AUTOMATIC MAPPING OF MARTIAN LANDFORMS USING SEGMENTATION-BASED CLASSIFICATION. S. Ghosh, *Dept. of Computer Science, University of Houston, Houston, TX 77204, USA, (somu_1983@hotmail.com)*, T. F. Stepinski, *Lunar and Planetary Institute, Houston TX 77058-1113, USA, (tom@lpi.usra.edu)*, R. Vilalta, *Dept. of Computer Science, University of Houston, Houston, TX 77204, USA., (vilalta@cs.uh.edu)*.

Abstract. We use terrain segmentation and machine learning-based classification techniques to interpret Martian topographic data and to map constituent landforms in Martian landscape. The method is applied to six Noachian sites to automatically obtain a six-landforms geomorphic maps geared toward rapid characterization of impact craters. The generated maps reflects well the actual geomorphology and have appearance reminiscent of what a human expert would map by interpreting image data.

Introduction. Landscape topography provides direct information on geological processes sculpturing the surface of Mars. The landscape can be divided into a set of mutually exclusive and exhaustive landscape elements or landforms. Mapping landforms over a given region on Mars establishes distributions and spatial extents of these features – crucial information used to infer surfacial processes responsible for the specific character of the studied site. Presently, such geomorphic maps are made through a labor-intensive, manual characterization of information from imagery data. However, availability of digital topographic data and advances in pattern recognition algorithms open a possibility of automating the mapping process. We have started to develop a system that enables automation of landforms mapping by means of segmentation-based classification of landscape scene into constituent landforms. This novel approach aims at the result that, in their appearance and content, mimics manually derived maps.

Methods. Our automated mapping system is based on topographic instead of imagery data. We use MOLA Mission Experiment Gridded Data Record (MEGDR) [1] with the resolution of 1/128 degree to extract a digital elevation model (DEM) raster of a site of interest. Additional rasters of terrain attributes, such as, for example, slope and curvature, are calculated from an original DEM. A set of all attributes at a given pixel forms a “feature vector" attached to this pixel. In the segmentation-based classification [2,3] the site is first subdivided into patches (fragments of landscape grouping pixels having approximately uniform feature vectors) that are then classified into a small set of landform classes. We have developed a novel segmentation technique, based on a simple k-means clustering, that, in addition to feature vectors, uses spatial coordinates of pixels. It produces a desirable segmentation by dividing the site into relatively small, approximately equal-sized patches. In order to approximate subtle qualities of manually constructed maps we use a supervised machine learning technique to classify the patches. A supervised learning uses a training set of patches, for which landform labels have been already assigned by an expert, to construct a labeling function that is then applied to label all other patches. Such labeling function is an extensive, computer-derived set of rules that reflects a connection between patches’ numerical features and landforms’ labels assigned by an intangible reasoning of an expert. As such it delivers more “human-like" classification quality than hand-designed labeling functions often employed in similar contexts [4,5].

Application to the test sites. To demonstrate the present abilities of our mapping algorithm we have applied it to a test site centered on Tisia Valles (46.13^{o}E, 11.83^{o}S). This 385×424 pixels site represents a typical Noachian terrain dominated by craters with various sizes, depths, and degrees of preservation. We have chosen to map six landform classes: crater floors, convex crater walls, concave crater walls, intercrater plateau, convex ridges, and concave ridges. The choice of the first three classes reflects our interest in automatic characterization of impact craters. The site contains escarpments that are not parts of craters dictating the choice of the last two classes. The site was segmented into 6593 patches using five-dimensional, pixel-based feature vectors (slope, curvature, flood, x-coordinate, y-coordinate). Each patch (containing ~ 100 pixels) is described by numerical features that include mean values of slope, curvature and flood, as well as information about the neighboring patches. The total of 829 patches, representative of all six classes, were expert-labeled to form a training set. To construct a labeling function we used the software package WEKA [6] that offers a choice of different classification methods. Different methods result in differently looking maps. The Support Vector Machines (SVM) method produced the best results for our purposes.

Fig.1 shows the topography of the Tisia Valles site (top-left), and the automatically generated map of six landform classes (top-right). A generated map offers a decent rendition of site’s geomorphology, although a closer inspection reveals a number of shortcomings. Most noticeably concave ridges are frequently classified as concave crater walls. This is not surprising as these two landforms are very similar in all physical characteristics and differ only by their larger-scale contexts. Notwithstanding these shortcomings the quality of the generated map is sufficient to form a basis for automated characterization of craters.

We have used the training set established for Tisia Valles site to map five other Noachian sites. Fig.1 shows the topography (bottom-left) of one of these sites centered on Vichada Valles (88.91^{o}E, 19.15^{o}S, 563×408 pixels) and its six-landform map (bottom-right). The quality of the Vichada Valles map is about the same as the quality of the Tisia Valles map despite using a “non-native" training set. This is because both sites have similar characters and the existing training set is representative for both sites. Generated maps of other four Noachian sites have also about the same quality as the Tisia Valles map. This demonstrated the practicality of our method – relatively small training set is sufficient to map many areas.

Discussion. Mapping landforms can be much more effi-

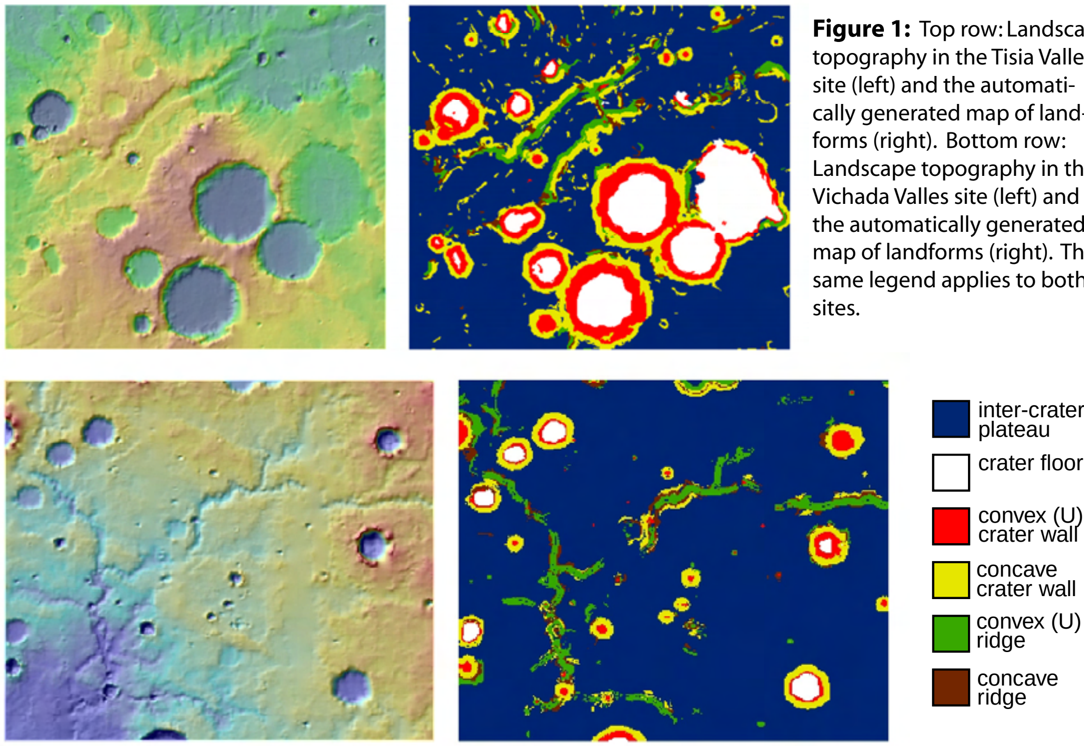

Figure 1: Top row: Landscape topography in the Tisia Valles site (left) and the automatically generated map of landforms (right). Bottom row: Landscape topography in the Vichada Valles site (left) and the automatically generated map of landforms (right). The same legend applies to both sites.

ciently and consistently carried out by computer than human. However, obtaining good quality maps by practical algorithmic means is a challenge. We are continuing to develop a system that would meet that challenge. Testing the present version of our system on the six Noachian sites reveals that practical machine mapping of Martian landforms is possible and the quality of the resulting maps are sufficient for some geologic analysis including characterization of impact craters – a focus of our interest. Increased accuracy of mapping can be achieved by incorporating more relevant quantities to feature vectors, both on the pixel and the patch levels, and by enlarging the training set.

The ultimate goal is to have a robust system capable of rapid generation of many maps that are then subjected to a comparative analysis by an another automated algorithm. Thus, not only the maps are automatically created, but they are seamlessly organized into groups and subgroups on the basis of predefined similarities. Such fully automated workflow would significantly increase our ability to process increasing volume of data. In the immediate future we will apply our mapping algorithm to automate the process of crater characterization. The system will be presented with a large number of small sites, each containing a single crater. For each site the algorithm will map different crater landforms and use the resultant map to calculate a list of parameters describing a structure of the crater. Such approach permits calculation of much more parameters than just a diameter and depth. For example, size and smoothness of the floor, slope of the walls, variability of the rim height can all be calculate once different elements of crater's structure are delineated.

References

(1). D. Smith, G. Neumann, R.E. Arvidson, E.A. Guinness, and S. Slavney, "Mars Global Surveyor Laser Altimeter Mission Experiment Gridded Data Record", *NASA Planetary Data System*, MGS-M-MOLA-5-MEGDR-L3-V1.0, 2003.

(2). Baatz, M., Schäpe, A., "Multiresolution segmentation – an optimization approach for high quality multi-scale image segmentation", *Angewandte Geographische Informationsverarbeitung*, vol. XII, pp. 12-23, 2000.

(3). Stepinski, T.F., Ghosh, S., Vilalta, R., "Automatic Recognition of Landforms on Mars Using Terrain Segmentation and Classification", *Lecture Notes in Artificial Intelligence*, vol 4265, pp 255-266, 2006.

(4). Dragut, L., Blaschke, T., "Automated classification of landform elements using object-based image analysis", *Geomorphology*, vol. 81, pp 330-344, 2006.

(5). Gallant, A.L., Brown, D.D., Hoffer, R.M., "Automated mapping of Hammond's Landforms", *IEEE Geoscience and Remote Sensing Letters*, vol. 2(4), pp 384-288, 2005.

(6). Witten, I.H., Frank, E., "Data Mining: Practical Machine Learning Tools and Techniques", 2nd Edition, Morgan Kaufmann, San Francisco 2005.