

Adjustment

Why do we need **Adjustment**? Which model is used and why? Which tests are applied and why?

These are some of the general questions that are addressed in this newsletter together with some practical tips for making the best use of the Adjustment component in SKI-Pro in practice.

Why use Adjustment?

Adjustment serves as one of the principle quality control tools. It enables the surveyor to assess whether the work, which has been done actually meets the requirements in terms of precision, accuracy and reliability. It also provides analysing measures, which assist the surveyor in identifying errors when the requirements have not been reached.

In addition, in 'Design' mode the Adjustment component can be used to design a network and thereby give the surveyor an indication of the expected precision, which can be achieved in advance. As such, **Adjustment** can also assist with **Quality Assurance** measures before a survey is done.

Adjustment is a tool, which helps to prevent costs associated with poorly designed networks or undetected errors.

In addition it provides the process through which you can determine the best coordinates from the data.

The Mathematical Model

SKI-Pro uses the powerful **MOVE3™** adjustment kernel. This is a fully rigorous three-dimensional model. The

model has the advantage that it is not necessary to reduce any of the observations before they can be used – the observations which are observed are those which are entered into the adjustment. This is particularly important because it means it is also not necessary to convert the stochastic information, which accompanies the observations.

It should be noted that the stochastic model is equally important as the mathematical model. The mathematical model describes the relationship of the parameters (coordinates) to the observations. The stochastic model describes the relative weights (or precisions) of the observations.

A least-squares adjustment is performed, in which the observations are adjusted in order to minimise the sum of the squares of the weighted observation residuals. It should be clear that in order to perform a meaningful adjustment with its associated statistical tests, redundant observations are required, otherwise there is nothing to adjust. However, you should also not include any of the so called 'trivial' GPS baselines in the adjustment in order to artificially raise the number of observations and redundancy.

Free and Constrained Adjustment

The recommended procedure is to first perform free network adjustments before the constrained adjustment.

The objective in the free network adjustment is to check for observational errors and this is best done without

imposing additional constraints from fixed points.

Once you are satisfied that outliers have been eliminated, fixed (Control) co-ordinates can then be added to perform a constrained adjustment. In the constrained adjustment the emphasis is on analysing the fixed coordinates and on computation of the final co-ordinates.

Statistical Testing

The main aim of the statistical testing is to identify outliers. It is also used as a general check on the 'correctness' of the mathematical and stochastic models. The tests are all based on the analysis of the least-squares residuals. There are three main tests implemented in SKI-Pro – the **F-test**, **W-test** and **T-test**.

The **F-test** is a general test, which tests the overall model. A failed F-test indicates there is a problem but it is not specific – the problem could be due to such things as an observation blunder or over-optimistic variance-covariance information. However, before attempting any scaling of the variance-covariance matrices you should eliminate any blunders. The **W- and T-tests** can provide assistance with this process.

The **W-test** is based on the principle of testing each observation element in a network for a blunder against a computed critical value. The critical value is computed based upon the chosen level of significance, which is typically set to 95% (100-alpha) % and the power of the test which is typically set to 80% (1-Beta) %. Because of the 1-dimensional nature of this

test, it works particularly well for TPS observations (directions, vertical angles and distances). For GPS observations, each element DX, DY and DZ are tested separately against the computed critical value.

The **T-test** is a multi-dimensional test and therefore is ideally suited for testing GPS baseline observations with the 3 elements together. The test is also useful for testing the coordinates of the known (Control) points where data entry (typing) errors may occur.

The **W-tests** and **T-tests** are both key indicators in the **data-snooping** process.

There is one additional test in SKI-Pro – this is the '**Antenna Height-test**'. This test is always computed if GPS baselines are included in the network. The test consists of separate W-tests for the East, North and Height residual components. The antenna height is only rejected if the height component is rejected and the east and north components are accepted.

Interpretation of the tests

As already mentioned the data-snooping investigations should mainly take place when performing free network adjustments. In addition, especially where large networks are concerned, it is good practice to build up the network gradually and analyse the network step-by-step rather than attempt to identify potential errors after all observations have been

imported. This is because the general testing concept is based upon the hypothesis of detecting a single error. In a situation where many errors are present, it is difficult to identify the specific errors because the errors tend to get spread by the least-squares process.

In general, with all testing results you must also keep in mind that all tests are based upon a certain degree of probability. The tests only suggest where outliers may exist, they do not categorically state that an outlier does exist. In the end it is the responsibility of the surveyor to combine the adjustment tools with other information drawn from experience, common sense and other external information when deciding whether to reject observations from a network.

One should also keep in mind that it is not the goal to get all tests accepted, but to detect errors and correct or eliminate them where possible. An observation or coordinate should never be edited in order to make it fit better with the other data in the network, unless there is clear evidence of the source of the error (eg. typing error). It is also sometimes quite acceptable to retain observations, which are marked as suspect, especially if they only just exceed the critical value for the test. Finally we have to keep in mind that, depending on the level of significance, there is always a chance of rejecting a valid observation!

Final results

Once you are happy with your adjusted coordinates, the next step is often to export them. If the network contains control coordinates, which are fixed in just position or height then it is recommended that you export the '**Adjusted**' class rather than the '**Main**' coordinates. This is because the **main co-ordinates** will choose the **Control** in preference to the **Adjusted** coordinates and the Control coordinates may contain only approximate co-ordinates for the parts that are not fixed.

Remember

- Adjustment assists in determining the best coordinates from your data.
- A fully rigorous three-dimensional model is used which does not require the observations or stochastic information to be reduced.
- Adjustment is a quality control tool which helps to identify errors from observed data.
- It is also a quality assurance tool when used in design mode prior to collecting data.
- Various statistical tests are provided to assist the data-snooping process but all test results must be considered together with user interpretation.
- Build up large networks step-by-step, conducting 'free' adjustments to help locate errors.
- Export class Adjusted to ensure that the best coordinates are exported.