Integrating SLRS results with Geodetic Network Adjustment. Markus Schlösser

Straight Line Reference

Network accuracy w/o SLRS (simulation)

Network accuracy with SLRS (simulation)

Network adjustment, SLRS data included

Adjustment models

There are three different models of Least Square Adjustment, that are based on Error and Unknown Linear Models (LSAM).

Least Square Model

\[ \mathbf{Q} = \mathbf{L}^\top \mathbf{L} + \mathbf{Q}_n \]

A similar model where each single observation from the total vector of observations (\( \mathbf{L} \)) has to be expressed as a factor of the unknown (\( \mathbf{Q}_n \)). This model is used in PANDA and lots of other geodetic network adjustment packages. When using only observations, \( \mathbf{Q}_n \) does not exist, but because of the fact, that the error is not the same for different observations, this is the most appropriate model because of its relative simplicity.

Generalized Least Square Model

The Least Square Model is a special case of the Generalized LSAM, when using non-standardized observations, or having unknowns other than coordinates of points, it is simple to separate the observations from the unknowns in the functional equations. In the case of the Generalized Least Square Model, the observations are represented by a stochastic model of a higher computation effort and a more complicated model.

Constrained Model with observations

This model introduces additional constraints between unknowns. It is possible to constrain certain network monuments to form a straight line, a well-defined curve, ellipse, circle, etc. This model generally has similar computational cost as the standard LSAM, especially when expressing each single observation as an observation of the unknowns.

Constrained Model with SLRS observations

SLRS observations constrain certain points to form a straight line. With being the number of SLRS measurements, we get n-2 constraints.

Network accuracy with SLRS (simulation)

This SLRS also performed very well, horizontal alignment stayed well inside the expected error band of ±0.5mm. The vertical alignment, while being inside the required error band, was performing slightly worse than for SL4. The reason for this is unclear, but some vertical alignment movements could be assumed in the area due to heavy ground work above the tunnel in the second half part of the undulator.

Summary

Adjustment model

While the constrained model seems to provide a nice and clean solution for the constrained adjustment, this approach has drawbacks. It is necessary to perform a lot of pre-calculations with the help of standard network analysis programs to a single straight line information that can be inserted into the constrained model. Whenever using derives observations, information is dropped from the model, which means a loss of information in the general least square model. This limits the usability of the model. For the SLRS adjustment there are a couple of generic parameters that can be used for the overall adjustment process and not estimated beforehand. By pre-estimation:

1. Observation error covariance
2. Functional parameters of targets
3. One or more observations
4. Overall orientation of SLRS in network

To estimate these additional parameters, it will be necessary to use a Generalized LSAM. The complete model is quite complex and not yet complete.

Preliminary model

Evaluation of existing data sets with a preliminary model has proven to work well (SASE1 and SASE2). The remaining errors were then clearly the result of the chosen model, according to the LSM results. Today's LSM still does not operate inside its specifications. While the vertical alignment remains well inside the space, the horizontal alignment is exceeding the allowed tolerance by almost a factor of three. Due to time constraints, it was not possible to successfully re-measure this version with geodetic techniques, which was a case in the simulation using the SLRS data. The simulations did not produce the same quality of results as the other two LSM, but at the moment the reason is unknown.