Concepts for astronomical data accessibility and analysis via relational database

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Abstract. Relational databases (DBs) are ideal tools to manage bulky and structured data archives. In particular for Astronomy they can be used to fulfill all the requirements of a complex project, i.e. the management of: documents, software (s/w) packages and logs, observation schedules, object catalogues, quick-look, simulated, raw and processed data, etc. All the information gathered in a relational DB is easily and simultaneously accessible either from an interactive tool or a batch program. The user does not need to deal with traditional files I/O or editing, but has only to build the appropriate (SQL) query which will return the desired information/data, eventually producing the aforementioned files or even plots, tables, etc. in a variety of formats. What is then important for a generic user is to have the tools to easily and quickly develop, in any desired programming language, the custom s/w which can import/export the information into/from the DB. An example could be a Web interface which presents the available data and allows the user to select/retrieve (or even process) the data subset of interest. In the last years we have been implementing a package called MCS (see dedicated paper in this proceedings) which allows users to interact with MySQL based DBs through any programming language. MCS has a multi-thread (socket) architecture which means that several clients can submit queries to a server which in turn manages the communication with the MySQL server and other MCS servers. Here we’ll focus on the real-world case of the robotic IR–optical telescope REM (placed at La Silla, Chile) which performs real time images acquisition, processing and archiving by using some of the MCS capabilities. Interested people can visit ross.iasfbo.inaf.it to have a hint of the potential of DB-based data management.

1. Introduction

Nowadays medium-large size astronomical projects have to face the management of a large amount of information and data. Typically dedicated data centres manage the collection of raw and pre-processed data and consequently make them accessible to the (authorized) users. Access is performed either via (s)ftp or http(s) (Web) and typically foresees only files transfer. The selection of the data of interest is usually performed acting on a few parameters (e.g. object name or coordinates). In a few cases, when large amounts of data are involved, no (or little) data transfer is allowed but the user can submit batch jobs that return the results of a particular analysis. In other, less common, cases the data are delivered to the user on tapes, DVDs, etc. In all cases the data acquisition, archiving, delivering, processing and the results accessibility are managed separately. Often the information are not collected into relational databases tables and when this happens, the delay between the date of collection and the archiving is of the order of days or even months. The same happens for the data production logging and project documentation. Luckily the use, in many cases, of standard file formats like FITS can help to track the data origin and processing status.

International projects like those GRID based (see e.g. www.grid.org, www.coregrid.net, grid.infn.it, omi-europe.org, etc.) and the International Virtual Observatory Alliance (IVOA – www.ivoa.net) represent an effort to give a robust and standard framework for data archiving, analysis and retrieval to physicists and astronomers. However these projects size and ambitions cause them to proceed quite slowly and the potential users do not get immediate advantages from them. Large ground and space based Observatories usually put some effort into observations bookkeeping and data accessibility by the users. Small and medium projects/experiments instead tend to optimize the data management for their internal use only.

Finally we note that the usage of standard data format have allowed the development of standard analysis packages, which eventually can be easily adapted to meet the requirements of new projects.

2. Databases in astronomy

The usage of databases to store data collected by astronomical instruments/experiments is very common. Still, in

1 See FITS Web page: fits.gsfc.nasa.gov
the majority of the cases, they simply contain the information about the collected data (date, object, wavelength, etc.) or/and a list of objects with their observed and derived characteristics (catalogues). In a few cases some level of remote processing is permitted (see e.g. ASDC – www.asdc.asi.it). Moreover accessing these information is permitted only via Web browsers (or http client emulators) or via dedicated programs which typically also require the data to be on the same machine where the program runs. Also when very advanced databases systems were implemented, like the one used by the SDSS project (www.sdss.org) which allows a direct access (again via http) with user built SQL queries, a “direct” communication between the user program and the database system is not allowed. One needs for example to submit the query, collect the output into an ASCII file and then perform all the other desired analyses on his own machine.

The Virtual Observatory project is aimed at removing the obstacles users have in finding and accessing the data, (cross)processing them and at last retrieve the results, whatever they are: images, plots, tables, etc. Still it does not foresee a “low-level” user interaction.

But why is it so important to make extensive use of databases in Astronomy? Here is a short list of answers:

- can track in an ordered form what a project produces and let the rest of the world know it;
- can manage all the information aspects of a project within a single framework;
- don’t need to worry about data management but concentrate on the analysis and interpretation;
- make data accessibility uniform for all the Observatories/Projects from any computer on the Internet.

3. Our proposed system: MCS

As mentioned above, the basic idea is that it is easier and more efficient to use databases for almost all the aspects related to a modern experiment/project in Astronomy. Archives with documents, s/w packages, data logs, observing schedules, objects catalogues, simulated data, quicklook graphs, raw and processed data, all can be managed by a modern database server without caring about computer architecture, programming language, access security and even about data sharing, backup and restore.

What do we propose? A system with users management, multi-threading capabilities, customizable, allowing inter-process messaging and file transfer, DB input/output from any internet node and using any programming language. Database insert/select queries can be performed by mapping the data into parameters array of different types) or files of various types including FITS, VOTable. Selected data can be filtered through s/w components producing graphs in vector (e.g. Postscript) or bitmap format (e.g. GIF), and so on.

Such a system would be also very appropriate to manage experiments in real time. Health and data acquisition status, automatic analysis results can be monitored from any place on the internet. The main advantages for a project collaboration would be: information easy to find, ready to use pre-processed data, shared high level processing s/w (automatic or on demand), per user backup and restore, data access security and easy replication. And again the users can have direct access to such a system by using custom s/w or Web based user interfaces. In other terms, the common tasks are performed on the server side whereas clients s/w (running on the user computer) can concentrate on specific analysis on the retrieved data.

3.1. The MCS library

In the last years we have been developing a package which meets all the above listed requirements: MCS (Calderone & Nicastro, this proceedings). An MCS based data manager system has the characteristics of a traditional DB based manager system but with the addition of several crucial advantages. It is flexible enough to allow users to easily and quickly develop tools to manage observation schedules and logs, real time data archiving and processing. It has a built-in user’s privilege system, SSL encryption and automatic management of commonly used file formats. In addition it allows users to easily distribute the data processing among various machines and keep track of the status via DB log tables. The MCS library has an interactive shell and it is interfaced toward (almost) all programming languages; this means that whereas an MCS server has to be written in C++, any other DB accessing program can be written in any language. This permits an easy integration of existing and newly developed s/w within a collaboration where the participants most likely don’t use one single programming language.

We have also started including user contributed (MCS based) and external libraries in the various languages to make even easier to perform DB communication and typical astronomical analysis/calculations like simple fitting, sky mapping, coordinates and time conversions, astrometric calculations. These libraries include well known and tested packages like:

- Hierarchical Triangular Mesh (HTM – www.sdss.jhu.edu/htm/) used for object catalogues indexing;
- Hierarchical Equal Area isoLatitude Pixelization (HEALPix – healpix.jpl.nasa.gov) used to produce sky maps;
- Naval Observatory Vector Astrometry Subroutines (NOVAS – aa.usno.navy.mil/software/novas/) used for computing astrometric quantities and transformations.

This in one single library which, in its simplest form, can be compiled with one single dependence: the MySQL (free ware) library. It is also worth noting that in the future we
plan to support DB systems other then MySQL. Data input/output can be performed in several standard formats like XML, FITS and VOTable. The latter immediately makes accessible data and products to a Virtual Observatory (VO). Noticeably communication between an MCS server and a VO allows to get real time view and access to the Observatory products. In other words the Virtual meets the Real. We plan to perform “real” tests in collaboration with Institutions involved in the IVOA in the near future.

4. REM–ROSS

REM (Rapid Eye Mount, Covino et al. 2004) is a robotic telescope equipped with IR (REMIR) and optical (ROSS, Tosti et al. 2004) cameras aimed mainly at catching GRBs afterglows as fast as possible. It is also used to monitor variable objects and to perform ToOs observations of other interesting objects. ROSS can produce direct or dispersed (via an Amici prism) optical images. Observation logging and real-time image processing/archiving is performed accessing local and remote DBs. As soon as the image is (pre)processed, it is available to the owner in the database. As usual it is accessible from any internet node. A web interface (written in PHP) allows a simple and fast access to the log and products (images and spectra). Each user has his/her own account and can access only proprietary data whereas the observation log is freely accessible. It is very easy to implement new facilities performing more tasks on images or spectra.

Moreover all the REM project documents, papers, pictures, etc. are stored into DB tables and are accessible through PHP written dynamic web pages. In addition people have a web accessible “work area” repository useful to exchange any kind of file. The REM observation scheduling and status information system (see ross.iasfbo.inaf.it/~trem/), which was initially implemented to work with ASCII files rather than with DB tables, will soon start work also in the MCS environment.

4.1. HTM indexed catalogues

In order to quickly access IR/optical objects catalogues to discriminate newly discovered objects in the observed fields, we have ported into DB tables many of them. The only relevant difference respect to the original ones is the fact that they are all indexed with the HTM scheme, which in turn allows a natural DB indexing of the tables. Typically a query to a one billion objects catalogue like the GSC 2.3, on a 10 x 10 arcmin area (which is the REM field of view), takes ~ 20 ms. Thanks to MCS, these catalogues can be queried by any (authorized) internet user directly with his own program, written in any language. A standalone program (written in C++) is available to perform simple select queries and get the result in various formats. Moreover a web interface (written in PHP) allows users to perform interactive queries with graphical visualization of the selected objects. All the catalogues are accessible at ross.iasfbo.inaf.it.

4.2. The ROSS images manager

The ROSS camera manager is in charge of setting the observation parameters and performing the images collection as FITS files. Another s/w component (RossOPipe) manages the objects extraction and matching with the list of objects present in the reference (or other) catalogues (e.g. GSC 2.3), this in order to check for the presence of new (we call them UFOs) objects. A schematic flow chart is shown in Fig. 1. Finally all the relevant information are collected in DB tables and made immediately available to the user which can view them either from a web interface or via custom programs.

4.3. The Web based data access

The observation log, images and spectral data can be browsed, (partially) processed and retrieved in real time via a PHP written web interface. Again, thanks to MCS, the same tasks can be performed using any other language, though interpreted languages like PHP or Python are more suitable for web pages creation. The advantages of having a centralized archiver/processing system with an easy access guarantees:

- minimum disk space occupancy (in general only post-processing results need to be transfered on the user machine);
- easy backup / restore;
- easy s/w maintenance.

A record level privilege system allows a selective view of the data in the database table. Each user can only view and access owned images together with the calibration.
files and the observation log. Selection of a sub-sample of images and browsing/viewing the images on the Web interface is very simple (see Fig. 2). Also getting the list of objects in the image with their photometric and astrometric characteristics requires one click. Again only one click to view the sky chart of the objects listed in various all-sky catalogues (see Fig. 3). The automatic spectral data analysis requires only to click on the spectra to get them plotted and have the corresponding FITS binary tables in counts or flux units ready to be viewed/downloaded (see Fig. 4). Note that all these operations are performed in real time.

5. Conclusions

We have proposed a new approach to the management of the (nowadays) huge amount of data/information modern astronomical experiments produce. In particular we have proposed the usage of a single package (MCS, Calderone & Nicastro, this volume) which allows users to manage all the aspects of a project, all built over a relational database system. Such data would then be more effectively exploitable by the astronomical community at large for example for multi-wavelength studies and for access from the various Virtual Observatories.

We welcome any interested group or single researcher willing to contribute in any aspect of this project.

Acknowledgements. The REM Observatory is supported by INAF.

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