AUTOMATIC RECOGNITION OF DIVERSE TYPES OF POLYGONS ON MARS. P. Pina, J. Saraiva, J. Antunes and L. Bandeira, CERENA, Instituto Superior Técnico, Av. Rovisco Pais, 1049-001 Lisbon, Portugal (ppina@ist.utl.pt).

Introduction: The existence of small-scale polygonal terrains on Mars raises the possibility of the occurrence of freeze-thaw processes in some areas of the surface of the planet. This idea is based on the similarities between many of the martian polygons and their terrestrial analogues – the origin of these can, in many instances, namely in periglacial areas, be directly related to the presence of ice in the soil, and to the seasonal changes in temperature that affect it.

Thus, these martian features have been under scrutiny by many workers in recent years; they concerned themselves with different aspects, such as the identification of areas of occurrence [1], the dimensions they attain [2], their evolution along the seasonal cycle of Mars [3], and their classification according to a set of morphological characteristics [4]. All these studies, more or less detailed, share one common methodology: the identification and all measurements made on the polygons were obtained on the basis of visual inspection and manual contouring of their edges.

To try and change that, we presented in previous works [5], [6], a methodology for the automated identification of polygons on images of the surface of Mars. This type of features is clearly suitable to the application of such a procedure, though the results may be influenced by the characteristics of the image, such as the contrast between edges (be they cracks or ridges) and enclosed areas. This approach has the advantage of permitting the analysis of large areas of terrain in a short period of time, thus saving the effort of human operators to the more important tasks of interpreting and trying to understand the origin of the features. The elucidation of this question requires the collection of data about the polygons, namely about their morphology (areas and shapes, among others) and topology (intersections, neighbours, for instance). This can easily be achieved after a correct identification of the polygons on images, and is described elsewhere [7].

Survey of polygonal terrains: Given the countless different settings in which polygonal patterns are present on the surface of Mars, we decided to conduct a survey of narrow angle MOC images, acquired between 1998 and 2006, and to select interesting images according to a number of conditions, namely latitude of the centre of the image (higher than 45º, N or S) and spatial resolution (better than 6 metres per pixel). The images that respected both of these criteria were all visually inspected, and those that presented adequate extensions of polygonal terrains were chosen for analysis. One of our first aims is to probe some of the classification schemes presented by different authors, and which were based on limited sets of geometrical characteristics.

Recognition of polygons: The first step in this endeavour is to identify the polygons and assess to what point we can trust in the automatic identification as a basis for the subsequent geometric and topological characterization. As previously presented [5], our methodology rests on the segmentation of the image by a watershed procedure, and the application of contour dynamics to reduce oversegmentation and preserve only significant contours.

In this instance, we present some preliminary results of the project we are developing, yielded by the application of our methodology to a number of images intended to represent very diverse types of polygonal terrain, according to dimensional criteria previously defined [4] in an attempt at a global characterization.

Results: The six images employed in this study were all visually analysed, and the polygons present in them were manually contoured. The lengths of contours (in pixels) were determined, and a global extension (sum) was obtained for each image. This was our ground-truth, *GT*, that formed the basis to evaluate the performance of our methodology in quantitative terms. For this purpose, all lines are given the same (unitary) width.

The results presented were obtained by comparing *GT* networks with those yielded by the automated methodology on the images contained in the data set. Two indicators were computed, the correct detection rate, *CDR*, and the false detection rate, *FDR*:

$$CDR = \frac{CD}{GT} \cdot 100 \,, \; FDR = \frac{CD}{CD + FD} \cdot 100$$

where *CD* is the number of pixels correctly detected and *FD* is the number of false detections.

The table presents the results achieved by the methodology for the set of test images. It is readily apparent that, in each case, the number of pixels correctly attributed by the automated procedure to the edges of polygons is very close to the number manually determined. The numbers of false positives are also relevant, since they show that the methodology does not create many false contours.

A detailed analysis of the results of the methodology allows for the identification of missing lines and

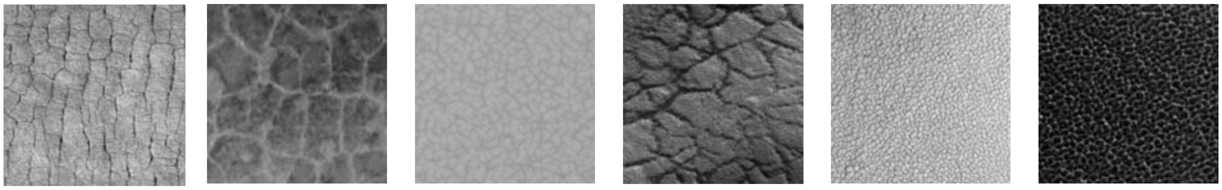

Fig. 1. Details of polygonal networks extracted from MOC N/A images [NASA/JPL/MSSS].

Table 1. Results of automated recognition of polygons

Image	*No. polygons*	*Type*	*Location of image centre*	*CDR (%)*	*FDR (%)*
M03-04331	438	LT	272.80°W - 44.46°N	89.86	3.11
R10-01796	25	LT	90.62°W - 81.84°S	96.98	2.08
M09-01292	1088	LPC	103.64°W - 84.93°S	97.74	0.08
R10-01555	47	LT	326.77°W - 54.62°N	93.87	3.81
M03-04266	6474	S	229.52°W - 54.16°S	99.89	0.02
M14-00154	3808	S	2.93°W - 60.66°N	99.94	0.04

false positives, which can lead to improvements in the methodology. This is shown for two of the images of the set, with very different numbers of polygons (Fig. 2 and 3).

It seems clear that there are no major mistakes: the detected networks are very similar to the physical reality as captured in the images. In both images, red lines mean false positives that must be removed and green lines are those that were missing from the automated identification.

It deserves to be mentioned that a manual identification and characterization of a complete network such as that present in Fig. 2, with large numbers of small polygons occupying a large area, is virtually impossible to achieve. In this case, we only treated a section of the image.

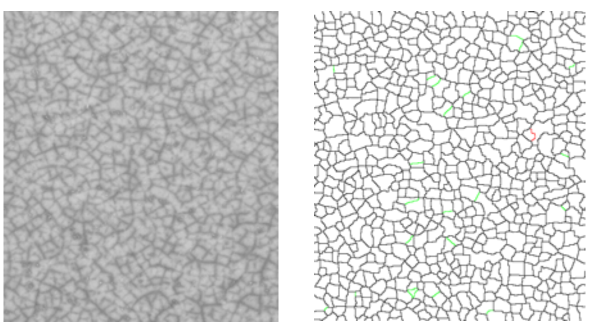

Fig. 2. Polygonal network and its automated recognition on detail of image M09-01292.

Also, it must be stressed that quantitative results for the larger polygons, though less impressive, can still be considered very good (as seen in Fig. 3).

On-going work: Although the results we have obtained so far are very good, we feel there is still room for improvement, especially in what concerns the identification of missing lines and the elimination of false positives. Thus, there are two steps of the methodology in which we plan to invest: the pre-processing phase, in which noise in the image is reduced (from the original) and some degree of highlighting is achieved for the contours; and the phase in which the dynamics of contours is computed – there are several alternatives that we plan to test.

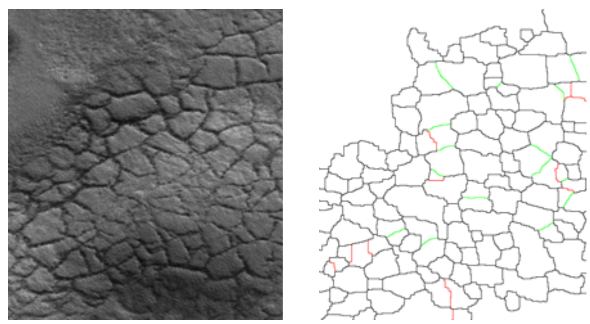

Fig. 3. Polygonal network and its automated recognition on detail of image R10-01555.

Also, there are still a number of images with different visual appearances in which to apply the methodology. However, even if it does not produce, for those cases, results that are on the same level of accuracy, we believe this is a tool that can be applied in many instances, and serve as a basis for further studies of polygonal terrains, on Mars or other planetary objects.

References: [1] Kuzmin R. and Zabalueva R. (2003) *LPS XXXIV*, Abs. #1912. [2] Langsdorf E. and Britt D.(2005) *LPS XXXVI*, Abs #2140. [3] van Gasselt S. et al. (2005) *JGR*, 110, E08002. [4] Mangold N. (2005) *Icarus*, 174: 336. [5] Pina P. et al. (2006) ICIAR2006: 691-699. [6] Pina P. et al. (2007) *LPS XXXVIII*, Abs #1315. [7] Pina P. et al. (2008) *LPS XXXIX*.

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