

PANDA

Program for the Aadjustment of Geodetic Networks and Deformation Aalysis

***General Information
about the
Software Package PANDA***

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Software Package PANDA

The software package PANDA has been developed to design, optimize, adjust and assess 1D, 2D- and 3D networks from all areas of ordnance and engineering surveying, as well as to analyse their deformations, based on congruency tests.

PANDA consists of the modules:

Data Pre-processing, accepting both terrestrial observations and GPS-baselines. Reduction and correction of data, the computation of approximate coordinates, seeking obvious observation errors.

Adjustment of the terrestrial and/or GPS observations by various equations or datum values. Various tools to enlarge models and for quality assessment.

Deformation analysis of 1D, 2D or 3D systems, in rigorous or approximation processes

Transformation of coordinates including best-fitting proximity adjustment

The core of the program is a graphic interface, into which the individual modules are integrated.

The modules **Deformation analysis** and **Transformation** are optional.

PANDA stores data in a relational database (MS-Access). Access to the data is realized through an ODBC-interface.

PANDA is protected against unauthorized copying by a HASP-Dongle.

PANDA requires Microsoft XP, VISTA and Windows7.

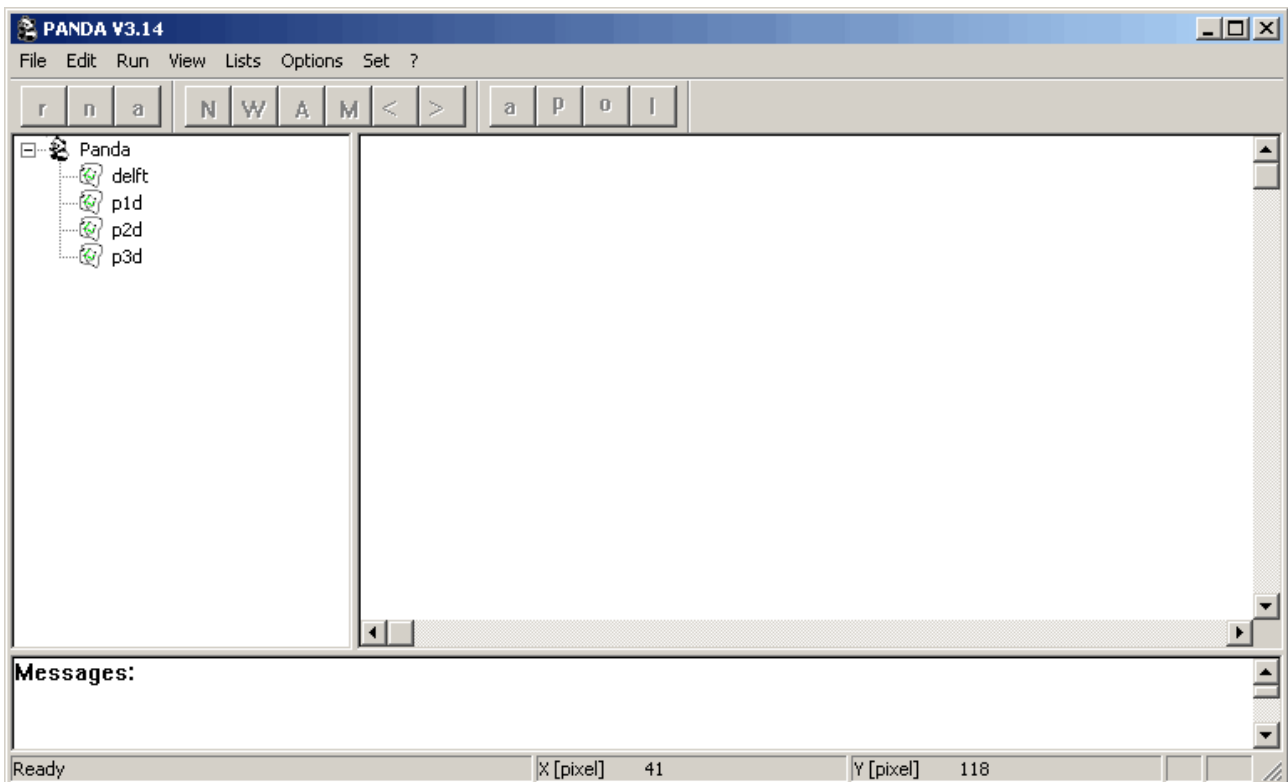


Figure 1: The user interface of PANDA

The User Interface

PANDA has a modern object-oriented, graphical interface.

The program runs object-oriented which means that, by clicking the right mouse button, object properties can be changed or tasks can be run.

The objects are each appointed a Status, graphically presented by colours. Further necessary steps (e. g. correction of erroneous observations) can be easily recognized.

Station and observation lists can be sorted according to various criteria. For example, it is possible to sort the observations after applying the normalized residuals; allowing gross errors to be easily localized.

Interactive network conception (including net optimization) is supported, whereby the stations and observations can be entered and immediately analysed on the screen.

New in Version 4:

- The size of several windows can be stored customer-defined.
- Field books can be added to or removed from existing adjustment. A successive processing of nets is possible.
- Polarpoints can be suppressed in the graphical presentation of a version and in the adjustment.
- All field books of one epoch can be reduced in one single work step.
- Defined informations can be carried to all observations-groups of one version.
- It is possible to change the name of the point list, the epoch, the field books, the adjustment and the deformation analysis. It is easy to mark final solutions.

Coordinate Systems in PANDA

The program can process points in the following coordinate systems:

- Local systems

Local Cartesian: (vertical axes parallel) and local spherical: (vertical axes point to centre of sphere). Usable for small engineering nets, where they can be accepted as Cartesian. Larger nets have to compensate curvature values and must, therefore, use a spherical model.

- Global Cartesian systems

Geocentric coordinate systems, e.g. WGS 84, useful for equalising pure GPS nets. Observation data can be entered as sets of coordinates or difference of coordinates (baselines). Observations with complete covariance matrices are supported.

- Mapping systems

Mapping systems for National Ordnance Survey. The mapping coordinates are transformed into, and adjusted rigorously as geocentric Cartesian coordinates. The results are then transformed back into the mapping system, thus allowing widespread networks to cover several central meridians.

PANDA supports the conform mercator and the conform Lambert projections. The following mapping systems are already defined and implemented for use:

- Gauss-Krueger (Germany, Austria, Switzerland)
- UTM

Personalized ellipsoids can be defined by entering their characteristics. As to date, the following ellipsoids are defined in PANDA:

- Bessel (Germany, Austria)
- Hayford,
- Krassowski (former GDR)
- WGS 72,
- WGS 84,
- ETRS 89

Instruments in PANDA

For each instrument precisions, specifications and time-depending calibration data are stored, as far as they are required for the reduction of the observations.

The following instruments are supported:

- Total Stations (Theodolite, EDM)

Only for distance measurements specifications and calibration data are stored:

- Specifications: Carrierwave length, fine scale and reference value for temperature and pressure.
- Calibration data: Addition constant, scale and cyclic phase error.
- Prism
 - Calibration data: Addition constant
- Level
 - No specification or calibration data
- Staff
 - Calibration data: Staff constant and -scale and thermal coefficient of expansion.
- Laser tracker
 - No specification or calibration data

Data Pre-processing

The pre-processing consists of the following tasks:

- Reading raw data and creating a field book.
- Evaluation and reduction of terrestrial field books.
- Control of observations against outliers and calculation of approximate coordinates.

Terrestrial observation processors

Raw terrestrial observation data can be input from various registration units. Automatic data flow has been implemented for the following formats:

- GSI-format by LEICA, for total stations and electronic levellers
- GEODAT (Spectra Precision)
- REC500 resp. M5-format by ZEISS, for total stations and electronic levellers
- JobXML files from Trimble instruments.
- Leica DBX 1200 database from modern Leica total stations.

Further registration systems and formats can be implemented on demand.

New in Version 4:

- The routine to read recognizes automatically the type of raw data-file. The extension of the file has not to adapted to PANDA.
- An individual definition file can be allocated to each raw data file. Within one project various store-schemes are supported.

GPS observation processors:

- GPSurvey (SSF- and SSK-files) (Trimble)
- SKI (Leica)
- GEONAP
- Geotracer
- GeoGenius

The input of results from these processing programs is implemented as standard. Further processors can be implemented on demand.

Reduction of Terrestrial Data

The program has several evaluating and reduction methods implemented. Their use depends upon the type of observation to be processed.

Primary instrument corrections are applied according to values found in the database, that are relevant to the instrument used. The registered values and accuracies are applied and, in the case of timestamped calibration data, the latest available calibrations found in the database are used. If there is no information available about the instrument used, the calibration will be carried out using standard values.

Levelling data (precise levelling, simple levelling)

Calculation of differences in height from the staff readings, comparison with height differences between known heights. Error calculation and control.

With a precise levelling, further tests are done, e.g. controlling the staff constants, comparison of readings left / right .

Horizontal directions

Normally, horizontal angles are observed and processed in sets. It is possible to process repeated observations of angles, the mean reading being computed. As far as possible, an error calculation is performed.

Vertical angles

Vertical angles are repeated observations. They will be sorted by stations and the mean readings of the repeated observations is calculated. If possible, an error calculation is performed. To calculate height differences from vertical angles, slope or horizontal distances have to be available.

For 3D processing, the vertical angles are reduced to the geodetic height level of the stations, using instrument and reflector heights. To calculate these reductions, either approximate station coordinates are taken from the list of coordinates, or the measured slope/horizontal distances are used.

Slope/horizontal distances

Slope distances are repeated measurements. The distances will be sorted by stations and the mean distance calculated from the repeated observations. If possible an error calculation is performed.

For 3D processing, the slope distances are reduced to the points geodetic height levels, using instrument and reflector heights. To reduce the slope distance, either the approximate station coordinates are taken from the coordinate file, or the vertical angles are used.

Calculation of approximate coordinates

We have developed a new program idea for the calculation of approximate 1D-, 2D- and 3D coordinates. It is based on a combination of rigorous solutions and conventional approaches.

In order to detect gross observation errors, loops are formed and their closing errors evaluated. Approximate coordinates are determined through a L1 equalisation.

This module includes many helper tools for adjusting and correcting the input data and for running plausibility tests.

Module Adjustment

The module adjustment allows the adjustment of multi-conditional 1D-, 2D- and 3D-networks from all fields of survey engineering and includes the possibility to calculate network-specific criteria, enabling it to analyse and optimize the networks

For the design of networks, a simulated adjustment can be carried out without real observations. The quality of the network design can be analysed according to criteria that the program calculates.

It is easily possible to optimize the network design, simply by modifying the original network data.

Possibilities of the Adjustment

- processing approximate coordinates from the different coordinate systems
- Adjustment of different types of observations
- Introduction of additional variables
- Different datum definitions
- Calculation of criteria to interpret and analyse networks

A further speciality of PANDA is the ability to combine GPS results (coordinate differences **or** coordinates with covariance information) with terrestrial observations. The datum can be defined from either the GPS or the terrestrial system. Another possibility is the use of additional parameters to define some parts of the datum by terrestrial, other parts of it by GPS data.

New in Version 4: A datum defect appearing during the adjustment will be noted in the protocol file with the concerned points.

An automatic search for gross errors/adaptation of accuracy is possible. If less than xx% of the observations among one group are incorrect, the observation will be de weighted. Otherwise the accuracy of the group will be adapted. The parameter xx can be predetermined.

Points

Approximate coordinates from the following systems may be entered as data:

- local Cartesian coordinate system
- local spherical coordinate system
- global Cartesian coordinate system
- global projection e.g. Gauss-Krueger Projection

In global systems, the deflection of the perpendicular may be considered by correcting the observations.

Datum of the network

The datum of the network can be defined as follows:

Constrained adjustment

A constrained adjustment will be made when there are more fixed components than the datum-defect. The datum defined by the fixpoints will be taken over into the network and the geometry of the net will be adapted. It is possible to accommodate all, or only some, of a point's components. The geometry of the network is affected.

Constraint free adjustment

If the number of fixed components equals the datum-defect 'd', this kind of adjustment is the correct one to use. The geometry of the network is not affected.

"Weak" datum

The datum can be defined by measured coordinates. The accuracy of a point's data determines its influence upon the definition of the datum and therefore, the whole network.

The geometry of the net and the definition of the datum influence each other.

Free adjustment

Choose this kind of adjustment if the net is based upon the approximate coordinates of several datum defining points. The net will be fitted to the approximate coordinates, similar to using a similarity transformation. The net can be based on all points (total trace minimizing) or only some of them (partial trace minimizing). The geometry of the net and the datum-definition are independent of each other.

Types of observation

The following types of observations can be processed:

- observed coordinates (2 D and 3D)
- coordinate differences e.g. GPS baselines (2D and 3D)
- directions (2D and 3D)
- zenith angles (3D)
- azimuths (2D and 3D)
- slope distances (3D) or horizontal distances (2D)
- height differences (1D and 3D)
- **New in version 4: Laser tracker data (3D)**

Laser tracker data consist of directions, zenith angles and slope distance. The orientation of the instrument is variable. In the adjustment the 3 rotation parameter are determined rigorously. A Combination with total station- and levelling-data is possible.

For each type of observation, several groups of observations can be entered, e.g. when using different instruments. Individual standard deviations can be assigned to each group, even to each observation. By doing this, sets of observations with different accuracies can be processed together.

Special parameter can also be allocated individually to each group, e.g. varying scale corrections can be applied to the individual instruments.

For distances, a distance-dependant weighting will normally be applied.

Introduction of additional variables

By introducing further variables to randomly selected groups of observations, it is possible to influence and modify the adjustment model of the network in several ways. A documentation of the adjusted parameter is provided.

- gyro constant (azimuths)
- unknown orientation, unknown refraction index, approximate value for the vertical angle refraction coefficient
- unknown scale of distance measurements
- unknown scale of height differences
- unknown translation, orientation and scale of observed coordinates (2D and 3D)
- unknown orientation and scale of coordinate differences (2D and 3D)
- **New in Version 4:** unknown orientation per laser tracker position (3D)

For a combined adjustment of terrestrial and baseline data, it is important to introduce additional parameter for the baselines. The baselines exist in WGS84, but the geocentric coordinates will normally exist in the national system (in Germany, this is the DHDN) and, because these systems are not identical, the baselines have to be transformed into the national system. In the PANDA package, the transition is guaranteed by the use of additional adjustment-parameter.

Quality analysis of networks

For the analysis of the quality of a network, the following accuracy and reliability criteria of the network - according to the requirements of many administrative regulations – are calculated by the program :

For the observations

- a posteriori standard deviations
- standardized residuals, redundancies and marginally detectable errors
- estimation of variance components for each group.
- DATA-SNOOPING is used to detect gross errors within the observations. An estimation of variances serves to control, or as a correction of, the accuracy weighting between the groups.

For the stations:

- standard deviations
- relative and specified error values and error-/confidence ellipses
- relative error or confidence ellipses (e.g. to determine the break through accuracy of underground measurements)

Module Deformation Analysis

General information

A deformation analysis is carried out to confirm the stability or detect the movement of stations. To attain this, a geodetic network is repeatedly measured and subsequently analysed to obtain statistically proven statements about the possible deformations. This module has been developed to carry out rigorous or approximate deformation analyses of repeatedly measured geodetic 1D-, 2D- or 3D-networks.

Possibilities of the Deformation Analysis

- PANDA allows an analysis of repeatedly measured geodetic networks, in order to detect the **movement of individual points**.
- By considering the available information (covariance matrices are not available or only station-relevant sub-matrices are present) an approximate analysis or, if covariance matrices for both epochs are complete, (e.g. created by the program PAN) a rigorous analysis can be carried out.

The crux of the analysis is a global congruency test to show significant discrepancies between the reference stations. To avoid datum influences on the test value, a S-transformation of the discrepancies and of the corresponding covariance matrix onto the reference stations is carried out.

There are two strategies implemented:

- The **backward strategy** is based on a group of reference stations. As long as significant deformations persist within a group, one station at a time will be localized and removed. The process ends when there are no longer any significant discrepancies within the remainder of the group, or when there are only two or three points left.
- With the **forward strategy**, a group of stations that is presumably stable is used as the reference. As long as no significant discrepancies among this group can be recognized, one station at a time from a group of "potentially displaced" stations is added. The process ends as soon as deformations appear, or when all points are recognized as stable.

Criteria for the localization of stations is the greatest (backward strategy) or the least (forward strategy) relative discrepancy of the stations

Analogue to the network design, it is possible to calculate either a

- **one-step-analysis** (relative model - all stations are regarded as reference stations) or a
- **two-step-analysis** (absolute model - the network is divided into reference and object points)

A two-step-analysis is used for the control of buildings.

Other, more comprehensive models can be implemented according to user's requirements without problems.

Module Transformation

The module **Transformation** supports the Helmert (similarity) and Affine-transformation methods. The similarity transformation is for 2D and 3D point clusters whereas the Affine-transformation is restricted to the 2D calculation.

Helmert (Similarity) Transformation (2D and 3D)

This module permits the transformation of coordinates between two global Cartesian systems or between two local Cartesian systems of coordinates.

The scale can be pre-defined.

An affiliated **covariance matrix** of the points is also transformed.

The transformation parameters can be derived from the coordinates of at least (obligatory) **3 identical points**. **Pre-defined parameter** for the transformation can also be used.

Affine-transformation (2D only)

This module allows the 2D Affine-transformation between two systems.

The parameters are always defined by identical points. A 6-parameter or a 5-parameter transformation (with 2 translations, 2 scales and 1 orientation) is possible.

Close Proximity Fitting

When calculating a 2D-transformation with identical points, the residual discrepancy (misclose) at the identical points can be eliminated with a close proximity adjustment. There are two calculation-methods available:

- The corrections are calculated using distance weighting. The misclose of each identical point is carried over to each non identical net point. The adjusting function for the influence of the discrepancy upon the net point is $s^{(-1.5)}$, 's' being the distance between the net point and the identical point.
- The corrections are determined by a Membran model. In this model, the point cluster is prepared by a Delaunay Triangulation into triangles and, subsequently, minimized by the square sum of all the triangle-area-weighted scale modifications.