Online Access to Visnjan Observatory Image Database

Authors: Mario Juric, Korado Korlevic,

Introduction

Visnjan Observatory is a scientific and educational institution situated in the Istrian peninsula of Croatia. Our primary scientific field of interest are the minor bodies of the Solar system, commonly divided into meteors, comets and asteroids. Of these three, asteroids (rocky bodies 1-1000 km in diameter) are by far the most abundant, projections of their numbers ranging from a couple of hundred thousands to millions. Besides being of purely scientific interest as the leftovers from the creation of the Solar system, asteroids are of wider concern to humanity because of the potential threat they pose. Tough most of the asteroid population resides in the "asteroid belt" between Mars and Jupiter, in recent years it's been found that a smaller population of asteroids, commonly referred to as NEOs (Near Earth Objects) resides in orbits crossing Earth's orbit. Such asteroids have the possibility of colliding with Earth, with possibly catastrophic results - an option that we (the global asteroid research community) hope to avoid by detecting a potential impactor early enough to divert and/or destroy such a civilization threatening object. We at Visnjan Observatory are helping this effort with our asteroid search and NEO orbit determination (astrometric followup) programs.

Currently, there are around 100,000 known asteroids, and around 1500 NEOs. That number has ballooned from a number in low tens of thousands from just a couple of years ago, propelled by heightened awareness and increased spending in asteroid related research. Each of these objects has it's motion through the solar system defined by it's orbit, a set of 7 numbers ("orbital elements") which unfortunately, due to deterministic chaos, is not cast in stone. Therefore, the position of each of those 100,000 asteroids has to be measured from time to time to, colloquially speaking, "improve it's orbit". It is obvious that with 100,000 objects, a number which is rising rapidly, the data analysis and decision making process has to be automated and a set of new tools developed. We have internally tried to answer the most commonly asked questions ("what part of the sky to image", "what asteroids needs to be measured", "is this asteroid already known or it's a new one") with a integrated database and software system called VOID (Visnjan Observatory Image Database), and it's second Oracle8i based incarnation VOID 2 (or V2 for short).

V2 consists of a central Oracle8i based database which contains at least the orbital elements of each of the currently known asteroids. That allows us to calculate where each of those asteroids is at the moment and plan our observations accordingly. In this database, we have also stored information on images taken at the Visnjan Observatory (coordinates of the images, time at which the image was taken and all other relevant information), and measurement information (astrometric measurements of asteroids).

The raw data, as just described, is of no use - to analyze and process it a set of Win32 based applications (known as the Rings suite) has been developed. Rings consist of a large number of smaller application each with it's own task (i.e. "Gandalf" - image processing, "Elrond" - database and sky visualization, etc.). These tools provide us with a unique datamining capabilities were already used successfully in developing a new method of asteroid observations which gained us a 2-fold increase in search efficiency (see Juric).

Web Requirements

As an effort to make these tools publicly available, we have chosen to create a World Wide Web interface to the database and these tools (the "V2 Web"). V2 Web has been conceived to have a dual purpose - both educational and of interest to the general public, and one of more scientific orientation. Also, we see the V2 Web as a portal to asteroid related information not only contained in VOID 2, but also located elsewhere on the web. It's requirements can be summarized in the following :

Of interest to asteroid research community :

- ?? Easy access to orbit information of all known asteroids
- ?? Extensive datamining capabilities
- ?? Visualisation capabilities (2D and 3D)

Of interest to general public

- ?? Finding information on asteroids in general
- ?? Discovery circumstances and naming descriptions (asteroid "trivia")
- ?? Simple, easy-to-use tools for common lookups (by name, by discoverer, etc...)

Our answer to these requirements is located at http://void.astro.hr/ and shall be described in the paragraphs to come.

Data retrieval and analysis tools

V2 Web is conceived as a web-based database query tool. Primary interaction of the user with the underlying VOID2 database system is by giving it predefined or user defined queries and receiving the response. The challenge in designing VOID 2 website was in simplifying this query-and-answer interaction to simplest possible terms, but not sacrificing the datamining capabilities of complex queries. Also, the form of the "answer" to queries had to be flexible - a 1000 row long table is sometimes as (un)usable as the whole 100,000 rows of the complete database - visualization in this case is a necessity.

We have (hopefully) at least partially solved the simple query problem by introducing a "Generalized Query Facility" or GQF, which shall be elaborated in the following section. To solve the visualization problem, we've chosen VRML 2.0 as the technology of choice. Through VRML, result sets (mostly asteroid positions or asteroid orbits) can be visualized in 3D.

Generalized Query Facility

Generalized Query Facility (GQF) is a web based graphical/textual interface to underlying tables of the VOID 2 database. VOID 2 is an Oracle8i database - therefore it consists of a series of tables, each of which contains a specific set of data. From the V2 Web user's point of view, there are three main tables (currently, only the Asteroids table is publicly available) :

- ?? Asteroids
- ?? Measurements
- ?? Images

Each of these tables consists of columns of data. For example, some of the columns of Asteroids table are designation, numeration, discovery place, etc. There are also columns relating to orbital elements (elements of standard Keplerian orbit and photometry related columns). A complete reference of Asteroids table columns can be found here. Analogous situation exists for Measurements and Images tables.

While such datafiles of different properties are nothing new to the astronomical community (see for some excellent examples [Bowell, E.], [Marsden, B. G. and Williams G.]), that data is usually distributed in bulk text or binary datafiles. While very convenient for some applications (calculating current positions, doing calculations on complete datasets), it is difficult to use such bulk data for more complicated analysis. To answer even simple questions like *Give me a list of asteroids whose major semiaxis is between 20 and 30 and inclination does not exceed 10 and observational arc is less than 100* programs or scripts have to be written. This significantly reduces the potential for quick data analysis, or for even more complex queries.

We have created GQF as a tool for rapid multidimensional analysis of data contained in VOID 2 datafiles. GQF enables the user to interactively query VOID 2 tables in a simple and yet powerful way. Before explaining how to write GQF queries, here are some examples :

- ?? Question : Give me the designations, numerations, observational arc and orbits of all asteroids with inclination greater than 45deg.

Select designation, numeration, arc, orbit where **i > 45**

?? Question : Give me names and numerations of all asteroids which were discovered from Visnjan, ordered by their discovery date

Select designation, numeration where **observatory is 'Visnjan'** order by discoveryDate

?? Question : Give me the number of asteroids whose orbits were computed by Gareth Williams

Select count(distinct ast) where **ocSurname is 'Williams'**

?? Question : Give me the number of asteroids computed by each orbit computer

Select orbitComputer, count(distinct ast) group by **orbitComputer**

Results of GQF queries are formatted tables of requested data, or as 3D VRML models, depending on the user's choice.

Using GQF

An example GQF entry form is shown below. This form is used to query for asteroid related data.

Figure 1 - A standard GQF entry form

Select row

In the first row, marked with 'Select', the user enters the columns of the table he/she would like the query to return. On pages throughout the void.astro.hr site, available columns for each GQF form are displayed just below it (for an example, look here). Columns are separated by commas. The red parts of GQF statements given in the previous chapter would go into this row. Besides columns, aliases can be used instead of groups of columns when the whole group is to be displayed. For example, all six standard orbital parameters are usualy needed, so as a matter of convenience an alias *orbit* stands for all six fields which contain orbital elements. Complete list of aliases is given together with the columns of the table.

Where row

The real power and advantage of GQF is in the second row. Using the 'Where' row, the user specifies the conditions each row from the table must satisfy to be displayed. Examples of where conditions are colored blue in previous examples.

Where conditions have the following general form :

?? **<column> <operator> [value]**

where <column> is a column name (or an alias to a group of columns) from the underlying table (i.e. designation, numeration, orbit), <operator> is a relational operator which specifies the relation

between the column and the specified value (i.e. '=', '<>', '>', '<'), and <value> is the value with which the column is being compared. If the operator does not require a value to compare against, it can be omitted (for example, to check for existence of numeration, the user would write 'numeration exists' condition).

Examples of conditions are :

- ?? numeration = 10
- ?? designation = 'Ceres'
- ?? a < 2
- ?? numeration exists
- ?? orbit exists
- ?? designation in 'Ceres', 'Pallas', 'Juno', 'Vesta'

There is an exception with the not operator, which can be used as a prefix operator when used with logical values. For example :

- ?? not renamed
- ?? not (ocSurname is 'Williams')

Individual conditions can (and should!) be connected to form more complex ones by a set of logical connectors. Currently available logical connectors are **and** and **or**. Also, it is possible to parenthesize the conditions and then join them with logical connectors. Here are a couple of examples :

- ?? (arc > 20 and orbit not exists) or (arc < 10 and orbit exists)
- ?? designation is 'Korado' or (orbit exists and ra between 120, 220 and not renamed)

Group by row

Group by row is used in queries which use aggregate functions like count or sum. Here the columns are listed according to which the user would like the result of the query to be grouped before the aggregating has occurred. For example, let's say a count of how many asteroids were numerated from each observatory is desired. Then, the user would write a query satisfying the "numeration exists" condition, and after evaluating that query, the results should be split in groups according to discovery place, after which each of those groups is counted. The result of the query is the number of asteroids in each group, that is, the number of asteroids which were discovered from each observatory.

Order by row

Here, the sort order of the returned rows is specified, that is, the columns which should be used for sorting. Columns are comma separated.

Data output

Depending on the user's choice, two forms of data output are available - tabular, returning a table of requested data and 3D output, returning a three dimensional VRML model of the orbits/positions of asteroid requested. While tabular data is self-explanatory, in this paper we shall concentrate on the 3D option.

Three dimensional VRML data output

What distinguishes V2 Web from other minor body related data retrieval options on the World Wide Web is the ability of rapid 3D visualization of query-selected datasets. For almost every GQF query (which returns rows of asteroids), VOID2 Web can be requested to produce a 3D output. There are two types of 3D output :

- ?? Plot asteroid positions
- ?? Plot complete orbits

First type of output (positions only) is useful in analyzing large sets of positionally correlated asteroids, returned by the underlying GQF query. It is always amazing to see how much information can be

compressed and made obvious to the human mind by such simple things as 3D visualization. As an example, let us analyze the following images :
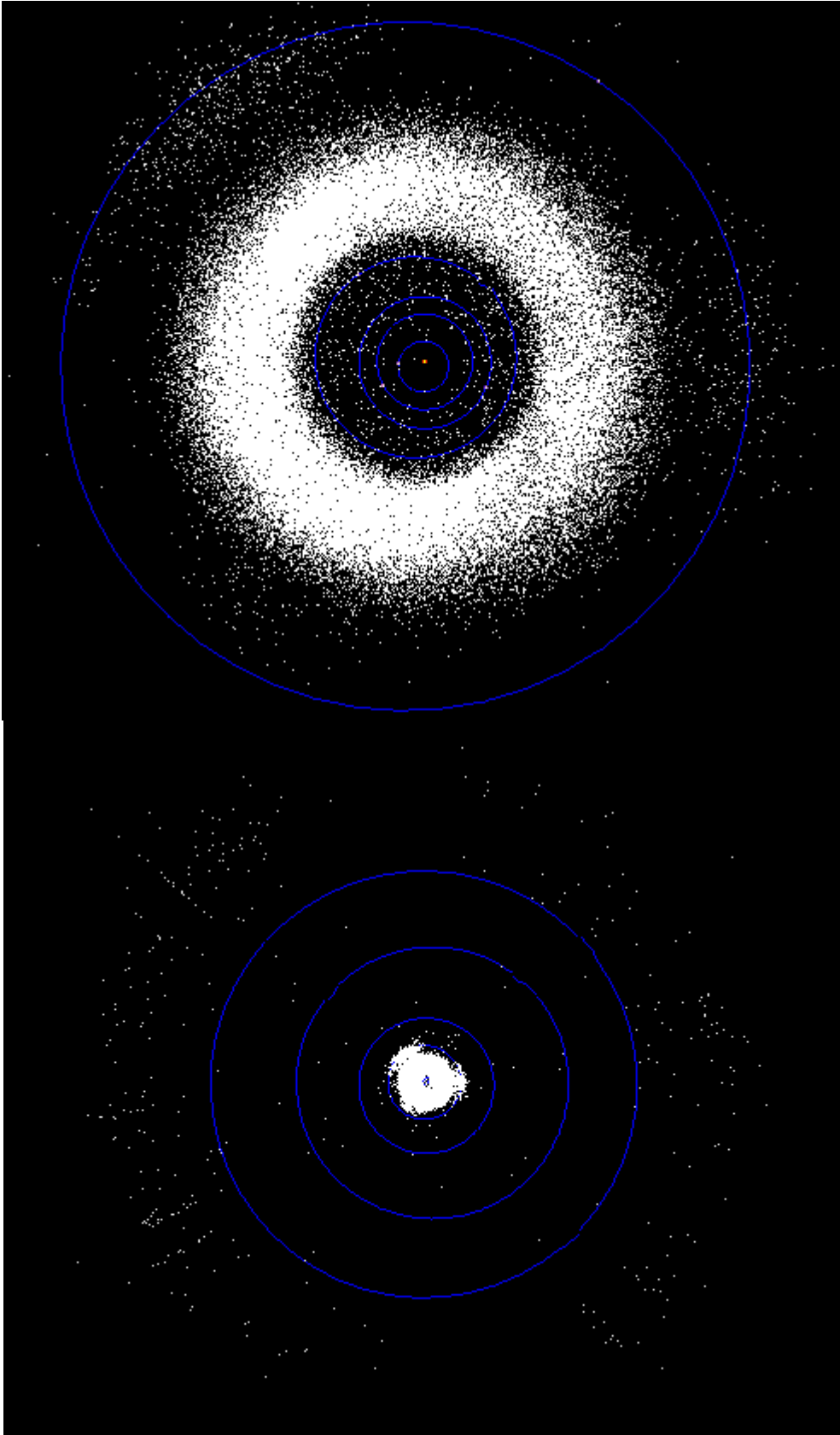
Figures 2. and 3. - A snapshot of VRML model of positions all currently known asteroids shown under two different zoom settings - the first image shows the inner part of the solar system, nicely showing

the asteroid belt between Mars and Jupiter, while the second image shows the trans-Neptunian object population of the outer Solar system.

This is the simplest possible 3D model - the database was queried for all known asteroids. The blue circles designate planet orbits - Mercury, Venus, Earth, Mars, Jupiter, etc. The white dots indicate the positions of the asteroids returned by the query at the time the query was given. A number of things can be seen from this image: most of the asteroid population (as expected) is concentrated between Mars and Jupiter in the asteroid belt. There are two large populations of asteroids situated at L4 and L5 Langrange points of Jupiter's orbit - the so called "Trojans". What is also visible is an apparent population of asteroids in the vicinity of L3 Langrange point - something, interestingly enough, not widely discussed in the current asteroid dynamics literature!

The second image is the same 3D model, just zoomed out. The last visible orbit in this case is the orbit of planet Neptune, and the asteroids residing beyond that orbit are known as trans-Neptunian objects (TNOs). There are also some pretty obvious (and interesting things) to note just from a quick glance on this image. For one, there are two diametrically opposing gaps in the distribution of TNOs, at the spot in the sky where the Milky Way, our galaxy, lies. This indicates the technical inability of today's survey programs to work in densely populated regions of the sky. The second thing to notice are "radial streaks" of asteroids - a result of the fact that most of TNOs have been discovered by a very few search programs. These streaks indicate the locations where the search took place.

What was shown here is just a 2D snapshot of a 3D model. For a full view we suggest you visit the gallery at the VOID 2 website.

Simplified access for the general public
Although we've endeavored to make the GQF as easy as possible, we realize that a limited number of users will want to use all of it's possibilities. As one of the goals of our website was to make VOID2 data available to everyone, we've created a simplified version for the general public, with a single line question-boxes for the most used queries. Specifically - get information on asteroid by it's name, and get all asteroids discovered by a given discoverer. The result of this query is a page, together with a VRML model of the asteroid orbit, with all the data available on the given asteroid.

We've also set up a gallery of predefined 3D views, which can be accessed by a simple click. We hope this will motivate the casual user to try using more complex GQF facility.

Conclusion

VOID 2 as a database and a backbone of the operations of Visnjan Observatory has been in successful use for over a year. Through VOID 2 website we have tried to make that functionality available to the rest of the scientific community as well as the general public. Specifically, we have tried to fill in a gap in datamining tools which existed before introduction of VOID 2 Web, by creating the Generalized Query Facility - a simplified, more user friendly form of putting SQL queries against the VOID2 tables. The output of those queries is a set of tabular data or a 3D models of the resulting dataset. This 3D visualization capability coupled with GQF querying ability is to our knowledge a unique Web service in this field of science (minor body research).

Finally, V2 Web is, as all web projects are, a never-ending story. New features are constantly being added and old are being revised to further improve and simplify access to immense quantities of data which are becoming available in the field of minor body science. By creating and updating V2 Web we hope to have given a valuable tool to the scientific community interested in asteroid research. V2 web is accessible at http://void.astro.hr/.

References
M. Juric, 1999,
   VOS - Nova strategija planiranja astrometrijskim mjerenja", a paper for University of Zagreb Dean's Award

Bowell, E., 2000,
    ASTORB Database, *ftp://ftp.lowell.edu/pub/elgb/astorb.html*
Marsden, B. G. and Williams G., 2000,
    MPC Orbit Database, *ftp://cfa-ftp.harvard.edu/pub/MPCORB/*

Mario Juric
Student at Faculty of Natural Sciences and Mathematics, University of Zagreb, Zagreb, Croatia;
majuric@astro.hr

Korado Korlevic
Visnjan Observatory, Visnjan, Croatia;
korado@astro.hr