UNCHANGING DESERT SAND DUNES

Surender Varma Gadhiraju[1], Vatsal Shah[2] and Krishna Mohan Buddhiraju[1],

[1]CSRE, IIT Bombay, Mumbai, India.
[2]Electrical Engineering, IIT Bombay, Mumbai, India.

Abstract:

Deserts are one of the major landforms on earth. They occupy nearly 20% of the total land area but are relatively less studied. With the rise in human population, desert regions are being gradually occupied for settlement posing a management challenge to the concerned authorities. Unrestrained erosion is generally a feature of bare dunes. Stabilized dunes, on the other hand, do not undergo major changes in textures, and can thus facilitate the growth of vegetation. Keeping in view of the above factors, better mapping and monitoring of deserts and particularly of sand dunes is needed. Mapping dunes using field instruments is very arduous and they generate relatively sparse data.

In this communication, we present a method of clustering and monitoring sand dunes through imagery captured by remote sensing sensors. Initially Radon spectrum of an area is obtained by decomposition of the image into various projections sampled at finer angular directions. Statistical features such as mode, entropy and standard deviation of Radon spectrum are used in delineation and clustering of regions with different dune orientations. These clustered boundaries are used to detect if there are any changes occurring in the dune regions. In the experiment's, remote sensing data covering various dune regions of the world are observed for possible changes in dune orientations. In all the cases, it is seen that there are no major changes in desert dune orientations.

While these findings have implications for understanding of dune geomorphology and changes occurring in dune directions, they also highlight the importance of a wider study of dunes and their evolution both at regional and global scales.

I. METHODOLOGY

A post-clustering based approach was developed for identifying changes in the orientations of dunes. Initially contiguous regions representing dunes with each region having similar dune orientation are generated. The images belonging to different timelines and corresponding to the same region are first registered in order to ensure the correctness of corresponding pixels for the change detection algorithm. The clustering algorithm is subsequently run on both the images individually while keeping the parameters constant. Histogram matching was initially performed on the corresponding imagery, to ensure that the changes observed are not due to radiometric differences. In order to get contiguous cluster regions, a block based processing technique is used. Block size is dependent on a host of factors such as the image resolution, size of the texture patterns on the dunes, distance between identically oriented dunes, etc.

Radon spectrum data has been used to provide statistical information regarding the textural content present in a block of an image.

$$\theta_{mode} = \{\theta_{max} : f(\theta_{max}) \geq f(\theta), \forall \theta \in [0, \pi]\}$$

$$\theta_{entropy} = -\sum_{i=0}^{\pi} p(\theta_i)\ln[p(\theta_i)] \text{ where } p(\theta_i) = \frac{\theta_i f(\theta_i)}{\sum_{i=0}^{\pi} f(\theta_i)}$$

$$\theta_{sd} = \sqrt{\frac{\sum_{i=0}^{\pi} f(\theta_i)[\theta_{mean} - \theta_i]^2}{\sum_{i=0}^{\pi} f(\theta_i)}}$$

Three different images of the same size as the original image are created by using the above calculated statistical features for each block. Next, each pixel is assigned the same attribute as that of the majority of pixels within a block. Thresholds are assigned empirically on the basis of the separation between features with similar orientation. A binary image is thus created for each feature. Once again, these discrete binary feature outputs are transformed into continuous feature output images using a recursive processing step. Here, if a given pixel has more than a certain number of 'on' pixels in a given neighborhood (3x3 window size, still bigger size windows are observed to over generalize the results), then it is assigned the value one. Finally, the texture segmented output is obtained by combining the feature outputs using logical operators.

All the operations explained in this section are performed for each type of texture orientation individually. For example, if an image has two major regions of different textural orientations, the image will be scanned successively to identify the regions having differing textural orientations one after another. If there are no changes over the temporal scale then the clustering algorithm should essentially give similar boundaries for each cluster region. On the other hand, changes in dune orientations will correspond to changes in the boundaries for the clusters. Final change outputs are depicted by taking difference of the individual clustered outputs.

II. RESULTS

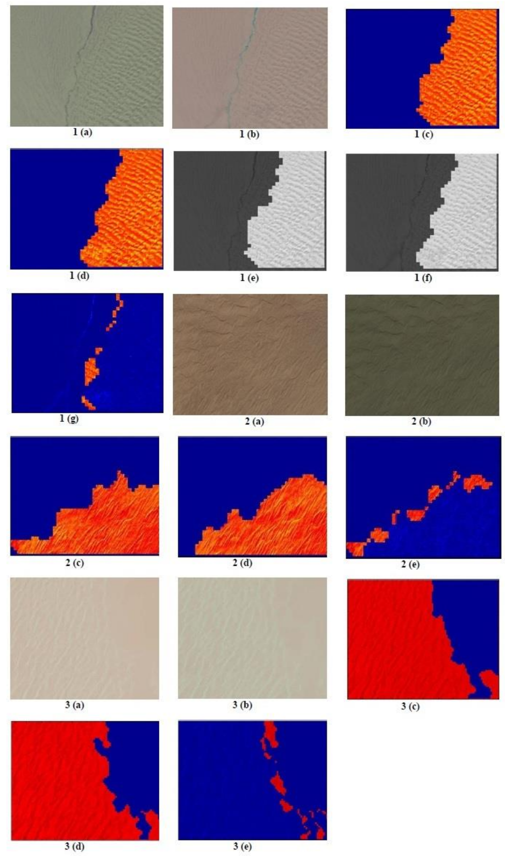

Fig. 1(a) and Fig. 1(b) are the images corresponding to the Gobi desert of central Asia in China-Mangolia region. Fig. 1(c) and Fig. 1(d) indicate the corresponding clustered outputs. Fig. 1(e) and Fig. 1(f) show the superimposition of input images and cluster outputs. Fig. 1(g) indicates the corresponding change output for dataset 1. Similar results are shown for 2nd dataset (Fig. 2(a) and Fig. 2 (b)) belonging to Thar desert region in the north western region of India and 3rd dataset (Fig. 3(a) and Fig. 3(b)) corresponding to Sahara desert region in Yemen.

Change detection of desert sand dunes was performed on desert data sets belonging to three different dune regions of the world. It has been observed that essentially the dune regions in all the considered cases remained constant in terms of their orientation structure since around three decades.