PHOTOGRAMMETRIC EVALUATION OF GALILEO SSI IDA IMAGES: PRELIMINARY RESULTS; J. Oberst, B. Giese, R. Wagner, R. Jaumann, G. Neukum, DLR, Institute for Planetary Exploration, Berlin-Adlershof, Germany; T. Ohlhof, M. Dorn, W. Zeitler, H. Ebner, Technical University Munich, Chair for Photogrammetry and Remote Sensing; E. Gill, O. Montenbruck, DLR, German Space Operations Center, Section Space Flight Dynamics, Oberpfaffenhofen.

INTRODUCTION. 79 images of Ida and its satellite Dactyl were obtained by the SSI camera during the second Galileo asteroid flyby in August 1993. These images provide a novel opportunity for direct measurements of the size, shape and motion of the two objects, as well as possibly also for mass and density of Ida. However, precise estimates of sizes and shapes cannot be achieved easily, as the images have a very narrow field-of-view, different resolutions and show the odd-shaped asteroid rotating under varying illumination conditions. In addition, the available camera pointing (attitude) data as well as the trajectory data of Ida and the spacecraft during the flyby are of limited accuracy. Hence, a combined evaluation of all images together with navigation data is required to extract the physical parameters of the two bodies.

METHODS. The first evaluation step involves the determination of a couple of conjugate points in the images. Each point must be visible in at least two images. Point identification and point measurement are carried out by a human operator. Since all points are related to topographic features (craters) on Ida's surface, they serve as control points in the further photogrammetric processing. The points should be distributed ideally uniformly on the ground surface in order to build up a global network.

In the second step 3D ground coordinates of the conjugate points are determined and the exterior orientation (position and attitude) of all images is reconstructed in a so-called bundle block adjustment [1]. The mathematical model of the bundle adjustment is based upon the collinearity equations. They formulate the relationship between the observed image coordinates x_{ij}, y_{ij}, the unknown ground coordinates X_i, Y_i, Z_i of the point P_i and the unknown parameters of exterior orientation $X_{0j}, Y_{0j}, Z_{0j}, \phi_j, \omega_j, \kappa_j$ of the image I_j. Additional observation equations are formulated for the position and attitude data, which are derived from the NAIF SPICE SP- and C-Kernels. To this end, the position and attitude data are transformed into an Ida-fixed non-inertial coordinate system with the origin in Ida's center of mass and the rotational parameters of Ida treated as constants using known values [2].

Third, a Digital Terrain Model (DTM) is generated as a shape model of the asteroid. Since the high resolution images of Ida (30-110 m ground pixel size) cover only one hemisphere, the DTM is obtained only for this region. The DTM generation involves the determination of a large number of conjugate points in the images, the computation of ground coordinates for these points and the interpolation of the object surface. Digital image matching is a suitable technique to find such a large number of conjugate points automatically. In our approach least squares image matching has been applied, which yields image coordinates with subpixel accuracy. The conjugate points determined previously are utilized as starting (seed) points for the matching procedure. A comprehensive description of the matching algorithm is given in [3]. The computation of ground coordinates can be carried out via forward intersection using the adjusted exterior orientation parameters. Alternatively a new bundle block adjustment can be performed. The derivation of the object surface by interpolation and/or filtering is a straightforward task in photogrammetry [4]. The DTM can then be visualized in different ways, e.g. by shading or by perspective views. With the help of DTM data, orthoimages can be generated using digital orthoprojection techniques.

In a further processing step the existing bundle block adjustment is supplemented by a rigorous dynamical modeling of the spacecraft motion to account for orbital constraints. This advanced concept ensures the proper utilization of Galileo trajectory information in the bundle block adjustment and, also vice-versa, allows the use of image information to improve the orbit determination and supports the estimation of dynamical parameters, e.g. the rotational parameters of Ida or the ephemeris of Ida's satellite Dactyl.

PRELIMINARY RESULTS AND FUTURE SCIENCE GOALS. *Ida.* From the first and second processing steps a dense global control network consisting of 96 points was obtained. These points were measured interactively in 37 images with a precision of about half a pixel. In Figure 1 those points which were identified and measured in image #61278 are represented.

Digital image matching was applied successfully to 11 images, which yields more than 5,000 points on

Ida's surface. Special methods were developed for automatic point transfer and for the consideration of scale differences between the images. In addition, matched points in deep space were deleted automatically using a given treshold value. Figure 2 shows the points which were matched in image #61278. After that a DTM was derived with a grid size of 100 m using the HIFI-88 software package [4].

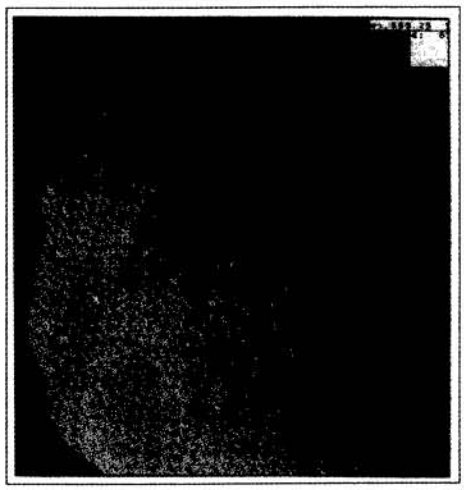

Figure 1: Conjugate points measured interactively by a human operator in image #61278.

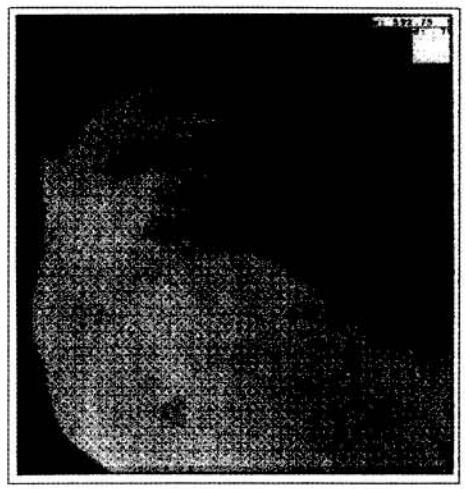

Figure 2: Conjugate points determined automatically by digital image matching in image #61278.

The DTM can then be used to rectify images acquired with different color filters for the generation of color orthoimages. Moreover precise photometric corrections will be possible, as the incidence and emittence angles of sunlight on the surface which are a prerequisite for the utilization of photometric functions, may be determined from the high resolution DTM. This will allow us to perform more precise spectral studies of the asteroid. In addition, improved photometric analyses may be carried out, as photometric functions can be fitted more precisely to the observed reflectance data.

Ida's satellite. Ida's satellite Dactyl is visible in 46 images in all [5]. Using the rigorous dynamical modeling concept described above the ephemeris of Ida's satellite Dactyl may be computed. From the knowledge about Ida's shape and Dactyl's ephemeris the mass and density of Ida may furthermore be determined.

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