GLOBAL GEOMORPHOMETRIC MAP OF MARS. J. Jasiewicz[1,2] and T. F. Stepinski[1], [1]Department of Geography, University of Cincinnati, Cincinnati, OH 45221-0131, [2]Geoecology and Geoinformation Institute, Dziegielowa 27, 60-680 Poznan, Poland, {jarek.jasiewicz@gmail.com , stepintz@uc.edu}.

Introduction: Digital elevation model (DEM) of planetary surface needs to be further processed in order to provide information for geomorphologic and/or geologic analysis. The standard procedure is to convert DEM data into a map of shaded relief (hillshade) that provides three-dimensional depiction of the terrain. Shaded relief map is an invaluable tool for *visual* analysis of the terrain but cannot be used as an input for algorithm-based, *automated* type of analysis. Automated analysis of planetary terrain [1,2] become increasingly necessary in order to cope with large amount of data, especially in studies requiring global or regional evaluation. The input data for automated analysis of the terrain must be either the DEM itself, or, preferentially, a thematic map of landforms – elementary units of terrain. Recently, we have introduced [3] a novel, highly computationally efficient and robust method for classification and mapping of landforms from DEM based on the principle of machine vision. As the method classify landforms on the basis of their morphology, rather than underlying geologic process or other semantic attribute, we refer to the resultant map as a "geomorphometric" map rather than a geomorphic map. Although such map can be analyzed visually, its main purpose is to provide an input to algorithm-based analysis. In this contribution we use our method to construct a global geomorphometric map of Mars using the 128pixels/degree MOLA-based DEM. In order to demonstrate the utility of this map to algorithm-based analysis we have calculated "landscape signatures" for two different Noachian geologic units. This exercise demonstrates that visually delineated geologic units, are characterized by different composition of landforms. This opens up a possibility that, in the future, geologic units could be delineated algorithmically or, at least, the process of their delineation can be significantly expedited by automated analysis of terrain.

Geomorphometric map: In [3] we introduced a novel method for automatic classification and mapping of landforms from DEM based on the principle of pattern recognition rather than the standard principle of differential geometry. Values of local relief are calculated in eight principal directions and used to construct a simple ternary pattern that encapsulates morphology of the local surface. Because of their simplicity, there are only 498 different possible patterns with each pattern representing an archetype of a specific terrain morphology. These patterns and they associated terrain archetypes are referred to as geomorphons (geomorphologic phonotypes). Geomorphons constitute a comprehensive and exhaustive set of all possible morphological terrain types. Thus geomorphons are both terrain attributes and landform types. This enables an efficient unsupervised classification and mapping of landforms; a DEM is scanned once and appropriate geomorphon is assigned to each of its cells resulting in a map of terrain types. It is worth pointing out that landforms are identified on a range of spatial scales as the method of calculating ternary patterns utilizes the line-of-sight principle.

We have applied our method to the global MOLA-based topographic grid (46080 x 22528 pixels) with 1/128 degrees/pixel spatial resolution. We have chosen to map only 10 most common landforms out of possible 498 geomorphons. Mapped forms (color on the map) are: flat (gray), peak (brown), ridge (dark red), shoulder (light red), spur (orange), slope (yellow), hollow (light green), footslope (dark green), basins or valleys (blue), pit (black). A lookup table was used to assign each of the less common form to a morphologically closest common form. The result is a global geomorphometric map of Mars with 1/128 degrees/pixel spatial resolution. Fig 1. shows this map divided into an equatorial and two polar regions. As this is a high resolution global map, its low resolution rendition in this abstract poorly reflects the character of the map. A close-up of a sample area gives a better idea of how the map depicts different landforms.

Geomorphometric map enables algorithmic identification of similarity or dissimilarity of landscape patterns. A character of a terrain in a given study area can be encapsulated by a mathematical description – a landscape signature - calculated from the patterns of the landforms. One possible landscape signature is based on two statistics: percentages of area occupy by different landform and percentages of area within a given landform belonging to land-patches of different sizes. A patch is a connected region of single landform. Thus, landscape signature is a two-dimensional histogram representing a landscape pattern.

Quantification of geologic units: We calculate landscape signature for different geologic units - regions of Martian surface delineated manually on the basis of visual inspection. Landscape signature quantifies geologic units. With such quantification a degree of similarity between different units can be calculated leading to possibility that units can be delineated algorithmically using a standard terrain as an example.

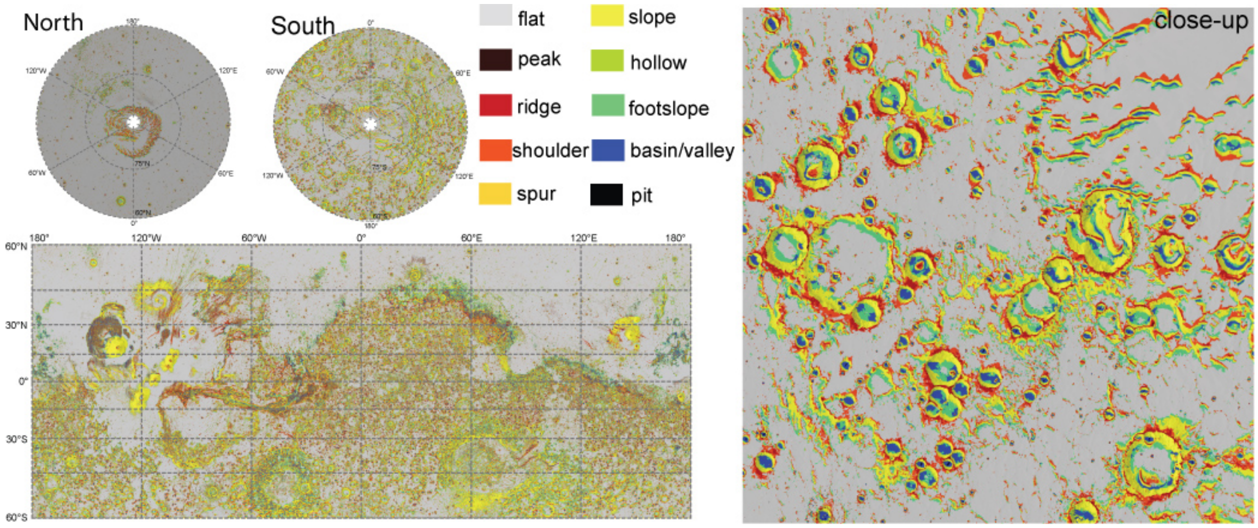

Figure 1: (Left) Global geomorphometric map of Mars. (Right) A close-up of a global map showing its typical character.

Fig. 2. shows a terrain located on the western flanks of Argyre impact basin and dominated by two Noachian units: Npl1 and Nplh. This units are described semantically [4] as: "highly cratered, uneven surface of moderate relief" (Npl1) and "rough, hilly material" (Nplh) which corresponds to what is seen at the bottom panel of Fig. 2. Using a geomorphometric map we are able to characterize these two surfaces mathematically as 2D histograms (top panel of Fig. 2.). This histograms show that Npl1 unit is enriched in "flat" landform, especially at large patch sizes, whereas Nplh unit is enriched in "slope" landform at medium patch sizes because slopes are the main parts of hills.

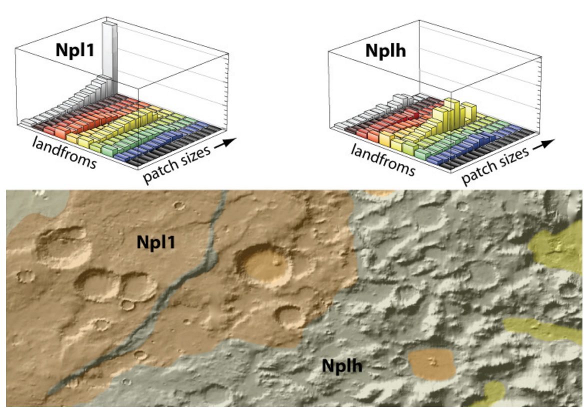

Figure 2: Landscape signature using geomorphometric maps. (Top) 2D histograms for tho Noachian units (calculate over the entire planet). (Bottom) Examples of Npl1 and Nplh units.

Conclusion: Global geomorphometric map of Mars with resolution of 128pixels/degree is a new tool available for analysis of Martian terrain. It can be utilized for visual analysis, but its main advantage is that it also can be utilized for automated analysis. We have presented an example of using the new map for quantification of geologic units. Exciting future application is a query-by-example landscape search tool. Using such tool an analyst can search the entire surface of Mars for instances of landscapes that are highly similar to a given example. Such "browser" for landscapes will enable an analyst to put a specific study area in a global context by gaining information about existence and spatial locations of similar areas over the entire Martian surface. It will also be possible to segment the surface of the planet into fragments characterized by a specific and distinct composition of landforms. As the composition of landforms correspond to a distinct visual appearance, such procedure is tantamount to automatic delineation of surface geomorphic units. The same technique is applicable to any planetary surface for which a global DEM is available.

References: [1] Luo, W. & Stepinski, T.F., JGR-Planets 114, E11010 (2009), [2] T. F. Stepinski, M. P. Mendenhall, and B. D. Bue (2009) Machine Cataloging of Impact Craters on Mars. Icarus, 203, p.77-87, [3] T. F. Stepinski, J. Jasiewicz, Geomorphons - a new approach to classication of landforms, in: T. Hengl, I. S. Evans, J. P. Wilson, M. Gould (Eds.), Geomorphometry 2011, 2011, pp. 109-112, [4] J Scott, D. H., and K. L. Tanaka (1986) U.S.G.S. Geo. Inv. Series Map I-1802.