DIRECTIONS OF MARTIAN DUST DEVILS MOVEMENT INFERRED FROM AUTOMATIC DETECTION OF THEIR TRACKS USING MATHEMATICAL MORPHOLOGY

T. Statella\(^a\), E. A. Silva\(^b\)

\(^a\)Federal Institute for Education, Science and Technology, Brazil, Zulmira Canavarros street n° 95, Cuiabá – MT, postal code: 78005-500, phone: +55 65 3624.5577. thiago.statella@cba.ifmt.edu.br

\(^b\)São Paulo State University, Brazil, Roberto Simonsen street n° 305, Presidente Prudente – SP, postal code: 19060-900, phone: +55 18 3229.5388. erivaldo@fct.unesp.br

Abstract – An automatic method for detecting martian dust devils tracks and inferring their directions from digital images is presented. The method is strongly based on Mathematical Morphology theory. The work aims to increase understanding about active aeolian processes on the planet, which may contribute to explain similar processes occurring on Earth. Besides, the results can be used to improve knowledge about risk areas, which is essential to plan manned missions. Two Mars Global Surveyor Mars Orbiter Camera images were used as study areas. For detecting the tracks the next steps were followed: preliminary filtering, enhancing and binarization. For inferring directions morphological granulometric analysis was carried out.

Keywords: Mathematical Morphology, Remote Sensing, Dust devils, Feature extraction, Aeolian processes.

1. INTRODUCTION

Dust devils are vortexes caused by unstable wind convection processes near the planetary surfaces, due to solar heat. They have been studied on Earth for centuries and were first observed on Mars in orbital images taken by the Viking (1975), Mars Observer (1992) and Mars Pathfinder (1996) programs. These phenomena can achieve miles in width and height, and knowledge about their activity contributes to the understanding of Martian climate, geology and surface modification which is essential to plan future manned missions. Two Mars Global Surveyor Mars Orbiter Camera images were used as study areas. For detecting the tracks the next steps were followed: preliminary filtering, enhancing and binarization. For inferring directions morphological granulometric analysis was carried out.

2. STUDY AREAS AND METHOD

Two portions of panchromatic MOC images with 6m spatial resolution were chosen as study areas. They were obtained from the NASA database of the MGS mission. Figure 1 shows a portion of the image MOC2-220-A, taken in 21/02/2000, depicting Argyre Planitia. Figure 2 shows a portion of the image E10-04279, taken in 27/11/2001, depicting southwest of Argyre.

In November 1996 NASA launched the mission Mars Global Surveyor (MGS) with the high resolution camera Mars Orbiter Camera (MOC) that took images of the planet between the years of 1997 to 2006 in a geometric resolution up to 1.5 m per pixel. There are hundreds of high resolution images depicting Martian surface, providing important data for, among others, researches in Geology, Cartography and Aeolian processes monitoring, at a level of detail never achieved before (Bridges et al., 2007; NASA, 1997). The amount of images taken (and therefore the amount of information on them) grew at a rate greater than the human capability to analyze and extract relevant information from these products to characterize the planet under study (Bandeira, Saraiva and Pina, 2007). That made room for automatic feature extraction processes. This paper is about using Mathematical Morphology (Soille, 2003; Serra, 1983) to automatically detect dust devils tracks and infer their directions, which contribute to a better understanding of wind circulation on mars surface. Images acquired by the Mars Orbiter Camera onboard Mars Global Surveyor depicting the regions of Argyre Planitia and Southwest of Argyre were used as study areas. Those images were pre-processed so that noise from radiometric distortions could be removed. Next, a top-hat filter was applied to remove illumination gradients from the scenes and to enhance the features of interest. Then, dust devils tracks could be detected by an automatic binarization. Track directions were inferred by granulometric analysis based on morphological pattern spectrum of the detected features.
Figure 2. Study area E10-04279.

Figure 3 shows in a flowchart the method developed to detect the tracks and infer their movement directions.

3 RESULTS AND DISCUSSION

The main difficulty in detecting dust devils tracks is that they don’t have specific size, shape, thickness or orientation. Besides, dust devils are short time phenomena (most of the time they last a few minutes) and a bunch of them may cross the same region, in the same season, making their tracks overlap each other forming a maze of dark streaks in the images. This not only interferes in the detection but also in the movement direction determination. Another aspect to be considered is the strength of the tracks. Fresh tracks (from recent phenomena) form dark well defined streaks, with good contrast. But after a few days the air circulation gradually covers them with dust and sediments so they become smoothed, without contrast. Weak smoothed tracks can be seen in a visual analysis but the automatic detection may fail in these situations, especially if there are fresh and old tracks (smoothed by dust) in the same region. However, two characteristics of the phenomena could be exploited: 1) dust devils tracks are very dark features (a few references related white tracks but they are very rare, depending on the lithology), contrasting with the surrounding objects; 2) they are assumed to be the biggest objects in the images. Besides, the tracks are topographically negative features, therefore appearing like valleys. So it is possible to enhance those features by applying a top-hat by closing filter.

According to the flowchart in the Figure 3, the first step of the method was to apply median (3x3 mask) and surface area open filters to the study areas. The median filter eliminates or smoothes salt-and-pepper noise. Even when noise caused by imaging process does not occur, rocks whose size equals the spatial resolution of the images produce a similar effect. The surface area open smoothes very bright features like dunes and ripples. After pre-processing, the images were binarized by Otsu method. A binarization is a transformation $T$ that maps gray levels from an image $f$ to the interval $[0, 1]$ (where 0 (zero) is black and 1 (one) is white) in $T( f )$, based on a threshold $t$ which is generally chosen from histogram analysis. In the Otsu method, $t$ is chosen so that the interclass variance is maximized (Otsu, 1979; Mcandrew, 2004). Next, a granulometric analysis with a family of increasing disk-like SEs was applied to its complements (the set of pixels belonging to its background). In morphological transformations the success depends on the chosen Structuring Element (SE), which can have many shapes, sizes and orientations. At this point, its shape and orientation were not relevant since the aim was to identify the size of the biggest connected components of the scenes. Thus a top-hat by closing with a disk-like SE whose size was defined by the granulometric analysis was applied to the scenes to enhance the tracks (once this filter enhances every connected component which doesn’t fit the SE). A new binarization took place to detect the tracks as it can be seen in Figure 4. The binary images were then skeletonized. There are several ways of thinning a binary image (or even a gray level image). The method chosen here was the one proposed by Zhang and Suen (Zhang and Suen, 1984). This method avoids segmentation at the corner of objects (an effect generally caused by other methods which is undesired once these segments may have a different orientation from the main structure) and preserves the connectivity of the skeleton. Over the skeleton of the images a second granulometric analysis was applied, this time using a family of line SEs oriented in the directions N-S, E-W, NE-SW e NW-SE.
For the MOC2-220-A image, as it can be seen from Figure 5, the frequency of pixels removed by openings with directional SEs was the highest (785 pixels removed) when the SE was oriented at N-S. Figure 6 shows that, for E10-04279 image, the highest frequency of removed pixels (1,123 pixels removed) occurred when the SE was aligned with the direction NE-SW.

Those are very good indicatives of the main direction followed by dust devils in the study areas. From binary images was also possible to determine the area covered by tracks for each scene. That resulted in 54,984 pixels for MOC2-220-A (≈ 14% of the image) and 27,872 pixels for E10-04279 (≈ 6% of the image).

Figure 4. Tracks detection.

![Figure 4](image)

![Figure 5](image)

Figure 5. Granulometric analysis of MOC2-220-A. The highest frequency of removed pixels (785 pixels) was reached when the SE was aligned with the direction N-S.
4 CONCLUSION

The proposed method is able to detect dust devils tracks and infer their main movement directions automatically. The main difficulty is that there may exist old and fresh tracks in the same region. Besides that, as it can be seen in Figure 4, fresh tracks were completely detected as well as (at least part of) the weaker (low contrast) track. Also, the method succeeds in finding out the main direction of movement of the vortexes. For MOC2-220-A scene the main direction was N-S, which agrees with that predicted by the global circulation model of the martian atmosphere; and for E10-04279 scene it was NE-SW, which agrees with the observations made by Fenton, Toigo and Richardson (2005).

Obviously any conclusion on the behavior of the phenomena can be made based in the analysis of only two study areas. The main objective of the present work was to develop an automatic method to get some information about the phenomena. Next step will consist in applying the method to a great number of images so we can have a better understanding of the behavior of dust devils and also martian atmosphere in layers close to the surface planet.

REFERENCES


