



Kartverket

Where

A geodetic software

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Introduction

- ▶ *Where* is a Python software package used for analyzing VLBI, SLR and GNSS data
- ▶ *Where* is currently being developed at the Norwegian Mapping Authority (NMA)
- ▶ *Where* is an open source project, available on github <https://github.com/kartverket/where>

International collaboration

- ▶ NMA has a cooperation agreement with IGN of Spain and the Yebes observatory
- ▶ IGN provides the receivers and technical assistance for the VLBI antennas in Ny-Ålesund
- ▶ NMA provides the *Where* analysis software and support for the analysis group at IGN

Analysis Center

- ▶ NMA is associated analysis center within the IVS and ILRS. Both the NMA and IGN, are in a test phase of deliveries of VLBI analysis results to the IVS with the Where software. Some of our activities in VLBI is documented in [2] and [3]
- ▶ Our goal is to be able to contribute to the ILRS after some improvements of the software, and in the future receive full status as operational analysis center for both VLBI and SLR

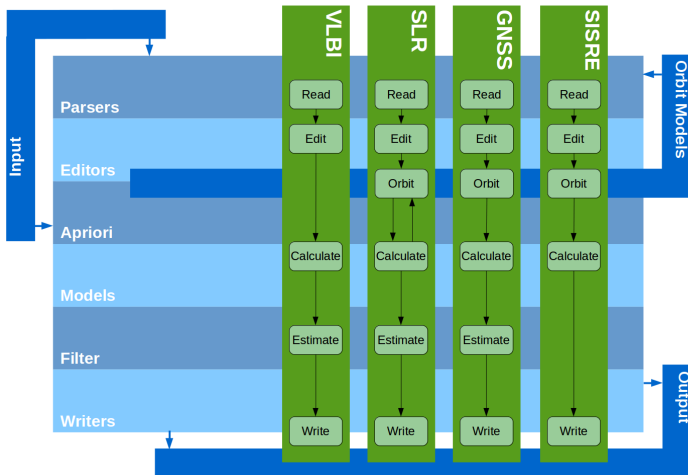
Technology

The **Where** software is mainly being written in *Python*

- ▶ Solid, flexible and fast libraries like `numpy`, `matplotlib` and `scipy` are available
- ▶ We use a **HDF5**-based format for storing data
- ▶ Python has effective interfaces to *C* and *Fortran* code, and we can use the **Sofa** and **IERS** software libraries directly

The Where Pipeline

The pipelines for the different techniques are shown in the figure below.



Models

- ▶ The implementation of the individual models follow the 2010 IERS Conventions, see www.iers.org/IERSEN/Publications/TechnicalNotes/tn36.html
- ▶ When possible we have used software libraries made available at the IERS ftp page <ftp://maia.usno.navy.mil/conventions/2010>
- ▶ The estimation of EOP parameters and station positions is done using a Kalman filter [5]. We use continuous piecewise linear functions for the estimation

Orbit determination

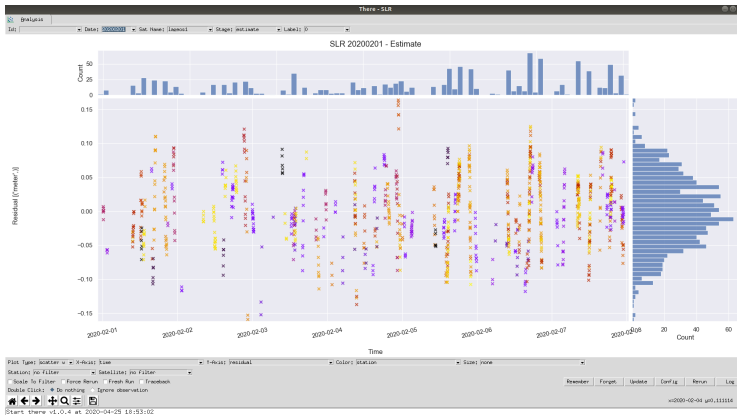
- ▶ Force models, variational equations and orbit estimation is computed following Montenbruck and Gill [4]
- ▶ Cowell orbit integrator following Oesterwinter and Cohen [6]
- ▶ The observation equation for SLR is following Beutler [1]
- ▶ All models are implemented, but...
 - ▶ Orbit residuals are a few centimeters too large, so we are currently debugging the orbit models
 - ▶ The orbit determination is a bit slow

Useful Features

- ▶ Logging of events that occur while software runs.
- ▶ Configuration files defines the details on how the analysis is done. Examples include what data is used, how to clean the data before analysis and which parameters to estimate.
- ▶ Dataset with time objects, position and velocity objects, including conversion routines.

There

Where is a command line tool, but the results can be inspected using the graphical tool called *There*. A screenshot is shown below.



Using Where

- ▶ MIT Open Source License: Permissive, use Where as you want
- ▶ But please acknowledge us if you use Where
- ▶ Get in touch if you are interested in Where

References



Beutler, G., *Methods of Celestial Mechanics, Vol I*, Astronomy and Astrophysics Library, Springer, 2005.



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