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Application of wavelet transforms to the automatic recognition of faults on MOLA data

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Automatic recognition of linear features on planetary visual imagery is a well established technique based on the identification of discontinuities or sharp change in the gray-scale values of the pixels.

In order to detect lineaments on images, several techniques have been developed, and they could be group in three main categories [1]:

- Edge detection techniques, for example Gradient Operators, Sobel filter;
- Optimal detectors, such as Canny algorithm;
- Operators using parametric fitting models like the Haralick operator.

In this study we present a method for the automatic recognition of faults on MOLA (Mars Global Surveyor, Mars Orbiter Laser Altimeter) data.

The MOLA data have at least one great advantage over visual imagery data: they are not influenced by lighting or atmospheric conditions, and they do not suffer from camera or mosaic artefacts.

As traditional image recognition methods aren't appropriate to work on altimetry data, the methodology we propose is based on wavelet analysis, which has been successfully used to study ocean bathymetric profiles [2] and maps [3], which are essentially similar to MOLA maps.

In this work we use the MOLA Mission Experiment Gridded Data Records (MEGDRs) with a resolution of 128 pixels per degree and the technique we present here is based on [3].

Altimetry data are not as intuitive as visual imagery so the first step is to recognise the presence of linear features (putative faults) by applying a linear B-spline wavelet filter to the data.

The linear B-spline function, $N_2(x)$ can be defined as

$x < 0 \Rightarrow N_2(x) = 0$

$0 \leq x < 1 \Rightarrow N_2(x) = x$

$1 \leq x < 2 \Rightarrow N_2(x) = 2 - x$

$x \geq 2 \Rightarrow N_2(x) = 0$

and the linear B-spline wavelet is

$W_2 = 1/12\ [N_2(2x) - 6N_2(2x-1) + 10N_2\ (2x-2) - 6N_2(2x-3) + N_2(2x-4)].$

A square filter of side 16 was built by replicating, in the N-S direction, sixteen discretised W_2 wavelets of sixteen points, each one in the E-W direction. Since the ultimate goal is to automate the recognition procedure, unlike in [2] the filter is not rotated to a preferential direction. This filter is not a 2-D wavelet.

The filter was then convolved with a MOLA map of the Southern Alba Patera region, a region that is crossed in the N10ºE direction by grabens that emanate radially from Tharsis [4].

The resulting image evidences the fault planes, albeit with considerable noise.

The second step is to discriminate East- from West-facing fault planes. This is achieved by the application of a filter built upon the first derivative of the cubic B-spline, which transforms a step up into a peak and a step down into a trough.

The cubic B-spline function, $N_4(x)$ can be defined as

$x < 0 \Rightarrow N_4(x) = 0$

$0 \leq x < 1 \Rightarrow N_4(x) = x^3/6$

$1 \leq x < 2 \Rightarrow N_4(x) = -(1/3) + x/2 + (x-1)^2/2 - (x-1)^3/2$

$2 \leq x < 3 \Rightarrow N_4(x) = (2/3) - (x-2)^2 + (x-2)^3/2$

$3 \leq x < 4 \Rightarrow N_4(x) = (5/3) - x/2 + (x-3)^2 - (x-3)^3/6$

$x \geq 4 \Rightarrow N_4(x) = 0$

The computational implementation of the first derivative, $N_4'(x)$, is straightforward. Analogously to what was done for the linear B-spline wavelet, a square filter of side 16 was built by replicating sixteen wavelets of sixteen points each. The filter was then convolved with the same MOLA map as in the previous test.

The results are encouraging, clearly discriminating the left and right limiting faults of the grabens and is also much less noisy than the output of the linear B-spline.

Much remains to be done, however, if the process is to be fully automated. Recall that the test area was cut by faults with a dominant direction. It is foreseen that, in a general situation, an automatic procedure shall convolve a MOLA map with several filters for several directions.

Work is already being done to that effect.

References

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