The Abstraction Layer for Ephemerides Library.
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Introduction: The U. S. Geological Survey's Astrogeology Science Center (ASC) has begun developing the Abstraction Layer for Ephemerides (ALE) library to support consistent collection and computation of sensor parameters across sensor models. The library is designed in such a way as to separate data sources and sensor model end-points. To begin, we are implementing NAIF SPICE kernels and ISIS cubes as data sources and ISIS [1] and the USGS Community Sensor Model (USGSCSM) implementation [2] as end-points.

Background: Photogrammetric processing and orthorectification is critical to the analysis of remote sensing data [3]. In support of this, there is a wide range of sensor model standards used by the planetary science community. The ISIS sensor model [1], CAHVOR model [3], Replacement Sensor Model (RSM) [4], and Community Sensor Model (CSM) [2] are just a few examples of sensor model standards used in planetary science. Processing pipelines that use data sets across applications, such as using ISIS to improve sensor pointing and then using SOCET SET to generate a stereo DEM, require consistent sensor parameters to ensure data quality and reproducibility.

Sensor model parameters vary based on the instrument being modeled, the data source, and the sensor model standard, but they can be broadly split into two groups; interior and exterior orientation [5]. The interior orientation is the data intrinsic to the sensor itself, such as the focal length, CCD configuration, optical distortion, and any filters. The exterior orientation describes the relationship between the sensor and the target being observed, such as the position and velocity of the sensor relative to the target.

The widespread use of SPICE kernels and the SPICE Toolkit has created a de facto standard for how exterior orientation is archived and accessed in planetary remote sensing. Well defined formats such as the binary SPK file format and high level interfaces to them support consistency when working with exterior orientation. Unfortunately, interior orientation is not as well defined or accessible using SPICE kernels and the SPICE Toolkit. Because the interior orientation is tightly coupled to the design and calibration of the instrument itself, interior orientation parameters in SPICE Instrument Kernels vary dramatically between missions and instruments. Additionally, SPICE kernels are excellent for archival purposes, but are challenging to use when sensor parameters need to be updated during processing, such as with photogrammetric control, instrument calibration, or ray gap analysis.

Goals of the ALE Library: The primary goal of the ALE library is to provide a simple and consistent interface for generating sensor model parameters. This will provide easier cross-compatibility between software packages and reduce duplicated efforts across the planetary science community. The secondary goal for the ALE library is to allow scientists easier access to the interior and exterior orientation used by sensor models.

Library Architecture: The ALE library will be written with a combination of C++ and Python. Most of the sensor model standards we are looking to support are written in C++, so having C++ bindings to get sensor model parameters is paramount. Collecting and computing data from a wide range of data sources in C++ becomes very complex and requires a lot of code. So, the I/O component of ALE will be written in Python because of its large number of I/O libraries and ease of development. The Python module will expose a single function to generate sensor parameters from an image file and/or label that will be wrapped in C++.

Python Module. The ALE library will need to take into account three factors when generating sensor model parameters for an image: the data source, the sensor model that will consume the parameters, and the instrument that the image is from. The Python module will separate these factors into mix-in classes. Each data source, instrument, and sensor model consumer will have a class that can be combined together to make drivers. For example, the driver for generating USGS CSM parameters for a PDS3 MRO CTX image from SPICE kernels combines together the SPICE, PDS3, and MRO CTX mix-ins via multiple inheritance. This pattern allows for ALE to support a wide range of data sources, instruments, and sensor models without broad code duplication or a restrictive object oriented class hierarchy.

C++ Module. The C++ module will contain one function that wraps the Python module and returns a JSON representation [6] of the sensor model parameters for an image. In addition, it will contain various interpolation and fitting functions for working with exterior orientations. In particular, it will support interpolation of positions and rotations from discrete data sets and polynomial and spline fitting. These functions will allow for consistent use of sensor parameters across libraries.

Testing Harness: The testing harness for ALE will consist of robust unit tests written using the PyTest [7] and googletest frameworks and a small number of integration tests. With the PyTest framework, unit tests can be written for all of ALE's various data sources without any test data files. From the Astrogeology Science Center's experience converting the ISIS software package to open source, large volumes of test data cause serious problems supporting external developers and limit continuous integration options. We have not yet identified a framework for high level integration testing. In keeping with industry best practices, continuous integration testing will improve code quality. Currently, we are using Travis CI because of its wide use across the open source community.

Development: The ASC has already begun exploratory development of the ALE library in support of our USGSCSM library. In the coming year, we plan to increase the number of instruments supported by ALE in tandem with USGSCSM. We also have written a request for comment document (https://github.com/USGS-Astrogeology/ISIS3/wiki/RFC-3:-Spice-Modularization) describing a plan for integrating ALE into the ISIS software library. The ALE source code is hosted on Github (https://github.com/USGS-Astrogeology/ale) and open source contributions are welcomed.

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References: [1] Gaddi L. et al. (1997) *LPSC XXVIII*, abs #1226. [2] Hare T. M. and Kirk R.L., (2017) *LPSC XLVIII*, abs #1111. [3] Di K. and Li R., (2004) *Journal of Geophysical Research: Planets*, *109*. [4] Taylor C. R. et al (2008), *ASPRS Annual Conference*. [5] Mikhail E. M. et al (2001) *Introduction to modern photogrammetry*. [6] Abd El-Aziz A. A. and Kannan A (2014) *International Conference on Computer Communication and Informatics*. [7] Krekel et al (2004), *https://github.com/pytest-dev/pytest*.