [...] could not be distinguished clearly."*

ISO-25000: *"It is important that any quality feature of a software product is determined and evaluated whenever possible using validated or generally accepted measures."*

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Milestones

- Sensor communication (e.g. Lösler et al. 2013)
- Prototype for 6-DOF bundle adjustment (e.g. Lösler & Eschelbach 2012)
- Toolbox for analysing geometric primitives (e.g. Lösler & Nitschke 2010)

Combining components → UNlTƐD

- Smart software solution for metrology and engineering
- Customised for survey engineers
- Restricted to essential components to ensure intuitive operation and handling
- Rigorous analysis using e.g. errors-in-variables model
- Focused on GUM to estimate traceable uncertainties
- Extending scope of operation e.g. congruence analysis

Sensors…

Metrology sensors

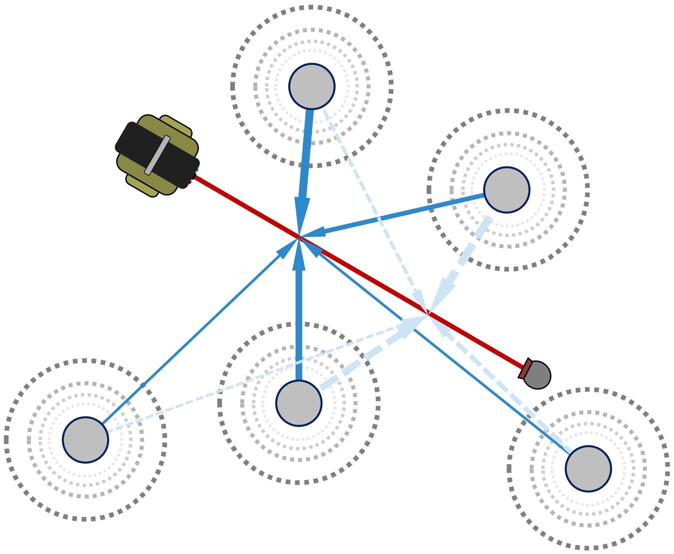
- Total stations via GeoCOM (Leica)
- Laser tracker AT40x (Leica) and Omnitrac 2 (API)

Meteorology sensors

- Wireless sensor network (TSYS01, SHT21, BMP280)
- Meteorological station GFTB100
- Data logger MSR145

First velocity correction (Ciddor 2002)

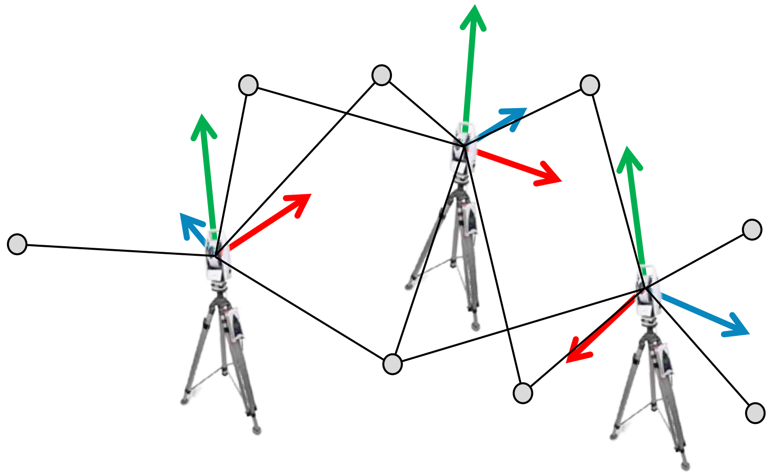
- Inverse distance weighting
- Piecewise correction of electronic distance measurement unit



Bundle Adjustment…

Functional model

- Rigorous combination of observations of k instrument locations
- Quaternion algebra for bilinear equations
- Gauß-Markov model with restrictions

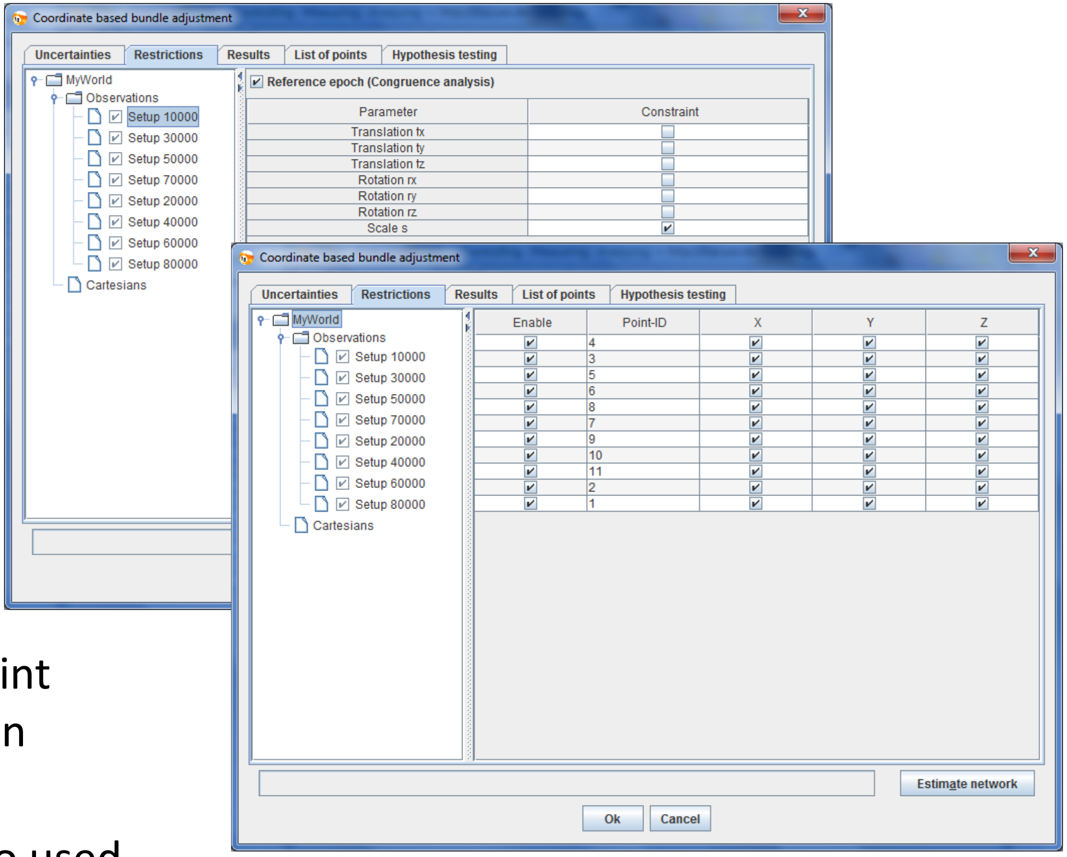


$$\begin{bmatrix} \mathbf{A}_{\tilde{\mathbf{p}},1} & \mathbf{A}_{\mathbf{T},1} & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{A}_{\tilde{\mathbf{p}},2} & \mathbf{0} & \mathbf{A}_{\mathbf{T},2} & \cdots & \mathbf{0} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \mathbf{A}_{\tilde{\mathbf{p}},k} & \mathbf{0} & \mathbf{0} & \cdots & \mathbf{A}_{\mathbf{T},k} \end{bmatrix} \begin{bmatrix} \mathbf{x}_{\tilde{\mathbf{p}}} \\ \mathbf{x}_{\mathbf{T}_1} \\ \mathbf{x}_{\mathbf{T}_2} \\ \vdots \\ \mathbf{x}_{\mathbf{T}_k} \end{bmatrix} = \begin{bmatrix} \mathbf{l}_{\mathbf{p},1} \\ \mathbf{l}_{\mathbf{p},2} \\ \vdots \\ \mathbf{l}_{\mathbf{p},k} \end{bmatrix} + \begin{bmatrix} \mathbf{v}_{\mathbf{p},1} \\ \mathbf{v}_{\mathbf{p},2} \\ \vdots \\ \mathbf{v}_{\mathbf{p},k} \end{bmatrix}$$

Bundle Adjustment…

Restrictions in functional model

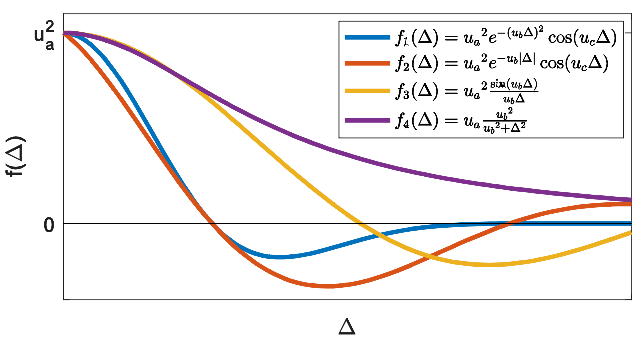
- Constraining the number of integration parameters e.g. fixing scale parameter
- Datum restrictions to solve the rank deficiency of normal equation
- Free choice of definition of geodetic datum, i.e. defining point components for datum definition
- Note: Non-datum points are also used to combine local instrument frames

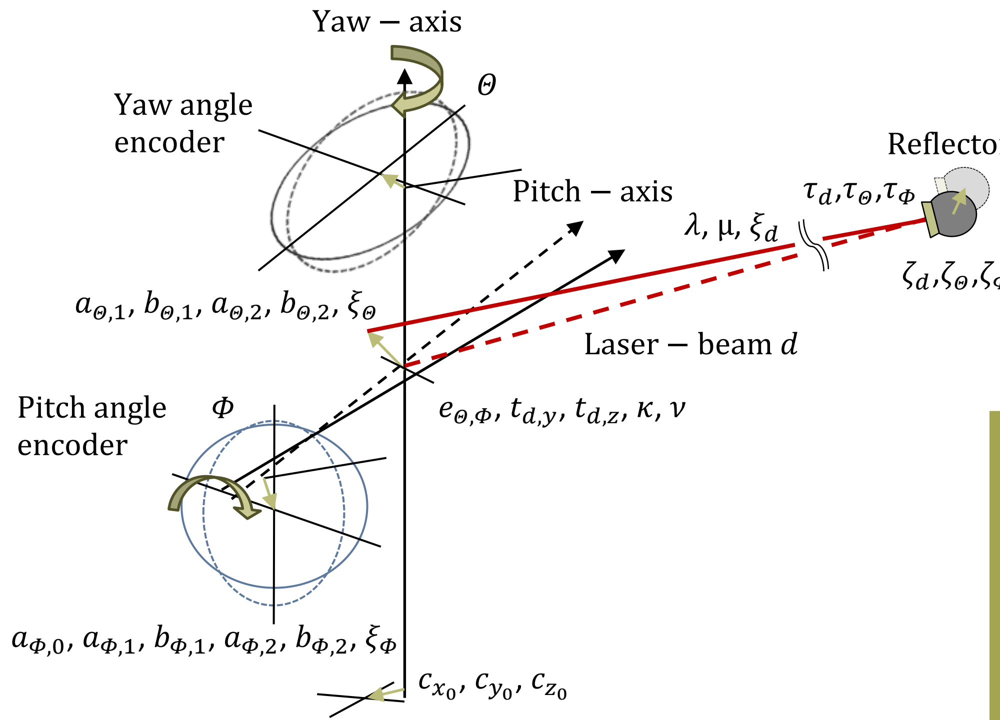


Bundle Adjustment…

Stochastic model

- Extended version of Hughes et al. (2011) compensation model, cf. Lösler et al. (2016)
- Converting polar observations to Cartesian coordinates
- Considering correlation functions for time-dependent covariances
- Fully populated variance-covariance matrix per instrument frame





J Geod: Lösler et al. 2016

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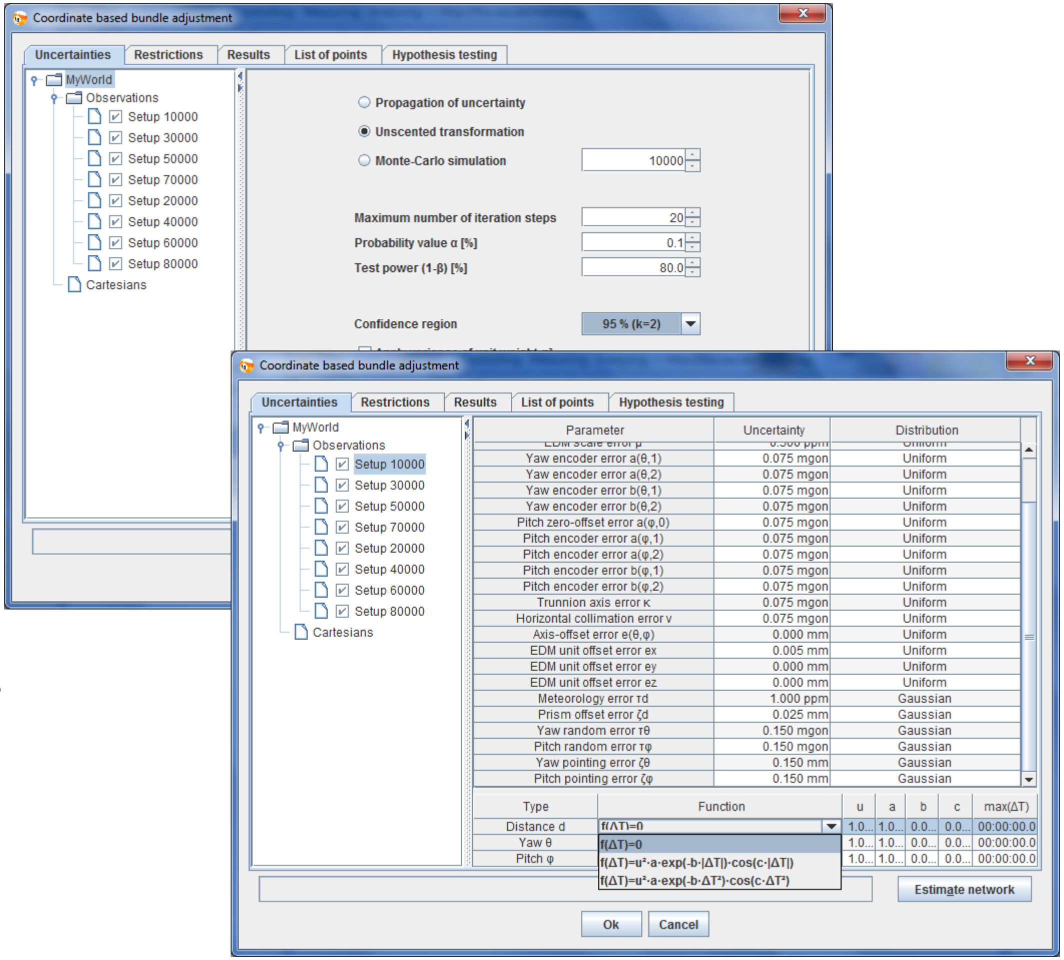
Bundle Adjustment…

Stochastic model

- Propagation of uncertainty
- Unscented transformation (2nd order Taylor expansion)
- Monte-Carlo simulation

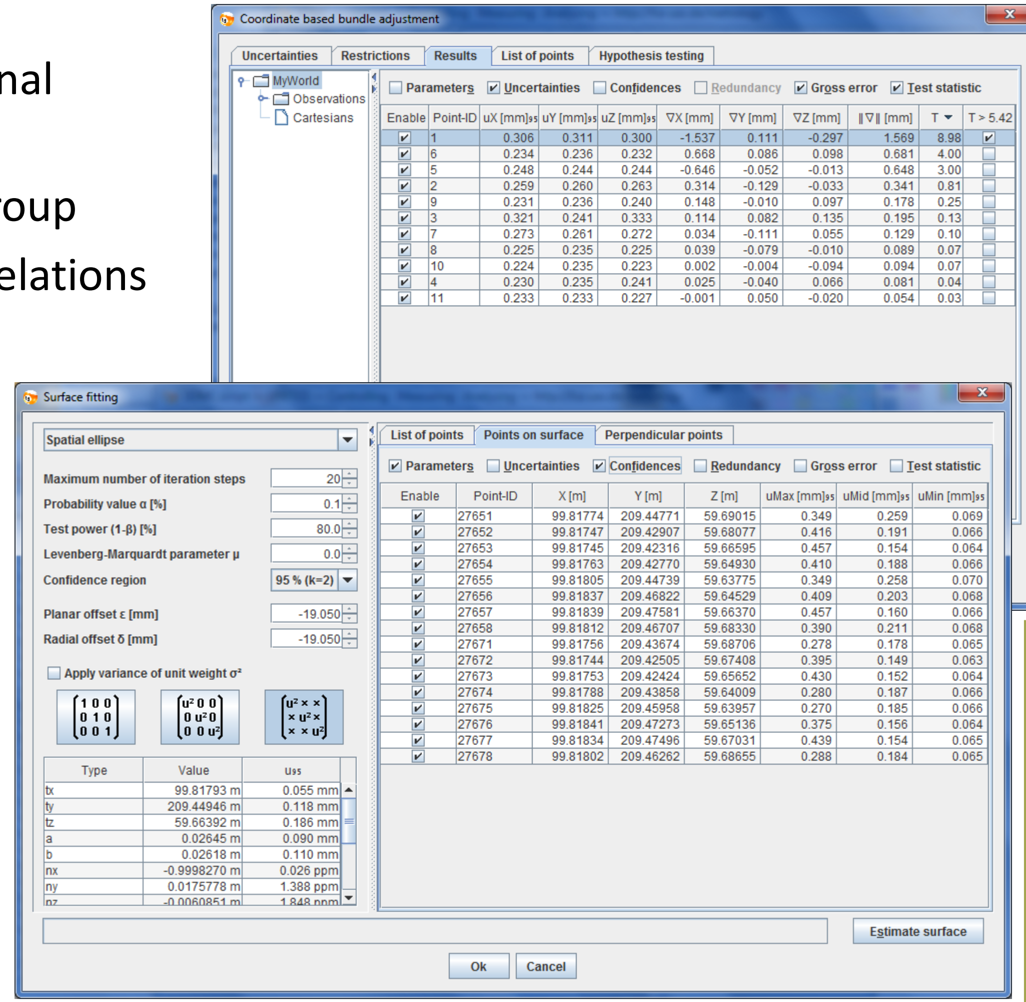
- 25 uncertainty-parameters per instrument frame

- Two correlation functions for time-dependent covariances



Further analyses components…

- Congruence analysis based on original observations
- Stability check of reference point group
- Consideration of inter-epochal correlations



- Fitting of geometric primitives, e.g. spatial ellipse, elliptic cylinder etc.
- Errors-in-variables model
- Taking fully populated variance-covariance matrix of bundle adjustment into account
- Applying offset correction during adjustment process

Thank you for your attention…

If the *kits* are

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