



USER MANUAL

Version 4.0

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Grontmij Nederland bv
Bovendonk 29, P.O. Box 1747, 4700 BS Roosendaal, The Netherlands
Telephone +31-165-575859; Telefax +31-165-561368
E-mail MOVE3@Grontmij.nl
<http://www.MOVE3.com>

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1. Getting started

- GPS Baselines;
- Observed GPS coordinates;
- Geometrical relations:
 - angle between 3 points (incl. perpendicular);
 - parallel lines (incl. mutual distance);
 - co linearity;
 - perpendicular lines;
 - distance from point to line;
 - chainage and offset;
 - double distance;
 - tape distance;
 - identical.

Processing Modes

3D, 2D and 1D geodetic networks can be processed in:

- Design mode, free network;
- Design mode, constrained network;
- Adjustment mode, free network;
- Adjustment mode, constrained network.

Projections

The following projections are supported:

General:

- Transverse Mercator;
- Lambert;
- Stereographic;

Specific:

- RD (The Netherlands);
- Lambert 72 (Belgium);
- Gauss Krüger (Germany);
- Local (Stereographic);
- BRSO;
- Malaysian RSO;
- Swiss.

Tools

MOVE3 includes separate tools such as fully automatic computation of approximate coordinates (COGO3), automatic loop detection and misclosure testing (LOOPS3) and adjustment pre-analysis (PRERUN3).

General

- Open file specifications (ASCII files);
- Language support : English, Dutch;
- Interfaces with GPS baseline processing packages (Ashtech, DSNP, Leica, Sokkia, Spectra Precision, Topcon, Trimble and Zeiss);
- Interfaces with total station files from Leica, Topcon, Sokkia and Trimble;
- Interfaces with digital levelling files from Leica, Topcon, Sokkia and Zeiss digital levels;
- Interface with Dutch, US and Canadian geoid models;
- Exporting DXF files;
- On-line help facilities.

1.2. Installation

1.2.1. Package Contents

The MOVE3 package contains the following components:

- MOVE3 installation CD;
- MOVE3 hardware lock.

1.2.2. Hardware and Software Requirements

The following hardware is required to run MOVE3:

- PC with parallel or USB port;
- hardware lock (included in the MOVE3 package).

The following software is required to run MOVE3:

- Microsoft Windows XP/Vista;
- MOVE3 software;
- Sentinel system drivers.

1.2.3. Installation Procedure

Consult the installation guide on the MOVE3 CD for the installation procedure.

1.2.4. Starting MOVE3

To start MOVE3 click the *MOVE3* item under *Programs* in the Windows *Start* menu. To start MOVE3 for Windows and immediately load a project use *Explorer* and double click the *PRJ* file.

1.2.5. Tutorial

See the MOVE3 tutorial to get familiar with processing networks in MOVE3.

2. Using MOVE3

2.1. Introduction

Part 2 of this manual provides the user with information about the use of the MOVE3 network adjustment software. The software consists of a Windows user interface and a number of computation modules. The Windows user interface provides the user with full control over all options and parameters necessary for the computation modules.

The options and parameters are described in the **on-line help utility** of the MOVE3 Windows user interface. The option parameters are examined in terms of defaults, possible values, and their effect on the software.

In this part of the manual the MOVE3 model is discussed. A major part is dedicated to one of the main features of MOVE3: the Dimension Switch. The use of the Dimension Switch itself is rather straightforward. The choice of dimension however, will have an effect on the handling of observation types. Therefore the chapter on the Dimension Switch is essential reading matter.

2.1.1. System Overview

All tasks, which are performed by MOVE3, are initiated from the Windows user interface. Hence the user never has to leave the user interface during an adjustment session in order to e.g. view or change the data. In general the data is managed, i.e. read, edited, displayed and saved, by the user interface and processed, i.e. prepared, checked and adjusted, by the other computation modules.

The software system comprises the following computation modules:

- COGO3 to compute approximate coordinates;
- GEOID3 to extract geoid heights from the Dutch, US and Canadian geoid models;
- LOOPS3 to detect network loops and compute loop misclosures;
- PRERUN3 to perform pre-adjustment analysis;
- MOVE3 to perform design and adjustment computations.

Although a variety of cases may occur, it is most likely in practice that the user has known stations in some map projection at his disposal. Then, by definition, the known stations must be given in the TCO file. In case the network includes GPS observations, approximate coordinates for the GPS stations must be given in the GCO file. Thus, the ellipsoidal model is completely concealed, and the user's only concern is the selection of the proper map projection and ellipsoid.

2.2.5. More information...

More information about using the MOVE3 network adjustment software can be found in the **on-line help utility** of the MOVE3 Windows user interface. To request Help, use one of the following methods:

- From the *H*elp menu, choose a Help command;
- Press F1;
- Choose the *H*elp button available in the dialog box. This method gives you quick access to specific information about the dialog box.

3. Geodetic Concepts

3.1. Introduction

This part of the manual introduces the user to some of the theoretical fundamentals of MOVE3. It is presumed that the user possesses some basic knowledge of surveying and adjustment computations. A complete presentation of all theoretical aspects is beyond the scope of this manual. The reader is referred to the literature list in paragraph 5.2, [Literature List](#).

The mathematical model in MOVE3 is rigorously ellipsoidal. The coordinate unknowns are latitude, longitude and height. Consequently it is necessary to select an ellipsoid as a reference system in the adjustment. In addition, in many cases a map projection is required to relate the input Easting and Northing to the internal ellipsoidal unknowns. Therefore, the paragraphs 3.2 and 3.3 deal with reference systems and map projections. Another reason for discussing reference systems is the vital role of the World Geodetic System 1984 (WGS'84) in GPS positioning.

Paragraph 3.4 is dedicated to GPS. GPS is now an important measurement tool in many surveys. Hence a separate chapter of this manual is dedicated to this subject. Of course this chapter will mainly focus on those aspects of GPS, which relate to MOVE3, namely relative positioning using phase measurements. Special attention will be paid to GPS in control networks. GPS allows for a different approach, especially when designing networks, as compared to the classical approach with terrestrial observations. Last but not least, the combination of GPS and terrestrial networks is discussed.

Paragraph 3.5, [Detail Measurements](#) treats the processing of detail measurements in the adjustment. Specific features as geometric relations, idealisation precision and offset measurements are explained.

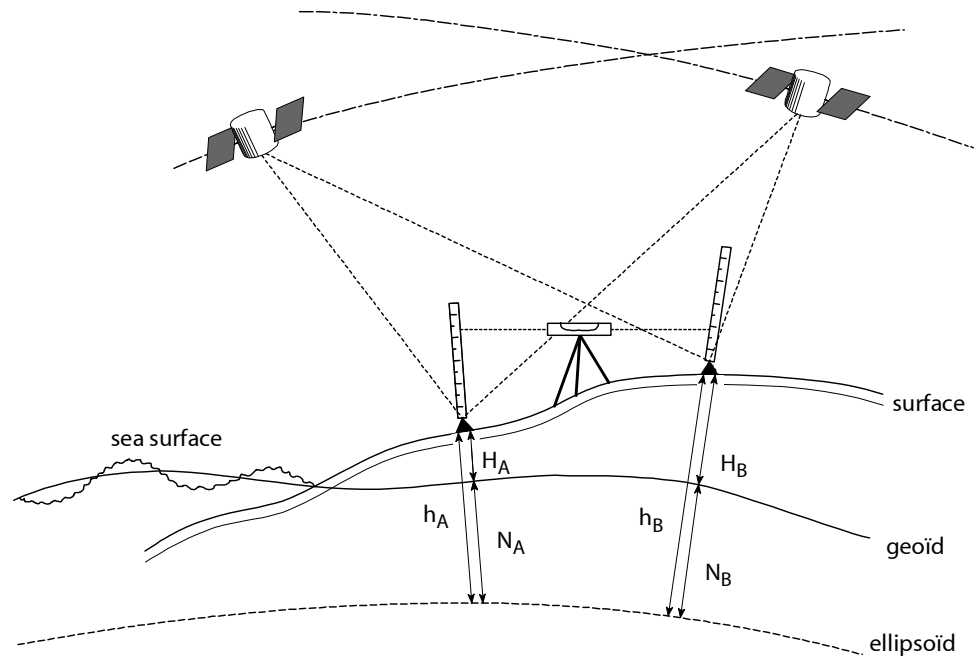


figure 3.2.3

The absolute error in the height differences may be up to 1 m over a 10 km distance. This error is mainly systematic, because the geoid is usually relatively smooth over the project site. Therefore the influence of the change in the geoid-ellipsoid separation will substantially be "absorbed" (and thus accounted for) by the GPS transformation parameters. Errors because of the unmodelled undulations are within the decimeter level.

The correct procedure, necessary for critical applications, is to convert orthometric heights and height differences into ellipsoidal heights and height differences before the adjustment, using the available geoid heights. After the adjustment the computed ellipsoidal heights are vice versa converted to orthometric heights.

3.2.4. Datum Transformations

GPS is indeed a global positioning system and is consequently based on a global datum. Characteristic for such a global or world datum is (see paragraph 3.2.2, [Global and Local Systems](#)):

- its origin is supposed to coincide with the earth's centre of mass;
- its Z-axis is supposed to coincide with the earth's rotational axis.

As seen earlier in this chapter, there are also local datums based on an ellipsoid, which best fits the earth's surface over a specific area. For the transformation of the coordinates from one datum to another, it is necessary to have knowledge about the relative positions of the various datums. A datum transformation can be carried out when the seven parameters of a 3D similarity transformation are known (figure 3.2.4): 3 translation parameters (T_x, T_y, T_z), 3 rotation parameters (α, β, γ) and 1 scale factor.

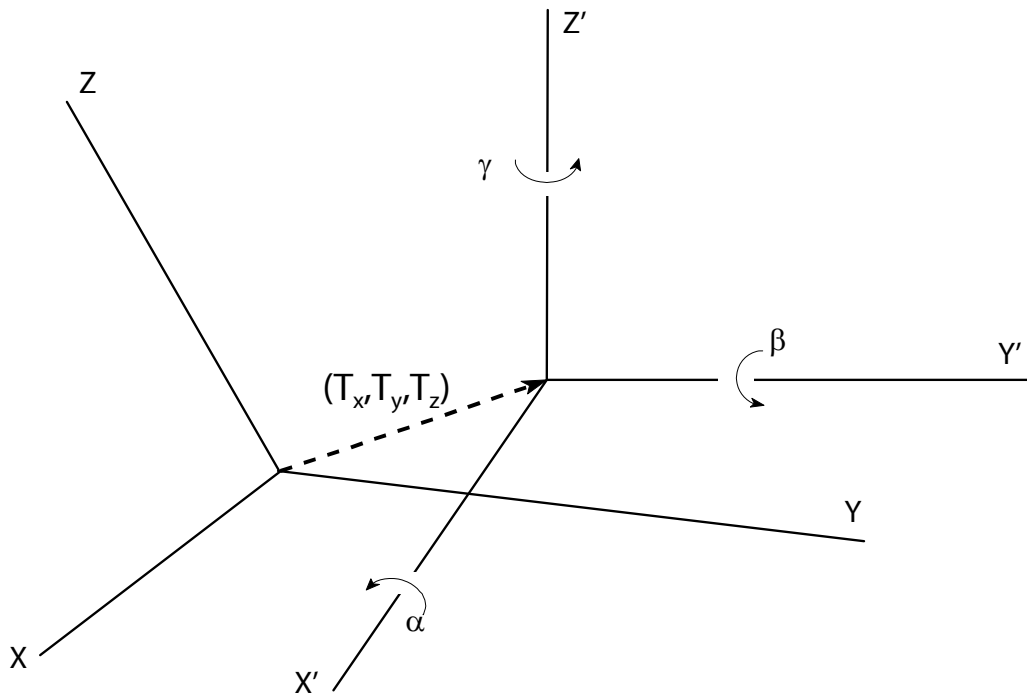


figure 3.2.4

Usually the rotation and scale differences between two datums are very small; in the order of a few arc seconds or a few ppm. The translation parameters, giving the shift between the two origins, can have values in the order of several hundreds of meters. For instance, the shift between the Dutch datum (Bessel 1841 ellipsoid) and the WGS'84 datum is approximately 593 m, 26 m and 478 m, in X-, Y-, and Z-direction respectively.

When GPS observations are to be included in a local datum, in which e.g. the known stations are given, a transformation is necessary. For GPS baselines, the translation between WGS'84 and the local datum need not be solved. Thus in the adjustment only 4 transformation parameters remain. In MOVE3 the 4 transformation parameters are solved as part of the adjustment. The user therefore does not have to enter these parameters. As a consequence these parameters only have a **local significance**, and cannot be presumed valid for areas beyond the extent of the pertaining network.

Besides **solving** the transformation parameters it is also possible to keep the transformation parameters fixed or weighted fixed.



It is possible to solve for all 7-transformation parameters when observed GPS coordinates are included. Observed GPS coordinates are a specific observation type in MOVE3 (see paragraph 2.2.2, [Observation Types](#)).

3.3.4. The Stereographic Projection

The Stereographic projection is based on the following parameters:

Longitude of Origin:	Longitude of the central point (the tangent point of ellipsoid and plane) of the projection, usually in the centre of the area of interest.
Latitude of Origin:	Latitude of the central point of the projection, usually in the centre of the area of interest.
Scale Factor:	The scale factor at the central point of the projection, as defined by the latitude and longitude of origin. The value assigned to the scale factor at this point is often slightly smaller than 1, so that the overall scale of the map is more neatly correct.
False Easting:	For some projections a False Easting is introduced to prevent negative coordinates. A False Easting is simply a large positive value that is added to the original Easting. In some cases the False Easting is assigned a specific value, making Eastings immediately distinguishable from Northings.
False Northing:	For some projections a False Northing is introduced to prevent negative coordinates. A False Northing is simply a large positive value that is added to the original Northing. In some cases the False Northing is assigned a specific value, making Northings immediately distinguishable from Eastings.

3.3.5. The Local (Stereographic) Projection

The Local (Stereographic) projection is useful when the network coordinates are given in your own local coordinate system. MOVE3 uses a stereographic projection with the following default values for the parameters:

Longitude of Origin:	0°
Latitude of Origin:	0°
Scale Factor:	1.0
False Easting:	0 m
False Northing:	0 m



The user is free to change these values.

In relative positioning (figure 3.4.2) the position of a point is determined with respect to another point. By processing the signals of both receivers simultaneously most of distortions can be eliminated. The result of the processing, the coordinate difference or baseline, is the input for MOVE3.

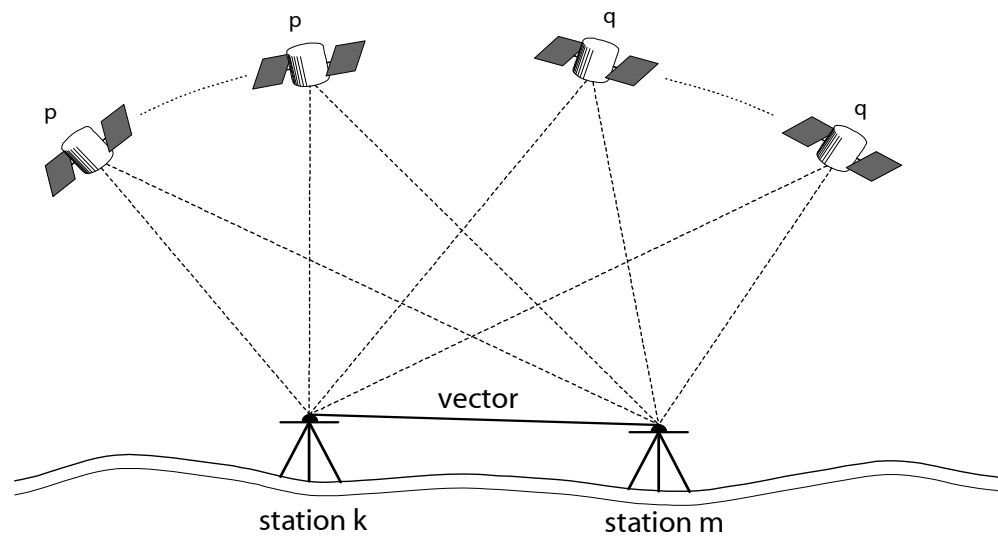


figure 3.4.2

3.4.3. GPS in Control Networks

A control network is a set of fixed points with coordinates attached to them. The aim of a control network is to allow the positioning of topographic features with respect to the fixed points. Thus a geodetic control network is the geometric reference of every Geographic Information System or any other system, application or tool requiring position information. In point of fact, a GPS baseline is just one in the list of observation types including directions, distances, zenith angles, azimuths and height differences (see paragraph 2.2.2, [Observation Types](#)). However, GPS possesses some features, which require a different approach when using GPS in control networks:

- The line of sight between adjacent network stations is no longer a necessity. This, added to the fact that there is practically no limit to the distance between receivers, provides the surveyor with an enormous amount of freedom when designing a network.
- GPS is a 3D-measurement technique. The strictly applied, though artificial distinction between horizontal networks and height networks no longer holds.
- A characteristic of GPS is that all coordinates and coordinate differences are given in the same unique world-wide reference system. This presents a problem when GPS observations are linked to existing known stations given in some local coordinate system. In such cases the parameters of a similarity transformation have to be solved (see paragraph 3.2.4, [Datum Transformations](#)).

3.4.4. GPS stochastic model

As a result of the GPS baseline processing besides the coordinate differences also a 3x3-variance matrix for the coordinates is computed (see paragraph 4.2.3, [Stochastic Model](#)). This variance matrix can be used in MOVE3 for the precision of the baseline. In most cases however the computed standard deviations are too optimistic. This may cause rejections in all of the baselines. MOVE3 contains two tools to solve this problem. The first is to scale the standard deviations of the baselines. A second possibility is to use an absolute and relative standard deviation per baseline. The relative part is usually expressed in ppm (parts per million of the baseline length). In this case the correlation between the components of the baseline is ignored.

3.4.5. GPS and Heights

Height differences measured with GPS are always ellipsoidal height differences. To convert ellipsoidal height differences to orthometric height differences a correction for the geoid needs to be applied (see paragraph 3.2.3, [Geoid and Height Definition](#)). The precision of the height differences is usually rather limited, thus influencing the total precision of GPS height determination.

Even when the geoid is not taken into consideration, GPS cannot compete with levelling.

4. Quality Control

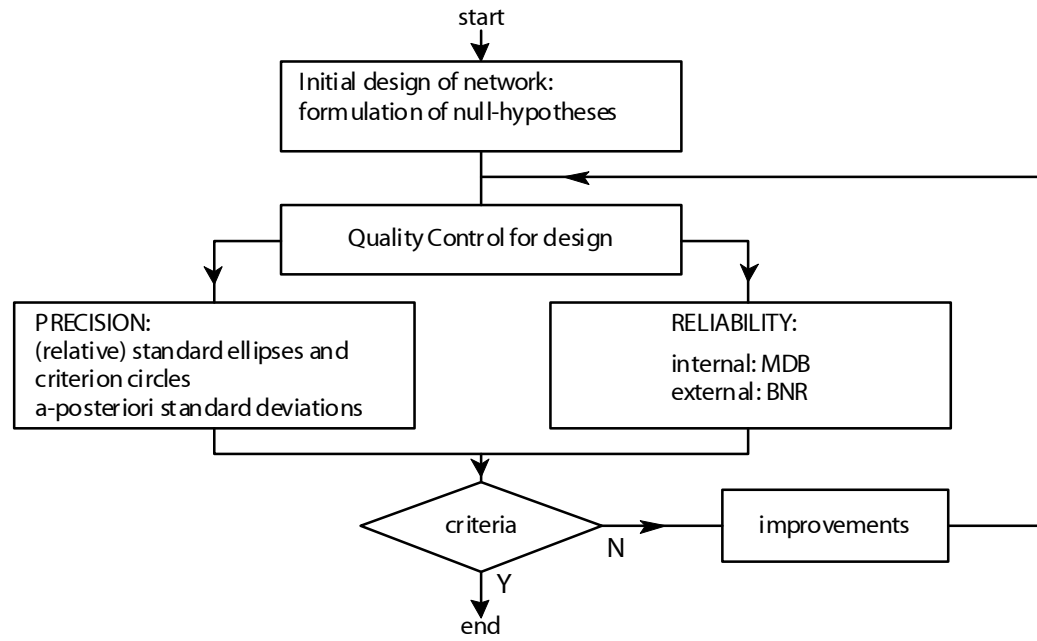


Figure 4.1.1: Design process

4.3. Precision and Reliability

The result of an adjustment must be precise **and** reliable. It is not enough for an observation to be precise, meaning that repetition will lead to a high degree of closeness. Observations should also be reliable, i.e. close to the **true** value. The accuracy or, more generally, the quality of a network can therefore be described by two elements: precision and reliability. In this chapter, the parameters, which quantify precision and reliability, will be reviewed.

4.3.1. General

Before proceeding to a more in-depth treatment, it is important to realise that precision and reliability are two separate notions. A measurement process can be very precise, but is therefore not necessarily reliable. On the other hand, a reliable process is not always a precise one. Compare the relative frequencies f_A and f_B of two measurement processes A and B (figure 4.3.1 and figure 4.3.2). The precision of process A is better than of process B; the degree of closeness of the observations in process A is higher. But although process A is more precise, it is not very reliable. A systematic error has resulted in a shift of the frequency distribution, away from the true value μ . Process B is not very precise, but definitely more reliable, since its distribution is close to the true value μ . In this chapter the precision and reliability concept is introduced, together with the tools implemented in MOVE3 for the analysis of precision and reliability of a network.

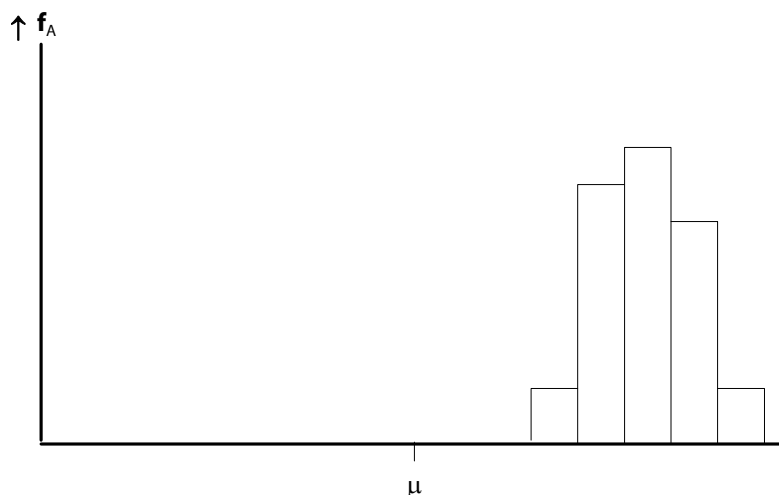


figure 4.3.1: Relative frequency of measurement proces A.

table 4.3.1: Example internal and external reliability.

In this example the distance A-B is an observation in a network which has been adjusted and tested. As follows from the last column of table 4.3.1, the testing has accepted this observation (critical value W-test = 3.29). The internal reliability is given by an MDB of 0.048 m. This means that an error of this size will probably be detected by the W-test (see paragraph 4.4.3, [W-test](#)). To verify this, an error Δ of 0.05 m is introduced in the distance A-B. The network is now adjusted and tested again, including this simulated error. Indeed as seen from the second value in the last column, the observation is now rejected by the W-test because the critical value is exceeded.

The external reliability is given by a BNR of 10.8. This means that the influence of the MDB of 0.048 m on any coordinate in the network is smaller than 10.8 times the a-posteriori standard deviation of the coordinate. For general-purpose networks it is desirable to have a homogeneous external reliability. The network in the example is considered as homogeneous, when the BNR values of all observations are on the same level. Alternatively the network is inhomogeneous when the BNR of e.g. distance A-B strongly exceeds the BNR of other observations in the network. In that case the network is unstable or inhomogeneous, i.e. the reliability depends mainly on the correctness of one single observation.

Remeasuring observations is an obvious but often expensive way to eliminate rejections, especially when the fieldwork is already completed. It is therefore recommended to process the data on the site.

- *Increase* the standard deviation of the corresponding observations. Increasing the standard deviation of an observation will always work, meaning that it will always result in lowering the F-, W-, T-test values. However, one should keep in mind that the goal is not to get all tests accepted, but rather to detect blunders or model errors.
- *Ignore* the rejections. This option is obviously very risky and is only applicable in case the W-test values just exceed the critical value. It is useful to look at the estimate of the error involved with the rejection, and to see whether it is acceptable or not. We also have to remember that, depending on the level of significance, there is always a probability of rejecting a valid observation.

It must be stressed that an observation must never be edited in order to make it better fit in with the other observations of the network, unless there is clear evidence of the source of the errors, e.g. a typing error.

4.4.6. Estimated Errors

The size of the error responsible for the rejection of an observation or known coordinate is estimated by MOVE3. This so-called estimated error is a useful tool, but should be handled with care:

- Only the estimated error associated with the largest W-test or T-test should be considered.
- As far as the W-test is concerned, the estimated error is based on the conventional alternative hypothesis that just one observation or known coordinate contains an error. Consequently if more errors are present in the network the result of the estimation could be meaningless, unless errors have been made (geographically) far apart.
- As far as the T-test is concerned, the estimated error is based on the hypothesis that just one GPS baseline or known station contains an error. Consequently if more errors are present in the network the result of the estimation could be meaningless, unless errors have been made (geographically) far apart.
- Known coordinates are tested by the W-test and T-test in a constrained network adjustment. The test results and estimated errors are only meaningful when observational errors have been filtered out in the foregoing free network adjustment and testing.

5. Lists

Central Meridian: 3° E for zone number 1
6° E for zone number 2
9° E for zone number 3
12° E for zone number 4
15° E for zone number 5

Latitude of Origin: 0° (the equator)

Scale Factor: 1.0

False Easting: 1500000.0 m for zone number 1
2500000.0 m for zone number 2
3500000.0 m for zone number 3
4500000.0 m for zone number 4
5500000.0 m for zone number 5

False Northing: 0 m

Ellipsoid: Bessel 1841

Great Britain:

Projection type: Transverse Mercator

Central Meridian: 358° E

Latitude of Origin: 49° N

Scale Factor: 0.9996013

False Easting: 400000.0 m

False Northing: 100000.0 m

Ellipsoid: Airy

Maryland (as an example for the US):

Projection type: Lambert

Longitude of Origin: 283° 00' 0.0" E

Latitude of Origin: 37° 40' 0.0" N

Standard Parallel 1: 38° 18' 0.0" N

Standard Parallel 2: 39° 27' 0.0" N

False Easting: 400000.0 m

False Northing: 0 m

Ellipsoid: Clarke 1866

The Netherlands:

Projection type: Stereographic (RD)

Longitude of Origin: 05° 23' 15.500" E

Latitude of Origin: 52° 9' 22.178" N

Point Scale Factor: 0.9999079

False Easting: 155000.0 m

False Northing: 463000.0 m

Ellipsoid: Bessel 1841

5.2. Literature List

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5.3. Glossary

- Azimuth:** The angle between the North direction and the direction to a target.
- Base stations:** The base stations are the stations to which the network is connected in a free network adjustment. By fixing the minimum number of coordinates (i.e. without extra constraints) only location, orientation and scale of the network is defined.
- Baseline:** A three-dimensional vector in WGS'84 between two stations.
- Bias to Noise Ratio (BNR):** The BNR gives the influence of a possible outlier (size MDB) in an observation on all coordinates. The BNR is regarded as the ratio between reliability and precision.
- Cartesian coordinate system:** An orthonormal coordinate system, with the same scale on all axes, with coordinates taken as segments on the axes denoted by, in case of a three dimensional system, (X,Y,Z).
- Co linearity:** The geometrical relation that three points are located on a straight line.
- Constrained adjustment:** In a constrained adjustment the network is connected to *all* known stations. MOVE3 discriminates between three types of constrained adjustments. In a **pseudo constrained** adjustment the known coordinates do not get corrections, and the standard deviations of the known stations do not change. In a **weighted constrained** adjustment the known coordinates are considered as normal observations and they will get corrections in the adjustment. In an **absolutely constrained** adjustment the known coordinates do not get corrections and the standard deviations of the known stations will be 0 after the adjustment.
- Correlation:** There is correlation between two quantities when these quantities are statistically dependent, i.e. the quantities influence each other. Correlation is expressed by ρ , the correlation coefficient.
- Criterion circle:** The criterion circles determine a theoretical model representing a homogeneous precision, with respect to the base stations. Criterion circles are used when judging the standard ellipses (which depend on the choice of the base stations) in a free network adjustment.
- Critical value:** The predetermined value, which decides over acceptance or rejection of a hypothesis, associated with a statistical test.
- Dat snooping:** Statistical testing method in which every observation is tested separately by the W-test.
- Datum:** A mathematical model, the ellipsoid, designed to best fit the earth's surface as a whole or over a certain region. It is defined by giving the ellipsoidal parameters (semi major axis, flattening) and the parameters to fix the position of the ellipsoid.
- Degree of freedom:** see redundancy.
- Design:** When designing a network the configuration, consisting of known and unknown stations and the observations between them, is established before realization in the field. The quality of the network design can be rated in terms of precision and reliability.
- Distance:** The length of the vector between two stations. The *slope* distance represents the directly measured distance from instrument to reflector, while the *horizontal* distance represents the distance after reduction.
- Eccentricity (e):** One of the parameters defining the geometry of an ellipsoid:
- $$e^2 = f(2 - f) = (a^2 - b^2)/a^2$$
- with
- f = flattening;
 - a = semi major axis;
 - b = semi minor axis.
- (See also flattening f .)

- Ellipsoid:** A mathematical figure formed by revolving an ellipse about its semi minor axis b . An ellipsoid is usually defined by its semi major axis a and by its flattening, $f = (a - b)/a$.
- Ellipsoid height (h):** The vertical distance to a mark above the ellipsoid.
- Expectation value (μ):** The expectation value of a stochastic variable is the weighted mean value over all possible outcomes of the measurement process.
- External Reliability:** The maximum influence of an error of the size of the MDB on the final coordinate.
- F-test:** Overall model test, which is used to check the null-hypothesis.
- Flattening (f):** One of the parameters defining the geometry of an ellipsoid:
- $$f = (a - b)/a$$
- with
- $$a = \text{semi major axis};$$
- $$b = \text{semi minor axis.}$$
- Free network adjustment:** Adjustment in which the location, orientation and scale of the network are defined by imposing a minimum number of constraints (i.e. by fixing only the base stations). A free network adjustment is used to test the observations before connecting the network to all known stations.
- Geometrical relations:** Collection of observation types: angle, perpendicular (3 points or 2 lines), co linearity, distance between point and line, parallelism and change and offset.
- Geoid:** The gravity equipotential surface, which best approximates the mean sea level over the whole earth. The geoid serves as vertical datum for orthometric heights.
- Geoid height (N):** The difference between ellipsoidal height and orthometric height: $N = h - H$.
- GPS:** Global Positioning System, a satellite-based system for determining three-dimensional relative and absolute positions.
- Hypothesis:** Set of assumptions on the behaviour of stochastic variables. A special hypothesis is the null-hypothesis H_0 that implies the correctness of the stochastic and mathematical model and the absence of gross errors in the observations. Statistical testing is used to verify hypotheses.
- Known station:** A known station is a station of which coordinates are given with a certain precision prior to the adjustment. A network is connected to the known stations in a constrained adjustment.
- Least squares adjustment:** A method for obtaining unknowns from redundant observations based on the least squares criterion. The unknowns are related to the observations by the mathematical model. The least squares criterion says that the sum of squares of the corrections to the observations must be minimal. The least squares corrections are also known as residuals.
- Map projection:** Set of mathematical formulae, which transfers ellipsoidal coordinates (latitude and longitude) into plane coordinates (X East, Y North), and vice versa. The transformation results in distortion of geometric elements, distance and angle. The most commonly used map projections in geodesy are Transverse Mercator, Lambert and Stereographic projection.
- Mathematical model:** A model, which expresses the relationship between the observations and the unknowns in an adjustment.
- Minimal Detectable Bias (MDB):** The smallest outlier in an observation or a known coordinate, which can be detected by the W-test with a certain probability. This probability is equal to the power of the statistical testing.
- Minimal Detectable Bias, normalised (MDBn):** Describes the internal reliability of the network. For uncorrelated observations equal to the MDB divided by the standard deviation of the observation.
- Observation:** An observation is the realisation of a stochastic variable.

W-test (datasnooping): One-dimensional statistical test used to trace erroneous observations by testing so-called conventional alternative hypotheses. A conventional alternative hypothesis assumes an outlier in one single observation while the other observations are correct.

WGS'84: World Geodetic System 1984; the global reference system for GPS observations since January 1987. In some cases its predecessor, WGS'72, is still utilised.

Zenith angle: The vertical angle between the direction to the zenith of the observer and the direction to a target. The zenith is the direction opposite to the local direction of the force of gravity.

Semi minor axis	26	Total station record	16
Singularity	49	T-test	62
Standard deviation	49, 55	Variance	50
Standard ellips	55	Variance-covariance matrix	51
absolute	55	WGS'84	26
relative	55	W-test	61
Standard Parallel	34	Zenith angle	16
Testing	45		