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Interoperability in planetary research for geospatial data analysis

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ABSTRACT

For more than a decade there has been a push in the planetary science community to support interoperable methods for accessing and working with geospatial data. Common geospatial data products for planetary research include image mosaics, digital elevation or terrain models, geologic maps, geographic location databases (e.g., craters, volcanoes) or any data that can be tied to the surface of a planetary body (including moons, comets or asteroids). Several U.S. and international cartographic research institutions have converged on mapping standards that embrace standardized geospatial image formats, geologic mapping conventions, U.S. Federal Geographic Data Committee (FGDC) cartographic and metadata standards, and notably on-line mapping services as defined by the Open Geospatial Consortium (OGC). The latter includes defined standards such as the OGC Web Mapping Services (simple image maps), Web Map Tile Services (cached image tiles), Web Feature Services (feature streaming), Web Coverage Services (rich scientific data streaming), and Catalog Services for the Web (data searching and discoverability). While these standards were developed for application to Earth-based data, they can be just as valuable for planetary domain. Another initiative, called VESPA (Virtual European Solar and Planetary Access), will marry several of the above geoscience standards and astronomy-based standards as defined by International Virtual Observatory Alliance (IVOA). This work outlines the current state of interoperability initiatives in use or in the process of being researched within the planetary geospatial community.

1. Introduction

The motivation to support common, interoperable data formats, tools and delivery standards is not only to improve access for higher-level products but also to address the progressively distributed nature of ever-increasing data volumes. Terabytes of data are available for nearly all extraterrestrial bodies and some of their moons. The use of standardized formats and delivery methods have been successfully adopted by many planetary facilities. For example, the strength of using an Open Geospatial Consortium (OGC) standardized approach is that it provides consistent access to data and services that are distributed across these facilities. Data-streaming standards are well-supported by sophisticated tools used in both Geographic Information Systems (GIS) and specialized applications for the analysis of remotely sensed data (Madden, 2009). In addition, data streaming standards enable mapping applications in web browsers which not only facilitate on-line science applications but also public use (e.g., the recent EU-FP7 funded iMars web-GIS dedicated to change detection on Mars, Walter et al., 2017). Adoption of a few of these OGC standards within the Virtual European Solar and Planetary Access (VESPA) effort will not only enhance their reach but also improve the overall Virtual Observatory (VO) efficiency by upgrading existing VO standards to adapt them for planetary sciences. A major goal for VESPA will be the addition of these geoscience capabilities in existing VO tools providing alternative but popular data mining, retrieval, advanced visualization and data analysis already available in many of the more astronomy-based VO tools (Erard et al., 2014). Herein, we provide an update of planetary geospatial interoperability initiatives, and examples of their successful application.

The most obvious difference between extraterrestrial data sets and terrestrial data sets is simply the shape or size of the planetary body (Greeley and Batson, 1990). For example, nearly all larger bodies in our solar system have defined geodetic parameters, documented by the International Astronomical Union (IAU), allowing capable mapping applications to study these bodies. Recognizing the need for standardized geodetic control on planetary bodies, the IAU established the Working Group on the Cartographic Coordinates and Rotational Elements of Planets and Satellites in 1976 (Archinal et al., 2011). This

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group reports every 3–5 years on the preferred rotation rates, spin axes, prime meridians, and reference surfaces for planets and satellites, which helps ensure that digital mapping endeavors are effectively comparable. This planetary standards group provides the critical foundation for the implementation of all the initiatives described below.

Discussed in this report are some of the different interoperable initiatives within the planetary community including interoperable raster formats and tools, web mapping standards, the communication of coordinate reference systems, cartographic mapping standards, and data portals.

2. Interoperable initiatives

2.1. Interoperable raster formats

Most planetary data acquired by both NASA and non-US spacecraft are archived in a Planetary Data System (PDS) format (McMahon, 1994). The PDS is managed by NASA Headquarters' Planetary Sciences Division and consists of a collection of external facilities to support archiving and distribution of planetary data. The bulk of the PDS data holdings are cataloged in their original raw instrument form, however, to best use these data sets within GIS applications, they should first be spatially referenced to the planetary body. Unfortunately, the PDS format, while well-documented with its focus on long-term availability of the archives, is not widely recognized by mapping applications although support is improving. Two formats which have been targeted for their planetary support and are now commonly used in the community include GeoTIFF and GeoJPEG2000.

2.1.1. GeoTIFF

Probably the most popular geospatial format is GeoTIFF. The GeoTIFF format, fully within the public domain, was created by Dr. Niles Ritter in the 1990s during his term at the Jet Propulsion Laboratory (Ritter and Ruth, 2000). GeoTIFF makes use of geospatial tags embedded within the TIFF file format. It is one of the only image formats which allow the flexibility to support tag structures without causing issues for applications that do not support those tags. The image format can support 8-bit grayscale images, and up to 16, 32 and 64-bit floating point elevation models. TIFF also supports a variety of compression and tiling options to increase the efficiency of image reading and online distribution. The BigTIFF extension allows single images to be greater than 4 gigabytes.

2.1.2. GeoJPEG2000

Although support might be retracted for version 4 of the standard, PDS has approved the use of the JPEG2000 format in the PDS3 standard. This format supports the exact same tags as the GeoTIFF format but it is stored within a Universally Unique Identifier (UUID) container. When utilized, this format is informally called GeoJPEG2000 (also GeoJP2™). In 2008, University of Arizona's Mars HiRISE instrument team was the first mission to release their map-projected PDS archives using a hybrid method combining the use of the GeoJPEG2000 standard and a detached PDS label (McEwen et al., 2007). The simple text PDS label is necessary to hold required PDS metadata, for example, author, instrument particulars, or mission dates which are not suitable for the geospatial container.

While this hybrid approach (detached PDS label and imbedded geospatial container) sounds like the best of both worlds, the JPEG2000 format does not have broad support for 32-bit floating point values. It is also unfortunate that the open Jpeg2000 libraries (e.g., OpenJPEG or Jasper) are still lacking in capabilities and speed to proprietary solutions like the Kakadu library (http://kakadusoftware.com/).

2.1.3. GeoFITS

The Flexible Image Transport System (FITS) has been defined for data acquisition and archiving in astronomical observatories and is used for spatial telescope data. FITS is one of the standard formats in the Virtual Observatory (VO). It is compatible with PDS archiving specifications and is supported by a large number of open libraries and software tools. The format has benefited from the well-established CFITSIO library (Pence, 1999) which provides simple high-level routines for reading and writing FITS files and is today well supported by the community driven software development project AstroPy (http://www.astropy.org/). Unfortunately, this format is not currently widely used within the planetary domain but there are initiatives to extend the FITS standard to support geospatial tags. This update to the standard, informally called GeoFITS (Marmo et al., 2016), could be an opportunity to allow more seamless sharing of data across the astronomy and planetary domains and potentially homogenize methods from acquisition to visualization.

2.2. Interoperable GDAL-based tools

The U.S. Geological Survey's Astrogeology Science Center (ASC) is a major contributor of software for cartographic data processing in support of National Aeronautics and Space Administration (NASA) missions and research programs, including the Planetary Program, Code S flight projects, research and data analysis projects, and the PDS (Hare et al., 2014). ASC supports the Integrated Software for Imagers and Spectrometers (version 3, ISIS3), a specialized image processing package for working with planetary image data (Keszthelyi et al., 2014; Edmundson et al., 2012). While ISIS3 can ingest and export several different formats, it is only able to process in its own specialized image format. In 2006 and 2007, PDS and ISIS3 format support was added into the Geospatial Data Abstraction Library (GDAL) to improve interoperability with other applications. This added capability to GDAL opened up these very planetary-specific formats for conversion and more importantly direct use within several mapping applications.

2.2.1. GDAL

GDAL, released by the Open Source Geospatial Foundation (OSGeo), offers powerful capabilities for converting and processing planetary data. GDAL is a format translation library for geospatial raster and vector data (GDAL, 2016). In addition to the aforementioned PDS and ISIS3 reader, GDAL also supports other planetary formats including ISIS2, and more recently the Video Image Communication and Retrieval (VICAR) format (Walter and van Gasselt, 2014). Mapping applications, which utilize the GDAL library for raster I/O (Input/Output), can directly access these formats. This has greatly reduced the need to standardize on a single format. And with GDAL's support for dozens of additional formats, it has allowed the community to more easily collaborate across groups that may prefer to work in differing formats, either due to their preference or software requirements. For applications that do not use GDAL for I/O, the bundled routines released with GDAL can be used to convert these formats into more universal geospatial formats (e.g., GeoTIFF).

2.2.2. Desktop GIS and GDAL

Some popular geospatial applications with GDAL support include QGIS, GRASS GIS, gvSIG, Esri's ArcMap and ArcGIS Pro, and Generic Mapping Tools (GMT). While Esri's applications are commercial, all the others are Free Open Source (FOSS) software. In particular, GRASS GIS and GMT implement a very large number of tools for geoprocessing. Similarly, gvSIG and QGIS contain a wide range of geoprocessing tools but also feature user friendly graphical user interfaces. ArcMap and ArcGIS Pro support both geoprocessing and a graphical user interface and additionally support the required symbologies for proper geologic map publication (see Section 2.5). It is not that the other applications cannot support these symbologies but no one has invested the time to convert the needed symbologies for geologic maps. Fortunately, an initiative is underway to import these symbologies for QGIS but the