RECONSTRUCTION OF THE EROS SHAPE MODEL USING NEAR LASER RANGEFINDER DATA E. G. Kahn[1], O. S. Barnouin[1], M. G. Daly[2], C. L. Johnson[3], J. Seabrook[2] [1]The Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, MD, USA (eliezer.kahn@jhuapl.edu) [2]York University, 4700 Keele St, Toronto, Ontario, Canada [3]University of British Columbia, 6335 Stores Road, Vancouver, BC. Canada.

Introduction: In preparation of the upcoming OSIRIS-REx mission to the Bennu asteroid, we are enhancing current algorithms for reconstructing the shape and local topographic models of the asteroid using data collected by the OSIRIS-REx Laser Altimeter (OLA), a scanning laser altimeter contributed to the mission by the Canadian Space Agency. We are testing our algorithms on data collected by the NEAR laser rangefinder (NLR), which acquired over 15 million returns while in orbit around the asteroid Eros. We present an approach to reconstruct a shape model of the Eros asteroid intended to minimize initial spacecraft position and attitude errors associated with lidar returns. The results will become inputs to a more rigorous cross-over, or strip-adjustment, approach to minimize any remaining errors.

Method: A shape model constructed from uncorrected (raw) lidar data contains errors due to spacecraft position and attitude uncertainties. To obtain a more accurate shape model, it is necessary to reduce these errors in a correction usually called a strip-adjustment.

We start with a low-resolution shape model using the uncorrected lidar data. We then perform strip adjustments to reduce the errors between the lidar data and the shape model. A new shape model is then generated with the adjusted lidar results. An iteration between estimates of the shape model and the lidar data is then repeated until errors are minimized and no further change in the shape model is achieved.

Shape Model Estimation. The Generic Mapping Tools (GMT [1]) is used to construct a gridded shape model. The median of all lidar points are collected in each grid, usually a 2 by 2 bin. These points are then modeled using a Delaunay triangulation to set up a spherical interpolation in tension [2]. The output grid is converted into a high-density shape model that is oversampled near the poles compared to the extremities of the asteroid. This oversampling can yield unrealistic shape model artifacts; therefore, the shape model is resampled so that the plate areas are more uniform. The shape model produced approximately reproduces the shape observed in images gathered by the NEAR spacecraft. With this initial low-resolution shape model in hand, we begin to undertake strip-adjustments.

Strip-Adjustment. The NLR data collected by the spacecraft were highly heterogeneous in spatial density and coverage. Experience indicates, however, that for data acquired over a short time window, a simple translation and rotation (i.e., a rigid transformation) is usually enough to adjust the lidar data so that they better match our initial (as well as updated) asteroid surface. Our algorithm begins by first dividing the lidar points into small windows such that during each window, the data does not wind too far around the asteroid, ensuring that rigid transformation is sufficient to correct the data within each window. For each lidar point in a set (S) of points, the closest point on the asteroid is computed. A corresponding set of closest target points (T) is formed. A point-matching scheme (a variation of the Iterative Closest Point algorithm described in [3]) is used to find the optimal translation and rotation to match the source points, S, to the target points, T. The optimal transformation is applied to the original lidar points, S, as well as to the spacecraft positions to produce the improved data. This procedure is repeated for each time window.

Results: We tested the algorithm using two approaches. First, we compared the reconstructed shape model with the Eros shape model derived by Robert Gaskell using Stereo-Photoclinometry, or SPC, [4,6] as well as the Eros shape model produced by the NLR team where gridded NLR data was fit with a high order spherical harmonic [5]. To do this we compute the mean distance between each vertex of the reconstructed shape model and the closest point in the SPC or spherical harmonic model. After running the surface reconstruction but before running the strip-adjustment, the mean error compared to the SPC shape model is $\approx$27 m and the mean error compared to the spherical harmonic model is $\approx$17 m. After running the strip-adjustment once and rerunning the surface reconstruction on the improved data, the error compared to the SPC model is reduced by 2 m to $\approx$25 m and the error compared to the spherical harmonic model is reduced by 4 m to $\approx$13 m. Some of this error in the SPC comparison is a result of a 10 m bias known to exist between SPC and NLR range measurements. Figure 1 shows images of these four shape models.

As an additional way to test the approach, we computed the mean distance of the lidar points to the closest points on the shape model both before and after strip-adjustment. After producing an initial shape model of Eros, but before undertaking a first iteration of the strip-adjustment, the mean distance is $\approx$33.5 m. After a first iteration of the our strip-adjustment algorithm, and the rebuilding of a new shape model, the location of our data are improved by over 50%, with

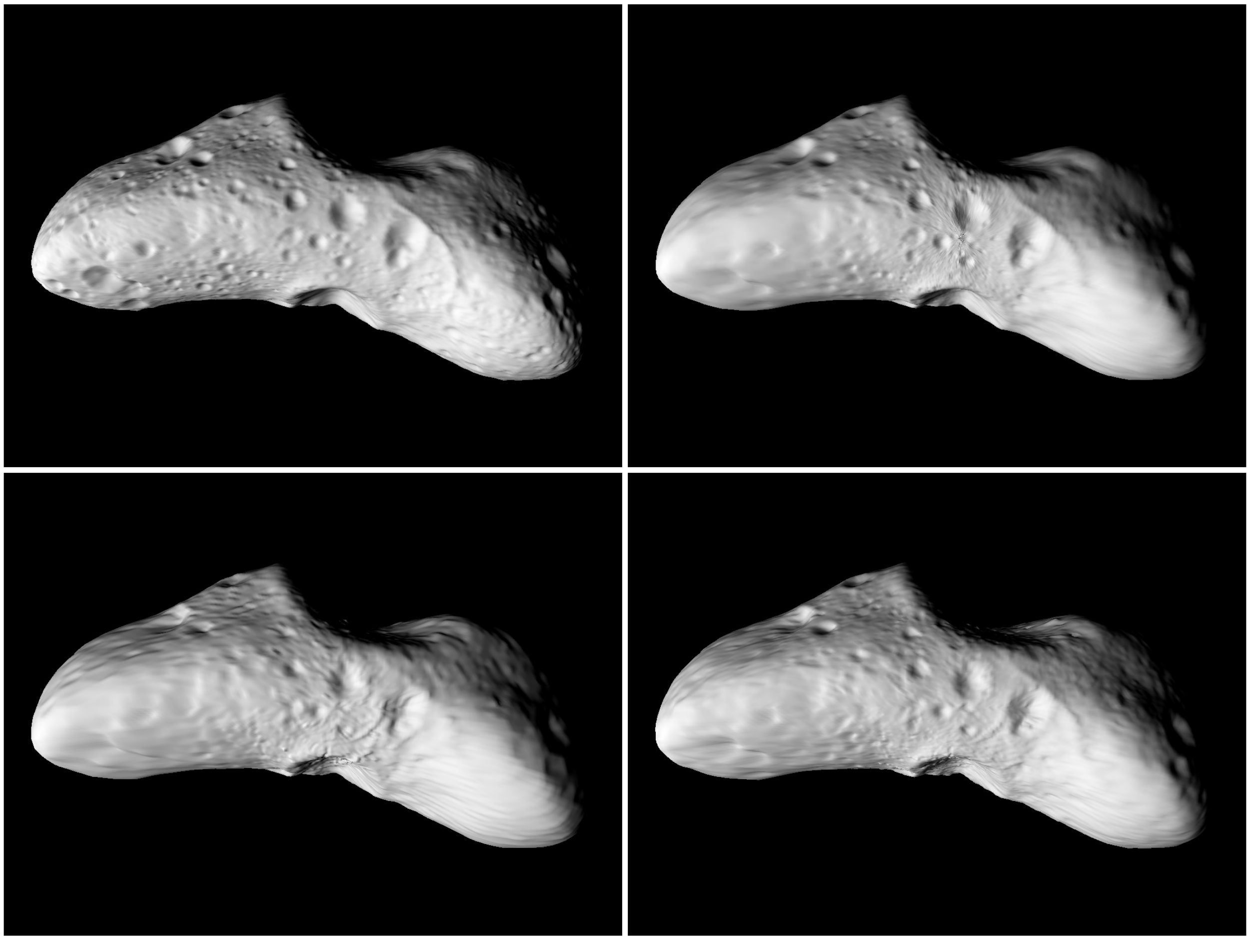

Figure 1: The shape model derived by SPC (top left, 196608 plates [4]), the NLR team (top right, 129600 plates [5]), shape model reconstructed as described in this paper before strip-adjustment (bottom left, 129792 plates), and shape model reconstructed as described in this paper after strip-adjustment (bottom right, 129792 plates).

the mean distance reduced to ≈15.5 m. Additional iterations typically produce more moderate changes. By way of comparison, before strip-adjustment the mean distance is ≈40.3 m compared to the SPC model and ≈35.0 m compared to the spherical harmonic model. After strip-adjustment, the mean distance is ≈31.5 m compared to the SPC model and 21.3 m compared to the spherical harmonic model.

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