The Virtual Observatory in Geodesy and Earth's Sciences: The French activities

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Abstract

This paper presents the context of the astronomical Virtual Observatory (VO), an ambitious international proposal to provide uniform, convenient access to disparate, geographically dispersed archives of astronomical data from software which runs on the computer on the astronomer's desktop. The VO could be of interest for the geodetic community: We present the efforts we made in that direction over the last two years.

Introduction

As mentioned on the *International Virtual Observatory Alliance* (IVOA) website (http://www.ivoa.net), the IVOA was formed in June 2002 with a mission to "facilitate the international coordination and collaboration necessary for the development and deployment of the tools, systems and organizational structures necessary to enable the international utilization of astronomical archives as an integrated and interoperating Virtual Observatory. The work of the IVOA focuses on the development of standards. Working Groups are constituted with cross-project membership in those areas where key interoperability standards and technologies have to be defined and agreed upon. The Working Groups develop standards using a process modeled after the World Wide Web Consortium. Recommendations are ultimately endorsed by the Virtual Observatory (VO) Working Group of Commission 5 (Astronomical Data) of the International Astronomical Union (IAU).

Several independent Java-based tools have been developed in the VO framework, that can be used in geodesy and more generally in Earth's Sciences. These tools can either be downloaded and set up in PCs as Java applications, or used through a web browser as Java applets. In particular, some of the tools we started to use with SLR data are "VOPlot" and "TopCat", which are devoted to astronomical data and time series plotting.

1. Basic principles of the Virtual Observatory

1.1. The VO-Table Data Exchange Format

VOTable is the XML-based format for representing astronomical data, recommended by IVOA (e.g. catalogues, as tables of the properties of celestial objects, celestial coordinates, brightness etc.). The VO-Table format has been defined in terms of XML in order to take advantage of computer-industry standards and to utilize standard software and tools. At the same time it is important not to loose the previous investment in astronomy-specific standards, such as the table variants of the *Flexible Image Transport System* (FITS) format.

Also, astronomical tables are rich in *metadata*, which in this context means annotation, interpretable by either computers or humans, both of the tables and the individual columns that they contain. It is important that these metadata should be preserved with the table and the VO-Table has features to permit this.

It is crucial to point out the fact adopting the VO-Table format does not mean giving up of its own data format: the VO-Table format can encapsulate existing files and simply supplies metadata to understand its content and facilitate data exchanges.

1.2. Why choosing the Virtual Observatory

There exists several software packages to treat metadata files, but the so-called "Virtual Observatory", as an ensemble of VO-Table-based software packages, is now widely used within the astronomical community, by several thousand users worldwide. The Virtual Observatory takes advantage on the notion of *Unified Content Descriptors* (UCD) to be inserted into metadata files to describe the data, following the self-descriptive format VO-Table based on these standards and XML. As a consequence, many tools already exist to manage, plot or analyze data supplied in VO-Table format. Converting ones own data in VO-Table format means benefiting of all existing tools, some of them providing a conversion from unformatted data files into the VO-Table format, as well. As a consequence, data will be described non-ambiguously, ensuring further exchange and better understanding between different scientific communities. By the way, the Virtual Observatory provides an easy access to all VO-Table data: they can be registered to a "registry", that means that any user can locate on the web, get details of, and make use of, any resource located anywhere in the IVOA space.

1.3. Using the Virtual Observatory in geodesy ?

VO standards have been developed for Earth-centered or body-centered reference frames in order to extend the VO to Earth and planetary sciences. Nevertheless, some improvements are to be made. Two years ago, our group proposed to the IVOA to adopt standards relevant to the Earth orientation data (polar motion, UT1—UTC, nutation, etc.) and to space geodesy, that were accepted in 2008. In particular, the list of official UCD now contains terms which permit to describe all the products built and analyzed by the ILRS community.

2. Web services developed by our team

2.1. Example in astronomy, and celestial reference frame

It is worth noting that the construction of the Large Quasar Astrometric Catalogue by Souchay & al. (2009) made an extensive use of cross identifications between a dozen of quasar catalogues that were facilitated by the use of VO tools like Aladin. Moreover, the Observatoire de Paris offers the IVS OPAR products and the IERS/ICRS-PC products in VO-Table format, including radio source and station coordinates and EOP time series. It means that all these catalogues and data can be read using VO tools and can be directly compared to any other similar data set contained in the astronomical VizieR database.

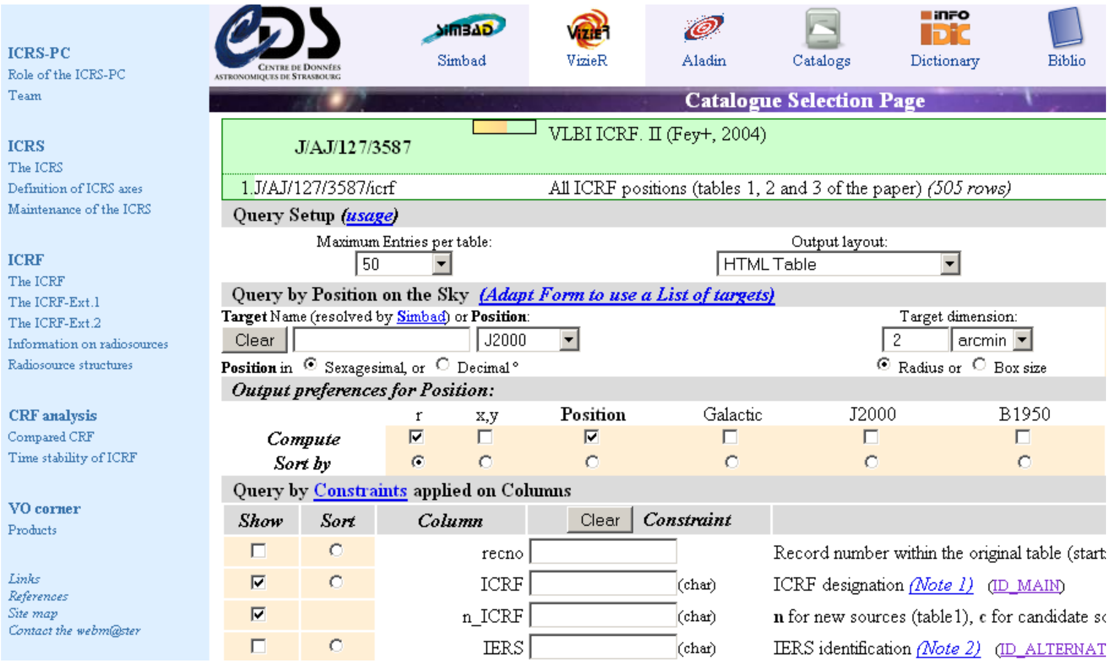

Figure 1. The ICRF–Ext.2 available through the portal of the ICRF product center web site

2.2. Products built by GRGS Analysis Center

GRGS-Grasse geodesy team provides short arc analysis to give an access to satellite orbit error, in particular in the framework of altimetric missions ; time series of observed station position, and of EOP based on SLR data, which are the results of the GRGS ILRS Analysis Center.

The Java applet gives the visualization and the comparison of the consistent EOP and site coordinate time series. Output files are either in ASCII or in VO-Table format.

2.3. International Terrestrial Reference Frame

The ITRF website takes benefit from a cartography host which enables one to visualize the different ITRF networks, spot networks from each technique, the velocity fields of the various ITRF since ITRF94 and also the border of plate tectonics according to two patterns. Also, it enables ones to a point selection in view of accessing to the ITRF coordinates of sub-network at the chosen period. In the close future, ITRF solutions tables will also be provided in VO-Table format, and dynamical tables of coordinates generated by the ITRF website users will also be supplied in VOTable format.

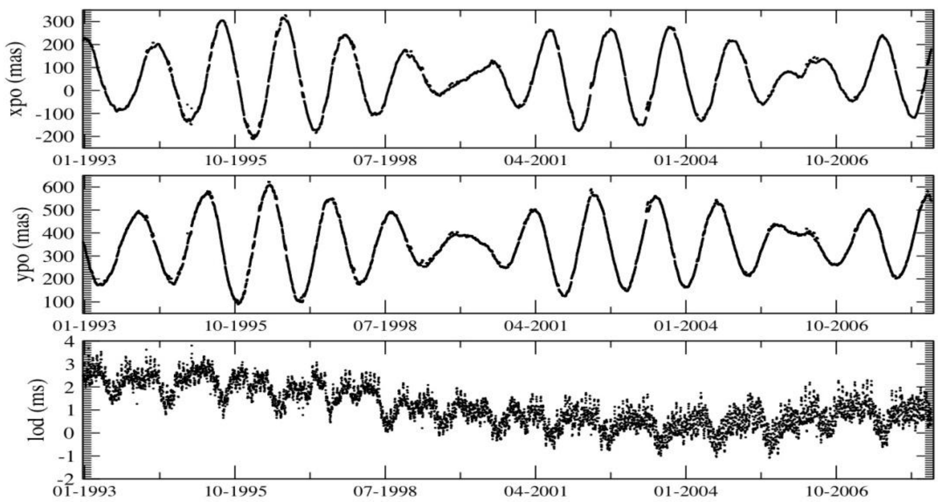

Figure 2. Polar motion, as plotted on the OCA/GRGS Virtual Observatory portal

3. Possible links between VO, GGOS, and the whole ILRS community

To our opinion, the fields related to geodesy that could benefit from the VO concept could be:

- Optimization of the estimation methods: biases, decorrelation of parameters, recognition of orbit's errors (for the determination of the Earth's rotation, its gravity field, reference frames)
- Optimization of the use of data: choice of the orbital configurations, according to altitudes and orbit inclinations, for instance
- New concepts: data combination, or simultaneous inversion of the gravitational field and the station's positions
- Orbital dynamics: improving simultaneously orbital modelling, and the determination of environmental parameters which act on the trajectories (gravitational origin or not)

The systematic use of approaches such as the VO is likely to be generalized in the next few years within various scientific communities. For the geodetic community, we think that projects such as the GGOS projet should investigate to what extent they can follow, or not, the reommendations provided by IVOA (namely: the VO-Table and associated web services).

4. Conclusions

The scientific community working on the field of space geodesy – that is: not only the community belonging to ILRS – can benefit from the VO concept mainly through two points. On the one hand, the concept of metadata (following or not the recommendations provided by IVOA) permits to gather up in a single file some data together with a description supposed to be exhaustive. This means, for example, that a user can immediately know, when comparing station coordinate time series, if these time series are expressed with respect to an homogeneous and compatible reference frame. If not, and this is the second point to be reminded of, this user can easily transform these time series through web services –providing an interface with classical geodetic software, running on local computers where the web service is set up –, to make these time series compatible.

To our opinion, such tools can give an extraordinary visibility of all data and products built by the ILRS community, and can reinforce in a strong way the links between the Analysis Working Group and the station network. Both corner stones of the SLR technique could discuss in "real time", and it is nice to see that several groups started to develop web services inside the AWG. Obviously, the VO-Table format is not mandatory for such a goal, but "only" a very efficient solution, anyway.

Many new applications can be expected using VO concepts in geodesy and associated fields. It should be very well adapted to use existing tools such as VOPlot, and Top-cat, devoted to data plotting and cross identifications, with SLR data. It would be very challenging to use in our context other tools originally developed for celestial bodies, such as the Aladin software package, an interactive software sky atlas allowing the user to visualize and manipulate astronomical images in multi-wavelength, superimpose entries from astronomical catalogues and so on. Developing such new applications and new web services will be a further step to come. Though we did not participate in the birth of the VO, we have been helping for a few years in the development of standards which permits the inclusion of astrometry and geodesy products in the VO. We now have to systematically deliver geodetic products analyzed by our group following all the recommendations provided by IVOA, fully compatible with the ones provided by ILRS.

5. Web links

Here are some VO and OV-GAFF resources:

The International Virtual Observatory Alliance web site: http://www.ivoa.net

The IERS/ICRS Product Center: http://hpiers.obspm.fr/icrs-pc

French activities: http://grg2.fr/

GRGS-Grasse Web services and data (in English):
http://www-g.oca.eu/heberges/pnaf/OV-GAFF/Webservices/webservices_group_en.html

Technical informations on the VO (in French):
http://www-g.oca.eu/heberges/pnaf/OV-GAFF/Asov/info-techniques.html

ITRF solutions: http://itrf.ensg.ign.fr

References

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