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Model comparison and data analyses for 2D/1D and 3D network adjustment with sample data of two vertical shafts and an inclined tunnel

Upwards view in the shaft[1]

Aerial photo of Kiruna Mine[2]

Introduction

Tunnel and shaft surveying have always been a special challenge. Especially the creation and continuous extension of geodetic networks are especially complicated due to the prevailing conditions. These circumstances require continuous adaptation to the conditions on site, experience in practical implementation and most importantly deeper knowledge of adjustment theory and quality assessment. Depending on the purpose of the measurement, different requirements are imposed on accuracy and reliability. In order to be able to meet these, the correspondingly suitable measuring instruments and measuring methods must be selected. The adjustment calculation is one of the basic methods for optimally solving overdetermined tasks, so that the result can be evaluated in its quality and quantity. It also provides an insight into the dimension, distribution and effect of the deviations and allows a judgement of the achieved accuracy and reliability of the measurement. In this thesis the special conditions of shaft and tunnel measurements shall be shown and a adjustment of shaft and tunnel networks be calculated and the results compared.

2D/1D Adjustment Approach vs. Quasi-Integrated 3D Approach

The classical network adjustment approach is still the 2D/1D approach in which, plane and height is adjusted separately using different weights. The measured slope distance and zenith angles are reduced to the ellipsoid (plane) and to physical or ellipsoidal height system (height). The resulting horizontal distances and height differences are then used for the adjustment process. In the quasi-integrated 3D adjustment approach the three dimensional measurements slope distance, direction and zenith angles are adjusted together. Mathematical dependencies in-between the coordinate components will be rigorously considered. It is therefore also possible to include different sensor, like GNSS or laser scanning to be adjusted in the same step. Also additional parameters like orientations, vertical deflections or integration parameters of GNSS baselines can be estimated.

2D/1D and 3D Comparison

The different adjustment approaches can not be compared directly due to differences in reference systems. A simplified way to compare the results of micro networks from both approaches is through coordinate conversions and a 3D-Helmert-Transformation in-between the resulting coordinates from the 2D/1D and the 3D calculation. In a first step the coordinates of the 2D/1D approach are converted into geographical coordinates (B,L,H) and then into “quasi”-geocentric coordinates. In a second step, these “quasi”-geocentric coordinates serve as sourcesystem and the coordinates of the 3D approach as targetsystem for the 3D-Helmert-Transformation. The resulting residuals represent the differences in respect to “position” and “height” components in-between the 2D/1D and 3D adjustment approach.

Conclusion

The various aspects and influences on measurements in a tunnel or shaft environment range from instrumental and algorithmic influences to influences of atmospheric conditions (refraction) and problematic measurement configurations. Particularly the measurements with ATR and the lack of corrections at steep visors are to be emphasised. Care should be taken to obtain the highest possible redundancy of the network and observations. This is an important factor with regard to a later adjustment calculation.

The comparison of the two adjustment approaches showed small differences for the sample data. Nevertheless, due to the rigorous consideration of mathematical dependencies and the wide range of applications, the 3D approach is to be preferred for the network adjustment in engineering surveying. More work and research should be done to find the best possible practice for this method for the usage in vertical and inclined shafts, just like it was done for the usage of total stations in tunnels.

[1] private image
[2] NASA Earth Observatory image by Joshua Stevens

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