AUTOMATIC IDENTIFICATION OF POLYGONAL PATTERNS ON MARS. P. Pina[1], T. Barata[2], J. Saraiva[1] and L.P.C. Bandeira[1], [1]CERENA, IST, Av. Rovisco Pais, 1049-001 Lisbon, Portugal, ppina@alfa.ist.utl.pt [2]Centro de Geofísica, Univ. Coimbra, Av. Dias da Silva, 3000-134 Coimbra, Portugal.

Introduction: The polygonal patterns that have been spotted on the surface of Mars occur in a wide range of locations and present dimensions and probable origins that are also diverse. One major point of interest in their study is the similarity between some of them and terrestrial analogs. We have been working in the development of a methodology for automated recognition and characterization of patterned terrains, through the application of a number of mathematical morphology techniques. The aim is, first, to identify their presence (locate the edges) and then obtain some measures of their dimensions and topological characteristics. Previous works on this subject have focused on qualitative descriptions [1], [2], with a couple of papers more concerned with a quantitative approach, [3], [4], [5]; in all these works there is no reference to any automated procedure to extract the relevant features. The only work where an automated approach was applied to the detection of polygonal terrains is concerned with Venus, where SAR images were obtained by the Magellan probe [6].

Polygon Identification: We present here an automated approach to identify polygonal patterns on the surface of Mars. Its detailed description, including the mathematical formalism, has already been published [7]. In here, the method is illustrated by its application to a section of a MOC image (R10-01796, Figure 1a) that we selected for this purpose. This is an image of high latitude (80º) polygonal terrain, which is very likely linked to periglacial processes occurring in the south pole of Mars. The spatial resolution on this image is 5.82 metres per pixel.

The methodology is constituted by two main phases and it is intended for application in the search for polygons independently of the type of terrain where they occur. The first phase consists of a pre-processing stage, where noise is filtered out and contours are enhanced. In the second phase, the contours of the images are identified through the application of the watershed transform. This is followed by the analysis of the contours detected according to their relevance relatively to the minima of the adjacent basins, which permits the construction of an image containing information about their dynamics. The adequate thresholding of this image leads to the identification of the most relevant contours that correspond in our images to the cracks separating the polygons.

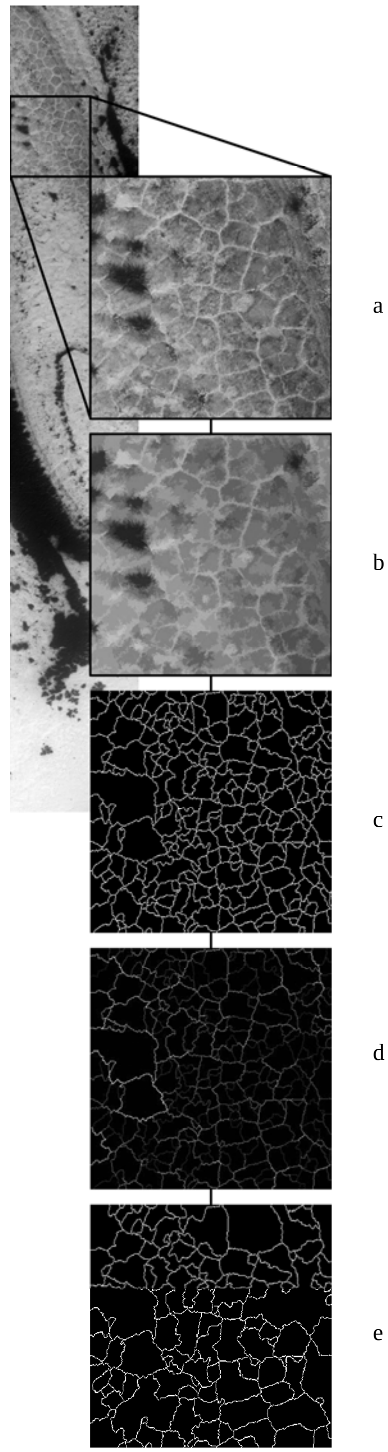

Figure 1. MOC/MGS image R10-01796 (NASA/JPL/MSSS) showing the sequence of steps of the methodology for automatic identification of polygonal patterns.

The edges of polygons in images acquired by the MOC instrument are usually not very well defined in some locations due to insufficient spatial resolution or to some unfinished physical process. We assume that these 'faulty' edges can be recovered when the distance is small. In addition, some local intensity variations on the images should also be filtered out. The need to submit the original image to a filtering phase becomes clear when we try to segment it directly. The result is a gross over-segmentation that would not permit the continuation of the process of identifying the sides of polygons. Thus, we must perform this filtering in such a way that the borders are enhanced and the noise in the image is greatly reduced. A good approach to enhance the edges and to filter some noise is to apply a sequence of morphological filters by reconstruction which leads to a simplification of the image, while preserving contours (Figure 1b).

The next step is the segmentation of the image by watershed [8]. We computed the watershed lines for the image at each step of the filtering sequence; as should be expected for this kind of image, the results for the early phases of filtering were heavily over-segmented, a trend that was minimized with further filtering. We ended up with an image in which the contours – the watershed lines – show a degree of regularity that can be accepted, as shown in Figure 1c. However, though the number of basins came steeply down, there are still a number of contours that do not correspond to true polygon sides.

In order to identify those that are relevant, and discard those that are not, we followed an approach [9] that takes into account the dynamics of the contours, by applying a contrast criterion that measures the difference in grey levels between a peak and its surrounding minima. In visual terms, each contour divides two basins, and each of these basins has a minimum. The higher the difference between the grey level of the saddle point (point of the edge with the lowest value) and the lowest minimum value of the two adjacent basins, the higher the dynamics of the respective contour. This is a major step for the evaluation of the relevance of the contours as can be seen in Figure 1d.

The previous image is finally the subject of a thresholding, which allows us to identify the contours that have meaning within the image, and that can be seen in Figure 1e.

Results: To evaluate the accuracy of the methodology for the identification of polygons that we are proposing, we compared those that the methodology detects and those that are manually identified on a set of five images that were selected for this purpose, and that correspond to details of the five narrow-angle MOC images identified in Table 1. To give a numeric significance to this comparison, we measured the length of the contours obtained with both approaches. The results obtained are presented below.

Table 1. Recognition rates of polygon contours.

Image	Visual (pixels)	Auto (pixels)	Auto (%)	False Pos. (pixels)
M19-00047	12342	9973	80.80	18
R10-01796	7918	6695	84.55	440
R08-01628	11323	9294	82.08	201
M03-04331	11201	9326	83.26	272
E09-00029	12593	12572	99.83	21

These results can be regarded as very good. The recognition rate is consistently above 80%, and there is one case where it practically reaches 100%. We are aware that the characteristics of the original images play a major role in determining the final results; the fact that, at the start, an image shows clear and defined lines against a uniform background leads to excellent results in the automated identification of polygons.

A word should be said about another characteristic of these results, which is the low numbers of false positives – that is, pixels that were identified by the methodology as being part of a contour but were not in reality (in visual inspection) integrated in the side of a polygon. In fact, these correspond mostly to 'ghost' contours that come into being by subdividing the real polygons.

Future Work: We intend to proceed with a study of much bigger scope, involving larger areas and other locations and styles of polygons, in order to further test and improve our methodology, and obtain statistically significant results that can contribute to a better understanding of the processes involved in the origin of this type of features on the surface of Mars.

References: [1] Seibert N.M. and Kargel J.S. (2001) *GRL 28*, 899-902. [2] Langsdorf E.L. and Britt D.T. (2005) *LPS XXXVI*, Abstract #2140. [3] Mangold N. (2005) *Icarus* 174, 336-359. [4] Hiesinger H. and Head III J.W. (2000) *JGR 105*, 11999-12022. [5] van Gasselt S. et al. (2005) *JGR 110*, doi: 10.1029/2004JE002385. [6] Smrekar S.E. et al. (2002) *JGR 107*, doi: 10.1029/2001JE001808. [7] Pina P. et al. (2006) *LNCS 4142*, 691-699. [8] Bleau A. and Leon L.J. (2000) *Comp. Vis. Im. Understanding* 77, 317-370. [9] Najman L. and Schmitt M. (1996) *IEEE Trans. Pat. Anal. Mach. Intell.* 18, 1163-1173.

Acknowledgements: This paper was developed in the frame of the project PDCTE/CTA/49724/03, funded by FCT, Portugal.