**TOWARD MACHINE CATALOGING OF MARTIAN CRATERS.** Tomasz F. Stepinski, *Lunar and Planetary Institute, Houston TX 77058-1113, USA, (tom@lpi.usra.edu)*, Erik R. Urbach, *Lunar and Planetary Institute, Houston TX 77058-1113, USA, (urbach@lpi.usra.edu)*.

**Abstract.** We report on two different approaches to automate the cataloging of craters on Mars. For larger craters ($D \geq 3$ km) the craters are best identified from topographic data. A process of assembling a global catalog using such a technique is underway; the results will be used to construct a global maps of depth/diameter ratio. For smaller craters ($D < 3$ km) the craters are identified from images. A novel algorithm for robust identification of such craters is under development; the results will be applied for precision counts of sub-kilometer craters.

**Introduction.** Recent advances in pattern recognition and machine learning make automatic recognition of craters a plausible proposition. Recognizing this opportunity, we are developing algorithms for machine cataloging of impact craters on Mars. In recent years two other independent investigations were undertaken to construct such algorithms, both geared toward identification of small craters from imagery data. First, in a series of LPSC abstracts culminating in [1,2] C. Plesco and collaborators had developed an automated crater identifier using Genie Pro, off-the-shelf pixel classification software for satellite imagery. The performance of this approach is difficult to judge because the usual quality assessment factors were not calculated. In any case this effort has never progressed beyond a testing stage and is now inactive. Second, a team at the University Collage London had developed an algorithm for identification of craters from images. They reported [3] good performance based on standard quality factors calculated for test sites using images taken by different cameras. However, their algorithm is not publicly available for independent verification and the development effort has now ceased. We are developing two different algorithms. The first algorithm identifies craters from topographic data in order to measure their depths. Due to a limited resolution of the MOLA data this algorithm can only identify and characterize relatively large craters having diameter $\geq 3$ km. The second algorithm, based on imagery data is capable of cataloging sub-kilometer carters.

**Topography-based algorithm.** Our topography-based crater identification algorithm uses MEGDR [4] digital elevation models with resolution of 1/128 degree as the input data. The algorithm (described in [5,6]) is currently used to generate a global catalog of craters with $D \geq 3$ km. The most important feature of this catalog is an estimate of depth for each crater. This makes possible global mapping of depth/diameter ratio. The catalog will be available as the ArcGIS shapefile, so it can be incorporated into Mars GIS framework. In [6] we calculated standard quality factors for our algorithm using eight large test sites and showed that the algorithm identifies craters in a robust and predictable fashion. We have made the code of our algorithm available for download at cratermatic.sourceforge.net. The subset of our machine-generated catalog, consisting of 7845 craters located in Terra Cimmeria region between 120E -180E and 0S -90S, was used [7] to map depth/diameter ratio in order to infer spatial distribution of ground ice. Fig.1 shows the raster maps of $d/D$ for six different crater size bins as indicated. The pattern observed in Fig.1 supports the notion that ground ice is located progressively closer to the surface at higher southern latitudes.

**Image-based algorithm.** For identification of smaller, and, in particular, sub-kilometer craters we are developing an image-based crater identification algorithm. This algorithm is based on the idea that each crater has a shadow and highlight segments. As illustrated on Fig.2 the algorithm processes shadow and highlight segments of an image separately using shape filters [8]. The last step is to match shadow segments to their corresponding highlight segments in such a way that only segments corresponding to craters are matched. The $14 \times 14$ km site shown in Fig.2 is in the region of Nanendi Valles and centered on -47.85E and 5.6N. The image is a portion of much larger HRSC image with the resolution of 12.5 m/pixel. Our algorithm has identified 63 craters ranging in size from 150 m to 2.4 km. All craters with $D \geq 250$ m have been identified. This is a very fast algorithm that will be used for cataloging subkilometer craters in regions where high resolution images are available. The lower limit on size of identified craters depends on image resolution. We are investigating plausibility of using photoclinometry to automatically estimation the depths of subkilometer craters.

**References**

**(1)**. Plesco, C.S. et al. “A comparison of automated and manual surveys of small craters in Elysium Planitia", LPSC #1971, 2005.

**(2)**. Plesco C.S. et al. “A statistical analysis of automated crater counts in MOC and HRSC data", LPSC XXXVII, #2012, 2006.

**(3)**. Kim, J.R. et al. “Automated Crater Detection, A New Tool for Mars Cartography and Chronology", Photogrammetric Engineering & Remote Sensing, vol. 71(10), 1205-1217., 2005

**(4)**. Smith, D. et al. “Mars Global Surveyor Laser Altimeter Mission Experiment Gridded Data Record", NASA Planetary Data System, MGS-M-MOLA-5-MEGDR-L3-V1.0, 2003.

**(5)**. Stepinski, T.F. et al. “Robust automatic identification of Martian impact craters"., LPSC XXXVIII, #1202, 2007.

**(6)**. Stepinski, T.F. et al. “Machine cataloging of impact craters on Mars"., submitted to Icarus 2007.

**(7)**. Stepinski, T.F. and Urbach, E.R. “Mapping craters in Terra Cimmeria, Mars: Implications for spatial distribution of ground ice"., 7th International Conference on Mars, 2007.

**(8)**. Urbach, E.R. et al. “Connected shape-size spectra for rotation and scale-invariant classification of gray-scale images"., IEEE Trans. Pattern Anal Mach. Intell., 2007.

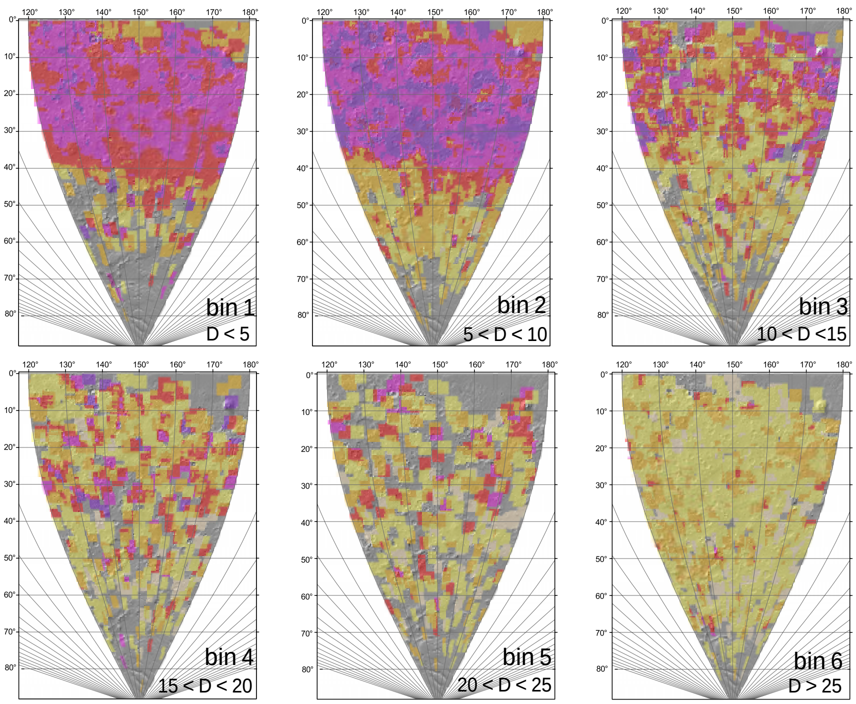



**Figure 1.** Maps of spatial variation of d/D in the Terra Cimmeria region on Mars. The maps are shown in sinusoidal projection. Each map shows d/D values as calculated from craters in the size bin as indicated. Different colors correspond to different values of d/D as shown in the legend above.

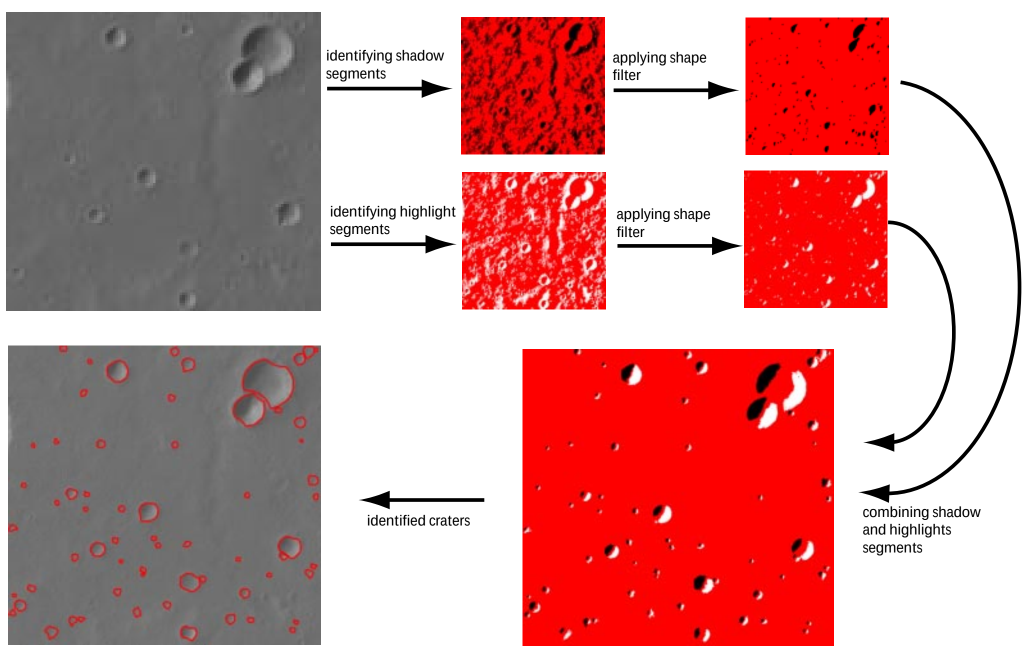


**Figure 2:** Diagram illustrating image processing steps in image-based crater detection algorithm.