Processing of High Precision Networks with the Multi-Station Post-Processing Software Geo++ GEONAP

Martin Schmitz, Gerald Boettcher,
Gerhard Wübbena

Geo++® GmbH
D-30827 Garbsen, Germany
www.geopp.de

Organization

- Introduction/High Precision DB_REF Network

- Geo++® GEONAP

- Benefit of Undifferenced Processing

- General DB_REF Network Project Terms

- Processing of GPS Sessions and Network

- Findings from DB_REF Network

- Summary

Introduction

- satellite-based surveying techniques

  - applications steadily increasing

  - accuracy range of: mm ... cm ... dm ... m

  - use of global cartesian coordinate systems

  - homogeneous coordinates

- problems in application

  - inhomogeneous coordinate systems
    basis of existing data

  - transformation of coordinates necessary

  - not sufficient density of known points in
    homogeneous network

Introduction

processing of a high precision network

- project of German railway company DB AG[*]

  - applications covering Germany

  - establishing Germany-wide homogeneously coordinated GPS reference stations

  - absolute positioning in official/legal ETRS 89 framework

  - high accuracy requirements

  - enabling rigorous use of modern surveying methods e.g. satellite-based track surveying

- processing with Geo++® GEONAP software

DB Netz AG
D-60486 Frankfurt

Die Bahn

Geo++® GEONAP

- GEONAP - Geodetic Navstar Positioning

  - **multi-signal**, **multi-station**, **multi-session** adjustment (rigorous adjustment of different signals and multiple kinematic and/or static stations, **rigorous 3D network** adjustment)

  - **undifferenced** observable with **complete variance-covariance** estimation

  - consideration of all major error components

- development and maintenance by Geo++® - since 1990

- advanced GPS software

  - for static and kinematic applications

  - for small, large and regional applications

  - different accuracy levels from mm ... m

# Benefit of Undifferenced Processing

- undifferenced processing using parameter estimation

  - **absolute coordinates**

  - **complete variance-covariance** matrix

  - rigorous **multi-station** sessions

- network adjustment of sessions

  - **rigorous 3D adjustment** of absolute coordinates

  - combines multi-station sessions

  - comparable of multi-station adjustment in one step (only correlation of not simultaneously processed stations is missing)

- **realistic accuracy** measure (standard deviation)

  - no scaling of internal accuracy measure necessary

General DB_REF Network Project Terms

- establishing of DB_REF network

  - partioning of railway network

  - 16 states into 10 lots

  - engineering/surveying companies
    or working groups for
    local works/GPS observations

  - one contractor to provide
    reference data i.e.
    SAPOS network (German Satellite
    Positioning Service)

  - one contractor for
    processing and adjustment
    of complete network
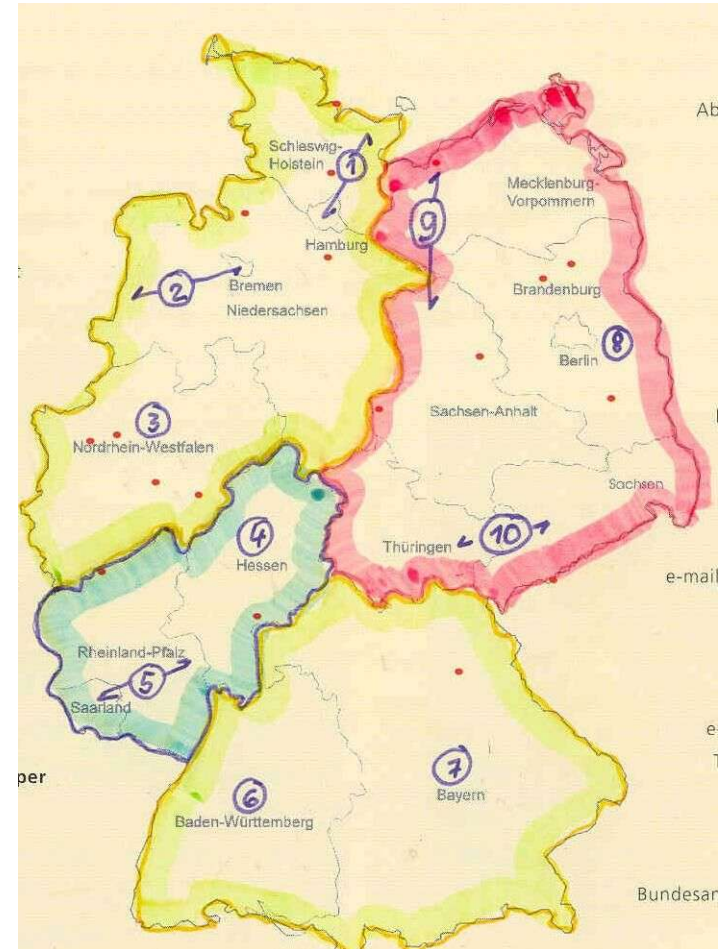
Time Frame

- start of project in 2000 at DB AG

- contracts on GPS measurements to private engineering companies

- start of measurements October 2001
  - reconnaissance, establishing of markers, GPS observation, documentation in 10 lots, generally state-wide

- processing of GPS-observations and network adjustment by Geo++ GmbH

- status September 2004
  - initial measurements/processing finished
  - execution/integration of repeated measurements finished
  - currently performing final analysis
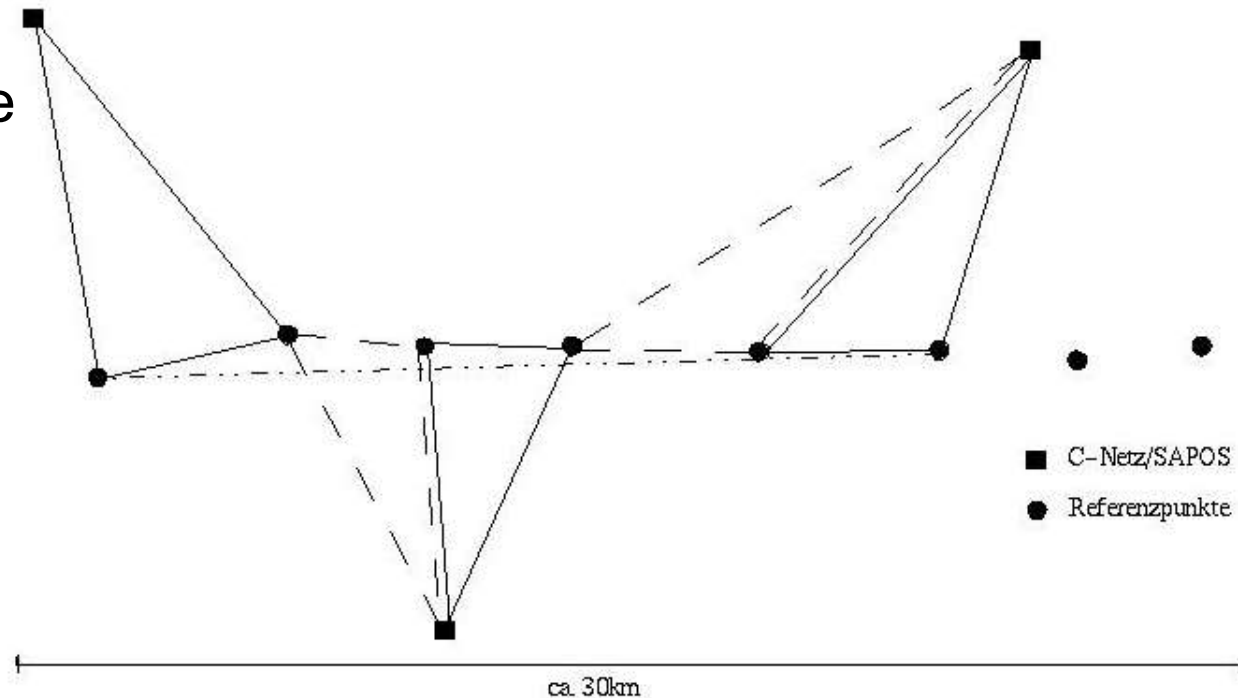
Location Requirements

- DB_REF network

  - save and stable location

  - 4 km distances along tracks

  - not necessarily beside the tracks
    (close to tracks)

  - generally on bridge constructions

  - suited as GNSS reference station

  - suited for
    data communication

Observation Scheme and Accuracy

- specified observations in DB_REF network

- session design
  - observation of all directly adjacent stations and one overlapping connection every 20-30 km

Legend:
- ■ C-Netz/SAPOS
- ● Referenzpunkte

ca. 30km

- accuracy goals
  - 3D accuracy (2 sigma)
    absolute   <   10 mm
    relative   <   5 mm
    (adjacent stations)

Requirements of GPS Observations

- minimum **diameter of antenna** ground plane 28 cm

- individual, absolute, **calibrated antennas**

- at least two times **30 min** observation time

- antenna **height readings** before and after observation using two different scales (m and ")

- **new set-up** for every session (change in height of 5 cm)

- check of **data quality** (UNAVCO TEQC)

  - data rate 10 s, elevation mask 5 deg
  - at least **6 satellites** simultaneously over 30 min
  - **number of cycle slips** <1% of all observations above 10 deg

- minimum **number/distance** to **reference stations**

  - 1 station   < 25 km
  - 2 stations   < 28 km
  - 3 stations   < 32 km

# GPS Observation Summary

- DB_REF network

    - status September 2004

    - observations from November 2001 to August 2004

        - ~7500 new stations

        - ~21000 datasets from new stations

        - ~8100 sessions

        - ~18200 datasets from SAPOS stations and C-network stations

Processing of GPS Sessions and Network

- Geo++ GEONAP/ GnHPPS NXO

  - automated import

  - digital data flow using RINEX Header

  - special procedures

    - ensure correct data import

    - assign sessions

    - assign reference stations
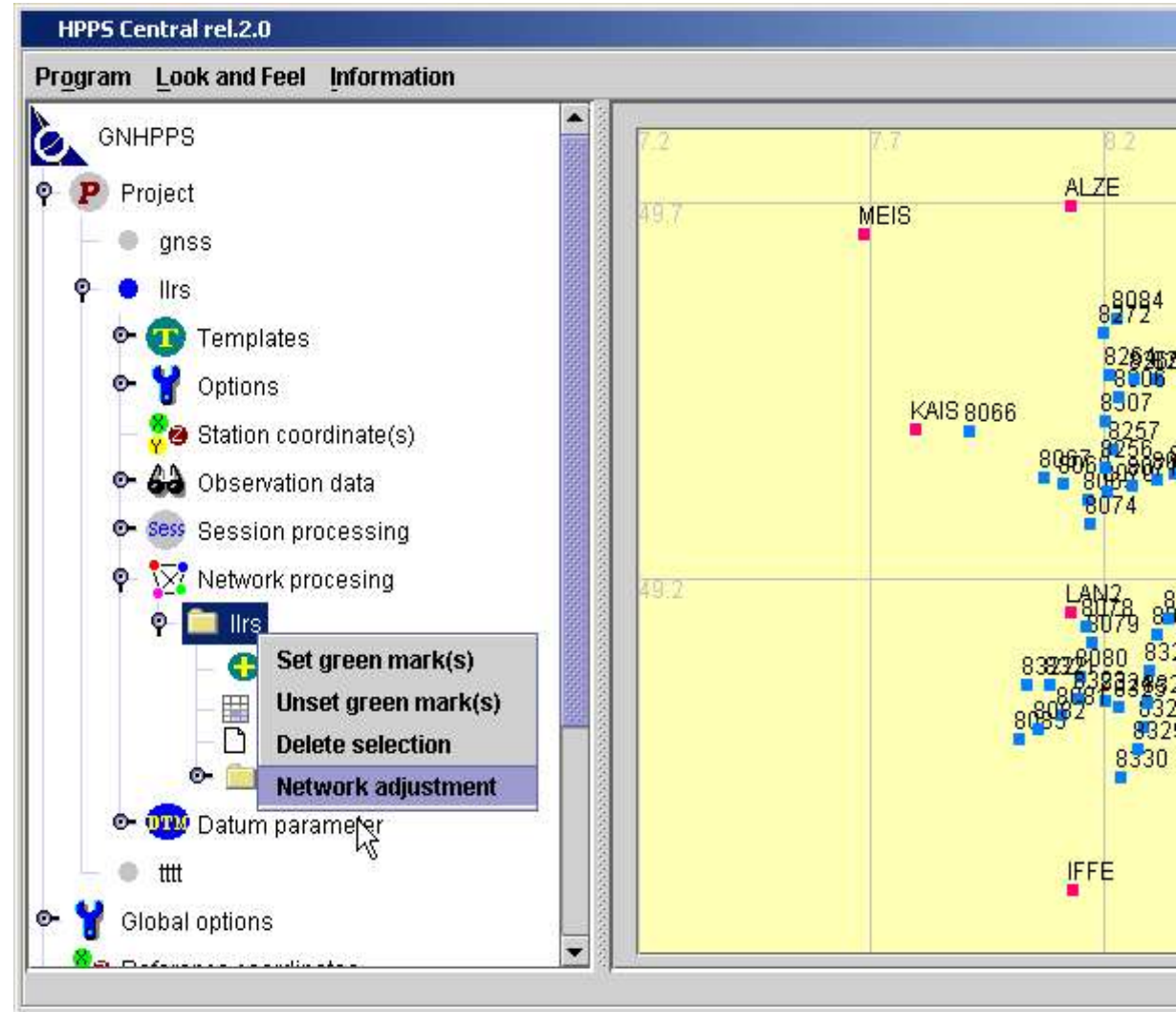
Details on GPS Session Processing

- GEONAP/GnHPPS NXO

  - consistent absolute antenna corrections

  - undifferenced GPS approach

  - simultaneous L1&L2 processing

  - estimation of ionosphere

  - temporal and spatial estimation of troposphere

  - precise ephemeris

  - complete variance-covariance matrix

  - use of *SAPOS* reference station coordinates

    - however, own estimation of *SAPOS* coordinates to proceed with project

Absolute ETRS 89 Positioning by *SAPOS*/C-Network

- ## *SAPOS* stations (ca. 250) in Germany

- coordinated in ETRS 89

- detection of discrepancies

  - within the networks

  - between states

- consequence

  - Geo++ coordinate estimation

  - "Diagnoseausgleichung" of AdV by BKG/LGN

- new official coordinates available January 2004

- densification through C-network

DB AG NXO-Project

Cylinder Projection   100 km   (o) 1991-2002 Geo++ GmbH
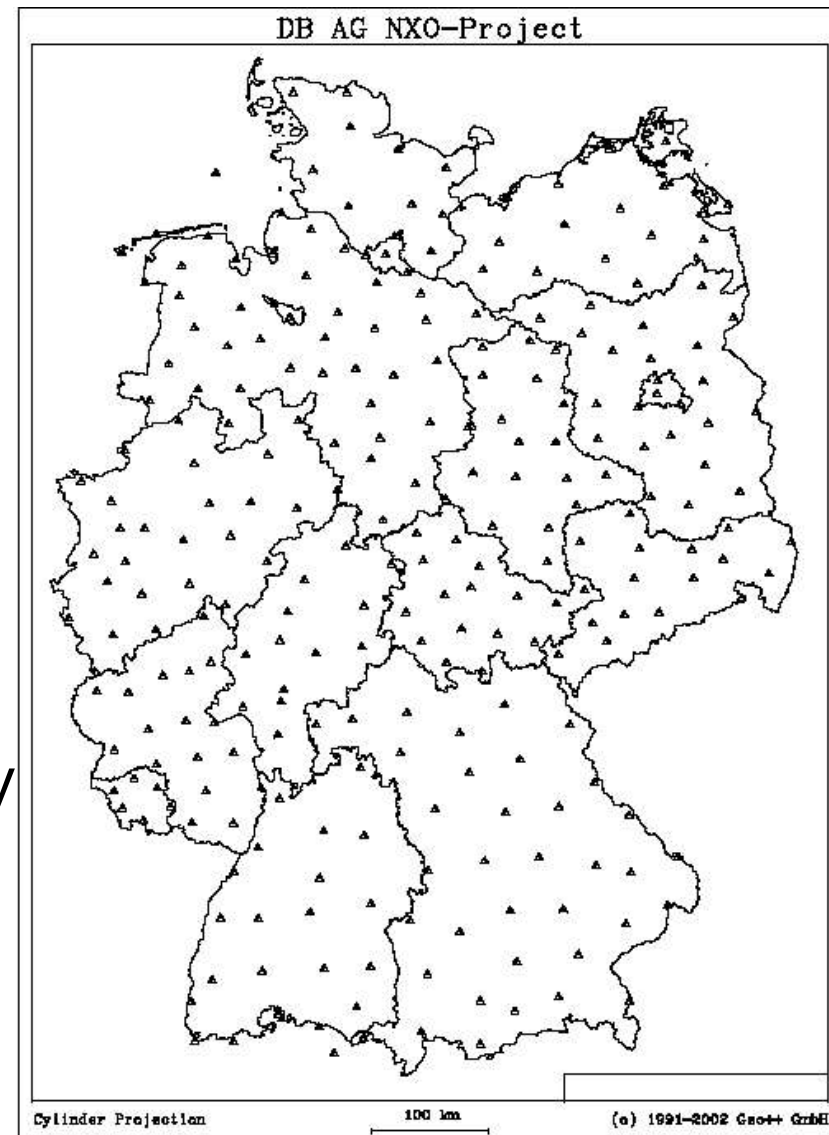
Network Processing Procedure

- beforehand: determination of homogeneous coordinates
  of *SAPOS*- and C- network with GEONAP
  (not planned nor intended in 2001)

- finally: transformation to new
  official *SAPOS*-coordinates
  (completely available January 2004)

- analysis: (session- and) network- adjustment in
  five blocks (lots); determination of measurements
  to be repeated (data quality, gross errors)

- network: German-wide, multiple stage,
  rigorous 3D Network adjustment
  with complete variance-covariance matrix

- result: homogeneous ETRF 89 coordinates of
  ~7500 new stations
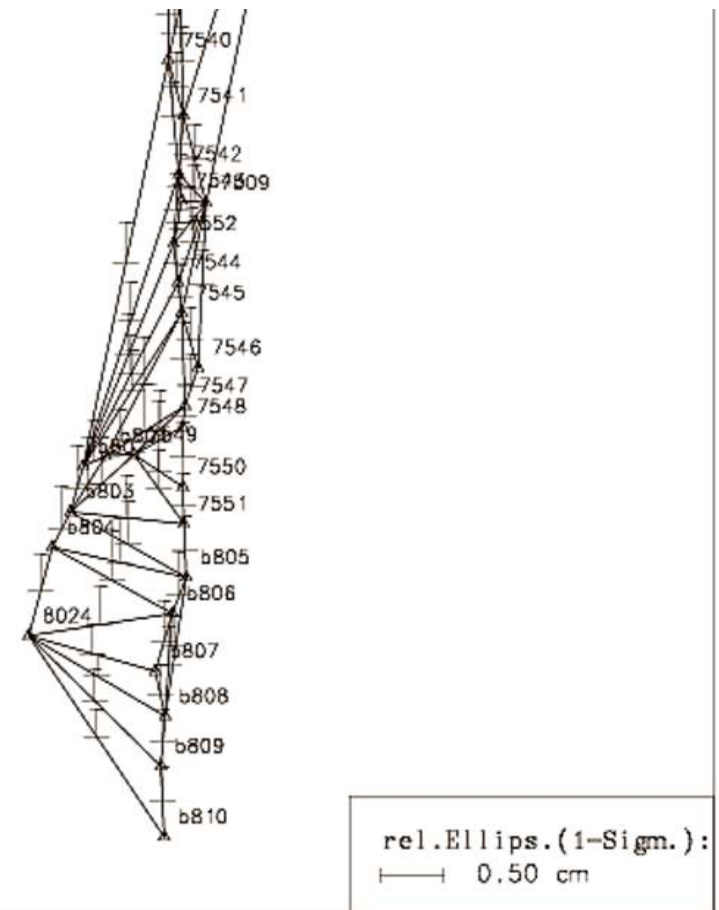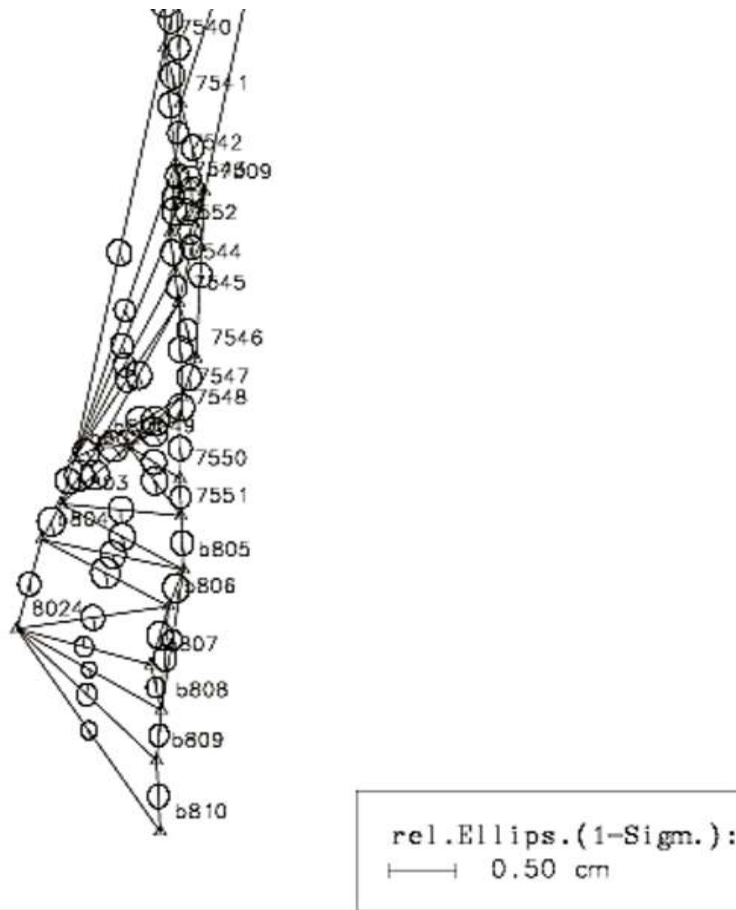
Details on Network Adjustment

- network adjustment

  - rigorous 3D adjustment (absolute coordinates) of all session solutions

  - using complete variance-covariance matrix

- multistage network adjustment

  - initial stage general check

  - first stage statistical gross error detection

  - second stage detection of large residuals

- restriction due to processing time and processing hardware

  - partioning of complete Germany-wide network adjustment

Achieved Relative Accuracy Snapshot from Network

relative horizontal accuracy   relative height accuracy

Findings from DB_REF Network

- establishing of German-wide DB_REF network
  - advantages of measurements and processing in one big effort
    - unique processing software and strategy
      - antenna correction
      - rigorous 3D network adjustment
    - control of higher order/datum defining network
      - detection of residuals/discrepancies
      - ensuring and maintaining consistency
      - compensation of site changes
  - finally enables high precision

Summary

- GEONAP processing capabilities revisited

- example of DB_REF network processing

- high accuracy and homogeneity

  - unique processing software and strategy
    of complete network

  - observation and processing in one big effort

  - consistency check of higher oder network

- homogeneous coordinates in
  official/legal framework ETRS 89 system

- enables optimal application of latest (satellite-based)
  surveying techniques

for publications on the presented topic refer also to

www.geopp.com

or directly to

http://www.geopp.com/publications/english/lit_e.htm