Recognition algorithm for craters, ridges, and grabens. N. Harada[1], T. Karino[1], N. Hirata[1], H. Demura[1], N. Asada[1], [1]The University of Aizu (Turuga, Ikki-machi, Aizu-wakamatsu, Fukushima, 965-8580, JAPAN, m5101123@u-aizu.ac.jp,)

Introduction: Many lunar explorations are planned to be launch in and after 2007. Japan also will launch SELENE (Selenological and Engineering Explore) in the summer of 2007. These missions will obtain a large amount of high-resolution images and topographic data that are valuable to analyze topographical features on the moon such as craters, ridges and grabens. The topographical features on planetary surface used to be mapped and counted manually, or partially supported by computer software. Even if excessive amounts of time are spent, scientists will not be able to analyze the massive volumes of data with those present procedures. Therefore, an automatic analysis tool is required. We develop new algorithm for recognition of craters, ridges and grabens on DTM (Digital Terrain Model). The main target is the DTM that will be acquired by Terrain Camera (TC) on SELENE. In this abstract, we describe the procedure of our method briefly, and report trial results on the MOLA (Mars Orbiter Laser Altimeter) topographic data of the Mars.

Procedures: Our algorithm includes the following steps: (1) Edge detection in DTM to extract topographic features, (2) Extraction of circular edge features to find craters, and (3) Recognition of lineaments including ridges and grabens.

Edge detection: Edge detection is one of the most important parts of the recognition algorithm. Two methods are tried and examined: (1) FFT with High pass filter, and (2) Haar Wavelet Transform with High pass filter. Both FFT and wavelet transform algorithms are popular operators in the field of digital image processing. With combination of a high-pass filter applied to the transformed image, edges in the images are detected. These operations are applied to DTM to detect edge of topographic slope, such as crater rim, ridge, and bottom of graben. Properties of those algorithms are examined with the MOLA Martian DTM. Edge detection by FFT shows a good result on major edges in the input DTM. However, it cannot detect small and/or complex topographic features (Fig. 1B). In contrast, edge detection with Haar wavelet transform has good sensitivity to small and/or complex features (Fig. 1C). However, this method tends to detect too many small edges, which would be noises at the following steps to extract craters and lineaments. As those results, we adopt both methods for edge detection. Results of the FFT and the Haar wavelet transform are combined, and used at the next steps.

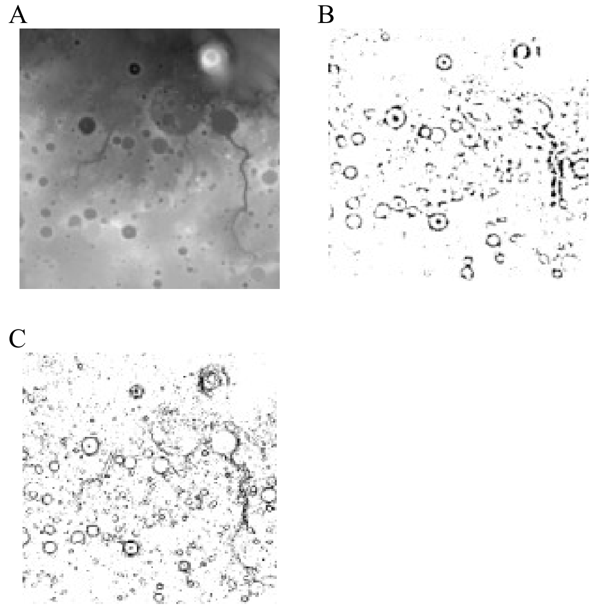

Fig. 1. Examples of edge detection. (A) Input MOLA DTM at Gusev crater region of the Mars. (B) Result of edge detection by FFT (C) Result of edge detection by Wavelet Transform

Crater detection: Crater is very important feature to clarify lunar origins and evolution, because ages of geologic units can be estimated by crater chronology. A technique for crater recognition should be robust, because craters on the planetary surfaces may overlaid by other craters, or partly eroded by ejecta from them.

Previously, many techniques for crater recognition have been investigated [1-8]. We adopt General Hough Transformation (GHT) as the core algorithm for detection of circular or ellipse crater rims. Our procedure with the GHT is as follows; (1) By regarding an edge as an arc of a circle, a tangent line is determined. The parameters of the determined tangent line is voted to the binned Hough space. This voting is repeated for all edges. (2) With the result of the voting, the best properties of a circle or an ellipsoid are solved. The GHT can detect even incomplete ellipses, because the GHT has a strong noise tolerance. Experimental results of crater detection show that the GHT can find craters with incomplete rims, nested craters, and craters overlaid on the rim of another crater (Fig. 2A-C). In our procedure, principal parameters of a detected crater, such as the location, the diameter, the depth, the ellipticity, and the direction of the major axis are also recorded for further analyses.

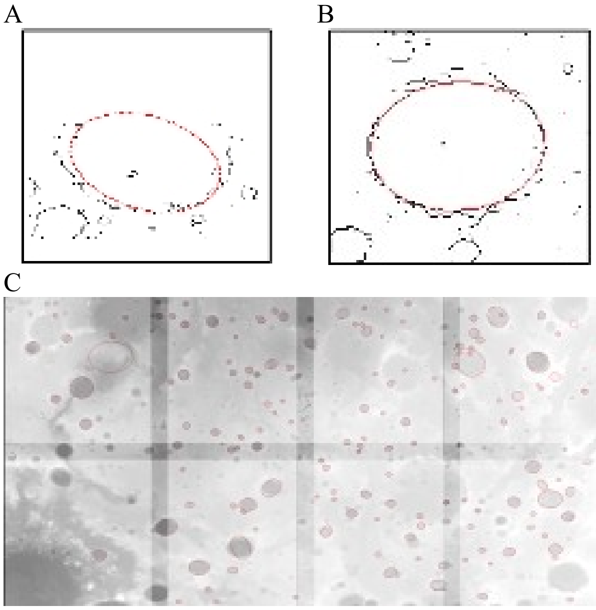

Fig. 2. Examples of crater detection by the GHT. This algorithm can detect a crater rim, even if it is incomplete, or not circular (A, B). Fig.2C shows a result at a region near Argyre crater.

Lineament detection: As lineaments including ridge and graben are formed by structural modifications, they are important targets in the investigation of the crustal evolution of the moon and planets.

After detection of craters, remaining edges would be candidates of lineaments. Most of them are, however, fragmented into short edges, and contaminated with false edges. The following procedure is adopted to extract long lineaments [9-10]. (1) Small edges are eliminated with median filtering. (2) By dilation and erosion operation, fragmented edges belonging to a single lineament are connected into a continuous line. Short edges are also deleted during this operation.

Once lineaments are detected, they are classified into ridges (positive lineaments) or grabens (negative lineaments) to compare the elevation on the lineament and that on the surrounding. The trial results on the Martian lineaments show that major lineaments are detected by the algorithm (Fig. 4, 5), and this algorithm gets some parameters such as the location, the length, and the direction. However, there are many parameters of the algorithm to be optimized to the individual input data and the target lineaments.

Summary: This algorithm has been improved with trial production. Current performance for detecting features competes with the appearance of beginners of geological mappers. Next step of this study is establishment of semi-automatic measurements of fundamental properties of craters such as a slope of size distribution and a ratio of diameter/depth. Further refinement and upcoming massive volume of SELENE data will bring complete and quantitative enumeration on a GIS analysis platform.

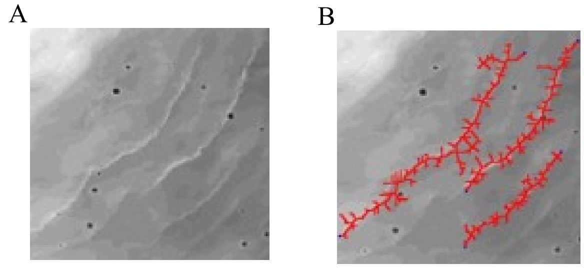

Fig. 4. Examples of ridge recognition (A) Input MOLA DTM at Solis Planum. (B) Result of ridge recognition. Three ridges are recognized.

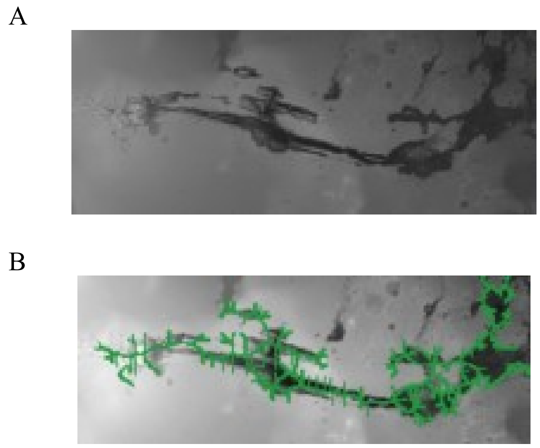

Fig. 5. Examples of graben recognition. (A) Input DTM at Velles Marineris and surroundings. (B) Result of graben recognition.

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