SURFACE CHARACTERIZATION AND OPTICAL NAVIGATION AT THE ROSETTA FLYBY OF ASTEROID LUTETIA

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ABSTRACT

The ESA interplanetary spacecraft (S/C) Rosetta was launched in March 2004 to rendezvous with comet 67P/ Churyumov-Gerasimenko ten years later in 2014. The overall trajectory contained several planetary swing-bys (Earth and Mars) and two asteroid flybys (Steins in 2008 and Lutetia in 2010).

During the Lutetia flyby in July 2010, the onboard instrument OSIRIS NAC (Narrow Angle Camera) obtained high-resolution images of the asteroid. An overview of the optical data processing for navigation was presented at the ISSFD2012[1], were pixel positions of landmarks were manually determined using a graphical user interface.

This paper presents an improvement in the optical navigation and shape reconstruction. A new procedure for identifying landmarks was developed with a technique that combines stereophotoclinometry and stereophotogrammetry to obtain landmark maps (L-maps).

Stereophotoclinometry[2] estimates the slope and albedo of a surface area when observed with different illumination conditions by means of a reflectance function. However, stereophotogrammetry[3] determines the three dimensional location of a surface point when identified from different observing angles. Algorithms from both techniques have been implemented, so that the information on slopes and heights are integrated in L-maps through a direct system solving method for sparse matrices.

Using L-maps it is possible to predict the expected landmark appearance in a future image. The prediction can be correlated with the actual image with great precision. This procedure generates automatic observations of the asteroid features for a wide range of both illumination and observing conditions.

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[2] R. W. Gaskell et al "Characterizing and navigating small bodies with imaging data" *Meteoritics and Planetary Science* 43, Nr 6, 1049-1061,2008.
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This technique is applied to the Lutetia scenario. L-maps are generated all around the observed surface of the asteroid, and automatic landmark observations are obtained for all the available images acquired within a certain distance from Lutetia. The visible areas are reconstructed with a broader coverage and the quality of the automatic observations is higher with respect to the visually obtained ones. This improvement in the measurement accuracy translates into a more precise orbit determination and asteroid dynamics estimation. The spacecraft relative position and attitude as well as the comet-fixed landmarks grid are reconstructed with two different estimation methods. The first, known as “bundle adjustment”, is based on purely optical information, whereas the second also includes radiometric data and dynamic information in the full orbit determination solution. The comparison shows that consistent residuals can be obtained with the two methods, confirming the good accuracy of the observations generated with the L-maps.

The L-maps are combined to assemble a high-resolution shape model which represents a significantly better characterization of Lutetia with respect to the previous method that involved a silhouette carving technique (ISSFD2012). The shape recovery’s accuracy is assessed with the support of an image simulation software. Synthetic images have been rendered using the shape of the asteroid and the reconstructed flyby geometry to be compared against the real pictures.

This technique was developed in the frame of the Rosetta cometary phase and it might be applied during the near-comet navigation phase to relieve the operational workload, as well as to increase the landmark coverage of Churyumov-Gerasimenko and to improve the quality of the optical measurements.