Approximately every 3 years since 1979, the Working Group on Cartographic Coordinates and Rotational Elements (hereafter the "WG") of the International Astronomical Union (IAU) has issued a report recommending how coordinate systems and related parameters (body orientation and shape) should be established and maintained, and used for making cartographic products (maps) of solar system bodies. These recommendations are intended to facilitate the use and comparison of multiple datasets by promoting the use of a standardized set of mapping parameters. Such recommendations are also open to further modification when indicated by community consensus and revision of parameter values. The WG encourages input and is available to assist users, instrument teams, and missions. See our website [1] for additional information. This abstract is intended to draw attention to the WG's efforts, to our previous reports (e.g. [2]), and to the 2015 report now nearing completion. We would also like input on the best ways to share the recommendations from the report with the community, e.g. in electronic forms beyond the primary publication itself. Currently, a subset of the parameters recommended for use by the WG is distributed by others, e.g. by the NASA Planetary Data System NAIF node, in their "Planetary Constants Kernel" (PCK) [3]. A further reduced subset in the form of recommended body spheroidal shape information is also available via Open Geospatial Consortium (OGC) Well-Known Text (WKT) [4] and Esri WKT [5] projection files and an OGC web service called SECORE [6] which is currently being tested. To better support the community, several questions should be asked. (1) Are these current compilations useful? (2) Are there other formats that would be useful to adopt or create to provide easier access to the data? (3) How should different versions (updates) of the recommendations be provided? (4) Is a complete update with every report desirable, or only constants that are changed at the time of a given report, and at what resolution are the changes important, e.g. by body, or individual equation or number? (5) Would it be useful to apply some designation at one of these levels, such as a DOI citation? Any input from workshop participants is welcome.

References
The PSA uses Postgres/PostGIS as a tool to store and process geometrical information coming from ESA planetary datasets. PostGIS is an open source software program that adds support for geographic objects to the PostgreSQL object-relational database. PostGIS follows the Simple Features for SQL specification from the Open Geospatial Consortium (OGC). This technology facilitates the task of having geometrical information stored in the PSA and ready to be processed by GIS tools. The proper geometrical handling and ingestion in the PSA will be of crucial importance for future missions like ExoMars Rover and Surface Platform, where we will keep track of the Rover route across Mars using the GIS Map and explore 2D and 3D visualisation of the data captured by the camera instruments together with footprints generated by other planetary missions like Mars Express and ExoMars16.
<table>
<thead>
<tr>
<th>Barnes</th>
<th>Robert</th>
<th>Imperial College London</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Imperial College London, UK,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Aberystwyth University, UK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Joanneum Research, Austria,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4) School of Physical Sciences, Open University, UK,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5) VRVis, Austria,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(6) Birkbeck, University of London, UK,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(7) STFC Rutherford Appleton Laboratory, UK,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(8) Mullard Space Science Laboratory, University College London, UK.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A key focus of planetary rover missions is to use panoramic stereo camera systems to image outcrops along rover traverses, in order to characterise their geology in search of ancient life. 3D reconstructions of this data are processed for quantitative analysis. The Mars Utah Rover Field Investigation (MURFI 2016) was a Mars Rover field analogue mission run by the UK Space Agency (UKSA) in collaboration with the Canadian Space Agency (CSA). It consisted of a science team based in Harwell, UK, and a field team including an instrumented Rover platform at the field site near Hanksville (USA). The Aberystwyth University PanCam Emulator 3 (AUPE3) camera system was used to collect stereo panoramas of the terrain the rover encountered during the field trials. Stereo-imagery processed in PRoViP is rendered as Ordered Point Clouds (OPCs) in PRo3D, enabling the user to zoom, rotate and translate the 3D outcrop model. Interpretations are digitised directly onto the 3D surface, and simple measurements can be taken of the dimensions of the outcrop and sedimentary features, including grain size and the dip and strike of bedding planes. In-simulation, AUPE3 was mounted onto the rover mast, collecting 16 stereo panoramas over 9 ‘sols’. 5 out-of-simulation datasets were collected in the Hanksville-Burpee Quarry. Stereo panoramas were processed using an automated pipeline and data transfer through an ftp server. PRo3D was used for visualisation and analysis of this stereo data. Features of interest in the area could be annotated, and their distances to the rover position measured to aid prioritisation of science targeting. Interpretation and measurement of the sedimentological features of the outcrops was also carried out. Development of Pro3D in preparation for the ExoMars 2020 and NASA 2020 missions will be centred on data validation and tool development. Collection of in-situ field data by a human geologist allows for direct comparison of viewer-derived measurements with those taken in the field.

Acknowledgements: The research leading to these results has received funding from the UK Space Agency Aurora programme and the European Community’s Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 312377 PRoViDE, ESA PRODEX Contracts 4000105568 "ExoMars PanCam 3D Vision" and 4000116566 "Mars 2020 Mastcam-Z 3D Vision".

<table>
<thead>
<tr>
<th>Burtsev</th>
<th>Mikhail</th>
<th>IKI/Russia</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Balashov, O. Batanov, M. Burtsev, V. Nazarov, V. Tolpin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space Research Institute of the Russian Academy of Sciences (IKI)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The report describes the features of the GEOSMIS technology developed by the Space Research Institute of the Russian Academy of Sciences (IKI). It is designed for creation of spatial data analysis user interfaces for web-based remote monitoring systems, especially for working with satellite data. The main goal of the technology is to provide the experts with both effective and convenient tools for remote data access, online processing and analysis just with common web browsers. Its’ main features are integration of the access and analysis tools with large distributed multi-dimensional archives of various satellite data and derived data products and flexibility of toolset creation and expansion. The described technology is used for various operational remote monitoring systems and has proven itself stable and effective. Now it is proposed for the development of the ExoMars, Mars Express and other Mars missions data access, visualisation and analysis toolkit. The presentation includes the description of GEOSMIS main capabilities, structure and architecture of integrated software solutions. The main focus is on the issues of development techniques for creation of satellite data analysis interfaces with use of IKI’s software framework. The technology’s capabilities are illustrated with IKI’s experience in creation of several specialized information systems.
During the last two decades, a fleet of planetary probes has acquired several hundred gigabytes of images of planetary surfaces. Since 1996, Mars has been particularly well covered thanks to the Mars Global Surveyor, Mars Odyssey, Mars Express and Mars Reconnaissance Orbiter spacecrafts. HRSC, CTX, HiRISE instruments allowed the computation of Digital Elevation Models with a resolution from hundreds of meters up to 1 meter per pixel, and corresponding orthoimages with a resolution from few hundred of meters up to 25 centimeters per pixel. On the ground, Spirit, Opportunity and Curiosity rovers have acquired tens of thousands of color and stereoscopic images. The integration of such huge data sets into a system allowing user-friendly manipulation either for scientific investigation or for public outreach can represent a real challenge. We are investigating how innovative tools can be used to freely fly over reconstructed landscapes in real time, using technologies derived from the game industry and virtual reality. We have developed an application based on a game engine, using planetary data, to immerse users in real martian landscapes. The user can freely navigate in each scene at full spatial resolution using a game controller. The actual rendering is compatible with several visualization devices such as 3D active screen, virtual reality headsets or 3D CAVE environment.
Introduction: An International Space Science Institute (ISSI) team project has been convened to study the northern plains of Mars. It uses geomorphological mapping to compare ice-related landforms in the three northern plains basins: Acidalia Planitia, Arcadia Planitia, and Utopia Planitia. This becomes problematic when attempting regional or global-scale studies of meter-scale landforms. However, we needed to map the distribution of such landforms across very large continuous latitudinal swath in the Acidalia, Arcadia, and Utopia areas (see results [2-3]). Rather than traditional mapping with points, lines and polygons, we used a grid "tick box" approach to efficiently determine where specific landforms are preferentially localized (see [4] for details).

Method: We conducted a geomorphological study of all landforms along a 3 stripes from 25°N to 75°N latitude of 250 km wide. The goals are to: (i) map the geographical distribution of the ice-related landforms; (ii) identify their association with subtly-expressed geological units and; (iii) discuss the climatic modifications of the ice-rich permafrost in UP. Our work combines a study with CTX (5-6 m/pixel) and MOLA, supported by higher resolution HiRISE (25 cm/pixel) and a comparison with analogous landforms on Earth. The mapping strips were divided into grid of squares for each study area, each approximately 20×20 km [4].

Preliminary Results: A grid-based mapping was finally used for rapidly determining the spatial distributions of small features over very large areas [5]. Then the basemap data are systematically examined, grid-square by grid-square 20×20 km [4] at full resolution. Over the 3 regions, ice-related landforms were identified and recorded as being either "present", "dominant", or "absent" in each sub-grid square displayed in a Cassini projection. The end result of the mapping is a "raster" showing the distribution of the various different types of landforms across the whole strip providing a digital geomorphological map. Conclusion: We find that grid-based mapping provides an efficient solution to the problems of mapping small landforms over large areas, by providing a consistent and standardised approach to spatial data collection. Acknowledgements: This work is a joint effort of an International Team sponsored by ISSI (International Space Science Institute).

References:
Due to the increasing volume of the returned data from space mission, the human search for correlation and identification of interesting features becomes more and more unfeasible. Statistical extraction of features and machine learning methods will increase the scientific output of remote mission and aid the discovery of yet unknown feature hidden in dataset. Those methods exploit algorithm trained on features from multiple instrument, returning classification maps that explore infra-dataset correlation, allowing for the discovery of unknown features. We present two applications, on Mercury and on Vesta. Mercury surface has been mapped in the 400-1145 nm wavelength range by the Mercury Atmospheric and Surface Composition Spectrometer (MASCS) instrument during orbital observations by the MESSENGER spacecraft. We have conducted k-means unsupervised hierarchical clustering to identify and characterize spectral units from MASCS observations. The results display a dichotomy, with two spectrally distinct groups: polar and equatorial units, possibly linked to compositional differences or weathering due to irradiation. To explore possible relations between composition and spectral behavior, we have compared the spectral provinces with elemental abundance maps derived from MESSENGER's X-Ray Spectrometer (XRS). Nonetheless, by comparing the VIS/near-infrared MASCS and XRS datasets and investigating the links between them, we can provide further clues to the formation and evolution of Mercury's crust. For the Vesta application, we explored several Machine Learning techniques: multi-step clustering method is developed, using an image segmentation method, a stream algorithm, and hierarchical clustering. The DAWN Visible and infrared spectrometer (VIR) data from Vesta is are testbest for our algorithm. The algorithm successfully separates the Olivine outcrops around two craters on Vesta’s surface[1]. New maps summarizing the spectral and chemical signature of the surface could be automatically produced.

References:

<table>
<thead>
<tr>
<th>Delaa</th>
<th>Omar</th>
<th>Geops</th>
</tr>
</thead>
</table>

Geographical Information Systems (GIS) are favored tools in geologist community to analyze planetary surfaces. The growing amount of available data and the increasing of distant interactions between scientists make the Web an ideal place to develop collaborative tools for planetary science. Unfortunately, current GIS tools, including those available on the Web, are not adapted for planetary sciences since they do not take into account specific definitions for other planets than Earth (e.g. reference surface, coordinate systems, projections). We will present our Web GIS application for planetary sciences. This application is based on the Cesium framework. Cesium is an open-source JavaScript library for world-class 3D globes and maps. It is based on the WebGL technology and contains several tools for Earth mapping. For Planetary mapping needs, we introduced additional features to Cesium in order to allow users to map other planets/satellite of the solar system. OGC codes for each Solar System bodies have been added.

For a given planet or satellite, several layers can be displayed in the same time using easily configurable widgets. Virtual Observatory Data can also be displayed. Using Cesium native features, we developed a dynamical drawing system to allow the user to draw lines, circles and polygons on the surface of the current body and save its mapping work in a geoJson format. Furthermore, we offer the possibility to flag entities displayed on the globe with a custom legend (see Anthony Langain presentation for a use case).

Current developments are centered onto map projections. Actually, Cesium support only the Geographical and Mercator projections. We are implementing the Sterographic projection for a polar view of planets and satellites.

---

**Omar-A_web_GIS...y_sciences.pdf**
Geographical information systems (GIS) is becoming increasingly used for planetary science. GIS are computerised systems for the storage, retrieval, manipulation, analysis, and display of geographically referenced data. Some data stored in the PSA have spatial metadata associated to them. To facilitate users in handling and visualising spatial data in GIS applications, the PSA should support interoperability with interfaces implementing the standards approved by the Open Geospatial Consortium (OGC). These standards are followed in order to develop open interfaces and encoding that allow data to be exchanged with GIS Client Applications, well-known examples of which are Google Earth and NASA World Wind, as well as open source tools such as Openlayers (2D) and Cesium (3D). Access to this data for use in World Wide Web applications can be provided through OGC Web Service (OWS) implementations. An existing open source server is GeoServer, an instance of which has been deployed for the PSA, that uses the OGC standards to allow the sharing, processing and editing of data and spatial data through the Web Feature Service (WFS) standard. Our final goal is to convert the recently released PSA (accessible through http://psa.esa.int) into an archive which enables science exploitation of ESA’s planetary missions datasets. This can be facilitated through the GIS framework, offering interfaces (both web GUI and scriptable APIs) that can be used more easily and scientifically by the community, and that will also enable the community to build added value services on top of the PSA.

<table>
<thead>
<tr>
<th>Docasal Ruben</th>
<th>ESAC/ESA Spain</th>
</tr>
</thead>
<tbody>
<tr>
<td>R. Docasal1, I. Barbarisi1, A. Macfarlane1, C. Rios1, J. Saiz1, P. De Teodoro1, F. Vallejo1, C. Arviset1, S. Bess1, C. Valla1, G. De Marchi2, M. Barthelemy1, D. Cola1, M. Costa1, D. Fraga1, E. Grotheer1, D. Heather1, T. Lim1, S. Martinez1</td>
<td></td>
</tr>
<tr>
<td>1ESA/ESAC Camino Bajo del Castillo s/n, Ur. Villafranca del Castillo, 28692 Villanueva de la Canada, Madrid, Spain; 2ESA/ESTEC, 2200 AG Noordwijk, Netherlands</td>
<td></td>
</tr>
</tbody>
</table>

The GIS data model for a generic mapping spectrometer

<table>
<thead>
<tr>
<th>Felli Giulia</th>
<th>La Sapienza, University of Rome</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Frigeri Alessandro</th>
<th>INAF Rome</th>
</tr>
</thead>
<tbody>
<tr>
<td>The GIS data model for a generic mapping spectrometer</td>
<td></td>
</tr>
</tbody>
</table>

2017_Roscoff-Ale...roFrigeri_LT.pdf RDOCASAL_20170...ny_Roscoff.pdf
Here we introduce the concept of a planetary spatial data infrastructure (PSDI) and provide ongoing efforts regarding the creation and maintenance of a broad range of PSDI goals. Spatial data are any data with sufficient positional information such that the data can be located on a body (e.g., Mars). As described in the existing U.S. Federal initiative [1], the National Spatial Data Infrastructure (NSDI) consists of "The technology, policies, standards, human resources, and related activities necessary to acquire, process, distribute, use, maintain, and preserve spatial data (e.g., information and process discovery, publishing data, publishing symbol libraries, query filtering, data fusing, Earth imaging, photogrammetry, location processing, and spatial analysis)". Though the NSDI report and a similar initiative in Europe called INSPIRE [2], clearly focuses on terrestrial applications, we find that that rationale, background, and resultant organizational themes and recommendations are entirely portable to the planetary science domain.

References


Hare_GIS_Resour...oscoff_PSDI.pdf
Impact craters on terrestrial bodies are useful to date geological units and help us to the comprehension of the resurfacing processes active on planetary surfaces. There are many crater databases available for Mars but the most complete is the Stuart Robbins one [1] which counts more than 380 000 craters larger than 1 km on the red planet. This database is presented as being manual, without automatic identification, and adapted to surface dating. However, its using reveals a large number of errors may distort results obtained on unit dating or other statistical studies. Two categories of errors could be identified: a confusion between craters and other types of circulars structures, a taking into account ghosts and secondaries craters not explicitly identified as such. The aim of this study is to check one by one each crater of the Robbins’ database and to classify each one among five categories: 1-Valid corresponding to a crater without specific characteristics, 2-Invalid corresponding to a structure that is not impact crater, 3- Ghost crater when an impact structure is covered by another geological unit [2], 4-Secondary crater corresponding to an impact feature formed from the ejection of materials during the formation of a larger crater [3] 5-Layered crater corresponding to a crater whose ejecta are lobate [4]. Checking and manually classifying more than 380 000 craters represent a huge work in term of time. Cesium Viewer is a collaborative and interoperable platform making possible remote interaction in a reviewer consortium. About thirty people from eleven laboratories are working on this project. Participants have received detailed procedure for classification and one or several geojson files containing the craters of the Robbins’ database that they have to check. The project started in August 2016 and for the moment, 60% of the database has been checked which corresponds to about 235 000 craters. Among craters that have been checked, 3.8% of them have been identified as being false detections. Sometimes these false detections are not associated with any circular structures. However the most important part of errors is associated with geological structures can be confused with impact craters (tectonic or periglacial features). When the database will fully revised, a comparative study between Robbins’ and ours will be performed. Several dating tests will also carried out. An online distribution of the database will also be done.

References

NASA’s Lunar and Planetary Mapping and Modeling Program (LMMP) produces a suite of online visualization and analysis tools. Originally designed for mission planning and science, these portals also offer great benefits for education and public outreach (EPO), providing access to data from a wide range of instruments aboard a variety of past and current missions. There is currently three web portals in the program: the Moon Trek (http://moontrek.jpl.nasa.gov), Vesta Trek (http://vestatrek.jpl.nasa.gov), and Mars Trek (http://marstrek.jpl.nasa.gov). Portals for additional planetary bodies are planned (e.g., Ceres Trek, CG Trek, and Phobos Trek). The portals provide analysis tools for measurement and study of planetary terrain. Planetary mapping is a critical component of these portals. The discussion of mapping standardization will be of a great interest to the expansion of this Program. Demonstration of these web portals will be given.
Hyperspectral analysis of CRISM images using PlanetServer Python API.

R. Marco Figuera (1), A. Halder (1), M. Minin (1), A. P. Rossi (1)

(1) Jacobs University Bremen, Department of Physics and Earth Sciences, Bremen, Germany

Mineralogical characterization using band math combination on hyperspectral imagery has been since long time used. In Mars, the so called CRISM products [1] are used on CRISM TRDR imagery. Commonly this has been pursued by using IDL code on the non open-source tool ENVI thus forcing researchers to buy licenses to analyze the mineralogy. PlanetServer [2] is the Planetary Data Analysis service of the Horizon 2020 Earthserver project and is made up of a web client [3] and a Python API [4]. Here we present an open-source Python API in the form of a Jupyter Notebook allowing the user to achieve such analysis and add them to existing Python pipelines. The CRISM cubes are stored using the Array DataBase Management System (DBMS) Raster Data Manager (Rasdaman) [5]. PlanetServer is equipped with two hyperspectral analysis tools: Spectral analysis of a pixel and band math RGB combinations. Both analyses use the Web Coverage Processing Service (WCPS) OGC standard [6], an SQL-like language that is capable to query information along an image cube and perform RGB combinations. The Python API has been divided in 3 parts: 1. A lookup table which links band names to their corresponding wavelengths and vice-verse. 2. A list of all the CRISM products in [1] written in WCPS. 3. The user input parameters: Coverage ID and the list of CRISM products in the corresponding RGB channel. Given the user input parameters, the PlanetServer Python API will output an image with the selected RGB combination. An example of collaboration can be found in the use of Matisse [7] together with PlanetServer in order to perform band math and create output mosaics. Ongoing work includes the option of performing spectral analysis of a pixel by clicking the output image in the notebook and automatically extracting the spectra.

References

Minin, Mikhail

Physics and Earth Sciences / Jacobs University / Germany

Status update on interoperability of VO and GIS.

M. Minin (1), A. P. Rossi (1), C. Marmo (2)

(1) Jacobs University Bremen, Germany (2) GEOPS, Université Paris-Sud, France

Geospatial data collected by remote sensing experiments can be accessed via Open Geospatial Consortium (OGC) data portals [1] or through Virtual Observatory (VO) tools [2]. The latter is being developed as part of EPN-RI H2020 VESPA [3]. As part of VESPA JRA4 [4] are developing interoperability between the OGC-compliant GIS tools and VO [5], and provide access to geospatial data via a Table Access Protocol (TAP) [6].

To improve planetary data distribution, we have upgraded DaCHS /enptap.rd mixin [7] to meet the EPN-TAP 2.0 standard and made it accessible at [8]. We have created a JavaScript wizard for generating new resource descriptors using a form-based interface, accessible at [9]. We used the new mixin and the wizard to populate tables on our dedicated DaCHS server [10]. We serve tables mars_craters, usgs_wms, and crism; source data for which was obtained from [11], [12], and [13] respectively. The input data was made to adhere to EPN-TAP 2.0 standard, and the epn1 server was registered with VO Registry of Registries [14], making it accessible to VO applications [15]. The access_url field of the table usgs_wms points to the GetCapabilities request, which can be used to open the map in QGIS [16]. Additionally, a web interactive preview based on OpenLayers3 [17] is provided for each layer. We provide a subgranule access to crism data using a JavaScript based interface, which also allows to send individual spectra in a Full Spectrum File (.fus) format to SAMP [18] enabled applications such as CASSIS [19]. The footprints of crism images and mars_craters granules can be transmitted via SAMP to VO applications such as Aladin [20].

To provide VO to GIS portability, we have developed a QGIS plugin which provides QGIS with SAMP capabilities. This makes it possible to send tables from VO data mining applications such as TapHandle or TOPCAT [21] to QGIS. The QGIS plugin interprets VO table sent via SAMP and converts it to a geospatial format, such as GeoJSON or SpatiaLite, with granules becoming features whose geometry is defined by their footprints. The dataset referenced by the granule can then be downloaded from access_url, or downloaded and georeferenced in a single step using another plugin we have developed.

To provide VO to GIS portability, we have developed a plugin which can send a command from QGIS to Aladin, for instance to display a polygon shape. Also, a python parser for WMS GetCapabilities XML has been developed to facilitate collection of data from WMS servers.

The usage example of our services has been described on GitHub [22]. The ongoing effort is to further improve and enhance the QGIS-SAMP plugins, as well as expanding the data available on EPN1.

References

One aim of the NASA Dawn mission is to generate global geologic maps of the asteroid Vesta and the dwarf planet Ceres. To accomplish this, the Dawn Science Team followed the technical recommendations for cartographic base map production. The geological mapping campaign of Vesta was completed and published, but mapping of the dwarf planet Ceres is still ongoing. The tiling scheme for the geological mapping is the same for both planetary bodies and for Ceres it is divided into two parts: four overview quadrangles (Survey Orbit, 415 m/pixel) and 15 more detailed quadrangles (High Altitude Mapping HAMO, 140 m/pixel). The most detailed view can be expected within the 15 mapping quadrangles based on HAMO resolution and completed by the Low Altitude Mapping (LAMO) data with 35 m/pixel. For the interpretative mapping process of each quadrangle one responsible mapper was assigned. Unifying the geological mapping of each quadrangle and bringing this together to regional and global valid statements is already a very time intensive task. However, another challenge that has to be accomplished is to consider how the 15 individual mappers can generate one homogenous GIS-based project (w.r.t. geometrical and visual character) thus produce a geologically-consistent final map. Therefore, the computer-based GIS environment used for the interpretative mapping process must be designed in a way that it can be adjusted to the unique features of the individual investigation areas. Within this contribution a template will be presented that uses standards for digitizing, visualization, data merging, and synchronization and adopted these to the individual requirements on the multiuser mapping project of Ceres. Using this template the map results are more comparable and better controllable. Furthermore, merging and synchronization of the individual maps, map projects and sheets will be far more efficient. Beside the specific use case Ceres, the template can be easily adapted to any other planetary body and or within future discovery missions (e.g., Lucy and Psyche which were selected to explore the early solar system by NASA) for generating reusable map results.
OpenPlanetaryMap (OPM) is a new OpenPlanetary [1] project, supported by CARTO [2], to build an Open Planetary Mapping and Social platform for planetary researchers and mappers, space enthusiasts and students, educators and storytellers. Our goal is to enable them to easily and collaboratively create and share location-based knowledge and maps of others planets of our Solar System. The project is a follow-up and evolution of the "Where On Mars?" outreach project [3].

References

As the world becomes increasingly interconnected, there is a greater need to provide interoperability with software and applications that are commonly being used globally. For this purpose, the development of the Planetary Science Archive (PSA), by the European Space Astronomy Centre (ESAC) Science Data Centre (ESDC), has been focused on building a modern science archive that takes into account internationally recognised standards in order to provide access to the archive through tools from third parties, for example by the NASA Planetary Data System (PDS), the VESPA project from the Virtual Observatory of Paris as well as other international institutions.

The protocols and standards currently being supported by the recently released new version of the Planetary Science Archive at this time are the Planetary Data Access Protocol (PDAP), the EuroPlanet-Table Access Protocol (EPN-TAP) and Open Geospatial Consortium (OGC) standards.

We explore these protocols in more detail providing scientifically useful examples of their usage within the PSA.
The New Planetary Science Archive (PSA): Exploration and Discovery of Scientific Datasets from ESA’s Planetary Missions

Abstract

C. Vallat1, S. Besse1, I. Barbarisi1, C. Arviset1, M. Barthelemy1, D. Coia1, M. Costa1, R. Docasal1, D. Fraga1, E. Grotheer1, D. Heather1, T. Lim1, A. Maclaren1, S. Martinez1, C. Rios1, F. Vallejo1, J. Saiz1

1ESA/ESAC Camino Bajo del Castillo s/n, Ur. Villafranca del Castillo, 28692 Villanueva de la Canada, Madrid, Spain; 2ESA/ESTEC, 2200 AG Noordwijk, Netherlands

The Planetary Science Archive (PSA) is the European Space Agency’s repository of science data from all planetary science and exploration missions. The PSA provides access to scientific datasets through various interfaces at http://psa.esa.int. All datasets are scientifically peer-reviewed by independent scientists, and are compliant with the Planetary Data System (PDS) standards. The PSA is currently implementing a number of significant improvements, mostly driven by the evolution of the PDS standard, and the growing need for better interfaces and advanced applications to support science exploitation.

The newly designed PSA will enhance the user experience and will significantly reduce the complexity for users to find their data promoting one-click access to the scientific datasets with more customized views when needed. This includes a better integration with Planetary GIS analysis tools and Planetary interoperability services. It will be also up-to-date with PDS3 and PDS4 standards. Users will have direct access to documentation, information and tools relevant to the scientific use of the dataset.

The new PSA interface was released in January 2017. The home page provides a direct and simple access to the scientific data, aiming to help scientists to discover and explore its content. The archive can be explored through a set of parameters that allow the selection of products through space and time. Quick views provide information needed for the selection of appropriate scientific products.

In the coming months, the PSA team will focus their efforts on developing a map search interface using GIS technologies to display ESA planetary datasets, an image gallery providing navigation through images to explore the datasets, and interoperability with international partners. This will be done in parallel with additional metadata searchable through the interface (i.e., geometry), and with a dedication to improve the content of 20 years of space exploration.
The detailed mapping of fresh simple craters for their structure, geometry, morphology, and mineralogy will help us to understand the early stage modification processes of simple craters on earth and other planetary surfaces.

The Lunar Reconnaissance Orbiter (LRO) Narrow Angle Camera (NAC) datasets having ~0.5 m/pixel spatial resolution and Chandrayaan-1 Moon Mineralogy Mapper (M3) hyperspectral datasets having spatial resolution of 140 m/pixel are used to study the morphology and mineralogy of the impact features.

In this study, we identified 37 craters out of ~1349 craters of lunar surface that falls under the diameter of 3-6 km and also displays freshly preserved impact structures. Interestingly, all of the 37 craters are found in the lunar nearside. 30 out of 37 are formed in the basaltic terrain.

One of these craters is Litchenberg B which has a diameter of ~5 km located at 33.25°N, 61.52°W. It is a fresh crater formed at the boundary of two lava flows in Oceanus Procellarum, namely P9 (~3.47 Ga) and P53 (~1.68 Ga) [1]. This crater preserves various morphological features including melts, fractures, boulders, slumping of wall, the crater floor polygons, detailed ejecta morphology with wrinkled symmetrical crescent ridges, and the rock outcrops in the crater wall showing the successive thin lava flows of Oceanus Procellarum as old as ~3 Ga.

We estimated the absolute model age of this crater using Crater Size-Frequency Distribution (CFSD) and found to be ~17.9±0.6 Ma.

Though terrestrial craters are studied in detail through field geology, these craters have undergone continuous weathering since their formation. One such example is Lonar crater on Earth which is formed in ~65 Ma old Deccan flood basalts at 19°58′N, 76°31′E, near Lonar village in Buldhana district of Maharashtra State in India [2].

Morphologically, Lichtenberg B is comparable to the Lonar crater as both are formed in the flood basalts in Oceanus Procellarum and Deccan plateau respectively. The detailed mapping of both geologic and mineralogic units of Lichtenberg B and other freshly preserved simple craters will give us a window to understand the early impact scenario of Lonar crater. Thus the studies of Lichtenberg B and Lonar will improve understanding of the formation of simple craters in basaltic targets.

MATISSE 2.0, new ideas to sustain planetary sciences

Angelo Zinzi (1, 2), A. Longobardo (3), S. Ivanovski (3), M.T. Capria (3), E. Palomba (3)
(1) ASI Science Data Center, c/o ASI, via del Politecnico snc, 00133, Rome, Italy; (2) INAF-OAR, Via Frascati n. 33, 00078, Monte Porzio Catone (RM), Italy; (3) INAF-IAPS, Via del Fosso del Cavaliere n. 100, 00133, Rome, Italy

The development of MATISSE [1] started in late 2012 with the main aim of providing a useful tool for visualization of data coming from small and irregularly shaped bodies. Therefore, its natural first application was the ESA Rosetta Mission, where a strong collaboration with the VIRTIS [2] science team quickly grew. During these years new applications have been set up, such as the one regarding the NASA Dawn VIR [3] team. Another example is within the Moon Mapping [4] program, the first one that required visualization of large targets urged looking for new solutions.

In the very last months two new features have been implemented and added to the tool, allowing direct querying to the PlanetServer Martian data [5] and integration of tasks designed to improve the quality of the data acquired by imaging spectrometers, such as applications of Akimov equiagonal albedo and photometric correction [6]. Finally, in preparation are dedicated applications concerning the coma dust distribution around comet 67P as seen by GIADA dust analyser onboard Rosetta [7, 8].

Even though its original modular structure really allowed expanding the functionalities in a straightforward way, now more than four years from its first release, MATISSE needs sensible modifications in order to be ready for the upcoming challenges, such as its complete integration within the VESPA Planetary VO project [9].

Therefore in 2017 a completely new version of the tool is planned, making use of all advanced technologies to fulfill the requirements: 1) a new BDMS best suited for geographical data (e.g., PostgreSQL + PostGIS); 2) optimization and parallelization of the algorithms used to process the data; 3) new solutions for online visualization, so that high resolution DTM s and shape models could be correctly viewed directly on the output page, without any need to download data; 4) implementation of standards used by VESPA (e.g., SAMP and EPN-TAP).

This new version of MATISSE will allow not only the visualization of data from the surface of minor bodies, but also an easy way to search and analyse data from a large variety of Solar System exploration missions, following the path already traced by projects such as Open Planetary [10] and Open Universe [11] that currently base some of their developments upon our tool.

Introduction: Web-based planetary image dissemination platforms usually show outline coverages of the data and offer querying for metadata as well as preview and download, e.g. the HRSC Mapserver (Walter and van Gasselt, 2014). Here we introduce a new approach for a system dedicated to change detection by simultaneous visualisation of single-image time series in a multi-temporal context. While the usual form of presenting multi-orbit datasets is the merge of the data into a larger mosaic, we want to stay with the single image as an important snapshot of the planetary surface at a specific time. In the context of the EU FP-7 iMars project we process and ingest vast amounts of automatically co-registered (ACRO) images. The base of the co-registration are the high precision HRSC multi-orbit quadrangle image mosaics, which are based on bundle-block-adjusted multi-orbit HRSC DTM.s. Additionally we make use of the existing bundle-adjusted HRSC single images available at the PDS archives. A prototype demonstrating the presented features is available at http://imars.planet.fu-berlin.de.

Multi-temporal database: In order to locate multiple coverage of images and select images based on spatio-temporal queries, we converge available coverage catalogs for various NASA imaging missions into a relation database management system with geometry support. We harvest available metadata entries during our processing pipeline using the Integrated Software for Imagers and Spectrometers (ISIS) software. Currently, this database contains image outlines from the MGS/MOC, MRO/CTX and the MO/ THEMIS instruments with imaging dates ranging from 1996 to the present. For the MEx/HRSC data, we already maintain a database which we automatically update with custom software based on the VICAR environment.

Web Services with time support: The MapServer software is connected to the database and provides Web Map Services (WMS) and Web Feature Services (WFS) with time support based on the START_TIME metadata attribute. It allows temporal WMS/WFS requests by setting additional TIME parameter values in the request. The values for the parameter represent an interval defined by its lower and upper bounds. As the WMS/WFS time standards only supports one time variable, only the start times of the images are considered. If no time values are submitted with the request, the full time range of all images is assumed as the default.

Dynamic single image WMS: To compare images from different acquisition times at sites of multiple coverage, we have to load every image as a single WMS layer. Due to the vast amount of single images we need a way to set up the layers in a dynamic way – the map server does not know the images to be served beforehand. We use the MapScript interface to dynamically access MapServer’s objects and configure the file name and path of the requested image in the map configuration. The layers are created on-the-fly each representing only one single image. On the frontend side, the vendor-specific WMS request parameter (PRODUCTID) has to be appended to the regular set of WMS parameters. The request is then passed on to the MapScript instance.

Web Map Tile Cache: In order to speed up access of the WMS requests, a MapCache instance has been integrated in the pipeline. As it is not aware of the available PDS product IDs which will be queried, the PRODUCTID parameter is configured as an additional dimension of the cache. The WMS request is received by the Apache webserver configured with the MapCache module. If the file is available in the tile cache, it is immediately committed to the client. If not available, the file request is forwarded to Apache and the MapScript module. The Python script intercepts the WMS request and extracts the product ID from the parameter chain. It loads the layer object from the map file and appends the file name and path of the inquired image. After some possible further image processing inside the script (stretching, color matching), the request is submitted to the MapServer backend which in turn delivers the response back to the MapCache instance.

Web frontend: We have also implemented a web-GIS frontend based on various OpenLayers components. The basemap is a global color-hillshaded HRSC bundle-adjusted DTM mosaic with a resolution of 50 m per pixel. The new bundle-block-adjusted quadrangle mosaics of the MC-11 quadrangle, both image and DTM, are included with opacity slider options. The layer user interface has been adapted on the base of the old layer switcher and extended by foldable and switchable groups, layer sorting (by resolution, by time and alphabetically) and reordering (drag-and-drop). A collapsible time panel accommodates a time slider interface where the user can filter the visible data by a range of Mars or Earth dates and/or by solar longitudes. The visualisation of time-series of single images is controlled by a specific toolbar enabling the workflow of image selection (by point or bounding box), dynamic image loading and playback of single images in a video player-like environment. During a stress-test campaign we could demonstrate that the system is capable of serving up to 15 simultaneous users on its current lightweight development hardware.

Conclusions/Outlook: The iMars webGIS is an expert tool for the detection and visualization of surface changes. We demonstrate a technique to dynamically retrieve and display single images based on the time-series structure of the data. Together with the multi-temporal database and its MapServer/MapCache backend it provides a stable and high performance environment for the dissemination of the various iMars products.

Acknowledgements: This research has received funding from the EU’s FP7 Programme under iMars 607379 and by the German Space Agency (DLR Bonn), grant 50 QM 1301 (HRSC on Mars Express).
<table>
<thead>
<tr>
<th>Name</th>
<th>First Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longobardaro</td>
<td>Andrea</td>
<td>INAF</td>
</tr>
<tr>
<td>Bentley</td>
<td>Mark</td>
<td>OEAW</td>
</tr>
<tr>
<td>Lewando</td>
<td>Myles</td>
<td>Codemacabre</td>
</tr>
<tr>
<td>Ordonez, Etxeberria</td>
<td>Inaki</td>
<td>Universidad del País Vasco</td>
</tr>
</tbody>
</table>