A Method for 3D Reconstruction from Asteroid Images with OpenCV. Y. Mori[1], R. Suda[1], N. Hirata[1], H. Demura[1], N. Asada[1], [1]The University of Aizu (ymaizu@gmail.com).

Introduction: 3D reconstruction of an asteroid is important in exploring missions for asteroids and scientific analyses of the missions. In the asteroid sample return mission (e.g., Hayabusa achieved by Japan Aerospace Exploration Agency (JAXA)), the shape model is also required to conduct a touchdown operation for the selection of landing sites in terms of security. 3D shape recognition of the asteroid has been done [1] by image based modeling. A program has also been developed to reconstruct the shape model of the asteroid from images with OpenCV [2]. OpenCV is an open library for computer vision. These previous researches reconstructed a shape model of Itokawa (Near-earth asteroid 25143), but they have some problems. The first previous research has a problem of program's readability because of full-scratching and the second previous research has problems about the handling of camera parameters and the shape model is reconstructed from one view. In this paper, we examine an improved method for 3D reconstruction from asteroid images using OpenCV and calculate point-clouds from various stereo pairs automatically. We also focus on estimation methods for fundamental matrices (an important component in epipolar geometry which describes point correspondences in a stereo camera system mathematically) and tried methods for estimations using two images and three images. However we failed to estimate camera-extrinsic parameters (required for determining scales of shape model) finally. Therefore, the calculated point-clouds are non-scale ones.

Method: One point-cloud is calculated from one stereo pair. Images are not captured in a stereo camera, but we assumed two images captured at different rotation phases of an asteroid as a stereo pair.

1. Extract feature points in images.
2. Calculate an optical flow to get correspondences of the extracted feature points.
3. Estimate a fundamental matrix between two images. Estimations were based on RANSAC.
4. Estimate a camera-extrinsic parameters (failed) that describe a rigid motion between the camera coordinate system and the world coordinate system.
5. Rectify a stereo pair using the fundamental matrix.
6. Search point correspondences densely between the left image and the right image and calculate a disparity map of the rectified stereo pair.
7. Reconstruct a point-cloud from disparity map.

In this paper, the integration and the triangulation of point-clouds are out of scope. Especially the estimation of camera-extrinsic parameters depends on the quality of the estimated fundamental matrix highly.

Results: A stereo pair used for testing this method, calculated disparity map and the example of scale-adjusted point cloud from a view are shown.

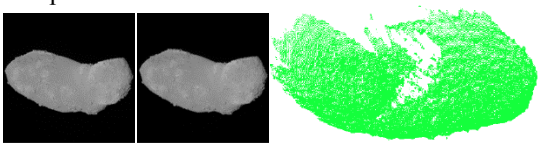

Figure 1. Example of used data (left two images) and the calculated point cloud (right). This point-cloud is de-noised and scale adjusted [3].

Evaluations. A shape model of Itokawa is calculated by R. Gaskell accurately [4]. Some comparisons about profile plots along lines are shown.

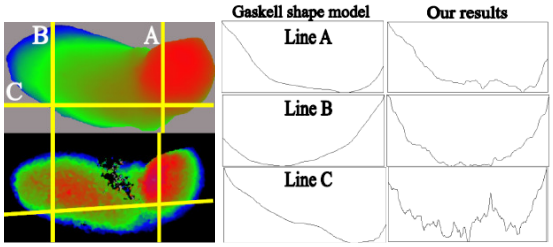

Figure 2. Two colored disparity maps (left) and 6 profile plots along line A, B and C. In colored disparity maps, red points are near from the camera and the blue ones far from the camera.

In the evaluation, we used altitude data calculated from Gaskell's shape model. It can be assumed the altitude data is equivalent to disparity maps. About the 6 plots, vertical ones (along line A and B) are similar in both maps, but the horizontal plot (along line C) is different completely. It is considered that this difference caused by the rectification process.

Conclusion: 169 non-scale point-clouds have been calculated with OpenCV automatically across various view points. To determine the scale of point-clouds, we must estimate camera-extrinsic parameters correctly or adjust using other information (e.g., navigation data of the explorer). We consider to use Point Cloud Library (PCL) to combine point-clouds.

References: [1] S. Kobayashi (2006), *Univ. of Aizu Master Thesis*. [2] K. Miyata (2011) *Univ. of Aizu Graduation Thesis*. [3] K. Isozaki (2012) *Univ. of Aizu Master Thesis*. [4] R.Gaskell et al. (2006) *AAS/AIAA Astrodynamics Specialists Conf.*