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Introducing Project PANCO, an open-source pansharpening and co-registration suite for planetary sciences

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Introduction

Planetary exploration studies can greatly benefit from integrating data acquired from diverse sources, each with unique spatial and spectral resolutions and often georeferencing inaccuracies.
The project PANCO (PANsharpening and COregistration) represents an open-source software suite dedicated to facilitating the integration of images of planetary surfaces through co-registration procedures and resolution enhancement by means of pansharpening techniques. In particular, pansharpening represents a family of data fusion and radiometric transformations that aim to merge lower-resolution multispectral data (MS) with a high-resolution panchromatic base images (PAN). In this way, the resulting data will be characterized by both high spatial and spectral resolutions, gaining the advantages and capabilities of both sources simultaneously [1].
The suite here presented will allow the use of different algorithms and will be accompanied by a series of studies currently in publication that focus on evaluating the methods' performance in real Mars and Mercury observation contexts.

Automatic alignment

An essential part of data integration is "co-registration," i.e., the alignment of data positioning in physical space to accurately overlay the various layers of information.
Despite being a common need for several applications, such as mosaicking, mapping, and photogrammetry, data coregistration remains a time-consuming process that, commonly, implies manual search for homologous features between the images in a Geographic Information System (GIS). In addition, the accuracy of this process is greatly influenced by the user's skills and perseverance.
Our current research presents an advanced approach using an automatic alignment methodology based on the Scale-Invariant Feature Transform (SIFT) algorithm [2], a powerful tool inherited from the photogrammetric and computer vision fields. The matching points are used to estimate the homographic transformation between the images, deriving the geometry of the images to be aligned. Even considering further manual refinement, this procedure considerably reduces co-registration time and permits the achievement of up to pixel-level accuracy across the whole image (Fig.1).

Pansharpening

Despite its appreciable advantages for morphological analysis [3, 4], image simulation [5], and the significant advances in this field [6, 7], the complex alignment and the lack of accessible tools have meant that pansharpening has rarely been used in planetary sciences outside the Earth Observation context.
To date, the suite allows the use of twelve different component substitution (CS) pansharpening techniques suitable for different fields of application and purposes.
The PANCO suite is designed to be flexible, capable of managing images from different sources and at any resolution range. The introduction of newer methods, such as the Gram-Schmidt Adaptative (GSA) and Band Dependent Spatial Detail with Physical Constraints (BDSC-PC), further enhances its applicability, making it suitable even for the hyperspectral field.

Validation and case studies

Instrument validation studies have been applied to two datasets concerning the observation of the surface of Mars. The first includes four-band colour images from the ExoMars Trace Gas Orbiter (TGO) CaSSIS (Colour and Stereo Surface Imaging System) using panchromatic data from the Mars Reconnaissance Orbiter (MRO) HiRISE (High Resolution Imaging Science Experiment) images [8, 9]. This dataset allowed to validate the accuracy of increasing spatial resolution of up to sixteen times the original, from the 4.5 m/px of CaSSIS to the 0.25 m/px of HiRISE, using the entire set of methods developed (Fig.2).
The second phase of studies, currently underway, consider the MRO Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) hyperspectral cubes using the weighted sum of CaSSIS Multispectral observations as the reference panchromatic. The focus of this study is the ability of recent methods to be used on high spectral resolution data, with 489 bands between 362 and 3920 nm [10]. In both tests, the chosen images were selected to range in lighting conditions, surface geological properties, and acquisition geometries, allowing the influence of these factors to be further analysed. The results were then examined using various numerical performance indicators and a visual survey. The evaluation indexes adopted include SAM, RMSE, ERGAS, UQI,

PSNR, and SSIM, considering the analysis from various aspects of images' spectral and structural properties.

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Fig.1 Example of CRISM image (on the left) aligned to a reference HRSC image on the right) through matching points between images (linked in green) acquired by SIFT operator.Fig.1

Fig.2 Detail of the maximum resolution increase obtained during testing, from 4.5 m/px (a) CaSSIS mosaic MY34_004209_158_0 –RPB) to 0.25 m/px (b) with PSP_010394_2025 HiRISE by Gram-Schmidt pansharpening algorithm.Fig.2

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