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

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Organization

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- 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
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
- partitioning 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

- 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
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
  - partitioning 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 order 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