# Detecting surface changes on Mars using principle component analysis of repeat imagery

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Change detection is an analytical tool of Remote Sensing in which repeat observations of a particular location can be overlain, subtracted, or ratioed to detect differences between images. High-resolution, repeat imagery on Mars has led to several discoveries of ongoing geologic processes operating at the sub-kilometer scale such as recurring slope lineae (RSL) [1-3], new, small impacts [4], aeolian dune migration [5], sublimation of polar ice [6], and gully formation [7]. Generally, the detection of these changes is done manually by overlaying, and “flipping” between the two images. As planetary remote sensing data sets continue to grow, so does the need for a more efficient means of change detection.

Principle component analysis (PCA) offers an advantageous means for detecting change because it considers the values of all pixels in all the repeat images to extract the most statistically significant variations. These variations are then isolated from one another as a hierarchical set of “principle components” of the image dataset. The user can quickly identify patterns or features of interest which are present in one or more of these components. To illustrate this method, nine HiRISE images [8] collected from Palikir crater on Mars between November 2007 and June 2011 documenting RSL formation will be used.

PCA changes the values of the pixels in each image by plotting the pixel data on a set of axes which capture the maximum variance in the dataset. In our example image set, each pixel in the image stack can be treated as a 9-dimensional vector since there is a value for that pixel in each of the nine images. However, each pixel can be plotted on a new set of axes that capture the most important, or PCs of the image stack.

The figure shows the result of the PC transform (performed using ENVI® software) on the stacked time-series. Because most of the variation in the images is captured in the first PC (PCA1), it uses a grayscale color bar spanning 0-255 pixel values. Generally, variations covering a large spatial extent or variations causing a big shift in pixel values will be captured in the lower PCA components. Higher components, on the other hand, will depict smaller amplitude variations occurring in fewer images (or over smaller spatial extents). Thus, components 2 and 3 (panels b and c, respectively) are dominated by variations caused by differences in lighting (sun direction and elevation angle) and possibly dust or frost deposition/erosion. RSL features are identifiable in PCA4 (panel d) as elongated blue “fingers” and become more dominant and appear red in PCA5 (panel e). Subsequent components capture smaller variations caused either by changes in lighting, RSL shape (in PCA 8 and 9), or camera noise.

After identifying the PCs which contain the feature of interest, the feature can be traced back to the original images via an inverting from PC coordinates to image coordinates. Although this step is not completely reliable, it is successful in determining which images contain the most prominent RSL. Eventual combination of this method with machine-learning algorithms may permit a more automated means of detecting interesting surface changes on Mars and other planetary bodies. Note this work was previously published in [9].

 

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