Standards-Based Open-Source Planetary Map Server: Lunaserv N. M. Estes, V. H. Silva, K. S. Bowley, K. K. Lanjewar, M. S. Robinson, School of Earth and Space Exploration, Arizona State University, nme@ser.asu.edu

Introduction: The Lunar Reconnaissance Orbiter Camera (LROC) is operated from the Science Operations Center (SOC) on the ASU campus. SOC operations require dynamically generated maps to support the functionality of a wide variety of tools and applications. Some of these uses include JMoon [1], web sites, and Geographic Information System (GIS) software. In addition to these applications, specialized map requests are used to generate frames for videos, figures for documents and publications, production of outreach materials, etc. To meet the widest variety of uses possible with a map tool and single set of map data, we first investigated the Web Map Service (WMS) standard. At the time, there were no WMS packages that supported non-Earth coordinate reference system (CRS) definitions out of the box, and many solutions had limitations involving large global sets comparable to LROC. As a result, we developed Lunaserv (2009) to provide a WMS compatible server software supporting planetary CRS [2], and capable of serving voluminous (terabytes) data sets.

While the initial version of Lunaserv supported only a small selection of CRS definitions for the Moon, subsequent updates expanded Lunaserv capabilities. Lunaserv now supports many planetary CRS definitions without any additional user configuration. The ability to serve map data for any planetary body in a variety of projections to WMS client software is valuable to many planetary researchers, so in 2013, Lunaserv was released as open-source software [3].

Capabilities: Lunaserv implements the Open Geospatial Consortium (OGC) WMS standard. The WMS standard was chosen because it is a protocol widely used by a variety of GIS software including QGIS, ArcGIS, Grass, OpenLayers, Leaflet, and JMARS. With the WMS standard, Lunaserv provides map data for the largest possible set of GIS data users from a single set of source data [4].

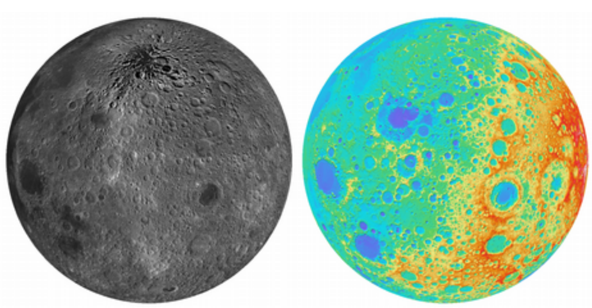

Figure 1: The Moon rendered in an orthographic projection centered at 45° N, 120° E. The left is a LROC WAC global mosaic, and the right is a color shade based on the GLD100 [12].

The WMS standard allows map data to be rendered in a variety of raster formats, and in any CRS understood by the WMS server. A WMS CRS specifies the combination of projection and planetary body spheroid [5]. While the WMS specification recognizes only Earth-based CRS definitions, Lunaserv supports all of the 8,250 IAU2000/IAU2009 planetary CRS definitions, and any arbitrary CRS that can be defined using the proj.4 library [6].

Supported Layer Types: The WMS protocol is primarily focused on presenting 8-bit visual map data for use in web applications or GIS software. Accordingly Lunaserv generates map products from both raster and vector source data..

Raster Image Data (Fig 1): Lunaserv supports both 8-bit grayscale and 24-bit RGB image data. This type of map is loaded from pyramidal TIFFs (PTIFF). These PTIFFs can either have embedded geographic meta-data, or the geographic meta-data can be specified in a separate file. The PTIFFs can also have a 1-bit mask file to specify the area of interest within the PTIFF that should be rendered. The PTIFF filenames for a layer are listed in the layer configuration file, or the list can be loaded from a database.

Lunaserv additionally can serve 32-bit floating point data for compatible client software that understands either 32-bit TIFF or 32-bit VICAR (currently support for Jmoon/Jmars). The source of the high-precision data is an Integrated Software for Imagers and Spectrometers (ISIS) cube [8]. Multiple ISIS cubes of different resolutions can be provided (similar to the internal structure of a pyramidal TIFF), and Lunaserv will render each request using the ISIS cube that is the most appropriate resolution for the map request. Future work may include support for 32-bit TIFF format .

Vector Data (Fig 2): Lunaserv loads vector data from flat files, shapefiles, or a database in the form of points, line-strings, polygons, annotations, or grids. The grid vector type is a specialized layer

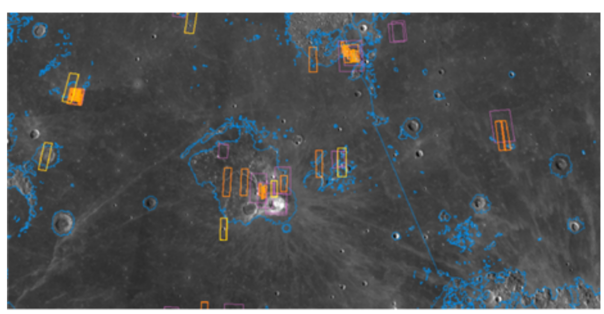

Figure 2: WAC global mosaic with ROI, DTM, Anaglyph, and shapefile RDR product layers overlaid as examples of vector layers.

configuration that requires no input data, but can generate any size latitude/longitude grid specified in the layer configuration file.

Lunaserv supports the PostgreSQL database by default, but support for other databases is possible by creating a simple software plugin. All database operations support a rich set of filtering capabilities and can use a predefined set of 5° bins to limit the query results to the area of interest for performance reasons.

Illumination (Fig 3): Lunaserv can generate illuminated maps using simple day/night shading, or topography-based illumination. Both options render the requested illumination dynamically based on the sub-solar point calculated using the NAIF SPICE toolkit [7]. For topographic-based illumination, a Digital Terrain Model (DTM) in the form of a 32-bit ISIS cube file is used to provide the necessary elevation data [8].

The illumination types use the current time by default, or will render the illumination conditions for any provided time or sub-solar point. As with the 32-bit raster image data support, work may be done in the future to support the PTIFF format.

Usage: The LROC SOC uses Lunaserv to provide data for operations, data portals, web site context maps, PDS web interface, "Where is LRO" webpage, digitizing, video generation, and other activities [9]. In addition to SOC uses, outside researchers also use Lunaserv for visualization with a variety of GIS software packages. The public Lunaserv hosted by the LROC SOC contains all of the LROC map projected PDS products. For demonstration purposes, it additionally serves base imagery, illumination and nomenclature for Mercury, Venus, Earth, Mars, Io, Ganymede, Europe, Callisto, Rhea, Tethys, Iapetus, Dione, Enceladus, Pluto, Charon, Vesta, and Ceres. Based on log file analysis, Lunaserv has been used by other researchers with QGIS, ArcGIS, Google Earth, OpenSceneGraph, OpenLayers, and Leaflet [10]. On average, the public Lunaserv service hosted by the LROC SOC handles more than 20k map requests per day, and during periods of high activity, has handled over 600k map requests in a single day.

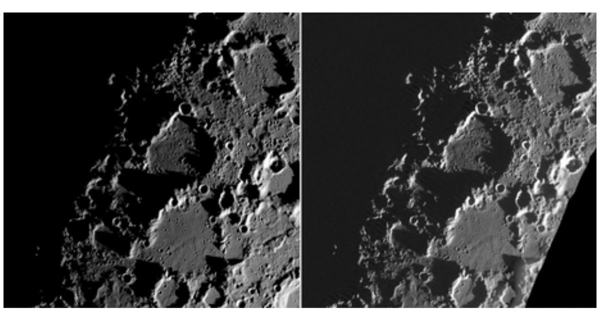

Figure 3: The north pole of the Moon on 2012-357. The left is a synthetic illumination map rendered by Lunaserv using the GLD100 DEM [12]. The right is a composite of actual LROC WAC observations from 2012-357.

In addition to using the LROC SOC hosted Lunaserv server, Lunaserv can also be installed and used by other groups to host their own map data. One such installation is the Lunaserv service supporting the I4 tool provided by Johnson Space Center [11].

Conclusion: The WMS protocol allows for GIS software users to easily combine data from multiple sources without first downloading or processing the data in any way. Lunaserv leverages this capability and extends it to provide support for the IAU2000/ IAU2009 planetary CRS definitions, and provides support for large global data sets. By making data available using Lunaserv, research groups can make accessing their data faster and easier using software that many GIS users are already familiar with, and exposes the underlying data to uses not originally envisioned without custom development.

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