AUTOMATIC CRATER RECOGNITION ON DIGITAL TERRAIN MODEL. N. Matsumoto[1], N. Asada[1], and H. Demura[1], [1]University of Aizu (Tsuruga, Ikki-machi, Aizu-wakamatsu-city, Fukushima-prefecture, 965-8580 JAPAN, demura@u-aizu.ac.jp).

Introduction: ESA, SMART-1 has orbited around the Moon [1], Space Agencies of Japan, China, and India have expressed subsequent moon missions, and USA announced a return to the moon in New Vision for Space Exploration Program [2]. We have a Moon Rush. Japanese SELENE mission [3] has 14 instruments, and is going to provide a dataset more than 20TB. These massive and diverse data raise awareness about the need for automatically extracting/dictating geologic information. Here we remark "crater" on digital terrain models, this is just preparation for analysis of SELENE DTM products.

Automatic crater recognition has been studied [4][5][6], and they are almost categorized into a type of template matching. Although their results have shown good results, this type requires diverse templates and a heavy load for processing. Moreover this matching tends to have trouble in overlay craters and a round pattern with small craters. We adopt a generalized Hough transform after extracting edges from DTM, and establish algorithm for detecting craters. This goal is a software development to detect craters automatically with following parameters; diameter, coordinates, depth, and direction of incidence.

Sample Data: We adopt Mars' topography (MOLA data) as sample data for verifying this developed software. Its spatial resolution, bit resolution, and dynamic range are 1.864 km/pixel, 1m/DN, 16bit, respectively.

Procedures: This main processing notifies two; tangent's properties and the generalized Hough transform [7]. This algorithm can detect ellipsoids robustly even if craters show lack of larger parts of edge/rim.

The first step is to detect candidates of crater rims as edges on DTM. This step disregards deficiency of ellipsoids, and brings binarized pictures with outlines of the candidates.

Next each ellipsoid is characterized. The generalized Hough transform can complement the outlines' deficiency up to 50%. This transform method provides following properties of each ellipsoidal outline; coordinates of the center, length of major axis and minor one, and rotation angle of the major axis from east-west direction.

Next, the ellipsoids are divided into isolated ones and overlay ones. The isolated ellipsoids are determined as craters with no hesitation. Another type should be determined the order of emplacement. Lower crater is chipped by upper crater, in turn, older crater should be always chipped by new craters. The degree of oldness is estimated by the degree of erosion of crater rim. In case a lower crater is newer than an upper one, the newer complemented ellipsoid is not a crater. This step is applied to all combinations of overlay ellipsoids. After this screening we can obtain true crater units with measured properties.

Results of ideal patterns and natural ones: All ideal patterns of ellipsoids were detected without any errors (Fig.1); an isolated ellipsoid, plural isolated circle of a size, overlay ones, concentric ones, and a compound pattern. Because each ellipsoid has a certain set of parameters, in the case of Fig.1(iii), it requires twice processing with two sets of parameters.

A cluster of ellipsoids with change of those rotation angles showed a good result (Fig.2). These results show robustness in any relationship of targets.

On the other hand natural target showed good record (Fig.3(iv)) with a suitable preprocessing. Because natural craters show jaggy deviation from ideal outlines, their tangent's information does not converge. In the preprocessing their thick outlines should be thinned (Fig.3(iii)). In the generalized Hough transform processing scattered coordinates of the center of ellipsoids should be merged. These additional preprocessing brings a good result.

Summary: Verifications with ideal ellipsoids showed that this tool detected them exactly in diverse cases. Order of emplacement was also determined. We found a vital parameter; distance for restriction [7]. Because each size of ellipsoid requires a set of certain parameters for detecting, a case of mixture with plural sizes of ellipsoids needs dynamic survey of certain sets.

Appended small craters prevent from detecting larger craters, because small crater disturbs tracing outline of the larger craters. Because parameters of larger craters, such as diameter, deviate from correct values, smaller craters are detected, and then their marks are erased one after another. This process is repeated. This idea would improve the prevision of these obtained properties of a crater.

References: [1] European Space Agency, SMART-1 Home http://www.esa.int/SPECIALS/SMART-1/ [2] Press release, http://www.whitehouse.gov/news/releases/2004/01/20040114-1.html, [3[Japan Aerospace eXploration Agency, SELENE Home http://www.jaxa.jp/missions/projects/sat/exploration/selene/index_e.html [4]Plesko1 et al. LPSC XXXV 1935.pdf (2004), [5]Salamuniccar and Selar-Glavocic, Sixth International Conference on Mars, abstract no.3202(2003), [6] Magee et al. LPSC XXXIV1765.pdf (2003), [7] T.Watanabe, M.Hatakeyama, A.Kimura, "Extraction of Tangent Information and Detection of Broken Ellipsoids Using Hough Transform", HIS, Vol.J82-DII, No.12 pp.2221-2229(1999).

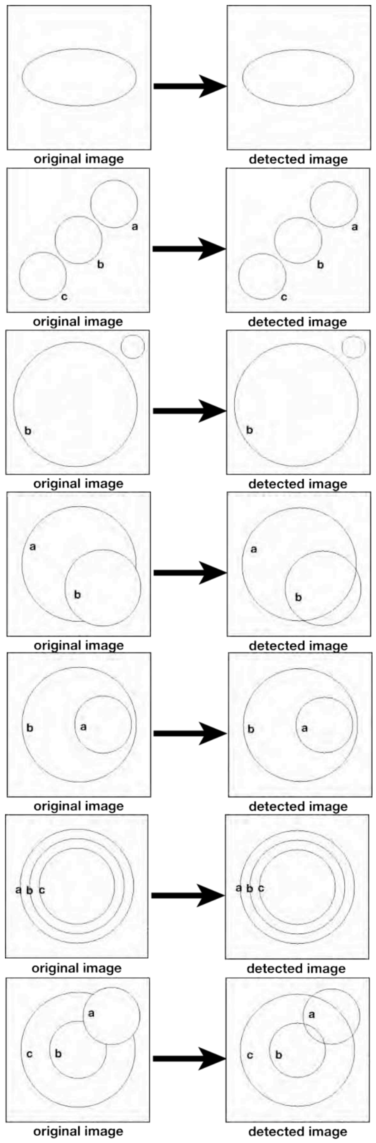

Figure 1. Comparison between ideal patterns and detected ones.

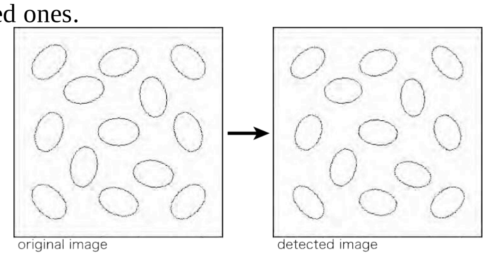

Figure 2. Results of verification with plural ellipsoids.

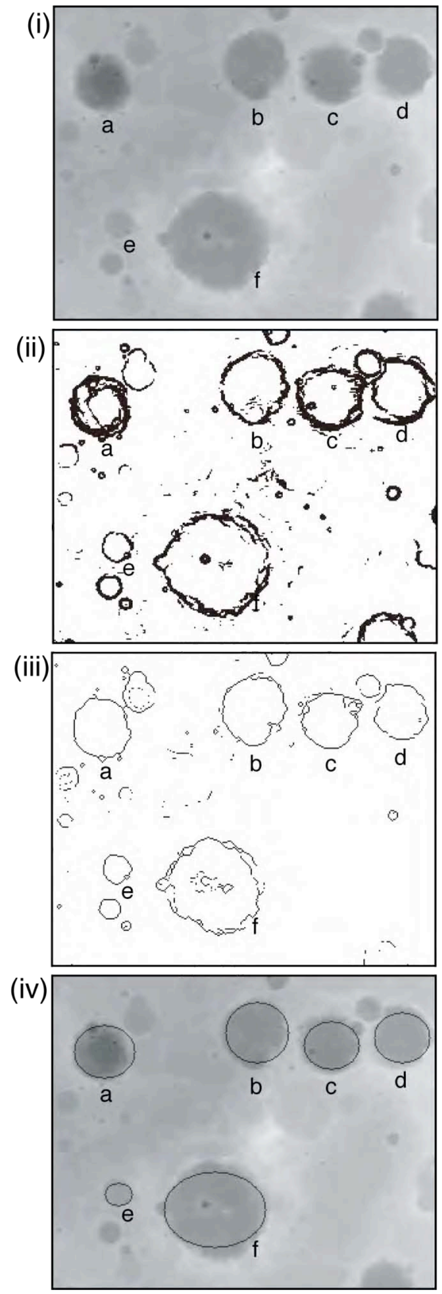

Figure 3. Processing flow of crater detection. (i) An image that corrected level of the original DTM image. (ii) An image that detected edge lines with Laplacian operation. (iii) Thinned image of (ii). (iv) Detected ellipsoids over (i).