AUTOMATIC RECOGNITION OF AEOLIAN RIPPLES ON MARS. P. Pina, J. Saraiva and T. Barata, CVRM/Geo-Systems Centre, Instituto Superior Técnico, Av. Rovisco Pais, 1049-001 Lisboa, Portugal (ppina@alfa.ist.utl.pt, jsaraiva@alfa.ist.utl.pt, tbarata@alfa.ist.utl.pt).

Introduction: Over the years, the evolution in resolution power of the instruments aboard planetary probes scanning the surfaces of planets and moons of the Solar System has allowed for the observation of ever smaller details, in narrower spectra regions with increased spectral responses and also in shorter time intervals. These higher resolutions (spatial, spectral, radiometric and temporal) are naturally leading to larger quantities of raw data. Although human analysis will always be fundamental for qualitative evaluation, there exists a vast field for automation of procedures through the application of digital image analysis methods, such as the following example.

One of the first features on the martian surface to attract our attention were aeolian ripples. Several studies of these features have been published recently, seeking to distinguish them from dunes [1], to take account of the variety of forms that may occur [2] and to compare these structures on Earth and Mars and extrapolate some of their characteristics [3][4]. Some aeolian features have even been studied in the context of the selection of landing sites for the NASA MERs [5], thanks to spatial detail available from recent instruments [6].

This paper presents a two-step algorithm to segment and recognise ripples in an automatic mode, based on mathematical morphology operators [7][8][9]. The images we used to develop our approach were acquired by the Mars Orbiter Camera (MOC) aboard Mars Global Surveyor (MGS). The image shown to illustrate our approach is MOC2-477 from Arabia's Auqakuh Vallis (28.9°N, 299.9°W).

Segmentation Phase: The objective of this phase is to identify the structures of interest in the initial grey level images and to transfer them into binary images. Normally, it is difficult to directly segment only the interesting structures. Thus, the binary images are constituted not only by the ripples but also by other structures with similar geometry and intensity.

The ripples are elongated structures, exhibiting preferential alignments and occurring sequentially in patches with a certain periodicity. The global shape of each patch or cluster of ripples varies greatly, depending on several factors such as wind and terrain morphology. The main steps of this phase of the algorithm are the following:

Size-Intensity Segmentation: Consists of identifying separately the lighter and the darker thin structures. The grey level separation line is the image of the morphological centre (fig.1b), which is computed from three images: the initial one (fig.1a) and two others obtained by applying alternating sequential filters (one that starts with an opening, the other with a closing). The residues correspond to the thin regions (positive residues for the lighter ones (fig.1c), negative for the darker ones) and are obtained from arithmetic differences between the initial image and the morphological centre. However, there are still some other structures present in the image.

Filtering: A closing (fig.1d) is applied to the union of the two images of residues, to reinforce the proximity factor of the structures. The ones that are closer, create "stronger" clusters, *i.e.*, with bigger dimensions, which allow them to resist to the following erosion-reconstruction filtering (fig.1e and 1f).

Recognition Phase: This phase consists of the recognition of the ripples. Its objective is to filter out all the non-ripple objects present in the image, and it consists of three main steps:

Binarisation: Application of a simple threshold to separate the background (white areas on fig.2a) from the ripples and other linear structures (black).

Directional recognition: Each ripple has a preferential alignment. Thus, the search for elongated structures is performed through directional openings using segments as structuring elements (see example in fig.2b). The closing of each opened set (fig.2c) followed by an erosion-reconstruction filtering (fig.2d) permits the identification of the structures oriented in one direction. By repeating the same procedure on other directions of the digital grid, sets with other orientations are obtained.

Clustering: The union of all these sets gives the oriented structures. The closing of this union (fig. 2e) permits to find a pseudo-hull (non-convex) of the ripples, whose intersection with the thresholded image (fig.2a) produces the final result (fig.2f).

Discussion: This algorithm seems robust since it is, in general, independent from the orientation and dimension of the ripples and also from some local differences in the illumination conditions. Anyhow, it is still under development and improvement in order to overcome some drawbacks, namely, to distinguish and filter some unwanted structures that are confounded with ripples.

References: [1] Zimbelman J.R. et al. (2002) *LPS XXXIII*, Abs #1514. [2] Bourke M.C. et al. (2003) *LPS XXXIV*, Abs #2090. [3] Williams S.H. et al. (2002) *LPS XXXIII*, Abs #1508. [4] Wilson S.A. et al. (2003) *LPS XXXIV*, Abs #1862. [5] Greeley R., Thompson

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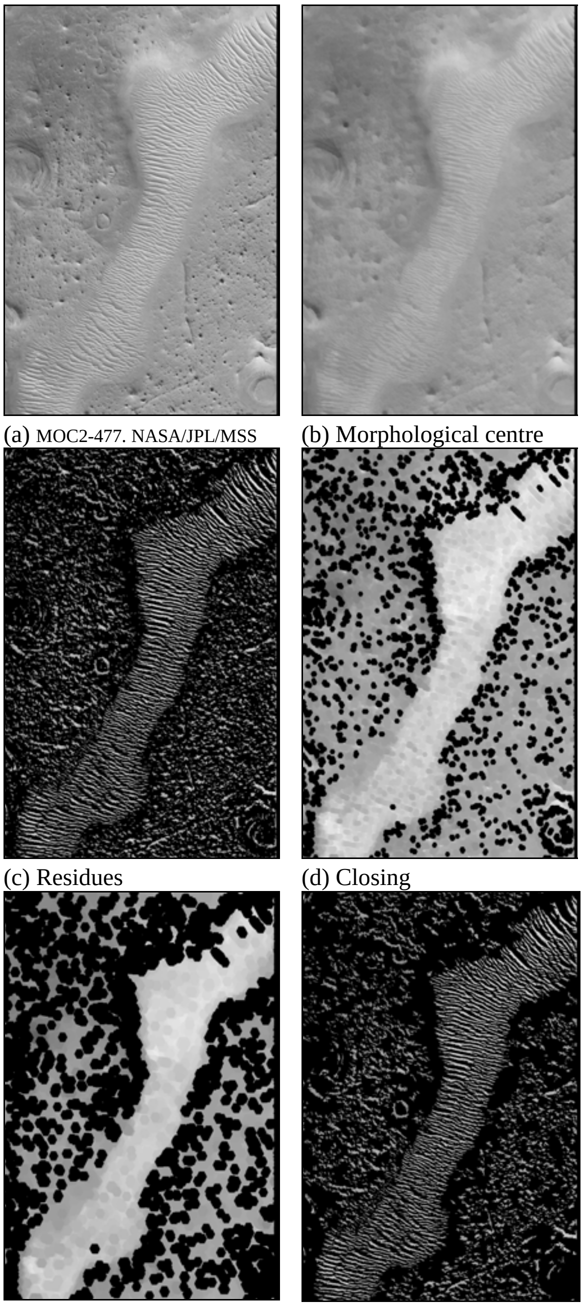
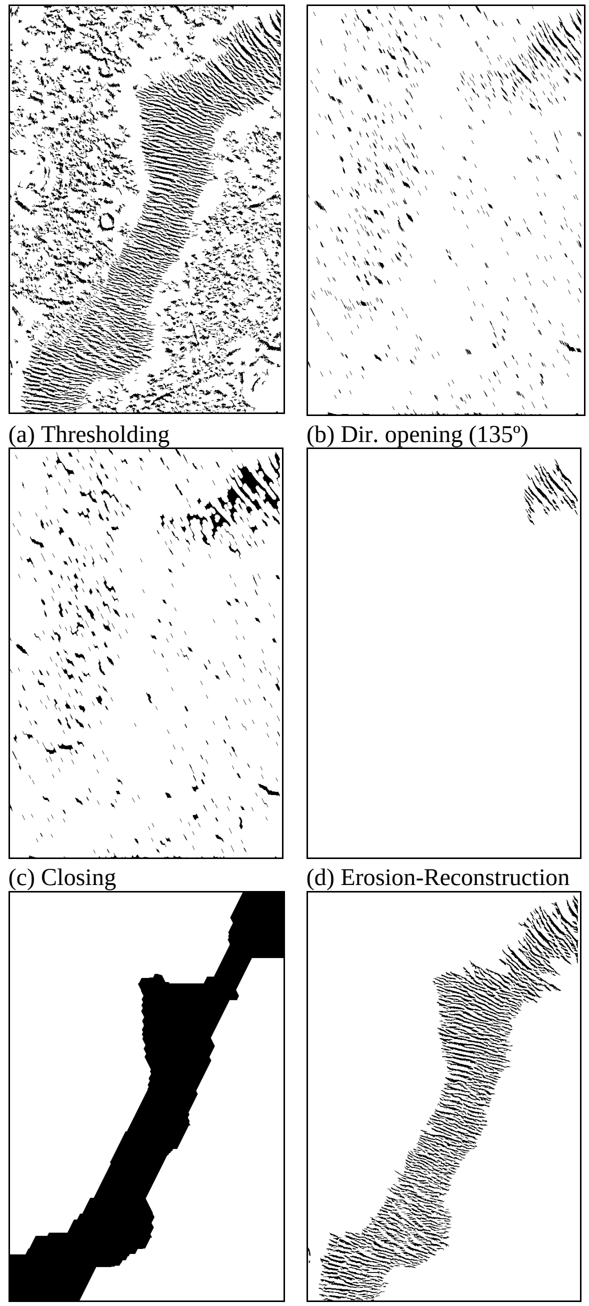


(a) MOC2-477. NASA/JPL/MSS (b) Morphological centre

(c) Residues (d) Closing

(e) Erosion (f) Reconstruction

Figure 1. Segmentation phase



(a) Thresholding (b) Dir. opening (135º)

(c) Closing (d) Erosion-Reconstruction

(e) Closing of union of directional filterings (f) Final result

Figure 2. Recognition phase