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Stereo-Multispectral analysis of Phobos by using CaSSIS images

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1. Introduction

The CaSSIS instrument (Colour and Stereo Surface Imaging System) [1], is the stereo imaging system onboard the European Space Agency's ExoMars Trace Gas Orbiter (TGO) that has been launched on 14 March 2016 and entered Mars orbit on 19 October 2016. During the first bounded orbits, CaSSIS acquired its first multiband images on 22 and 26 November 2016.

The system operates in "push-frame" mode and, differently by other Mars instruments with the same resolution [2], it provides images at different wavelengths thanks to a FSA (Filter Strip Assembly) with a panchromatic (PAN, centred at 675 nm) and 3 broadband colour filters within the visible range (the BLU filter being centred at 499 nm, the RED one at 836 nm and the NIR one centred at 937 nm). Furthermore, the CaSSIS instrument provides stereo pairs fundamental for the initialisation of the photogrammetric process to 3D reconstruct the Martian surface.

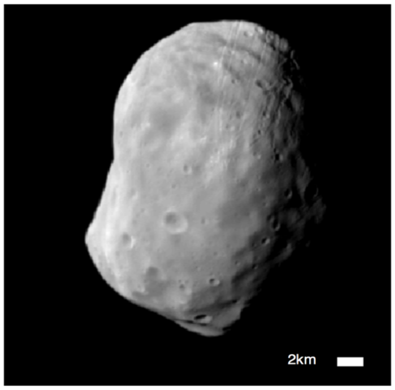
The availability of 3D data of a planetary surface enabled the morphological analysis of multiple features, providing a fundamental step forward for planetary geology. Indeed, enlarging the number of known details of the surface, allows a wider range of scientific investigation. Previous studies [3] reported that the use of chromatic information can significantly reduce the ambiguity between candidate matches of terrain features in the production of disparity maps between stereo image pairs. In this context, the CaSSIS multispectral images constitute an interesting dataset that allows the extraction of more accurate and detailed information. Therefore, a new approach in the stereo reconstruction pipeline is here proposed by taking advantage of the potentialities that can be obtained using CaSSIS multispectral data and, specifically, using Phobos images.

2. Phobos acquisitions of CaSSIS

On November 26, 2016, CaSSIS has imaged the Martian moon Phobos during the closest approach of the spacecraft around Mars at a distance of 7700 km. CaSSIS acquired a set of framelets in stereo mode with an average pixel scale of ~ 85 m. The Phobos CaSSIS framelets in four different filters (0.499, 0.675, 0.836 and 0.937 μm, [1]) have been mosaicked in order to provide the images (for each filter) of the entire shape of the satellite as shown in the Figure 1 (a). The mosaicking process has been performed through an algorithm that corrects the first solution provided by the SPICE kernels with a recursive process that implements the SURF (Speeded Up Robust Features) feature based operator [4].

3. New stereo approach for multispectral images

The common procedures based on automatic stereo image matching provide the so-called Digital Terrain Model (DTM). In the CaSSIS case study the stereo image processing should benefit from the usage of information coming from all bands contents. DTMs profiting from additional spectral input may have higher fidelity and resolution according to previous studies [5]. However, a direct assessment remains to be carried out for planetary surface images. The correlation based matching is the most common way to solve the point matching problems, however, it can introduce false matches (outliers), especially in regions lacking of both texture and information. These areas, which are very diffuse on the planetary surfaces (covered by regolith, smooth planes, poor in superficial variegation etc.), remain unsolved or low in accuracy after the matching process.

a) 

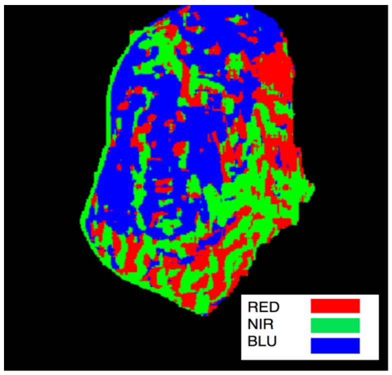
b) 

Fig. 1 a) Mosaicked image of Phobos using PAN filter acquisitions. b) Pixel identification as function of the best filter accordingly to the higher local contrast (higher local standard deviation).

In this context, the idea proposed is to exploit the additional information coming from the spectral data in order to improve the performance of the common stereo PAN image matching, hence, providing more accurate and complete three-dimensional data. To achieve the goal, different areas have been identified on the image accordingly to the image content, which is evaluated by the local signal standard deviation (σ) (mark of the local contrast). Firstly, for each filter, the corresponding points on the images are ordered into different areas as function of the degree of image content. Then, the matching algorithm can be addressed selecting the best image of a specific area. This choice is based on the observation that points of larger gradient (σ) have higher probability to be matched and, in addition, each filter is supposed to provide different content in relation with variations in perceived reflectance properties, even across smooth regions of dust [6]. Primarily, the procedure will foresee a previous analysis of the image quality by means of gradient intensity and image content indicators as the local standard deviations (Figure 1 (b)). Then, the DTM generation pipeline could be developed in multiple stages:

1) a matcher that takes one stereo pair (at a single wavelength) and produces a DTM;
2) combining multiple DTMs generated independently from different spectral wavebands;
3) employing "addressed"-correlation between the spectral wavebands.

Finally, the quality assessment of the results will be done in terms of coverage and accuracy. The impact of spectral data on the DTM production will be reported in comparison with results obtained through common pancromatic based DTM products.

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