KyivGeodynamics++: software for processing satellite laser ranging data

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We present the software package KyivGeodynamics++ intended for processing satellite laser ranging data. Review of architecture, the main algorithms, results of the first tests are presented.

Introduction

The Earth as a planet is characterized with a list of dynamic and geodethic parameters: the radius, the mass, the instant rotation axis position, the rotation speed, the geopotential Stockes coefficients, the nutation parameters, Love and Shida numbers etc. To observe and deduce them different geophysical and astronomical methods are used.

Until the end of seventies the only method applicable for this problem was astrometric observations of the stars. In the last 40 years new methods, including Very Long Baseline Interferometry (VLBI) of distant radio sources, radio observations of Navigation Satellites and Satellite Laser Ranging have become the main players in that game. The last one is the oldest among these methods: it has been used since 1976 until now. This method lies in measuring the distance between ground stations and specially designed satellite with specially designed equipment. The distance can be measured with centimeter precision. Having sufficient amount of observations any of the Earth's parameters can be determined.

KyivGeodynamics software was created in Space Geodynamics department of the Main Astronomical Observatory (MAO) on National Academy of Sciences of Ukraine in early eighties. Written in old version of Fortran it is mostly outdated now. The algorithms included in old version are no more used by geospatial community and need to be updated.

Current version is not revitalized old KyivGeodynamics, which was used for processing satellite laser ranging (SLR) data by Ukrainian Data Analysis Centre from the time of MERIT project. KyivGeodynamics++ is written in C++ language from scratch using modern software developing technologies. It uses plugin approach and is automatized as much as possible.

The application is cross-platform (tested under Windows XP, Linux-Suse and Mac OS X). It uses its native DBMS engine which is designed to hold normal points and full-rate SLR data. Simultaneous processing of the data from multiple satellites is possible. Manipulation with force and transformation models, used in equation of satellite motion is very user-friendly and intuitive.

The Method

Let us denote the station and the satellite geocentric position with $\vec{R}$ and $\vec{r}$ correspondingly. Vector between station and satellite is:

$$\vec{\rho} = \vec{r} - \vec{R}. \tag{1}$$

It is convenient to write down $\vec{R}$ in Earth-based reference frame, but $\vec{r}$ — in space-based one. If transformation matrix between them is denoted as $\mathbb{Q}$, then

$$\vec{\rho} = \vec{r} - \mathbb{Q}\vec{R}. \tag{2}$$

Transformation matrix comprises instant rotation axis position, nutation parameters, tectonics model etc.

Satellite position $\vec{r}$ can be obtained by integration of satellite motion equations:

$$\frac{d^2\vec{r}}{dt^2} = \vec{F}_{geo} + \vec{F}_{light} + \vec{F}_{planets} + \vec{F}_{others}, \tag{3}$$

where *geo* stands for Earth geopotential force, *light* — for direct and indirect radiations pressure, *planets* — for influence of Solar system bodies etc.

The most modern algorithms for calculation of forces in (3) and transformation in (2) are collected by International Earth Rotation Service in [2].

The calculations are doing by cycling according the scheme in Fig. 1 (clockwise from 1: observations collected by `ObsManager` are put into linear equations system together with modelled values from `ModelManager` and derivatives provided by `Derivator`. Here ρ_o is the *observed* distance, ρ_c is the *calculated* distance, $\frac{\partial \rho_c}{\partial E_i}$ are estimated parameters derivatives of distance, ΔE_i are corrections to models parameters (to be solved for).

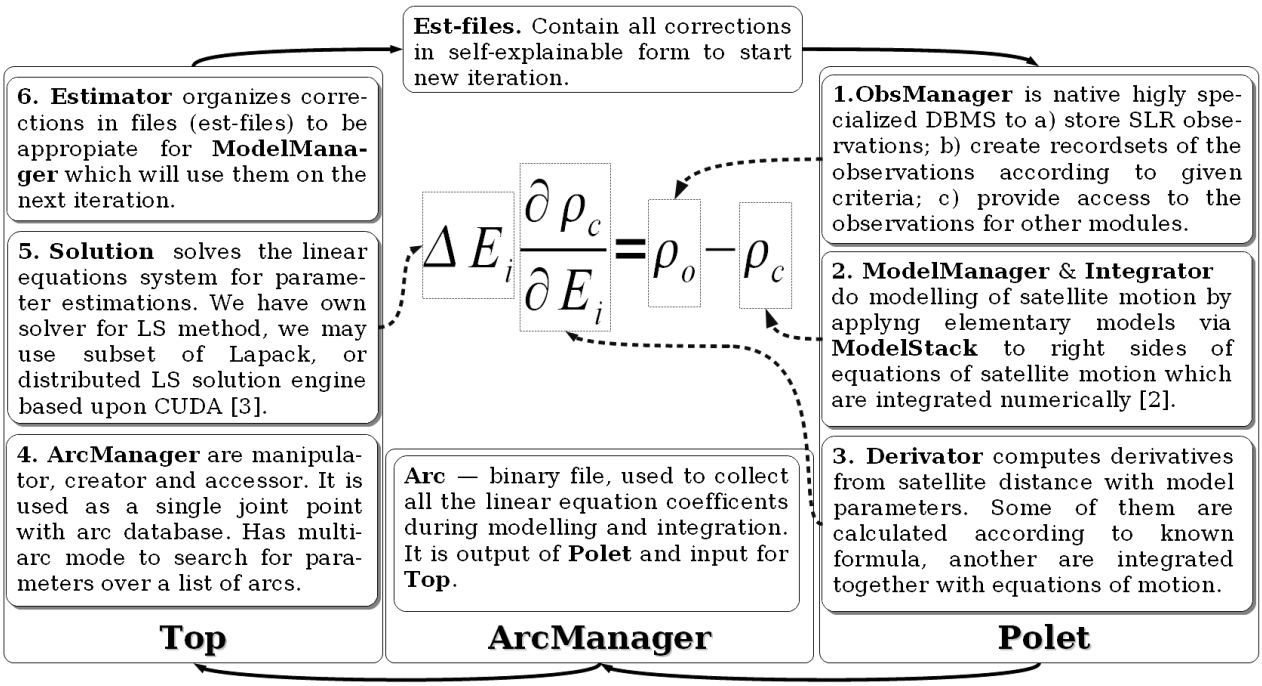

Figure 1: Flowchart of `KyivGeodynamics++` work.

Overview flowchart of `KyivGeodynamics++` is presented in Fig. 2. Portion of screenshot of developer screen with all the models listed is presented rightmost. As one can see from Fig. 2 the software consists of a list of libraries and managers. They manipulate the files (`FileManager`), observations (`ObsManager`), arcs (`ArcManager`), models (`ModelManager`) to fulfil the tasks.

The software is based on component oriented architecture, with wide usage of plugins — the lightweight components designed for easy replacement and exchange. Different models are manipulated in the same way: to change the models one should not recompile code, but just change line in `ini`-file. The software uses ordinal differential equation integration routine VASOMI (VAriable Step and Order Method of Integration) [3]. The routine adapts itself to the equations right sides and selects optimal integration step and order automatically. Adams–Moulton integration scheme is used. There is no upper limit for amount of integrated equations: the routine can integrate hundreds of them which means ability to process data from hundreds of satellites simultaneously. The software has user friendly interface and serious efforts were made to make the software distributed: our integration subsystem may work under `CUDA` [1].

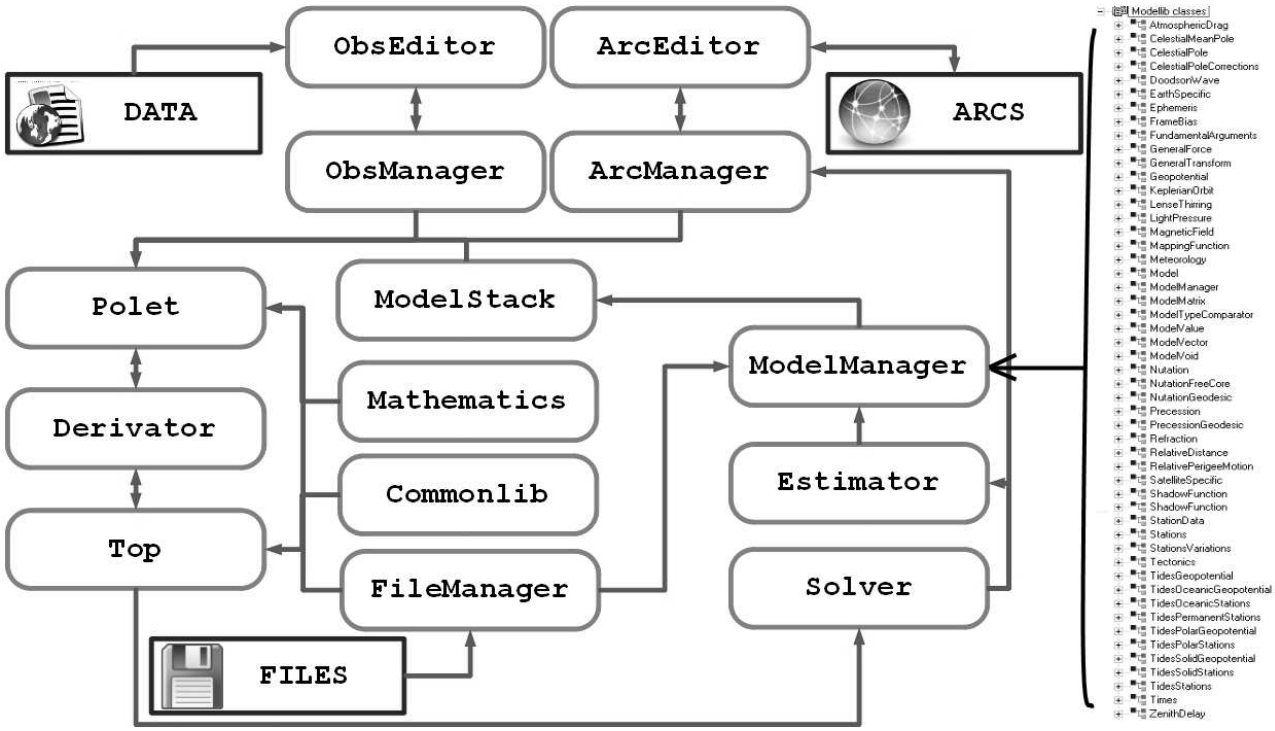

Figure 2: Flowchart of `KyivGeodynamics++` structure.

Results and conclusions

For testing purposes we selected 15 days time interval between MJD 51911 and 51926. Equation of motion of seven satellites: Starlette, Stella, Lageos-1, Lageos-2, Beacon-C, Etalon-1, Etalon-2 were integrated together. Total amount of estimating parameters was 42 orbital + 4 Earth's related (pole coordinates, time and Earth's rotation velocity) + 7 empirical acceleration coefficients for every satellite. With 2GHz Athlon 32 bit processor one `Polet+Top` cycle took 1 min 20 sec for modeling and 12 sec for estimation.

New software is very suitable for SLR data processing centers. We plan to restore activities in Ukrainian Satellite Laser Ranging Processing Center with `KyivGeodynamics++`.

Acknowledgement

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References

[1] `http://nvidia.com/CUDA`

[2] IERS Conventions (2003), IERS Conventions Center (2004)

[3] Taradiy V. K., Tsesis M. L. ITPh preprints 84-92R and 84-96R (1984) (in Russian)