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SPICE-based Python packages for Solar System Exploration geometry exploitation

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Abstract

SPICE is an information system that provides the geometry needed to plan scientific observations and to analyze the obtained. The ESA SPICE Service generates the SPICE Kernel datasets for missions in all the active ESA Planetary Missions. Sometimes it is hard to find a particular functionality that a user or a group might require and it is not uncommon that users need to develop their own functions with a given combination of SPICE APIs, at ESA we have identified a set of functions and wrapped them up in a series of Python packages along with other features that improve the user experience with SPICE. This contribution provides an overview of those packages.

1. Introduction

SPICE is an information system the purpose of which is to provide scientists the observation geometry needed to plan scientific observations and to analyze the data returned from those observations. SPICE is comprised of a suite of data files, usually called kernels, and software -mostly subroutines [1]. A customer incorporates a few of the subroutines into his/her own program that is built to read SPICE data and compute needed geometry parameters for whatever task is at hand. Examples of the geometry parameters typically computed are range or altitude, latitude and longitude, phase, incidence and emission angles, instrument pointing calculations, and reference frame and coordinate system conversions. SPICE is also very adept at time conversions.

2. SPICE for ESA Missions

The ESA SPICE Service (ESS) leads the SPICE operations for ESA missions. ESS generates the SPICE Kernel Datasets (SKDs) for missions in operations (ExoMars 2016, Mars Express) missions in development (BepiColombo, JUICE) and legacy missions (Rosetta, Venus Express). ESS is also responsible for the generation of SPICE Kernels for Solar Orbiter. The generation of SKDs includes the operation software to convert ESA orbit, attitude, payload telemetry and spacecraft clock correlation data into the corresponding SPICE format. ESS also provides consultancy and support to the Science Ground Segments of the planetary missions, the Instrument Teams and the science community. ESS works in partnership with NAIF [2]. In addition to the services described in the previous section, ESS is developing several services in the shape of Python packages to enhance the exploitation of SPICE data.

3. spiops a Python package for SPICE

spiops is a Python package that uses SpiceyPy [1] (a Python wrapper for the C implementation of SPICE) to use SPICE Toolkit APIs in order to provide higher-level functions than the ones available with SPICE. spiops is aimed to assists the users to extend the usage of SPICE. These functions have been identified in the day-to-day work of the ESS and its clients from having to implement multiple times a series of SPICE APIs to obtain a given derived functionality which is not directly available as a SPICE API. Functionalities vary from the computation of the illumination of a given FoV to obtaining the coverage of a given S/C for a particular MK, plotting Euler Angles or comparing different kernels. All that providing integrated plotting capabilities as well. In general, by design spiops offers three different types of functions:

1. SPICE based derived functions,
2. non-SPICE based derived functions and
3. an object Oriented SPICE interface

The underlying idea of spiops is to be used as a multi-user and multi-disciplinary pool of re-usable SPICE based functions and to provide an easier interface to

[1] https://github.com/AndrewAnnex/SpiceyPy

certain SPICE functionalities with objects to provide cross mission and discipline support of SPICE for ESA Planetary and Heliophysics missions. The ultimate goal is to provide:

1. A Pool for functions that ESS uses needed to work with SPICE,
2. an Interface to provide solutions to users, a Library for SPICE-based applications.

spiops is publicly available as a Python Package Index (PyPI) package and is accessible via BitBucket as well[2]. spiops is also open to contribution from external users. Fig.1 provides a Jupyter notebook-based example that outlines the usage of spiops

3.1 adcsng a pipeline to process auxiliary data

SPICE Kernel Datasets of missions in operations (Mars-Express and ExoMars2016) are regularly updated in missions with new predicted and reconstructed trajectory and attitude information - usually provided by the mission's flight dynamics team- and with Housekeeping Telemetry that provides information of moveable parts of the S/C or the science payload [2]. With these data time-varying kernels are generated (SPKs, CKs and SCLKs) with an automatic processing pipeline: the Auxiliary Data Conversion System next generation (adcsng). adcsng is made available to the ESA missions as a Python Package.

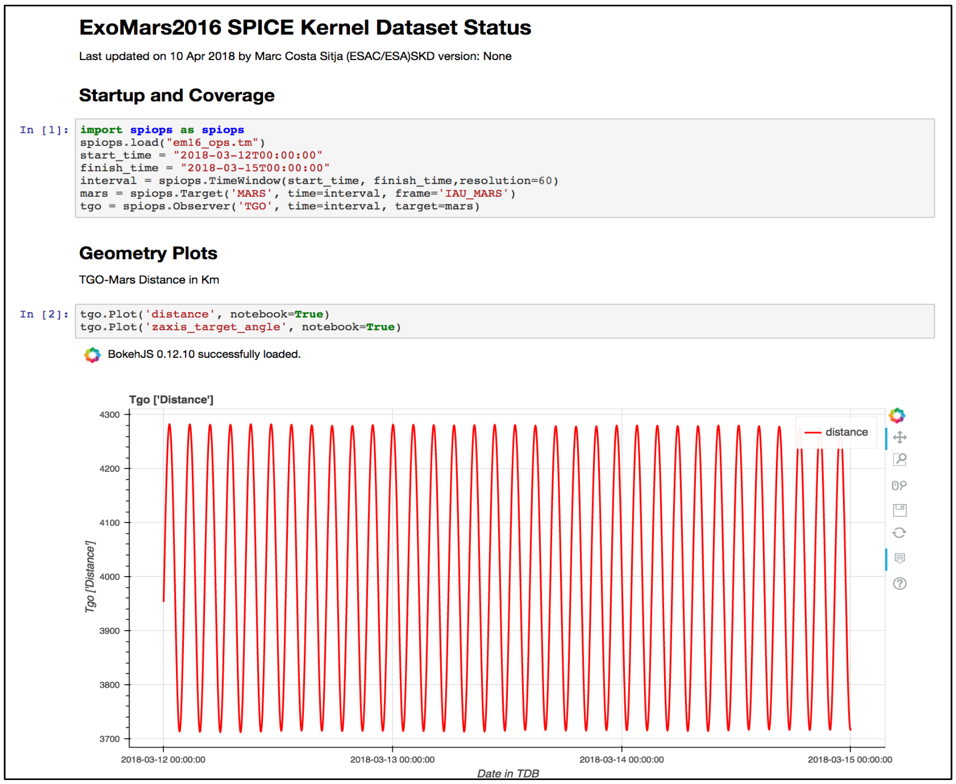

Figure 1 Jupyter notebook snippet outlining the usage of spiops

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[2] https://repos.cosmos.esa.int/socci/projects/SPICE/repos/spiops

3.2 spispy and spival more Python packages for SPICE

Although these package is not open to contributions, ESS is also developing Python packages which in combination with adcsng and spiops will provide to the ESA SPICE users a web-based quick-look of a complete SKD.

In order to validate the SKD, to report the validation and to be used as a quick-look analysis spival**,** a private Python package has been to developed. spival features:

- Validation of the TVK-updated SKD after an execution of the Auxiliary Data Production Pipeline.
- Output of a Jupyter Notebook with a report of different geometry and S/C structures status:
    - S/C-Target Distance/Altitude
    - Sub-S/C point on Target
    - Boresight of interest angle w.r.t. Sub-S/C vector (e.g.: Offset from Nadir Pointing)
    - HGA Antenna Phase Center angle w.r.t. Earth
    - Solar Arrays Angles
    - Solar Aspect Angles for S/C Panels
    - S/C Groundtrack on target
    - ... and many more (open to suggestions)

In order to generate the reports spival heavily uses spiops. This reporting also provides information about the coverage and applicability of the given SKD[3].

Using Cosmographia has the main drawback that the user needs to install it locally, sometimes a quick-look of a given mission 3D geometry context is of interest. Following that need we developed the private Python package spispy**.** spispy allows you to, in the shape of a Web app and by providing a time and a mission**:**

- Obtain a snapshot and the Cosmographia configuration of the 3D context of a given sensor that has a Field of View (FoV) defined in SPICE or a S/C reference frame direction.
- Obtain a snapshot of the trajectory of the S/C around a given body.
- Extend WebGeocalc functionalities with additional APIs available as a web-app

[3]Reports will be made available: spice.esac.esa.int/status

References

[1] Acton C., Ancillary data services of NASA's Navigation and Ancillary Information Facility (1996), Planet. And Space Sci., 44, 65-70.
[2] Costa M., SPICE for ESA Planetary Missions: geometry and visualization support to studies, operations and data analysis, this conference.