Lunaserv Performance and Planetary CRS Improvements

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Introduction: Lunaserv is a planetary-capable web map service (WMS) written by Lunar Reconnaissance Orbiter Camera (LROC) Science Operations Center (SOC) personnel [1]. In 2016, we improved Lunaserv in two key ways: low-level caching and IAU2009 Coordinate Reference System (CRS) support [2]. These new developments increase the average reponse times by a factor of two and increase the planetary support to include all available planetary CRS definitions.

Low-Level Caching: The Lunaserv Cache Service is a stand-alone WMS-specific caching service using an open-source network RPC protocol framework (GRPC w/Google Protocol Buffers [4, 5]), and a structured query language (SQL) database for metadata storage. The Lunaserv cache layer is implemented at a lower level than the typical HTTP cache. Even though WMS is a HTTP protocol and Lunaserv sets appropriate cache expiration times in the HTTP header, a typical HTTP cache is of limited use for WMS requests. Instead, by inserting the cache layer within Lunaserv, faster cache access times can be achieved (11 ms per tile), and the capability to caching individual layers before combining them in the output map is possible.

Prior to the new cache service, Lunaserv rendered every map request on demand; rendering individual layers, and creating composites of these layers to form a requested map tile. The new cache service stores frequently requested layers prior to compositing. By not having to re-render these stored layers, especially layers with large render times, the speed of requests significantly improves while greatly reducing the load on Lunaserv servers by an average factor of two. Tools requesting high bit-depth, numeric data, such as LGE 3D [6], or tools that frequently request the same areas, such as desktop GIS software, show a significant improvement in overall performance, much higher than the average two times improvement.

Lunaserv cache performance is maintained by utilizing cache expiration, and a process that prunes unused tiles that runs independently from the cache request to keep access time low. Stale layer data is expired based on when a layer configuration was first seen. When a change in either the layer configuration or the data modification timestamp is detected, the newest configuration is kept while the older configuration is deleted. Cache pruning utilizes least recently used (LRU) expiration, where the least used tiles are expired first. This process is repeated until the size of cache is brought down to the user-specified cache size parameter. This allows the cache to remain robust enough to ensure a low miss rate for best performance while keeping cache size within specified limits. The LRU cache expiration and pruning processes can be scheduled to run periodically.

To estimate the impact of the cache service on Lunaserv, all map requests from the logs for the year 2015 were extracted, and the requests were split into individual layer requests. This resulted in 7.1 million tile requests. These requests were submitted to the cache server in order resulting in 3 million cache misses and 4 million cache hits. The result of the real-world request cache test indicates that over the course of a year, the cache may more than double the capacity of each server it's running on. Based on this test, the cache overhead, including network RPC, filesystem, and database, is just over 11 milliseconds per request, and this time remained constant from the beginning to the end of the test indicating that the addition of millions of tiles in the cache does not have any significant effects on performance as the cache scales in size.

Using the real-world requests, we also found requests with range errors and type errors. The range errors were numeric parameters such as width or bounding box values that exceeded what a 64-bit integer can hold, and the type errors were numeric fields with text values. To ensure cache consistency and prevent potential security vulnerabilities, the cache RPC protocol ensures robust

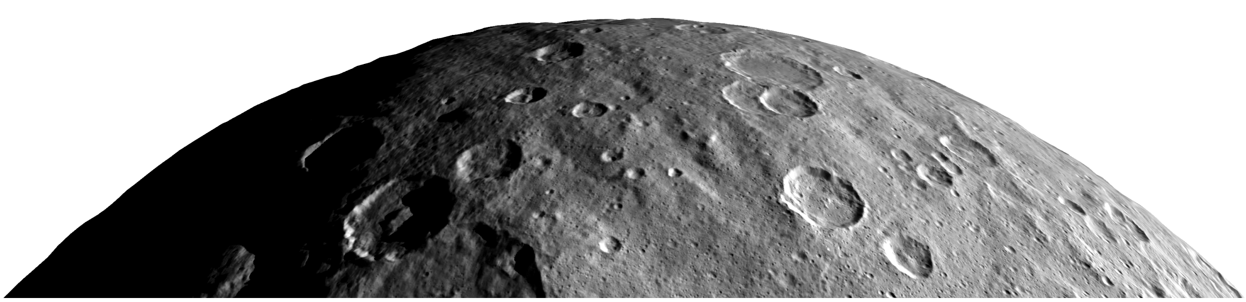

Figure 1: One of the new bodies now supported by Lunaserv is Ceres. This is a 3D view generated by LGE 3D using the Dawn FC Mosaic [3] with DTM-based illumination.

data type checking and memory safety. Additionally, the cache service detects the error and throws out the request.

Planetary CRS Support: Starting with the version released in 2013, the IAU2000 CRS namespace [7] has been supported by Lunaserv. This namespace has been expanded to include new projections and new bodies, and Lunaserv now supports those additions (Figure 1, 2). A new namespace was also introduced to support body radius changes in the IAU 2009 report [8]. This IAU2009 namespace is now also supported by Lunaserv. These namespace changes required reworking how Lunaserv supports the IAU WMS namespaces as the previous implementation only allowed one set of radii to be specified for a body. The new configuration now consists of planetary CRS templates and per-namespace body radius CSV files. This will allow for easily adding other projections and bodies to the CRS namespace for future planetary CRS updates.

Lunaserv Usage in 2016: In 2016, the Lunaserv installation at LROC served 1.3 terabytes of map data to external users. Aside from web-based GIS clients, Lunaserv also handled map requests for JMARS, QGIS, ArcGIS, and NASA WorldWind.

Future Work: The LROC SOC deploys Lunaserv to a cluster of servers. For redundancy and reliability, each server runs its own cache service. The ability for those cache services to communicate peer-to-peer in a fault-tolerant way improves the performance of the cache system. It may also be possible to improve upon the least-recently-used cache mechanism by taking advantage of other metadata available. For example, non-centered AUTO CRS requests are generally far less likely to be requested again than non-AUTO CRS requests.

The LROC SOC previously worked with QGIS develoers to get IAU2000 support into QIS. We plan to do so again to get the expanded IAU2000 support and IAU2009 support into QGIS [9].

Once the next IAU planetary coordinates report is official, support for the IAU2015 CRS namespace will be added to Lunaserv.

References: [1] Estes, N. M., et al.; LPSC 44; p. 2609; 2013. [2] Rossi, A. P., et al.; volume 47; p. 1422; 2016. [3] Russell, C. T., et al.; *Space Science Reviews*; 163(1):3; doi:10.1007/s11214-011-9836-2; 2011; ISSN 1572-9672. [4] gRPC Dev. Team; *gRPC*; Google, Inc.; 2016. [5] Protocol Buffers Dev. Team; *ProtoBuf*; Google, Inc.; 2016. [6] Miconi, C. E., et al.; in *Planetary Data Workshop*; volume 1846; 2015. [7] Hare, T. M., et al.; volume 37; 2006. [8] Archinal, B. A., et al.; *Celestial Mechanics and Dynamical Astronomy*; 109(2); doi: 10.1007/s10569-010-9320-4; 2010. [9] Estes, N. M., et al.; in *Lunar and Planetary Science Conference*; volume 45; 2014.

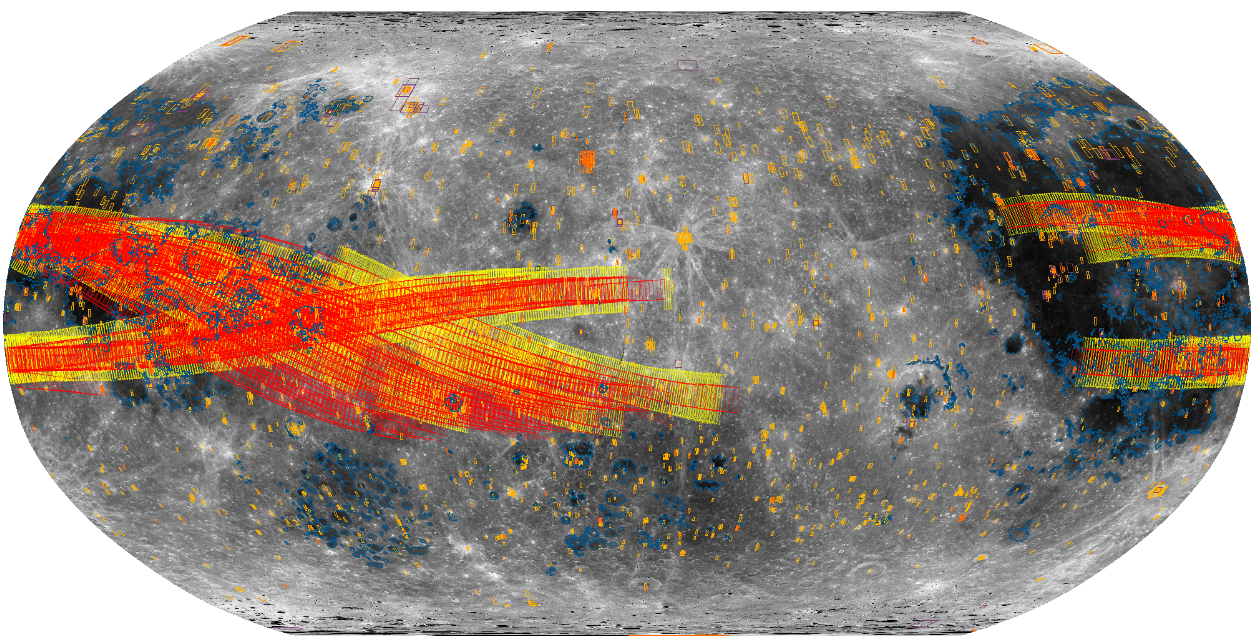

Figure 2: LROC WAC normalized reflectance map using the newly supported CRS definitions IAU2000:30128 and IAU2009:30128 which is the Robinson projection for the Moon, centered on 180° longitude, overlaid with footprints from Apollo metric and panoramic cameras, LROC RDR footprints for Anaglyphs, Shapefiles, ROIs, and DTMs.