PANDA

The Software Package for Precise Engineering Networks

by

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Abstract

PANDA means Program for the Adjustment of Networks and Deformation Analysis. It is a recently developed software package for handling lD-, 2D- and 3D-networks in engineering surveying. It's objective is to serve as a tool for tasks like :

- data - preprocessing of the original readings
- network preanalysis and optimization
- adjustment, quality analysis and error detection
- deformation analysis and
- graphical representation of results.

The package allows to handle large data sets, even on a PC, can treat all modern observation techniques, including gyro- azimuths and GPS-data-sets, and represents latest developments in network theory and deformation analysis.

A user-surface with numerous help panels, developed for MS-DOS computers, makes the system easy to understand and easy to use.

Presented Paper

Second Accelerator Workshop
DESY, Hamburg, Sept. 1990

1. INTRODUCTION

PANDA is a new software package for handling networks in surveying engineering. To serve for most applications of the surveying practice PANDA has to

- be conceptionally really l-, 2- and 3-dimensional , so that it can treat levelling and ordinary horizontal networks, as well as real 3D - nets, which are up to know mostly found in engineering surveys,

- be able to handle networks up to several hundred points , even on a personal computer,

- have a user-surface , which allows an easy understanding and handling of all the computational steps,

- have a module for preprocessing of the original readings , with input from electronic fieldbooks or by hand,

  account for all modern observation techniques , that can be found today, and to allow an easy extension, if new techniques arise,

- include all the possible datum definitions , which are in use today, like total or partial minimum trace, the concept of a weak datum, but as well the classical concept of fixing points,

- allow the use of additional parameters , like various scale factors and orientation unknowns, whenever this seems to be adequate,

- allow a detailed quality analysis of the observations and the coordinates with real or simulated data,

- contain a well-established and easy to handle module for a rigorous deformation analysis for two or more epochs,

- allow a graphical representation of the results of the adjustment and the deformation analysis, preferably with a direct connection to CAD - systems.

As any software, PANDA is not a static product, it matures and improves with the feedback of the users. The system will be continuously updated and completed, and if a user has some extensions, which are of general interest, these modifications will be made available for all users.

The authors believe, the actual system is widely applicable and well-tested and should be presented to a broader audience.

2. CONCEPT OF PANDA

The program system PANDA has a modular structure. It covers the field pre-processing of original readings, adjustment, deformation analysis and graphical representation.

Every module is realized by independent programs. This means

- the modules are exchangeable;

- the system can be modified to fit the requirements of the user;

- each program can operate as stand alone program outside the system.

The system has been developed for use on personal computers with the operating system MS-DOS respectively PC-DOS. Installed on a PC or Laptop it is possible to make all computations and analysis in the field office.

All programs are written in standard FORTRAN 77. It's possible to install the system on different computer systems, for example on workstations or on main frames. System depending parameters can be set in the program, an optimal adaption to different computer systems is practicable.

3. USER SURFACE

All programs of the system are integrated in a user surface. It allows a user friendly handling of the complete system:

- Edit the input files
  Every program needs input files. The user surface allows the comfortable input and modification of these files.

- data flow
  The communication between the programs is done by files. The user surface manages the data flow, it creates the input files and stores the result files.

- on-line help
  The user surface has context sensitive help messages, which are activated by function keys, for example description of choices or data.

- project management
  The user surface has a project management to handle various the project and the project data.

The user surface is realized by panels, which allow the choice of functions and the input of data.

The appearance of a standard panel is shown in Fig. 1.

4. THE ADJUSTMENT MODULE

The adjustment module is developed for the preanalysis and optimization of a network (simulated adjustment during the design phase) and an adjustment and quality analysis of the observations and resulting coordinates with real data.

A survey of the adjustment module of PANDA is shown in Fig. 2.

4.1 Observations

The following types of observations are generally treated :

- sets of bearings/directions
- horizontal angles
- vertical angles
- height differences
- slope and horizontal distances
- azimuths
- offsets
- "observed coordinates or coordinate differences"

For the observed coordinates or differences of coordinates a full covariance matrix can be introduced, while all other observations are considered to be uncorrelated.

For each type of observation a grouping is possible, which is meaningful, when various instruments are used or the outer conditions are different. For each group an a priori standard deviation has to be introduced. Within the adjustment a variance-component-estimation will be carried out to check the correctness of the a priori precision estimate.

Besides this a different standard deviation can be assigned to individual observations . This is a useful modification, if e.g. in a series of bearings one line of sight is very short compared with the average.

A further tool to account for extremely different distances between points, a situation, which is found quite often in accelerator nets, is the introduction of a mean centering error . This error will be considered in estimating the weight of each corresponding observation.

Within the adjustment process possible gross errors will be indicated . The user has to check the individual observation; he can eliminate the wrong observation or modify its weight (robust method).

4.2 Additional Parameters

To achieve greatest flexibility, additional parameters for groups of observations can be introduced. A widely used approach is the use of scale factors , which might be identical or different for various groups of distances.

As gyrotheodolits normally have a gyroconstant, it's often meaningful to introduce one or more gyro orientation unknowns as additional parameters into the adjustment model (Tengen 1984, Niemeier 1987).

For a set of given coordinates, e.g. results of a GPS - campaign, it's also possible to introduce additional parameters. As pointed out by Niemeier (1987), this is meaningful, if one is only interested to use the relative information of the GPS - observations.

The full set of additional parameters for one group of 3D - coordinates are:

- 3 translations
- 3 rotations
- 1 scale factor

Introducing all 7 parameters leads to a really free adjustment, where the datum has to be defined with one of the techniques, described in section 4.3. In PANDA it's also possible to use only subset of these additional parameters. This is e.g. useful , if one wants to orientate a local network within the GPS - coordinate system, without using the up-to-now often critical scale factor of the GPS - information.

4.3 Datum Definition

It's in general not possible to determine coordinates only with the use of the observations itself . One has to solve the datum problem , i.e. to define in one sense or another a relation between the inner geometry of a net and a coordinate system (Illner 1985, van Mierlo 1978, Niemeier 1985a, 1989). Of importance here are the so-called free datum parameters d , which have to be determined during the adjustment process.

For determining the datum of the adjustment, with PANDA the following selections are possible:

- hierarchical adjustment ; i.e. the fixation of a number of more than d coordinates by setting their approximate or given values as true or unchangeable.

- unforced adjustment ; i.e. the fixation of =d given coordinates. Here the inner geometry will not be destroyed and this procedure is also known as minimum constraint solution.

- total or partial minimum trace solution ; positioning of the network geometry on all (total) or a subset (partial) of the approximate coordinates. This is a positioning of the net on the selected given coordinates in the sense of a similarity or Helmert - transformation (Niemeier 1985a). The total minimum trace solution is also known as inner constraint solution in general network theory.

- weak datum ; especially for densification networks it often makes sense to use the coordinates of higher order points for the determination of the datum. If also the covariance information of these points is considered, this positioning method is called weak datum, as the given coordinates are not fixed absolutely.

The determination of an adequate datum is essential for the results of an adjustment. Not only the adjusted coordinates are dependent on this datum fixation, but also most of the precision and some of the reliability measures of the coordinates.

The partial minimum trace solution has to be applied, if in an adjustment process there are point coordinates and additional parameters as unknowns: It's only meaningful to use the approximate values of the points (and not of additional parameters) for positioning the network geometry.

4.4 Analysis of the Quality of a Net

In network theory numerous articles can be found with philosophical, pure theoretical but also really practical concepts for analysing the quality of a network. Widely accepted are the concepts of precision and reliability , the detection of outliers and simplified models for variance component estimations (Baarda 1967, 1968; Caspary 1987; Niemeier 198Sa, 1989; Welsch 1984)

Within the system PANDA the quality of the observations is analysed by computing the following values :

- standard deviation after adjustment,
- residuals and normalized residuals,
- redundancy numbers,
- marginal detectable errors,
- information on probable gross errors,
- estimates of variance components for observation groups.

The quality of the estimated unknowns is analysed by computing the following values:

- standard deviation of coordinates and additional parameters,
- error or confidence regions/ellipses/ellipsoids of points,
- relative error or confidence regions/ellipses/ellipsoids between points,
- outer reliability measures.

Additionally the standard or confidence error for special functions can be computed. Essential for tunnel networks is the well known break-through-error , see Kriiger and Niemeier (1984).

The computation of most of these criteria is possible even during the design phase of a network by making a simulated adjustment . Then an optimization of the proposed network is possible considering various criteria for precision and reliability. Furthermore it’s relatively simple to add new points and/or to use different types of instruments.

5. NUMERICAL TREATMENT OF AZIMUTHS AND OFFSETS

As accelerator networks are often linear systems, here the design of a reliable net is quite difficult. In Krüger and Niemeier 1984 various models for improving this geometry with overlapping observations or by forming triangular or diagonal chains are presented. If such an improvement of the configuration is not possible one can strengthen the network geometry by considering additionally

- use of gyrotheodolites

As presented in Korittke (1988), with the gyrotheodolite GYROMAT the determination of azimuths with a standard deviation of better than 0.9 mgon is possible. The effect of the use of these gyroazimuths on the precision of points in linear networks is shown in Fig. 3.

Another kind of accelerators are almost circular. To improve the geometry of circular networks the observation of

- offsets

has been introduced.

The offset is defined as the height in a triangle, composed of three succesive points in a circular network, see Fig. 4.

The effect of the use of these offsets on the precision of points in circular networks is shown in Fig. 5.

6. ANALYSIS OF DEFORMATIONS

The program system PANDA allows an analysis of repeatedly observed networks on single point movements.

According to the available information a rigorous or an approximate deformation analysis is possible.
The rigorous analysis requires the coordinates with the complete covariance matrix. The adjustment module of PANDA provides the required data.
If the covariance matrix is incomplete e. g. only the point precision is available or is missing e. g. only a coordinate listing of a former epoch is available a approximate deformation analysis will be made. A missing covariance matrix is replaced by a unit matrix.

The results of geodetic observations are always relative, but in engineering networks often one has an idea on probably stable areas; these are the areas, where the so-called reference points are located.

The essential part of the deformation analysis is a global congruency test (Pelzer 1971, Niemeier 1976, 1988b) to determine significant displacements within the reference points. To avoid datum influence on the global congruency test the displacements and the according covariance matrix are transformed on the new datum by a S-transformation. (Niemeier 1988b, 1989)

Two strategies are realized:

The backward strategy bases on a group of reference points. As long as there exist significant deformations within this group, one point will be localized and removed. The procedure ends, when no longer significant discrepancies are detectable.

The forward strategy bases on a group of probable stable reference points. As long as no significant deformations within the group exist, one point out of the group of the ‘potentially moved points’ is added. The procedure ends, when significant deformations appear.

Criterion for the localization of points is the maximum (backward strategy) or the minimum (forward strategy) relative discrepancy of the points.

This combined forward- and backward strategy is very efficient, it is really fast and it allows the user to bring in his expert knowledge on the project.

According to the structure of the network a one or two step analysis can be carried out:

One step analysis : All points are regarded as reference points (relative model).

Two step analysis : The network is divided up into reference and object points The reference points are tested of deformations, subsequently the discrepancies of the object points (relatively to the detected stable reference points) are subjected to a single point test.

As the character of real movements sometimes can not be described by the simple model of single-point-movements, more sophisticated deformation models like block movements, strain, nonlinear trend or others will be added to the deformation module.

A general idea on the deformation module of PANDA is given in Fig. 5 .

For more than two epochs repeated two-epoch-analyses can be performed, using successive epochs or compare each new epoch with the first. A rigorous multi-epoch-analysis is possible as well, using the cumulative approach (Niemeier 1979) , i.e. analysing a new epoch against the cumulated information out of all previous epochs.

7. GRAPHICAL REPRESENTATION

Very important for the acceptance of our results is an adequate graphical representation of the results of an adjustment and a deformation analysis.

As result of the adjustment the following information can be plotted:

- distribution of points
- observations
- error- or confidence ellipses of points
- relative error- or confidence ellipses between points

As results of the deformation analysis

- the vectors with significant movements of points and
- error- or confidence ellipses of points

can be plotted.

The plott module fits to HPGL and CalComp plotters. The results can be presented nowadays on real plotters, but as well on laser printers or - with loss of quality - on normal printers, too.

A connection to common CAD systems via DXF files is also available. This allows the use and presentation of the results of PANDA in an external CAD environment. All features of modern CAD systems like ZOOM technique or visual perspective view of 3D networks are possible.

An example of an output is shown in Fig. 7.

8. CLOSING REMARKS

The system PANDA claims to be an adequate tool for most problems and projects in engineering surveying. Whether this is true or not, has to be proven by each user. The authors are open for criticism further extensions, improvements and modifications of their system, as no software package ever is really complete.

For the next year(s) the following extensions are proposed:

- Inclusion of an adequate own data base system and/or link to the data base system of the user (embedded SQL).

- Implementation of a user surface, which is applicable on UNIX and MS-DOS computers. This is to have the same panels in the field (MS-DOS computers) as on the mainframes in the office (more and more UNIX systems).

The system is in use now in 3 accelerator centers in Germany and various public institutions and private companies in Europe, North- and Latinamerica and Australia. In correspondence a English, Spanish and German version exists.

9. LITERATURE

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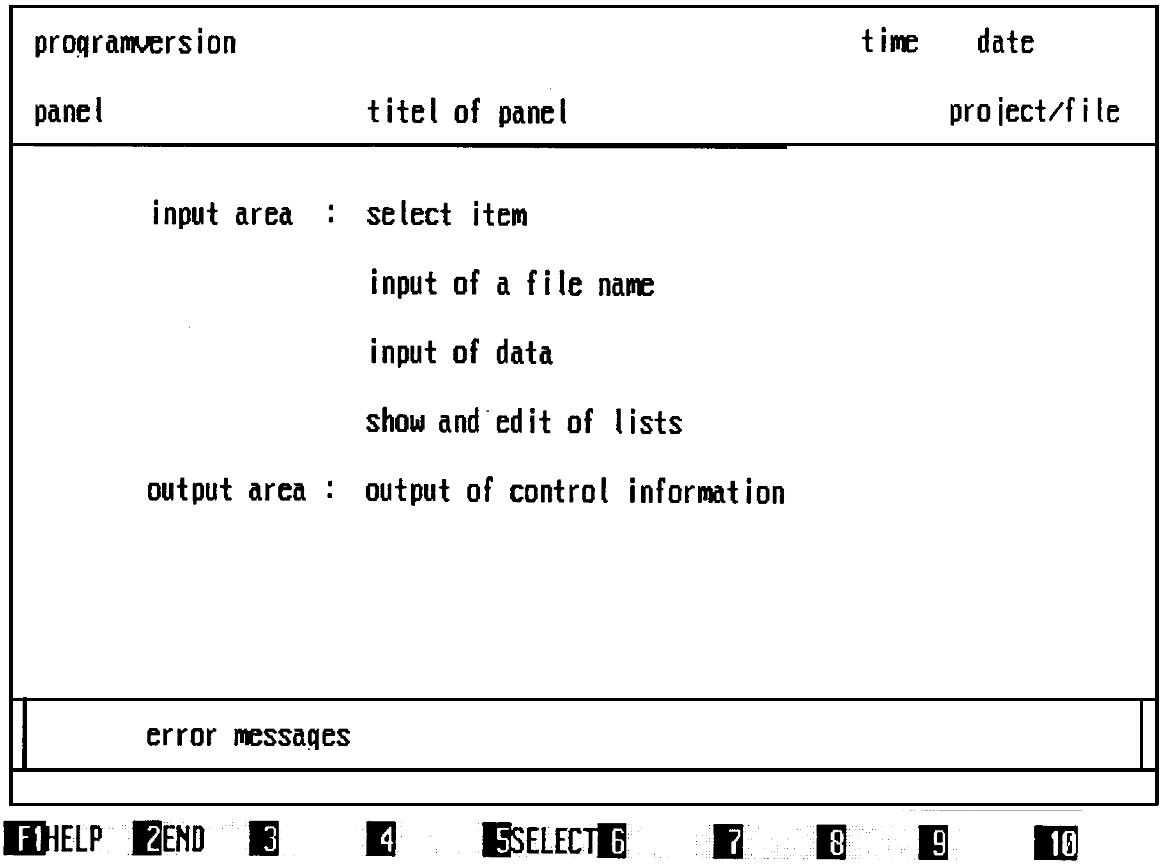


Fig. 1: Appearance of a standard panel

ADJUSTMENT

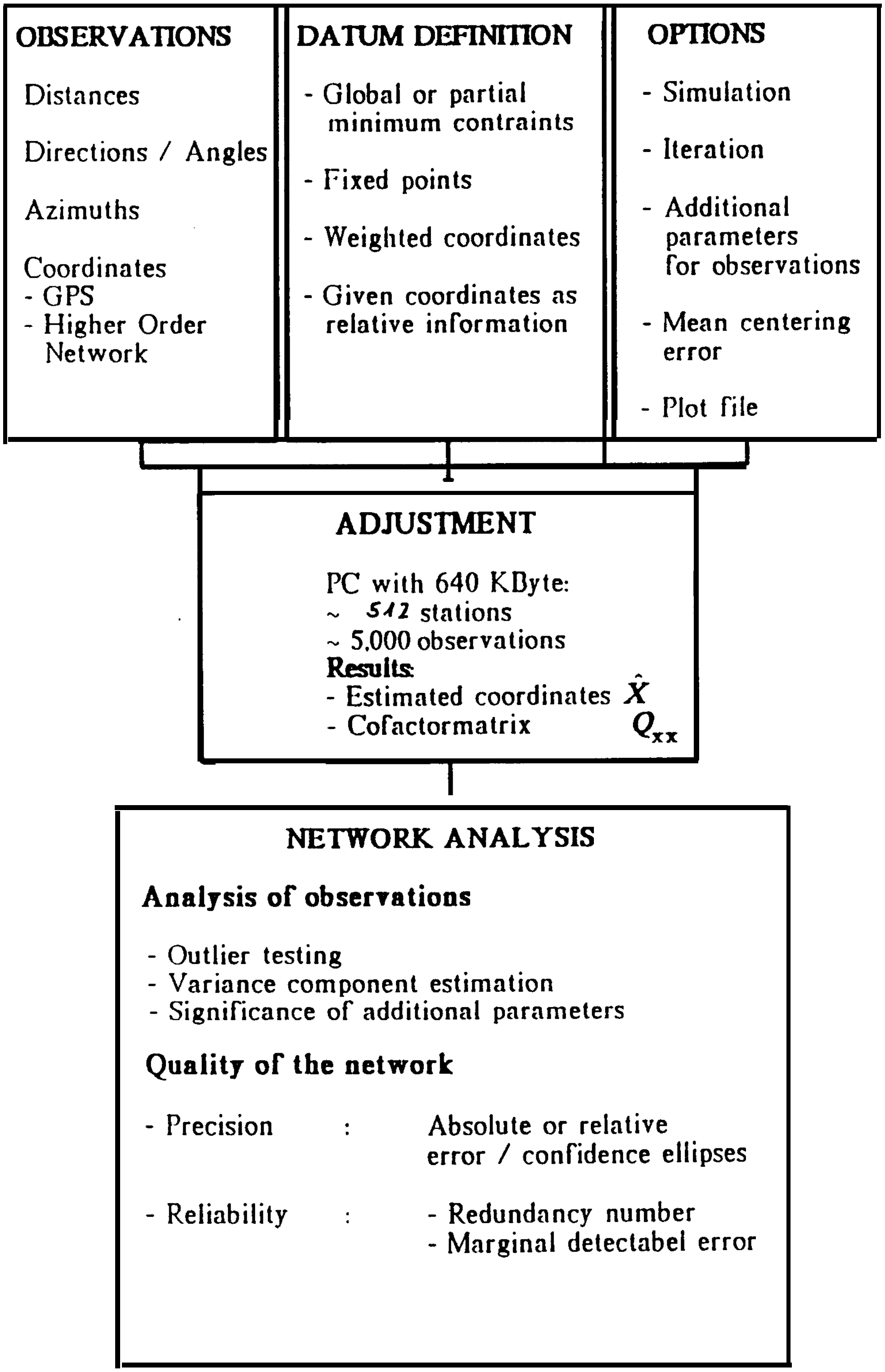
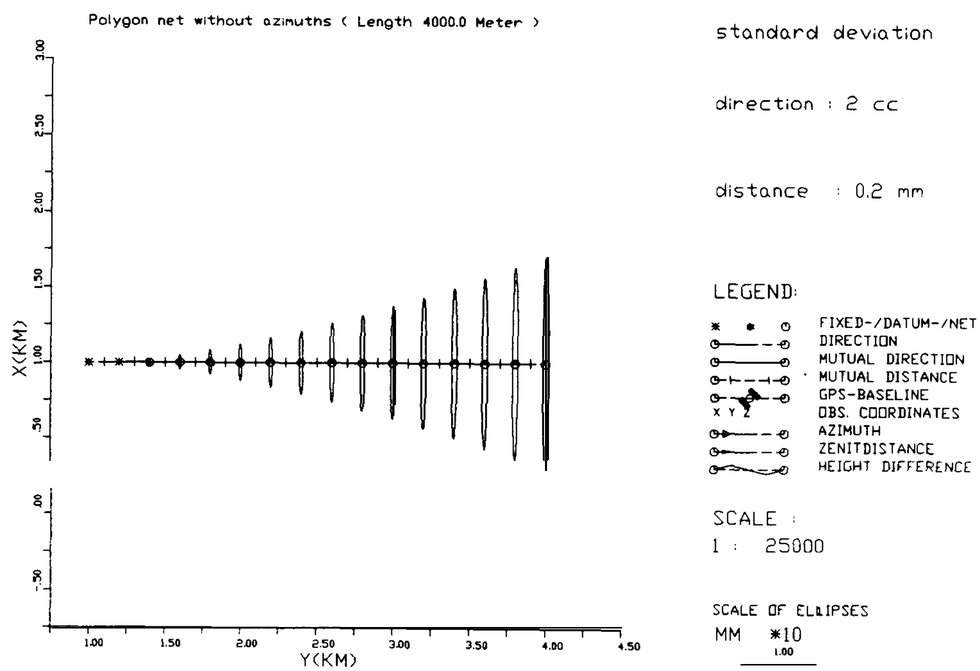


Fig. 2: The adjutstment module of PANDA



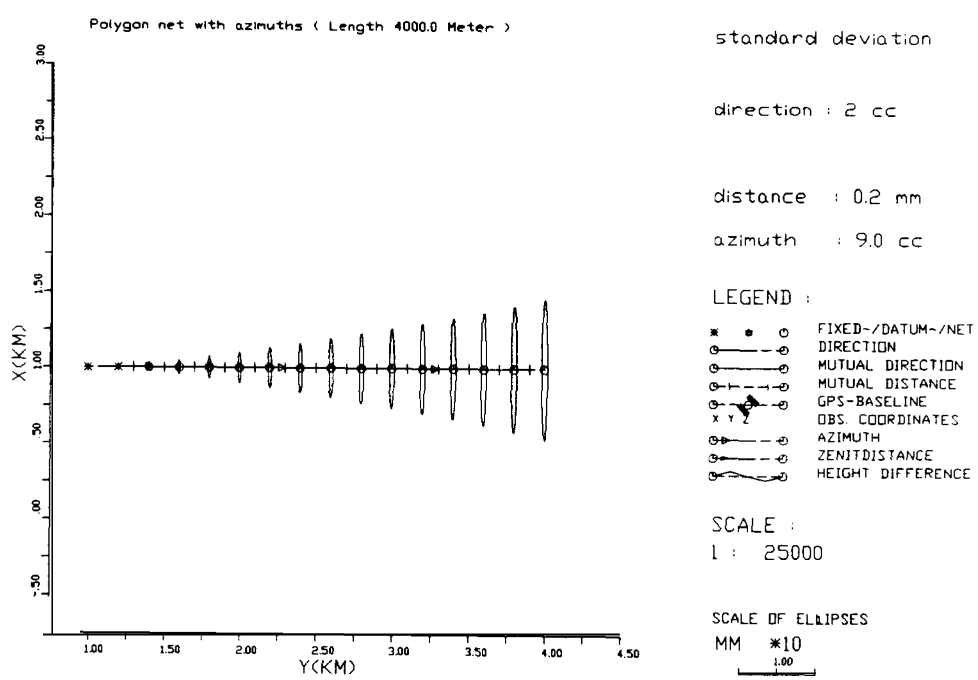


Fig. 3: Improvement of open polygon nets with azimuths

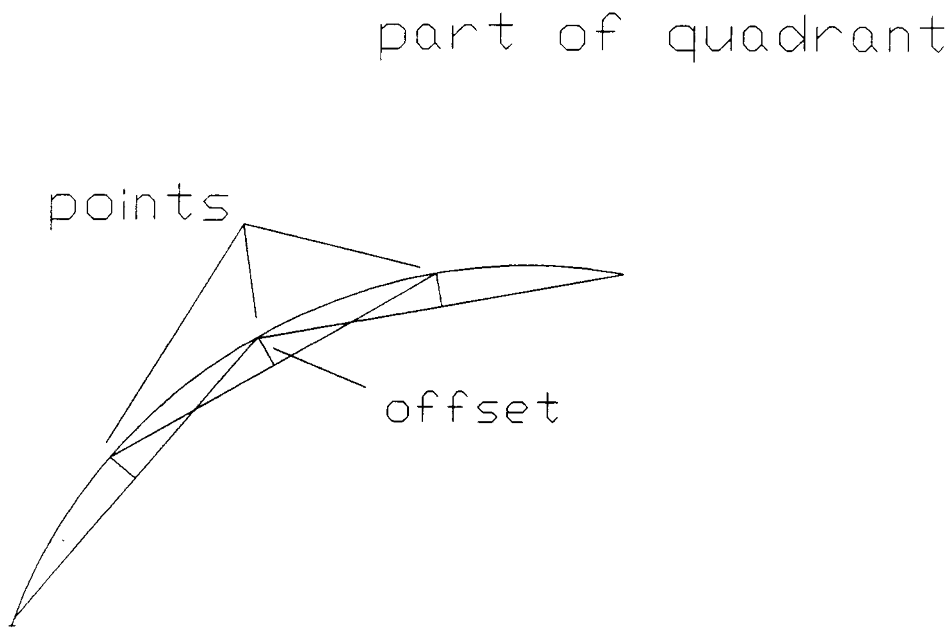


Fig. 4: Definition of offsets in circular nets

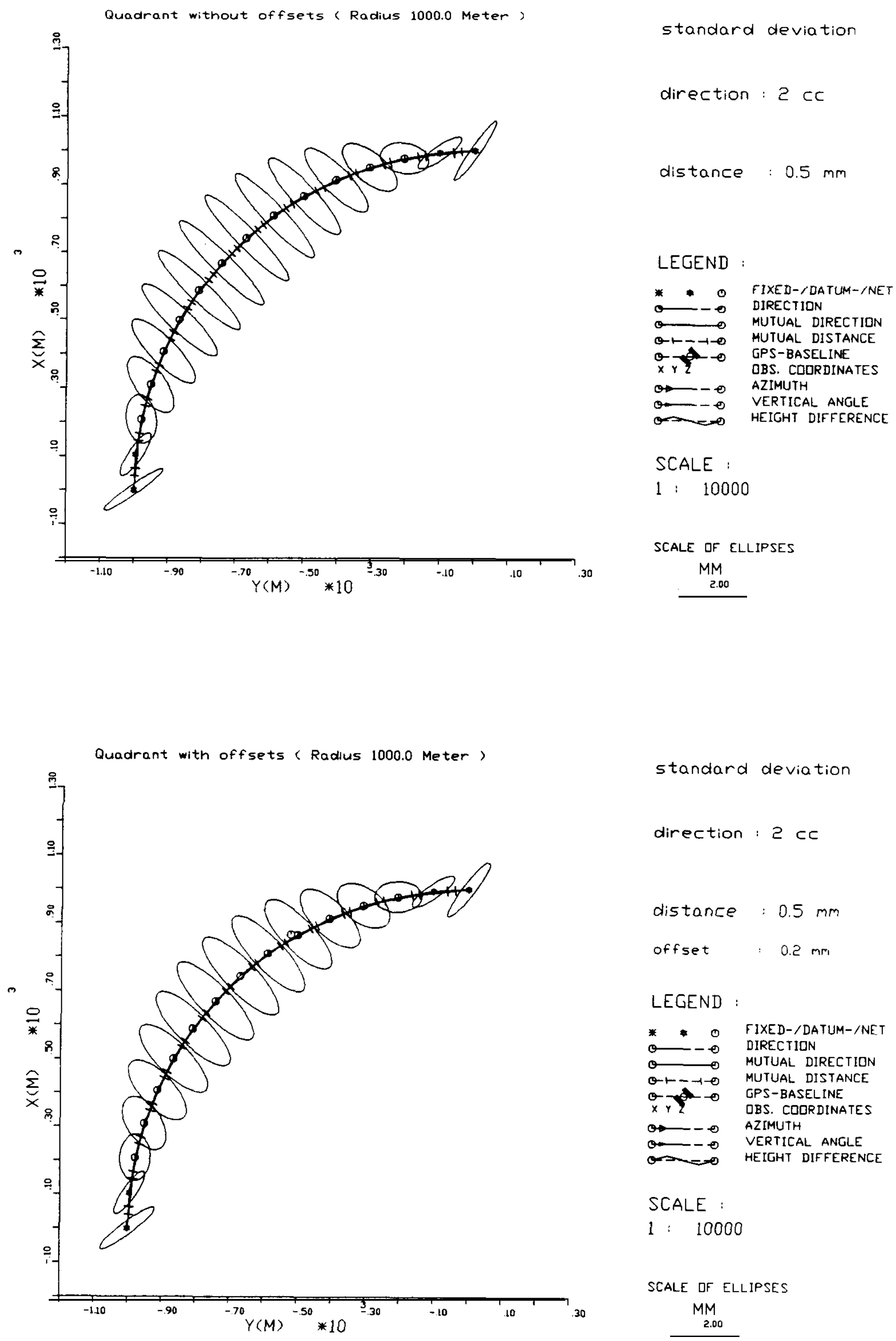


Fig. 5: Improvement of circular nets with offsets

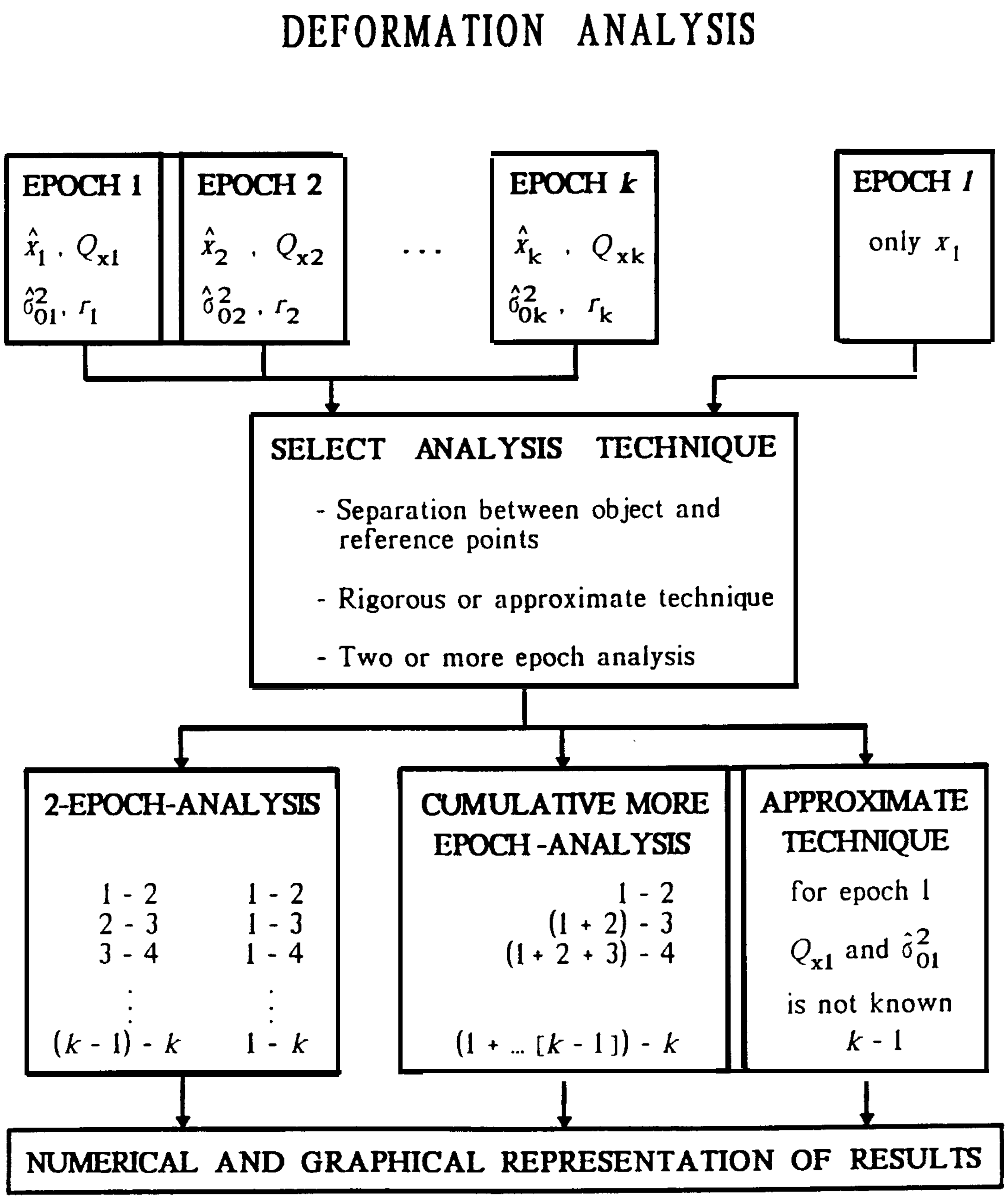
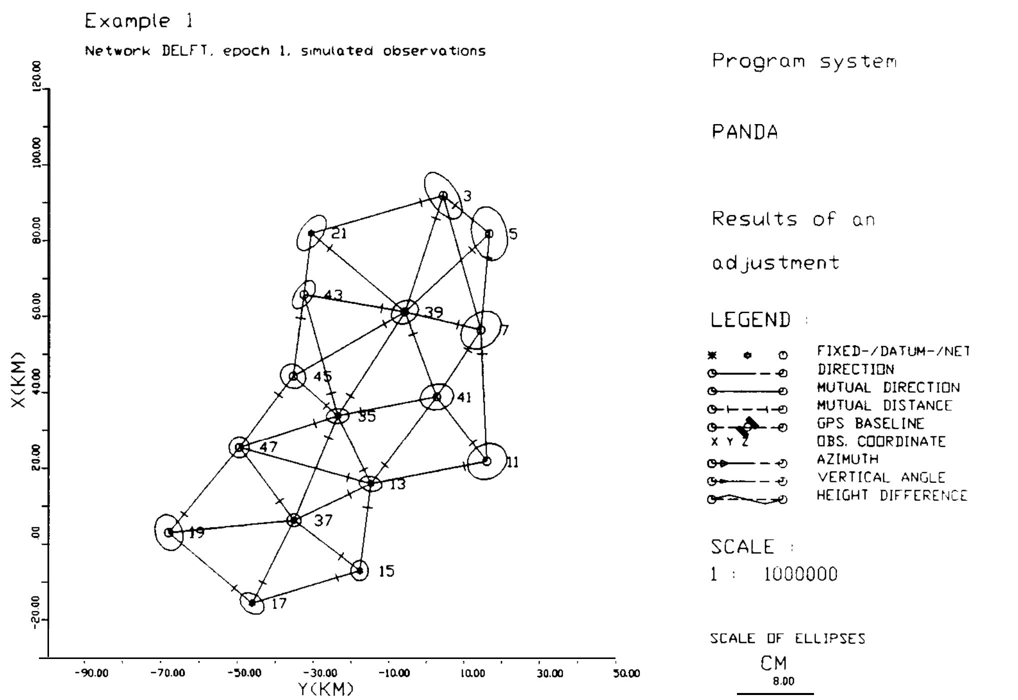


Fig. 6: Various strategies for a deformation analysis



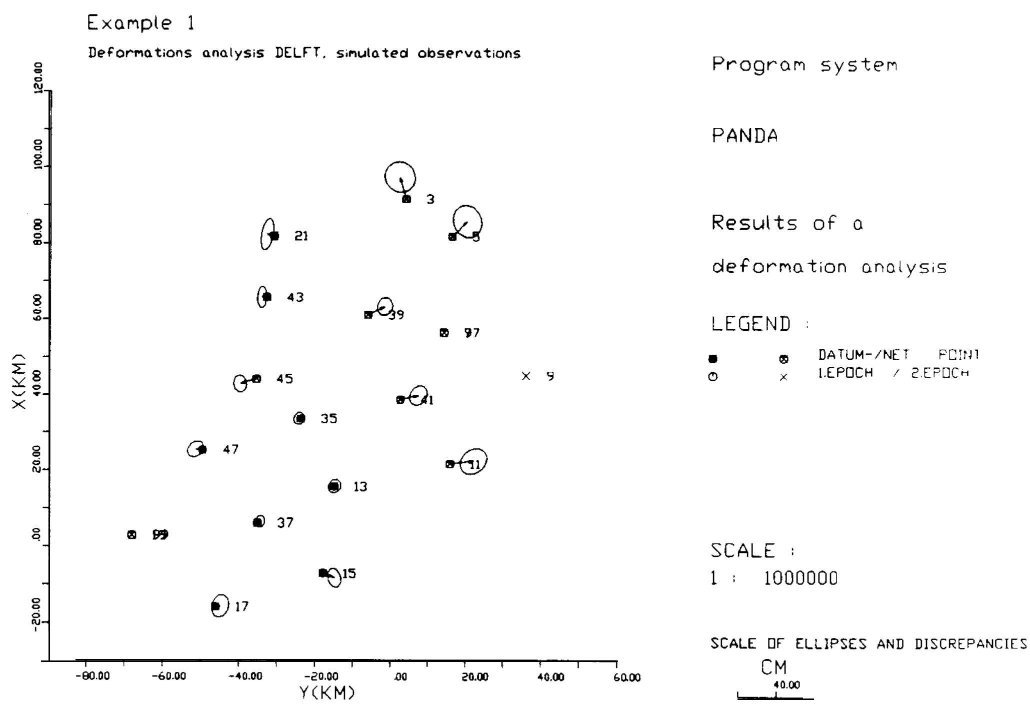


Fig. 7: Graphical representation of an adjustment and a deformation analysis