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c5++ - Multi-technique Analysis Software for Next Generation Geodetic Instruments

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Abstract

Processing of space geodetic techniques should be carried out with consistent and utmost up-to-date physical models. Therefore, c5++ is being developed, which will act as a framework under which dedicated space geodetic applications can be created. Due to its nature, combination of different techniques as well as automated processing of VLBI experiments will become possible with c5++.

1. Introduction

An analysis software package based on Java and named CONCERTO4 [3] 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.

2. Space Geodesy with c5++

Basically, c5++ provides the framework (Figure 1) under which space geodetic applications can be built. Thus, stand-alone technique specific applications can be developed or multi-technique solutions can be realized. Thereby 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 32-bit and 64-bit 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.

2.1. Libraries Resp. Classes Contained Within c5++

Table 1 lists the most relevant classes together with their functionality. Space-geodetic software can be built by interfacing the required modules, and other applications can be realized from this framework.

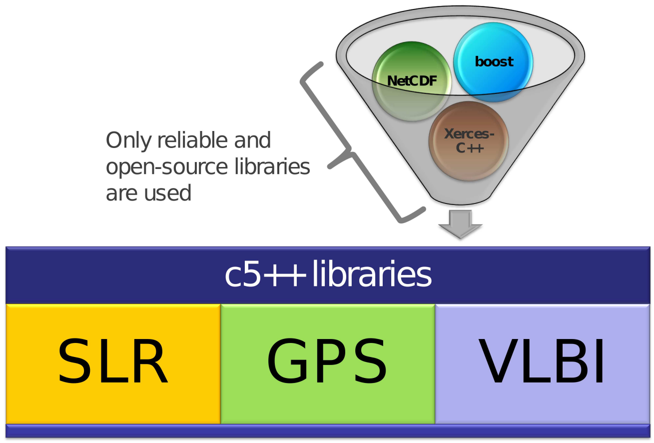

Figure 1. Building space geodetic analysis software for SLR, GPS, or VLBI by interfacing the c5++ libraries.

Table 1. c5++ libraries and their functionality.

Name	Functionality
C5Time	Implements internal time container, allows input of UTC, TAI, TT, MJD, JD and converts between the time systems using an internal storage format.
C5Math	Main math library, which provides dedicated matrix operations and geodetic tools.
Transform	Transforms positions between TRF and CRF
Ephm	Reads JPL binary ephemeris and provides position/velocity of any given celestial body in a user-defined frame
Displacement	Computes solid Earth tides, ocean, and atmosphere loading corrections
Accel	Provides various accelerations respectively forces which act on a satellite
Cowel	Fast and accurate orbit integrator
Param	Is the backbone of c5++ which manages all kind of selectable parameters and carries out automatic interpolation for time-dependent parameters.
ParamIO	Reads and writes parameters/results in XML format
Relativity	Computes relativistic corrections for GPS and SLR and transforms VLBI delays into the TCG frame
C5ObsData	Reads observational data and stores it in an STL container class.
Antenna	Antenna/telescope specific corrections models (deformations, axis offsets, ...)

2.2. VLBI with c5++

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 supported within c5++:

- NGS
- NetCDF
- Mark III
- Raw correlator (K5 format)

In the first stage all modules are designed to work properly and give correct results. Optimization concerning the improvement of processing speed will be made, once the testing and verification phase has been completed.

3. Multi-technique Combination

Since all space-geodetic techniques can utilize the same physical and geophysical models from c5++, consistent combination across the techniques can be realized. Thereby, results can be either combined on the normal-equation level or on the observation level, in accordance with the goals of the Global Geodetic Observing System (GGOS). Moreover, novel applications like spacecraft tracking can be developed, whereas orbit calculations based on multi-technique observations (GNSS, SLR, and VLBI) are expected to provide an utmost accurate 3D trajectory of the satellite.

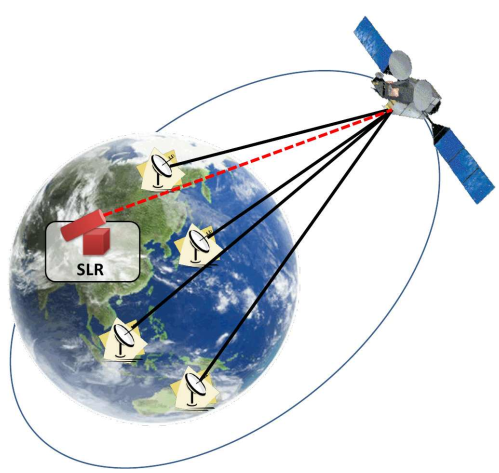

Figure 2. Since c5++ is also designed for satellite techniques, existing modules and models can also be utilized to do space-craft tracking either by VLBI or by a combination of several techniques. E.g., an integration of SLR and VLBI tracking will allow the computation of highly accurate orbit arcs.

4. Automated UT1 Processing

Beside multi-baseline sessions, regular single-baseline VLBI experiments are scheduled in order to provide estimates of UT1 for the international space community. As shown by [4] and [2] the latency of these Intensive experiments could be improved tremendously and results could be made available within less than an hour if e-VLBI and automated processing routines were applied. If the whole processing pipeline works well, results can be obtained even within minutes after the last scan has been recorded, which is highly appreciated by the user community as discussed in [1]. Based on the experience gained over the last two years, the automated processing chain will be improved and the analysis software used until now will be replaced by c5++. Since the correlator output format can be read directly with c5++, no intermediate interface is necessary. Moreover, ambiguity resolution and ionosphere correction can be done within the framework of c5++. Not only the target parameter, i.e., UT1, will be estimated with c5++, but also databases for the VLBI community are expected to be created with that software. As shown in Figure 3, it will also be possible to input a-priori delay models into the correlator in order to achieve highest possible consistency between all the data processing stages.

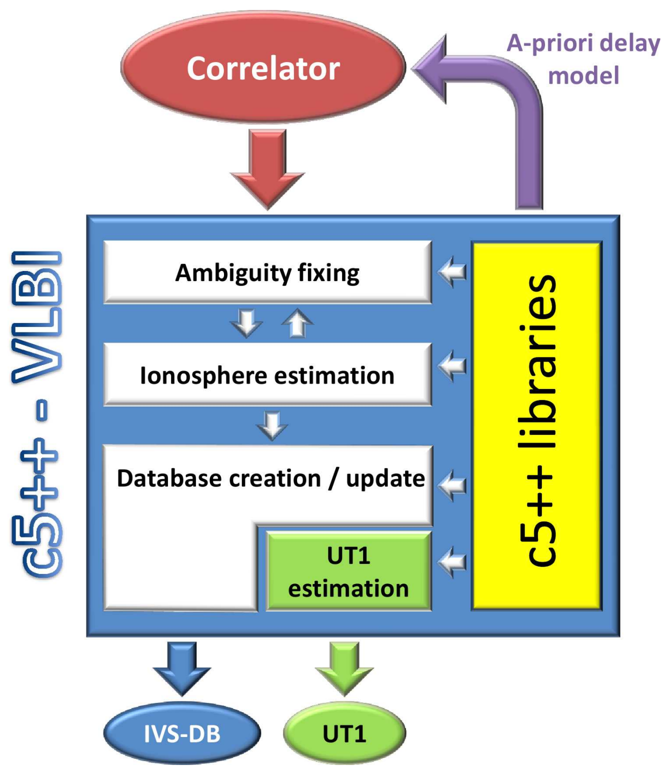

Figure 3. Flow-chart of automated VLBI analysis and UT1 estimation.

A focus will be set on robust and reliable automated ambiguity resolution, in order to allow for completely unattended operation. Additional functions will include automated reporting of results to international services as well as export of standard formats for independent analysis within the space-geodetic community.

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