Architecture for All-Sky Browsing of Astronomical Datasets

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Abstract. A new architecture for all-sky browsing of astronomical datasets has been designed and implemented in the form of a graphical front-end to the yourSky custom mosaicking engine. With yourSky, any part of the sky can be retrieved as a single FITS image with user-specified parameters such as coordinate system, projection, resolution and data type. The simple HTML form interface to yourSky has been supplemented with a graphical interface that allows: (i) All-sky, web-based pan and zoom; (ii) Interactive, multi-spectral viewing; (iii) Vector graphic overlays from object catalogs; and (iv) Invocation of the yourSky mosaicking engine once a desired view has been selected in the browser.

1. Introduction

A number of "Virtual Observatory (VO)" efforts exist around the world, including the National Virtual Observatory (NVO 2002) in the United States, with the objective of applying modern information technology to facilitate all aspects of the access, processing, analysis, and visualization of massive astronomical datasets. As a community effort, the VO will consist of many widely distributed components developed and deployed by domain experts in different areas. Many of these components will need to exploit state of the art high performance computing and communications assets due to the sheer size of the datasets or the complexity of the algorithms. However, much of astronomical research is being conducted by students or researchers without direct access to these expensive computing assets. Therefore, the VO will need to deploy portals that provide access to these assets, supercomputers, massive data archives, and the high bandwidth networks that interconnect them, but these portals will also need to be able to cope with meager computing resources and low bandwidth network connections on the client side.

In this paper we present a working implementation of an image mosaicking and all-sky browsing service that fits the distributed architecture of the VO, described above. This computational architecture is used in two complimentary ways. First, a "Browse Mode" provides a web-based, interactive, all-sky pan and zoom capability for astronomical images and catalogs. In this mode a very rapid, interactive response is required, with a delay of no more than a few seconds from the time a user requests an image of some part of the sky to the time when that image is delivered. To achieve the necessary interactive response, it is expected that the astronomical data in remote archives would have to be preprocessed into an online data store from which a cutout image of any part of the sky can be rapidly extracted. The second mode of operation is a "Batch Mode," which provides a science quality image mosaicking service that can retrieve the highest science quality data available from remote, possibly off-line, archives, and deliver custom image mosaics based on this data to the scientist's desktop. The yourSky web portal at `http://yourSky.jpl.nasa.gov` provides both all sky browsing and a highly customizable parallel image mosaicking capability that together provide a very powerful tool for accessing modern terabyte-level astronomical datasets.

This synergy between all sky image browsing and more focused science quality custom image mosaicking enables a number of important science activities in astronomy: (i) the overall region of coverage of any included dataset can be determined at a glance by browsing the all-sky, coarse-resolution representation of the dataset, (ii) any region of the sky can be retrieved from any included dataset in a specific coordinate system and projection as a single, high science quality image regardless of how that data is stored in the native archive, (iii) mosaicking multiple wavelengths to the same grid enables novel, multi-spectral analysis of astronomical data.

The remainder of this paper describes in more detail the yourSky custom mosaicking engine (Section 2) and all-sky browsing capabilities (Section 3).

2. yourSky Custom Mosaicking Engine

The yourSky custom mosaicking engine (Jacob et al. 2002) includes subsystems for: (i) construction of the image mosaics on multiprocessor systems, (ii) managing simultaneous user requests, (iii) determining which image plates from member surveys are required to fulfill a given request, (iv) caching input image plates and the output mosaics between requests, and (v) retrieving input image plates from remote archives. The only client software required to access yourSky is the ubiquitous web browser.

The parallel image mosaicking software emphasizes custom access to mosaics, allowing the user to specify parameters that describe the mosaic to be built, including the datasets to be used, location on the sky, size of the mosaic, resolution, coordinate system, projection, data type, and image format. Values for these parameters are specified using a simple form interface found on the yourSky web page (`http://yourSky.jpl.nasa.gov`). The galactic, ecliptic, J2000 equatorial and B1950 equatorial coordinate systems are supported, as are all of the sphere to image plane projections specified by the World Coordinate System (WCS) (Greisen & Calabretta 1995). Pixel data types may be 8-, 16-, or 32-bit signed or unsigned integer, or single or double precision floating point. The mosaic may be output in the FITS data format, well known in the astronomy community, or in another common image format such as JPEG, PGM, PNG, or TIFF.

The yourSky portal may be used to access any region of the sky as a single image, regardless of the size of the region or how the image data is partitioned and stored in the native archives. The image mosaics are constructed from the highest science quality data product in the remote archives. Currently all of the publicly released data from the Two Micron All Sky Survey (2MASS) and the Digitized Palomar Observatory Sky Survey (DPOSS) are accessible with yourSky. The only requirements on the input images to yourSky are that they be FITS format images with valid WCS information stored in the FITS header. The mosaicking software developed for yourSky is designed to support input images and output mosaics of any size, including all-sky images at sub-arc-second resolution.

3. yourSky Interactive All Sky Browser

The simple yourSky form interface described in Section 2 has been supplemented with a graphical front end that permits interactive, web-based pan and zoom over an all-sky representation of each yourSky dataset. This image browser features efficient navigation by either mouse point-and-click or by directly inputting a right ascension, declination, and zoom level to jump to the desired view. Multi-spectral viewing is supported by allowing the user to map any wavelength from the included datasets to each of the red, green, and blue video channels to produce a pseudocolor image. Catalogs of tabular data may be visualized as vector graphic overlays that pan and zoom in concert with the image. Finally, this interactive, graphical front-end is interoperable with the yourSky batch mosaic engine described in Section 2. Once a desired view of the sky is centered in the interactive display, a simple click of a button brings up the yourSky custom mosaic form with dataset and location fields filled in to match the browser view. This enables the user to easily order a higher science quality version of the image being viewed with the desired coordinate system, projection, data type, and resolution.

The images delivered to the interactive browser are cropped from a set or image plates that were constructed a priori and stored on-line for rapid interactive response. The yourSky all-sky browser is intended to permit effective interactive viewing of any part of the sky. This would not be possible if we simply enabled pan and zoom over a single all-sky image mosaic, due to the severe distortion that would be apparent in regions far from the projection center. Therefore, instead of using a single all-sky image, the browser images are served from multiple, overlapping image plates. The image plate sizes are small enough to limit the image distortion due to projecting pixels from the sphere to the image plane. The plate sizes are also large enough to ensure full coverage of the sphere and to allow for sufficient overlap between plates that a typical display image can be computed by simply cropping from a single image plate.

Each image plate is in a tangent plane projection, with tangent points located at various locations around the sphere. The tangent point positions are based on a sphere subdivision scheme called the Hierarchical Triangular Mesh (HTM), which was first adopted by the Sloan Digital Sky Survey as a means of organizing astronomical data into bins based on spherical triangles on the sphere (Kunszt et al. 1999). Each yourSky browse image plate is tangent to the sphere at an HTM vertex as illustrated in Figure 1. A set of plates is provided at resolution steps from 8 arc seconds per pixel (258 plates covering the sphere) to 2,048 arc seconds per pixel (1 plate covering the entire sphere).

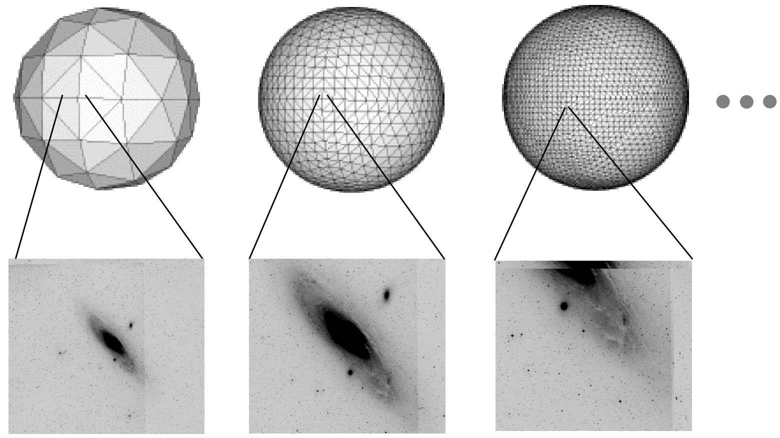

Figure 1. The yourSky browse image plates are positioned based on Hierarchical Triangular Mesh vertices.

4. Summary

The yourSky architecture supports two modes of operation: (i) batch mode, science quality, potentially compute intensive custom mosaic processing, and (ii) browse mode, interactive, web-based, all-sky pan and zoom. This synergy between interactive browse capability with science quality custom mosaic processing makes yourSky a flexible portal for astronomical data access, analysis, and visualization. The yourSky portal is at `http://yourSky.jpl.nasa.gov`.

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