Network RTK in Areas with High Geodynamic Activity

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Introduction

- multiple permanent GNSS reference stations
- **RTK-networks state-of-the-art** application providing
  - RTK services
  - DGNSS services
- **demand** of RTK service users for
  - consistency of framework
  - integrated access to user datum
- **pre-requisite** of RTK service provider
  - up-to-date coordinates of reference stations
  - optimum performance of RTK network
- **need** of RTK-network to provide transformation
GNTRANS

- development of Geo++ GNTRANS
  - GNTRANS transformation model can account for
    - varieties of local datum
    - distortions of current networks
    - high geodynamic activity
  - GNTRANS transformation modules
    - Germany-wide DB_REF* module
    - local or regional patches in Germany
    - Japan-wide module
GNTRANS – Model

- multistage transformation
- applicable stages
  - 7P- transformation
  - continuous functional transformation
    - mathematical functional approach to describe remaining residuals after 7P- transformation or directly residuals
- stochastic part
  - stochastic prediction of remaining discrepancies considering topological neighborhood (decorrelation along topology of discontinuity)
GNTRANS – Model Properties

- properties of transformation models
- preservation of adjacent metric properties
- uniqueness/standardized
- homogeneity
- continuity
- consideration of discontinuities
- biuniqueness (one-to-one mapping)
Principle of GNTRANS
Coordinate System Transformation

“reference system” (e.g. ITRF)

7P₁ | datum (7P) | 7P₂

X, Y, Z

(a, f₁) | ellipsoid | (a, f₂)

φ, λ, h

proj₁ | projection | proj₂

R, H, h

N₁ | geoid (H=N+h) | N₂

R, H, H

system 1

system 2
Major Geotectonic Plates
Modern Coordinate Systems

• three-dimensional coordinate system
  • geocentric, i.e. earth's center-of-mass origin (in practice within a few cm)
  • Z-axis aligned with the earth's axis of rotation (IERS reference pole)
  • X-axis IERS reference meridian
  • Y-axis completes right-handed coordinate system
• why?
  • satellite geodesy, ...
  • accuracy, consistency, internationally, globally, ...
• e.g. WGS 84, ITRS/ITRF xx, ETRS/ETRF xx, ...
ITRF Coordinates

- ITRF positions characteristics are generally
  - accuracy of a few centimeters or better
  - accurate even over continental or global distances
  - ongoing tectonic plate motion (continental drift) as well as other forms of crustal motion must be accounted for at this level of accuracy
  - ITRF positional coordinates valid for a specified epoch date, and appropriate velocities must be applied to estimate positional coordinates for any other date
  - relative to ITRF, even points located on a stable plate move continuously (e.g. North American plate at a rate of about 2.5 cm/yr)

extracted from http://www.ngs.noaa.gov/CORS/metadata1/
PAS Network in Japan

- Positioning Augmentation Services (PAS)
  - Mitsubishi Electric Corporation (MELCO)
  - GPS RTK network
  - using approx. 350 stations of GEONET network
  - commercially operated since September 2003

- GPS Earth Observation Network (GEONET)
  - Geographical Survey Institute (GSI)
  - established since 1994 to monitor crustal deformation
  - 1200 stations throughout Japan
  - typical separation 25 km
  - sub-set of stations transfer real time data
  - 1 Hz data provided to commercial users
Japanese Geodetic Datum 2000

- Geographical Survey Institute (GSI)
  - constructed new framework
  - referring to ITRF94 at epoch of 1997.0

  - using domestic VLBI stations
  - 950 stations of GEONET
  - first- to third-order triangulation points (resurvey and re-computation)
  - GRS80 ellipsoid
  - since April 1, 2002
## Magnitude of Geodynamics in Japan

- **station velocities** (two VLBI anchor stations of JGD2000)

<table>
<thead>
<tr>
<th>station velocity (ITRF2000)</th>
<th>latitude m/yr</th>
<th>longitude m/yr</th>
<th>height m/yr</th>
<th>3D m/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>KASHIMA</td>
<td>-0.0116</td>
<td>-0.0038</td>
<td>-0.0041</td>
<td>0.0129</td>
</tr>
<tr>
<td>SHINTOTSUKAWA</td>
<td>0.0215</td>
<td>-0.0156</td>
<td>0.0230</td>
<td>0.0351</td>
</tr>
</tbody>
</table>

- **station movements** (GEONET network)

<table>
<thead>
<tr>
<th>coordinate differences (930)</th>
<th>latitude m</th>
<th>longitude m</th>
<th>height m</th>
</tr>
</thead>
<tbody>
<tr>
<td>after 7yrs</td>
<td>min</td>
<td>max</td>
<td>mean</td>
</tr>
<tr>
<td></td>
<td>-0.618</td>
<td>0.105</td>
<td>-0.132</td>
</tr>
<tr>
<td></td>
<td>-0.132</td>
<td>0.838</td>
<td>0.067</td>
</tr>
<tr>
<td></td>
<td>-0.390</td>
<td>0.043</td>
<td>-0.107</td>
</tr>
</tbody>
</table>
Principle of GNTRANS Transformation
JGD2000/JGD2000 current Epoch

“reference system” (e.g. ITRF)

- datum (7P)
  - X, Y, Z
- ellipsoid
  - φ, λ, h
- projection
  - R, H, h (distortion free)

GNTRANS

- vertical adjustment
  - R, H, h
- horizontal adjustment
  - R, H, h

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Differences JGD2000/JGD2000 2003.9

height differences before and after transformation
Magnitude of Position Changes

north-south component

east-west component
Magnitude of Height Changes

height component
Accuracy of GNTRANS Module Japan

- internal accuracy
- standard deviation derived from given station coordinates before transformation

<table>
<thead>
<tr>
<th>area</th>
<th>sN [m]</th>
<th>sE [m]</th>
<th>sh [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>0.149</td>
<td>0.119</td>
<td>0.123</td>
</tr>
</tbody>
</table>

- standard deviation derived from given station coordinates after transformation

<table>
<thead>
<tr>
<th>area</th>
<th>sN [m]</th>
<th>sE [m]</th>
<th>sh [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>0.003</td>
<td>0.003</td>
<td>0.009</td>
</tr>
</tbody>
</table>
Update of GNTRANS Module

- situation in Japan
  - continuously deformation of network due to tectonic movements (dynamic datum)
  - maintain temporal consistency of framework by removing crustal deformation
  - frequent update of GNTRANS module using GEONET coordinates (1200 stations)
  - important for public survey using RTK network
  - agreement with Japan Geodetic Datum 2000
Providing GNTRANS Transformation

- RTK network service provides:
  - transmitting GNTRANS module parameter
  - position correction computed at user site
  - using same simplex communication link as GPS data
  - broadcast solution

- RTK network user:
  - sends coordinate to provider
  - GNTRANS computation at RTK network center
  - modification of GPS correction data
  - duplex communication link required
Summary

• RTK networks in high geodynamic areas
  • coordinates constantly changing
  • frequently update of reference station coordinates required
  • consistency of framework required
• RTK network service users
  • demand for consistency and transformation
• GNTRANS model applied to compensate tectonic movements of coordinates
  • applicable within RTK network service
  • demonstrated with GNTRANS module Japan
for publications on the presented topic refer also to

www.geopp.com

or directly to

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