Astronomical Data Analysis Software and Systems XXIX
ASP Conference Series, Vol. 527
R. Pizzo, E.R. Deul, J-D. Mol, J. de Plaa and H. Verkouter, eds.
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Visualising Virtual Observatory Data in Digital Planetaria

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Abstract. The Virtual Observatory provides a rich source of material for preparing presentations for the general public in digital planetaria. However, the effort required in preparing the data for displaying in most planetaria is considerable. The most common software used in domes today (e.g. Sky-Skan's DigitalSky 2 E&S' Digistar) cannot read data from standard astronomical formats. We present plans for a simple interface which will enable the extraction of catalogue data from the Virtual Observatory and its conversion into formats which can be used by both commercial and open-source systems. It is intended to explicitly use this capability with a relatively new open-source visualisation system, called Openspace. A prototype has been used to extract data from the second Gaia data release and the third KiDS data release. The work is complementary to that of the Data2Dome consortium, which concentrates on images and recent events rather than the access to archival catalogues.

1. Introduction

In Groningen we have access to one of only a handful of 3D digital planetaria in Europe. This facility is a modern building containing a 3D Full-Dome theater, which is regularly used by astronomers from the Kapteyn Astronomical Institute to give shows aimed at explaining science to the general public. In this paper we report on a project allowing us to import data from the Virtual Observatory (VO) and visualise it in a digital dome. To do this we make use of visualisation software such as Openspace and DigitalSky 2.

1.1. Speck and octree files

A common file format used by visualisation software in domes is the Speck format. A less common file format, the Octree, is used by OpenSpace.

- *Partiview (Speck) files*. All the current planetarium systems use the Partiview format, which was invented at Hayden Planetarium. It is a very simple Ascii table containing a header and at least three columns: x, y, z coordinates centred on the Solar System Barycentre.

- *Octree files*. An Octree is a tree data structure in which each internal node has exactly eight children (Meagher 1982). Octrees are most often used to partition a three-dimensional space by recursively subdividing it into eight octants. One of the big advantages of using the Octree format is that data can be stored in multiple files that can be uploaded or removed from memory, allowing to handle data sizes larger than the available memory of the computer.

1.2. OpenSpace and DigitalSky 2

For space limitations, here we only briefly describe the two visualisation tools used in our planetarium, although there are other tools like the WorldWide Telescope (WWT), Uniview, and Digistar.

- OpenSpace is an open-source interactive data visualisation software system designed to visualise the entire known universe. The stated aim of OpenSpace is visualising dynamic datasets in real time. Openspace can visualise different datasets such as the Digital Universe and Gaia DR2. Openspace can also import data in either Partiview or Octree format. For more details on OpenSpace, including informative demos, see `https://www.openspaceproject.com/`

- DigitalSky 2 is Sky-Skan's digital full-dome planetarium software for Definiti theaters. It shows the night sky with classical planetarium functions as its base. DigitalSky 2 comes with data sets covering everything from deep space to molecules. Users can explore these visuals in real-time, or use presets to assemble shows. Data must be imported into DigitalSky 2 in Partiview format.

2. Method

Bringing astronomical data into domes requires basically four steps. First, download the data from the remote storage server. Second, perform some astronomical calculations for further usage. Third, transform the data into the appropriate coordinate system. Finally, save/send the data in the appropriate format for visualisation purposes.

The first step involves selecting the dataset, identifying the required variables (e.g. RA, DEC, parallax, magnitude, redshift, etc.). These variables can have different names across datasets. Once the variables have been identified, the way of downloading the data can also be different across datasets. For example, Astronomical Data Query Language (ADQL) can be used to query the Gaia archive and Structured Query Language (SQL) can be used to query the Galaxy and Mass Assembly Survey, GAMA. The use of astroquery is becoming increasingly popular, with 80% of Gaia data reportedly being downloaded by this method. In the worst case, the whole dataset may have to be downloaded if only data files are available. For example, there are available FITS files of the Kilo-Degree Survey (KiDS).

The second step may or may not be required to perform some calculations. For example, distances (used to calculate the coordinates in the third step) are available in the Gaia archive (Bailer-Jones et al. 2018) but not in the KiDS catalogue. For the latter, distances have to be estimated as a function of redshift values.

The third step may require some transformation between different coordinate systems. For example, the WWT can handle RA, DEC, and distance to visualise astronomical datasets. However, Digistar uses the International Celestial Reference System

(ICRS) in terms of equatorial angles RA and DEC and requires Cartesian coordinates (x, y, z). DigitalSky 2 can use Cartesian coordinates in either Equatorial, Galactic or Supergalactic reference frames. Uniview and OpenSpace use the Galactic Coordinate system and Cartesian coordinates.

In the fourth step, the data is prepared for visualisation using the available software in the domes. This can be done using an Application Programming Interface (API) such as the one provided by the WWT which can send the data to a remote server. Digistar uses VOtables to visualise astronomical data. Uniview and DigitalSky 2 use the speck format. OpenSpace can read speck, FITS, binary, and BinaryOctree formats.

The whole process can be implemented using tools such as Python and Astropy.

3. Astronomical catalogues converted to date

To date we have converted data from the following two surveys into formats allowing them to be viewed in OpenSpace.

- *KiDS*, a large optical imaging survey in the Southern sky, designed to tackle some of the most fundamental questions of cosmology and galaxy formation as of today. Using the VLT Survey Telescope (VST), located at the ESO Paranal Observatory, KiDS has mapped 1500 square degrees of the night sky in four broad-band filters (u, g, r, i). As a recent survey, KiDS is not present in the Digital Universe collection. We pre-processed 440 FITS files, estimated comoving distances based on redshift using the Planck13 cosmology Astropy Python-package. We estimated galactic Cartesian coordinates using the *astropy.coordinates* Python-package. The coordinates and other variables of about 48 million objects were stored in a speck file and then converted into an octree binary file. A visualisation is shown in Figure 1.

- *Gaia* relies on the proven principles of ESA's Hipparcos mission to create an extraordinarily precise three-dimensional map of more than one billion stars throughout our Galaxy and beyond. Although OpenSpace offers the possibility to download some predefined Gaia datasets, customised datasets have to be created directly from the raw data. As an example, we downloaded data of the M4 globular cluster using ADQL. Data selection was performed using the following parameters $241.8 < RA < 249.8$, $-30.5 < DEC < -22.5$ and $1200 < distance < 3200$. Then, galactic coordinates were estimated using the Astropy Python-package. A visualisation is shown in Figure 2.

4. Conclusions and future work

The public release of data as collected from astronomical devices are made available for the general public. Tools and techniques to visualise the data in digital planetaria are available as well. However, preparing the data for such visualisations is still time consuming. Here, we present a possible pathway to accelerate this process. In the near future we plan to develop a graphical user interface to facilitate data preparation for digital planetaria.

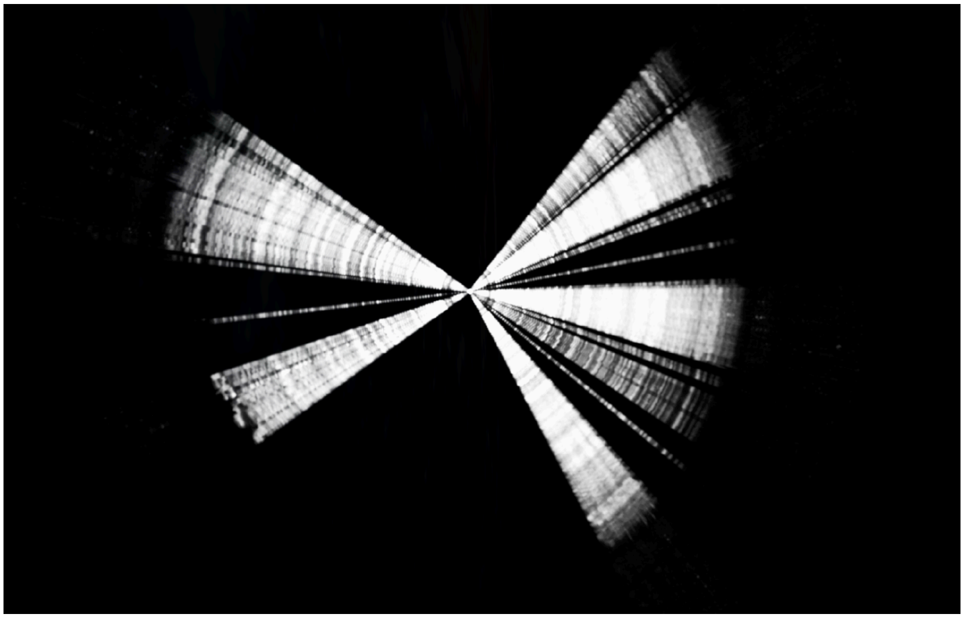

Figure 1. OpenSpace visualisation of about 48 million objects from KiDS DR3.

Figure 2. Globular cluster of M4 or Messier 4 (NGC6121) which has about 30,000 stars. It features a characteristic "bar" structure.

References

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