VieVS - Analysis of a single session

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VieVS Structure

VIE_SETUP (Graphical User Interface - GUI)

VIE_SCHED → VIE_SIM → VIE_INIT → VIE_MOD

VIE_LSM → VIE_LSM_scan

VIE_GLOB
- GUI for Vienna VLBI Software
- Easy to use (windows style)
- Comes with plotting tool
Without previous knowledge:

- Visualize estimated parameters
- Visualization for analysts (clock breaks, exclude stations ...)
- Plot world map, baseline length repeatability, covariance matrix
- Output EOP, baseline lengths
Matlab interface

- .m file - Code
- .fig file – Objects
- Starts by running .m file
Minimum for VieVS

- Select session(s)
- Click „Save + Run“
More options

- A priori models (vie_mod)
- Estimation options (vie_lsm)
- Scheduling (vie_sched)
- Simulation (vie_sim)
- Global solution (vie_glob)
Plotting

- In menu Plotting
  - Residuals
  - Parameters
  - Session information
  - Output EOP, baselines

(new)
Plot residuals

- First (only clock+zwd) → Clock breaks
- Main solution
  - Baseline-wise
  - Station-wise
  - Source-wise
Plot residuals

- Outliers are shown in red
- Show station/source numbers
  
  new

+ Change reference clock
+ Clock breaks adding
+ Outlier selection
Plot parameters

- One/all session(s) in folder
- Parameters per station
- Comparison (up to three) possible
- Save values as text
- Print to any format
Plot session information

- Session network*
- Baseline length repeatabilities*
- Correlation matrix

* Up to four sessions
Plot session information

- Session network*
- Baseline length repeatabilities*
- Correlation matrix

* Up to four sessions
Plot session information

• Session network*
• Baseline length repeatabilities*
• Correlation matrix

* Up to four sessions
Save and load GUI state

- Get GUI options from a parameter file
  → Same parameterization
- Defaults
- Current – before very latest action
- Save process_list
Program structure

- `>> view` opens current GUI version (2.2)
- `>> view('xx')` opens GUI of version x.x
- `>> view('batch')` runs batch version of `view`

<table>
<thead>
<tr>
<th>GUI</th>
<th>= Prepare processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batch</td>
<td>= Do processing</td>
</tr>
</tbody>
</table>
Save runp („Last user action in GUI“)
- Creates input protocol
  - Saves runp.mat
  - Saves process_list.mat
  - Saves parameter.mat file(s)
- Saves sched, sim and glob parameters
Input protocol

- `input_protocol.txt` in `/WORK/`
- Saves GUI options (models,...) in textfile
- For user information (not used in processing!)
Runp.mat

- In /WORK/
- Is overwritten (exists once)
- Gives:
  - paths (LEVELx subfolders)
  - 1|0 for all modules
Process_list.mat

- In /WORK/
- Is overwritten (exists once)
- Gives VLBI experiments (one line = one session)

```matlab
>> load('D:\VieVS\WORK\process_list.mat')
>> process_list
process_list =
2011/11APR04XA_N005
```
Vie_batch (1)

- Does (batch) processing
- E.g. vie_batch2_2.m
- Independent from GUI
- Does processing (vie_init, vie_mod, vie_lsm, ...)
What does VIE_INIT do?

- Reads observations from the NGS file
- Reads station coordinates and velocities from the superstation file
- Read source coordinates from supersource file
- Possible to:
  - Remove outliers (specified in an outlier file)
  - Exclude stations, sources, baselines (specified in OPT-file)
  - Introduce an elevation cut-off angle
Superstation file

- Can be created/updated using the GUI
- Contain station coordinates, velocities, and additional antenna info (mount, axis offset, eccentricity, etc.)
- If a station is not found in the chosen TRF, the coordinates from the backup VievsTrf are used

- .txt files in TRF directory:
  - User defined TRF in ASCII format
Supersource file

- Can be created/updated using the GUI
- ICRF_Ext2, ICRF2, VieCRF10a, and VievsCRF
- Contain source coordinates
- If a source is not found in the chosen catalogue, the VievsCrf coordinates are used.
Outlier file

- Contains list of outliers for the session
- Created in VIE_LSM
- Outliers are removed in VIE_INIT. To detect and remove outliers you need to run VieVS twice:
  - In the first run outliers are detected in VIE_LSM and saved it in an outlier file
  - In the second run this file run is used in VIE_INIT for removing the outliers
• Can be used to:
  – Specify reference clock
  – Introduce clock breaks
  – Exclude stations, sources, and baselines
  – Not use the cable cal of a station

• ASCII files in sub-folders of **DATA/OPT/**, e.g. **DATA/OPT/DEFAULT/2009/09JUN23XH.OPT**
OPT file

CLOCK REFERENCE: ONSALA60
CLOCK BREAKS: 3
WETTZELL 55818.51
WETTZELL 55818.9
KOKEE 55818.43
STATIONS TO BE EXCLUDED: 1
ONSALA85

SOURCES TO BE EXCLUDED: 3
1830+011
1612+339
0334+004

BASELINES TO BE EXCLUDED: 2
HOBART26 HOBART12
MATERA MEDICINA

NO CABLE CAL: 1
FORTLEZA
# This is a comment

- ONSALA60 is the reference clock
- Three clock breaks
- Exclude all observations including ONSALA85
- Exclude all observation to sources 1830+011, 1612+339, and 0334+004.
- Exclude all observations of baselines HABART26-HOBART12 and MATERA-MEDICINA
- Do not use cable cal corrections for FORTLEZA
STATIONS TO BE EXCLUDED: 1
HOBART12 1302080100–1302080700

- a certain downtime for stations rather than excluding them for the whole session can be defined

- observations including HOBART12 between 01UTC – 07UTC on Feb 8, 2013 will be excluded
- useful also for simulations
Welcome to VIE_INIT!!!!!!

Stations to be excluded: 0
Sources to be excluded: 0
Baselines to be excluded: 0

Start reading 2013/13AUG01XE_N004
[antenna,_sources,scan]=read_ngs(ngsfile,trffile,crffile,ini_opt,pt, tp, trf, crf)
No vtrf2008 coordinates for YEBES4OM in ../TRF/superstation.mat ... get viewsTrf coordinates
No vtrf2008 coordinates for TIGOCONC in ../TRF/superstation.mat ... get viewsTrf coordinates
Asterisk(s) found in NGS file!! Value(s) treated as zero!
Done reading the file!
A total of 8 stations, 66 sources and 508 scans were found
The following stations were found:
YEBES4OM
ZELENCHK
MEDICINA
TIGOCONC
BADARY
FORTLEZA
KOKEE
SVETLOE
VIE_INIT finished!!! You can now continue with VIE_MOD
These stations have no TRF coordinates.
Command Window output

Number of stations, sources, and scans
Names of the stations:

- YEBES4OM
- ZELENCHK
- MEDICINA
- TIGOCONC
- BADARY
- FORTLEZA
- KOKEE
- SVETLOE

VIE INIT finished!!! You can now continue with VIE_MOD
The computed delay $\tau$ is given by:

$$\tau = -\frac{\vec{b} \cdot \vec{k}}{c}$$

- **Computed delay**
  - Vie_mod

- **Observed delay**
  - from NGS-card file, corrected for ionosphere

**Theory**

**Adjustment (lsm)**
models

+ EOP (oceanic & gravitational high frequency terms, nutation corrections)
+ solid Earth tides
+ troposphere delay (VMF / GMF / NMF) + gradients
+ ocean loading
+ thermal antenna deformation
+ atmosphere loading
+ hydrology loading

computed delay
• Vie_mod

\[ \tau \text{ in TT-frame} \]

observed delay
• from NGS-card file, corrected for ionosphere

partial derivatives
\[ \frac{\partial \tau}{dVAR} \]

adjustment (lsm)
TRF:

- stored at: ../TRF/
- station coordinates (TRS)
- reference epoch
- station velocities

Other:
- self-created TRF
- ../TRF/*.txt
- specified format
  8 char. stat. name,
column-mode

<table>
<thead>
<tr>
<th>station</th>
<th>x [m]</th>
<th>y [m]</th>
<th>z [m]</th>
<th>vx [m/y]</th>
<th>vy [m/y]</th>
<th>vz [m/y]</th>
<th>epoch</th>
<th>start</th>
<th>end</th>
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<tbody>
<tr>
<td>ALGOPARK</td>
<td>-918034.6948</td>
<td>-4346132.2778</td>
<td>4561917.1788</td>
<td>-0.0157</td>
<td>-0.0442</td>
<td>0.0042</td>
<td>3154</td>
<td>0</td>
<td>99999</td>
</tr>
<tr>
<td>BR-VLBA</td>
<td>-2118065.0172</td>
<td>3705355.5129</td>
<td>4728813.7718</td>
<td>-0.0143</td>
<td>0.0003</td>
<td>-0.0076</td>
<td>3154</td>
<td>0</td>
<td>99999</td>
</tr>
<tr>
<td>BADARY</td>
<td>-392626.7126</td>
<td>3865741.5854</td>
<td>4967670.9332</td>
<td>-0.0272</td>
<td>-0.0020</td>
<td>-0.0019</td>
<td>3154</td>
<td>0</td>
<td>99999</td>
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<tr>
<td>CRIMEA</td>
<td>3789521.0045</td>
<td>2551207.4646</td>
<td>4439796.4156</td>
<td>-0.0203</td>
<td>0.0159</td>
<td>-0.0102</td>
<td>3154</td>
<td>0</td>
<td>99999</td>
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<tr>
<td>CTVASTJ</td>
<td>2623154.6380</td>
<td>3426878.7527</td>
<td>4668561.1070</td>
<td>-0.0162</td>
<td>-0.0042</td>
<td>0.0111</td>
<td>3154</td>
<td>0</td>
<td>99999</td>
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<tr>
<td>DSS43</td>
<td>-4460925.3060</td>
<td>2682760.7052</td>
<td>3674381.0520</td>
<td>0.0237</td>
<td>0.0010</td>
<td>-0.0437</td>
<td>3154</td>
<td>0</td>
<td>99999</td>
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<tr>
<td>DSS65</td>
<td>4853936.6707</td>
<td>-3604885.7368</td>
<td>4417478.8877</td>
<td>-0.0068</td>
<td>0.0189</td>
<td>0.0135</td>
<td>3154</td>
<td>50155</td>
<td>99999</td>
</tr>
<tr>
<td>DSS66</td>
<td>4853936.6853</td>
<td>-3604885.7368</td>
<td>4417478.8876</td>
<td>-0.0068</td>
<td>0.0189</td>
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<td>50155</td>
<td>99999</td>
</tr>
<tr>
<td>DSS15</td>
<td>-2353538.8964</td>
<td>-4631569.4590</td>
<td>3676669.9703</td>
<td>0.0183</td>
<td>0.0062</td>
<td>-0.0027</td>
<td>3154</td>
<td>48600</td>
<td>99999</td>
</tr>
</tbody>
</table>
Vie_MOD - usage

**CRF:**
- stored at: ../CRF
- right ascension ra
- declination de

**Other:**
- self-created CRF
- not finished yet
Ephemerides:

- stored at: ../EPHEM/jpl_421.mat
- Earth, Sun, Moon, planets
- remembered for 2nd run
  (jpl_421_05SEP12XA_N004)
- not critical for "normal" VLBI
- default: gravitational bending (GRT) off all planets is taken into account.
Pressure and temperature:

- Met data from NGS-file
- GPT2 as backup
- External .trp files
Mapping function:

- for atmospheric corrections on the delay
- **VM1:** ../VM1/yyy_VM1.mat regular update!
- **GMF:** applied when no VM1 available; no files necessary
- **GPT2**
Vie_MOD - usage

A priori troposphere gradients:
**Vie_MOD - usage**

**Ionosphere correction:**
subtracted from the observed delay

**External ionosphere correction:**
- must be created in advance
- stored at ..:/ION/MAPS
Vie_MOD - usage

Station corrections:
- tidal & non-tidal
- Thermdef:
  [A. Nothnagel, J. of Geodesy, 2008]
Earth Orientation Parameters:

- **c04 08 (daily)** series from the IERS webpage; ./EOP/C04_08_1962_now.txt; updates might be necessary;
- **predefined EOP:** ./EOP/*.txt; watch format
- **finals:** necessary for recent sessions
- **dX, dY:** include/exclude from c04 table; mainly contains FCN
Earth Orientation Parameters:

- high frequency EOP
  - ocean tides: interpf; table 8.2 (xp,yp) & 8.3 (ut) diurnal & semi-diurnal
  - libration: table 5.1a (xp,yp) & 5.1b (ut)
- IERS Conv 2010
- Precession/Nutation Model
Interpolation of EOP:

- **lagrange:**
  window of 4 data points

- **linear:**
  interpolation between the midnight before and after observation time.
  For a session from 18:00 to 18:00 this means, that there are 2 a priori lines and a break at midnight.

- tidal UT variations: removed before interpolation, re-added
Vie_MOD - usage

**Quality code limit:**
- Accept observations < or = limit
- Good quality observations have quality code 0

**Cut-off Elevation angle:**
- all observations below this local elevation [°, degrees] are skipped
Vie_MOD - usage

• For more information on the formalism, check the code (vie_mod.m) or
  → DOC/vie_mod.pdf

• Partial derivatives are also set up

• Results are stored in
  → DATA/LEVEL1/sesname_antenna
     _parameter
     _scan
     _sources

  → DOC/structures.pdf
• VIE_LSM is a module of VieVS, which estimates geodetic parameters with least squares adjustment from VLBI observations.

• All the parameters are estimated as continuous piece-wise linear offsets (CPWLO) in sub-daily and daily temporal resolution.
continuous piece-wise linear offsets (CPWLO)

\[ x_i = x_1 + \frac{t - t_1}{t_2 - t_1} (x_2 - x_1) \]
Estimated parameters:

- Clocks (offset (cm), rate (cm/day), quadratic term (cm/day^2), CPWLO (cm)),
- Zenith wet delays (cm) as CPWLO,
- Troposphere gradients (cm) as CPWLO,
- EOP (mas and ms) as CPWLO,
- Antenna coordinates in TRF (cm) as one offset per session or as CPWLO,
- Source coordinates in CRF (declinations in mas and right ascensions in ms) as CPWLO.
Parametrization for Least Squares
Parametrization for relative clock errors

Relative constraints on the clock offsets. Observation equations are added to the design matrix telling that the difference between two piecewise linear clock offsets is zero ± a certain standard deviation $\sigma$. (Mainly important to bridge gaps without observations to avoid singularity of the normal equation system.)
Troposphere delay

\[ \Delta \tau_{trop} = 10^{-6} \int_0^{H_{trop}} \left[ N_h(s) + N_w(s) \right] ds \]

\[ \Delta \tau_{trop}(\alpha, \varepsilon) = ZHD m_h(\varepsilon) + ZWD m_w(\varepsilon) + m_w(\varepsilon) \cot(\varepsilon) \left[ G_n \cos(\alpha) + G_e \sin(\alpha) \right] \]

reduced from observations a priori to the adjustment
Troposphere delay

- **zwds**
- **gradients**
Parametrization for EOP

To estimate one constant value per session
- strong relative constraints of 1e-4 m(a)s/day have to be set

Example: The session is from 18 UT to 18 UT. Then, three piecewise linear offsets are set up for each EOP.
(midnight before the session, during the session, and the midnight after the session)
The strong constraints take care that all three estimates per session are the same.
VIE_LSM scan-wise update
Scan-wise update of normal equation system

1 A-matrix per scan

Scan 1

\[ A_{s1} \]

Scan j

\[ A_{sj} \]

Design matrix of real observations (A)

\[ N_{s1} = A_{s1}^T \cdot P_{s1} \cdot A_{s1} \]

\[ N_A = N_{s1} + N_{s2} + \ldots + N_{sj} \]

\[ b_{s1} = A_{s1}^T \cdot P_{s1} \cdot oc_{s1} \]

\[ b_A = b_{s1} + b_{s2} + \ldots + b_{sj} \]

\( j \) : number of scans in the session
• VIE_LSM estimates parameters as CPWLO from single session adjustment

• VIE_LSM corrects clock breaks and detects outlier observations

• VIE_LSM provides SINEX input and datum free normal equations for global solutions (VIE_GLOB)
Thank you for your attention!