Prospects of IVS-Intensive Sessions with Twin-Telescopes

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Introduction

INT3

- weekly intensive session
- 3 stations
- estimate dUT1

NYALES20

WETTZELL

TSUKUB32
INT3 with Twin-Telescope Wettzell

- Twin-Telescope Wettzell
  → 4 stations
- various constellations
INT3 with Twin-Telescope Wettzell

- pairing
- Twin-Telescope Wettzell → array-mode
INT3 with Twin-Telescope Wettzell

- pairing
- Twin-Telescopes with single telescopes

Improvement of dUT1?
Scheduling concept based on singular value decomposition

- choosing observations subsequent according to a criterion of singular value decomposition (SVD)
- stepwise optimization of the geometry
- objective criteria
**Parametrization**

- **Target parameter:**
  - the phase of the earth rotation \( dUT1 \)

- **Other parameters:**
  - clock offset \( CL_0 \), clock rate \( CL_1 \) and frequency drift \( CL_2 \) per station w.r.t. one reference clock
  - atmospheric wet zenith path delays \( AT \) per station

**Jacobian Matrix**

\[
X = \begin{pmatrix}
\frac{\partial \tau_1}{\partial CL_{0,A}} & \frac{\partial \tau_1}{\partial CL_{1,A}} & \frac{\partial \tau_1}{\partial CL_{2,A}} & \cdots & \frac{\partial \tau_1}{\partial AT_A} & \cdots & \frac{\partial \tau_1}{\partial dUT1} \\
\vdots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\
\frac{\partial \tau_m}{\partial CL_{0,A}} & \frac{\partial \tau_m}{\partial CL_{1,A}} & \frac{\partial \tau_m}{\partial CL_{2,A}} & \cdots & \frac{\partial \tau_m}{\partial AT_A} & \cdots & \frac{\partial \tau_m}{\partial dUT1}
\end{pmatrix}
\]
Singular Value Decomposition

\[ X = U \cdot S \cdot V^T \]

**Singular Values** \( \sigma_i \)
- \( S = diag(\sigma_1, \sigma_2, \ldots, \sigma_r, 0, \ldots, 0) \)
- \( r = rank(X) \)

**Left Singular Vectors** \( u_i \)
- columns of the \( m \times m \) orthogonal matrix \( U \)
- \( U_r = \{u_1, \ldots, u_r\} \) span a basis for the column space \( R(X) \) (data space) of \( X \)
Singular Value Decomposition

Data Resolution Matrix / 'Hat Matrix'

\[ H = U_r U_r^T \]

- elements indicate how much weight each observation has on the adjusted observations
- main-diagonal elements of \( H \) are called impact factors \( h_i \)

\[ h_i = diag(H) \]

- close relation between impact factors and partial redundancies

\[ r_i = 1 - h_i = (I - H)_{ii} \]

the higher the impact factor, the bigger the effect on the observing geometry

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March 5th, 2012
Choice of the observations

**wanted:** scan with the greatest impact (factors)

**problem:** subnets

- varying number of observations (depend on the number of observing baselines)
- compare unequal number of impact factors
- the greater the number of impact factors the lower the values of the impact factors

**solution:**

\[
\frac{1}{n} \sum_{i=1}^{n} IF_i \cdot \sqrt{n}
\]

\(n:\) number of impact factors per scan

(other solutions feasible)
Validation

formal errors (INT3)

- only geometry
- no information of the variance of unit weight

⇒ simulation of observations
Simulation of observations

Monte-Carlo Simulator (VieVS)

\[ o - c = (zwd_2 \cdot mfw_2 (e_2) + clk_2) - (zwd_1 \cdot mfw_1 (e_1) + clk_1) + wn \]

- zenith wet delay \( zwd_{1,2} \)
  \( \rightarrow \) turbulence model
- station clock \( clk_{1,2} \)
  \( \rightarrow \) random-walk and integrated-random-walk
- baseline dependent white noise \( wn \)

\[
\Delta \tilde{x} = \left( X^T \Sigma_{ll}^{-1} X \right)^{-1} X^T \Sigma_{ll}^{-1} \Delta l, \quad v = X \Delta \tilde{x} - \Delta l
\]

\[
s^2 = \frac{v^T \Sigma_{ll}^{-1} v}{f} \cdot \sigma^2 \quad f: \text{degree of freedom}
\]
SVD schedules improve the standard deviation of $d_{UT1}$ by approximately 20%.
1. Allow all possible subnets

2. Force pairing (allow all baseline combinations)

3. Force pairing (always one twin with a single telescope)
Twin-Telescope Scenarios

1. allow all possible subnets

2. force pairing (allow all baseline combinations)

3. force pairing (always one twin with a single telescope)
INT3 with Wettzell Twin-Telescopes

**formal errors**

\[ \sigma_{dUT1} [\mu s] \]

- all possible subnets
- pairs 1 (all)
- pairs 2 (twins)

**standard deviations**

\[ \sigma_{\mu} [\mu s] \]

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INT3 with Wettzell Twin-Telescopes

**formal errors**

- Precision improvement w.r.t. 'standard INT3' only for 'all possible subnets'.

**standard deviations**

- all possible subnets
- pairs 1 (all)
- pairs 2 (twins)
Twin-Telescope Parametrization

**individual setup:**
- clock and atmospheric parameters per twin-telescope
  \[ cl_{0t_1}, cl_{1t_1}, cl_{2t_1}, at_{t_1} \quad \& \quad cl_{0t_2}, cl_{1t_2}, cl_{2t_2}, at_{t_2} \]

**common setup:**
- clock parameters per twin-telescope and common atmospheric parameter for both
  \[ cl_{0t_1}, cl_{1t_1}, cl_{2t_1}, at_{t_1} \quad \& \quad cl_{0t_2}, cl_{1t_2}, cl_{2t_2}, at_{t_2} \]
  \[ \rightarrow at_{twin} \]
- common clock parameters for both and atmospheric parameter per twin-telescope
  \[ cl_{0t_1}, cl_{1t_1}, cl_{2t_1}, at_{t_1} \quad \& \quad cl_{0t_2}, cl_{1t_2}, cl_{2t_2}, at_{t_2} \]
  \[ \rightarrow cl_{0twin}, cl_{1twin}, cl_{2twin} \]
- common clock parameters and common atmospheric parameter for both
  \[ cl_{0t_1}, cl_{1t_1}, cl_{2t_1}, at_{t_1} \quad \& \quad cl_{0t_2}, cl_{1t_2}, cl_{2t_2}, at_{t_2} \]
  \[ \rightarrow cl_{0twin}, cl_{1twin}, cl_{2twin}, at_{twin} \]
e.g. all possible subnets

**Formal errors**

\[
\sigma_{dUT1} [\mu s]
\]

- all parameters
- AT
- CL
- AT & CL

**Standard deviations**

\[
s_{dUT1} [\mu s]
\]

2009.0 2009.2 2009.4 2009.6 2009.8 2010.0
Conclusions

scheduling based on SVD

- improvement of the standard deviations of dUT1 for INT3 sessions

INT3 sessions with Wettzell Twin-Telescopes

- standard deviations w.r.t. 'all possible subnets' worse for 'pairing' by approx. 35%
- precision improvement w.r.t. 'standard INT3' for 'all possible subnets'
- loss of precision at 'pairing' w.r.t. 'standard INT3'
- number of observations for 'all possible subnets' more than twice than for 'pairing'
- ignored correlations between the Twin-Telescope observations
various Twin-Telescope parametrization

- common AT parameter $\rightarrow$ observation errors are absorbed by the clock parameters
- common CL parameter $\rightarrow$ observation errors are absorbed by the atmospheric parameters
- common AT & CL parameters $\rightarrow$ increased residuals