c5++ - multi-technique analysis software for next generation geodetic instruments

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Preface

An analysis software package based on Java and named CONCERTO4 (Otsubo and Gotoh, 2002) enabled the user to consistently process SLR, GPS and other satellite tracking data. The next version of this program package will also include VLBI as additional space-geodetic technique. As the software is currently being redesigned and completely re-written in C++, the requirements for VLBI data analysis could be taken into account. Moreover, combination of space geodetic techniques was considered during the design phase.

Space Geodesy with c5++

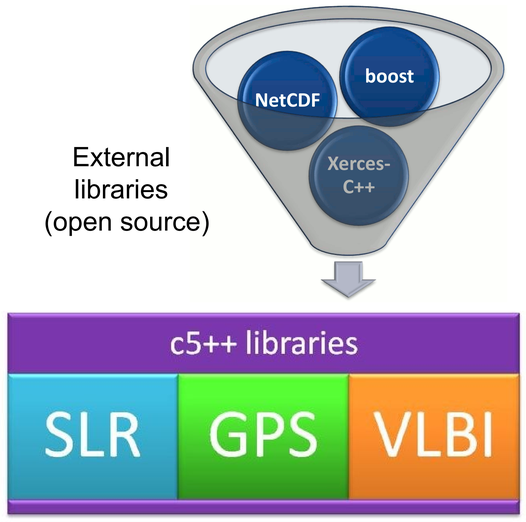

Figure 1: *Dedicated space geodetic analysis programs for SLR, GPS or VLBI can be derived by interfacing the c5++ libraries*

Consistent geophysical and geodetic models, based on the IERS conventions 2003, are applied to each technique, which enables the combination either on the observation level or on the normal-equation level. External libraries, which are available as open source packages, are utilized for data input/output as well as vector and matrix operations. c5++ has been successfully compiled and tested under Windows, Linux and Mac OS using 32bit and 64bit environments. Modules are commented within the code and information is extracted via Doxygen, which outputs on-line the documentation (in HTML) and/or an off-line reference manual.

Main c5++ classes

Name	Functionality
C5Time	Implements internal time container, allows input of UTC, TAI, TT, MJD, JD and converts between the time systems
C5Math	Math library, provides dedicated matrix operations and geodetic tools
Transform	Transforms TRF ↔ CRF
Ephm	Reads JPL binary ephemeris and provides position/velocity of any given celestial body in a user-defined frame
Deformation	Computes solid Earth tides, ocean and atmosphere loading corrections
Accel	Provides various accelerations respectively forces which act on a satellite
Cowel	Orbit integrator
Param	Manages all kind of selectable parameters, automatic time interpolation, backbone of c5++
ParamIO	Reads and writes parameters in XML format
Relativity	Computes relativistic corrections for GPS and SLR, transforms VLBI delays into TCG frame
C5ObsData	Reads observational data and stores it in STL container class
Lsq	Least squares adjustment
Kalman (future)	Kalman filter implementation

Table 1*: c5++ libraries and their functionality*

VLBI processing module

Based on the main classes of c5++ a dedicated VLBI analysis chain can be implemented with minimal efforts. Thereby, modules can be attached like building blocks and even dedicated/specialized VLBI software solutions can be realized, without in-depth knowledge of the specific classes. In order to fulfill the requirements of different applications the following observation formats are or will be supported within c5++

- NGS (implemented)
- NetCDF (implemented)
- MK3 (planned)
- Raw correlator (planned)

In the first stage all modules are written to work properly. Optimizations concerning the improvement of processing speed will be made, once testing has been completed.

Automated UT1 processing

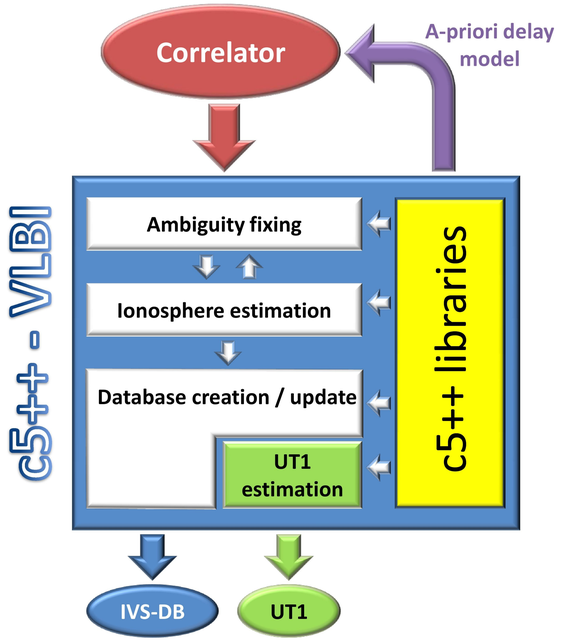

Figure 2: *Flow-chart of automated VLBI analysis and UT1 estimation.*

Space-craft tracking

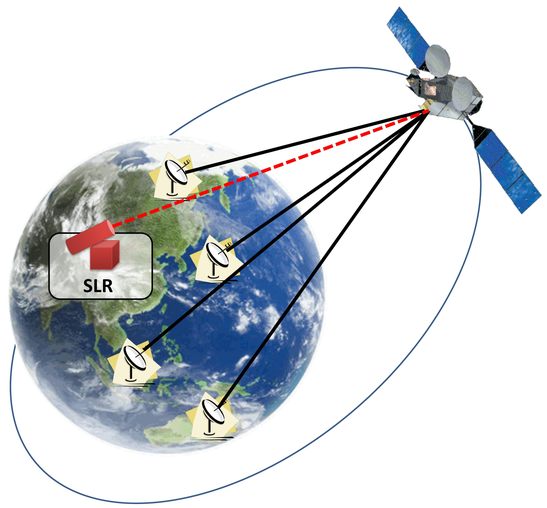

Figure 3: *Since c5++ is also designed for satellite techniques, existing modules and models can also be utilized to do space-craft tracking either by VLBI or by a combination of several techniques. E.g. a combination of SLR and VLBI tracking will allow a computation of highly accurate orbit arcs.*

Results

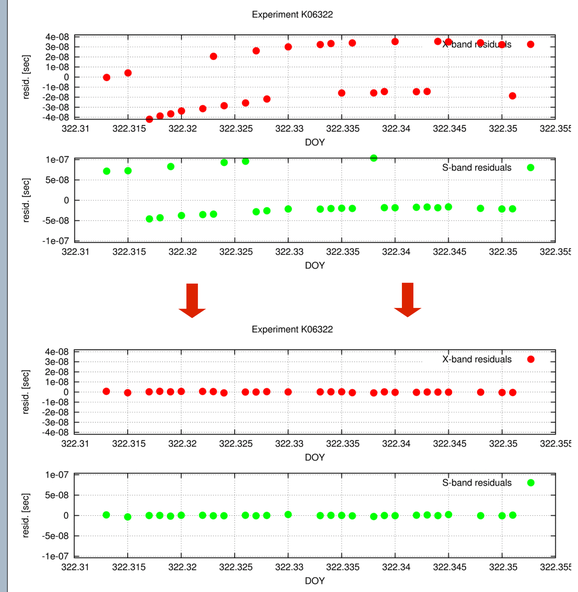

Figure 4: *Automated ambiguity resolution for ultra-rapid UT1 experiments, tested with an INT2 session from 2006. Residuals before (upper plot) and after fixing (lower plot) the ambiguities for X- and S- band confirm the correctness of the algorithm. Calculation of ionospheric corrections and determination of UT1 follow thereafter.*

Outlook

The VLBI module of c5++ is currently undergoing internal and external validations. Thereby, results from the "Comparison Campaign of VLBI Data Analysis Software", are utilized to confirm the correctness of the (geo-) physical models. Once all modules have been verified, the following applications will be developed:

- Automated processing of ultra-rapid UT1 experiments
- Highly precise time-and frequency transfer via VLBI
- Space-craft tracking and orbit determination
- Analysis of VLBI2010 experiments
- Combination of space geodetic techniques on the observation level

References

Otsubo T. and T. Gotoh, SLR-based TRF Contributing to the ITRF2000 project, IVS 2002 General Meeting Proceedings, pp. 300-303, 2002.

This work was supported by a Grant-in-Aid for scientific research (KAKENHI, No. 21241043).