Automated Dune Crest Line Detection

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Abstract

TODO

1 Introduction

TODO

2 Previous Work

TODO

3 Methodology

3.1 Dune Crest Segment Detector

3.1.1 Adaptive Threshold Image Process

Dune crest images typically have a shaded and a light side. Depending on the conditions and image quality, the actual edge or dune crest line may not be clearly defined. Some image processing typically improves the quality and allow the extraction of the dune crest lines.

Many approaches revolve around edge detection, but because the conditions and image quality can vary, edges may not be accurately extracted. In this approach, we use a thresholding method to extract the light side of a dune. Using a fixed threshold may not be sufficient to extract the dunes since the illumination across an image is usually not uniform. An adaptive threshold can be a useful tool to threshold an image with non-uniform illumination. An example of this type of thresholding is shown in Figure 1.

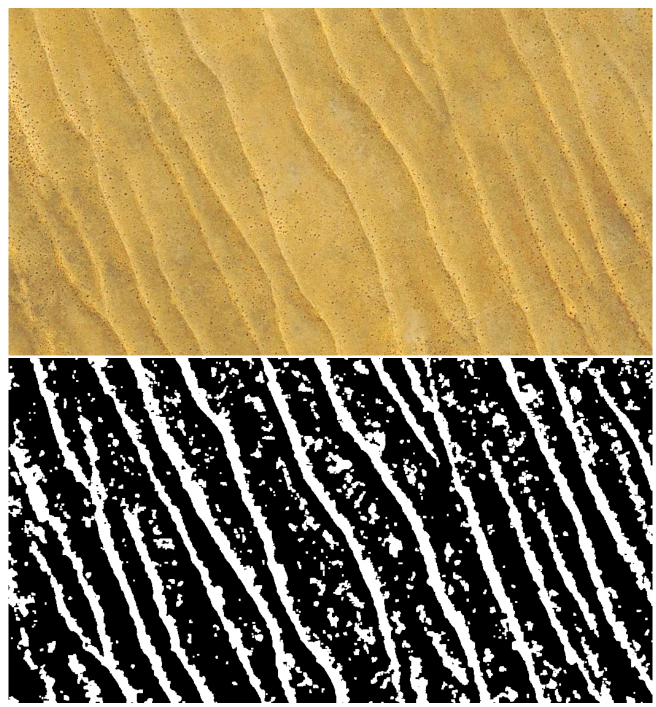

Figure 1: Example of an adaptive thresholding method applied on a dune crest image with poor illumination and contrast.

3.1.2 Dune Crest Line Extraction

Once the image has been preprocessed, the bright regions can extracted from the resulting binary image. As shown in figure 1, the bright regions shown consist of the sun illuminated side of the dunes and some noise.

From the regions, contours can be extracted, which can be filtered by size of the region. Smaller regions are considered as noise, and can be rejected from the potential dune candidates. The remaining region contours are used as potential candidates for dune crest lines. From the coutours, figure 1 shows that typically one of the

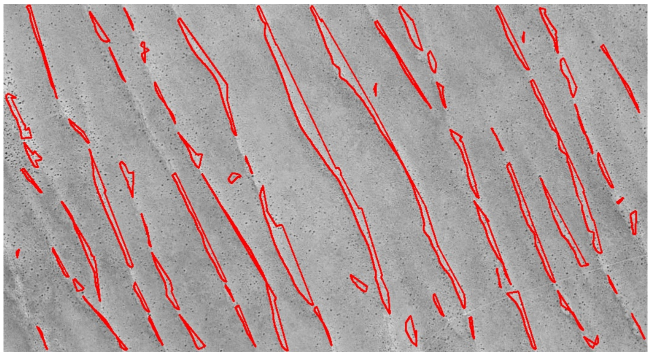

Figure 2: Contour extraction from binary processed image

edges of the contour is located very nearly on the dune crest line. On the opposite side of the region is essentially the base of the dune. Figure 2 shows the results of the extracting the contours from the processed image.

Because the regions tend to be noisy, the contours are therefore smoothed using a Gaussian kernel, define as:

$$G\left(i\right)=\frac{1}{\sqrt{2\pi}\sigma}e^{\frac{-i^{2}}{2\sigma^{2}}}$$

The Gaussian kernel is convolved on the contour, which a collection of two dimentional points (x,y). The result of this convolution is a smoother contour which can be more reliably used as a dune crest line candidate.

Typically, the dune crest lines are located on an area in the image where the derivatives are larger, or consistant along the edge of the dune. For each contour, the average magnitude μ of the derivative $\delta(i)$ of the image in the x and y directions is computed. Then, for each point within a contour compares its derivative with K neighbor's gradient magnitudes. Dune crest line candidate points will tend to have neighbors with similarly and consistantly high gradients. To determine if a point $P(i)$ on a contour belongs on the dune crest line, we use the following criteria

$$P\left(i\right)=\begin{cases}1 & \phi(i)\geq r\\0 & otherwise\end{cases}$$

where

$$\phi(i)=\frac{\sum_{k=0}^{K}\begin{cases}1 & \delta\left(k\right)\geq\mu\\0 & \delta\left(k\right)<\mu\end{cases}}{K}$$

and $0<r\leq 1$, which is the ratio of how many strong consistant edges to neighbors around a point i on the contour. Typically, r would be larger than 0.5, which means most of the neighbors of a point most have strong edges for a point to be considered a dune crest line candidate. The parameter r can be fine tune to allow more or less points to fit the criteria. This method will group common contour points based on gradient magnitude.

Once the dune crest line candidates on the contour have been extracted, the contour can be split into contiguous crest line segments. Some further processing can be applied to the segments, such as filtering out smaller or less significant segments (potential false positives). More work needs to be done in this area.

3.2 Dune Morphology

With the reliable crest line data extracted, morphology parameters of the target image can be computed. The desired properties include crest line lenght, dune scale, distance between dune crests, and other properties. TODO (more research on this later).

4 Experiments

Since the goal of this project is to automatically segment dune crest lines, a dataset of images with labeled ground truth is used to measure the accuracy of the dune detection algorithm. The current dataset is a small sample set of six images taken from different regions, at various scale and various illuminations. The regions include: Kalahari, Namib, Simpson, Skeleton Coast, WDC, and White Sands, as shown in figure 3.

TODO.

5 Results

The dune line crest detector is applied to the labeled benchmark images shown in figure 3. The results we are interested in for detection purposes are the true positives (correctly detected dune lines) and false positive (segments that are not dunes). The results are computed in a brute force manner:

1. **True Positives**: The TPs are computed by taking each ground truth pixel, and finding the nearest detected dune segment pixel. If the distance between the nearest detected and the ground truth is smaller than some error e, the ground truth is considered to be detected. The TP rate is then the number of correctly identified ground truth points, over the total number of ground truth points.

2. **False Positives**: The FPs are computed by taking each detected dune candidate, and finding the nearest ground truth point. If that distance is greater than some error e, then the detected dune candidate is a false positive. The FP rate is then expressed as the number of incorrectly detected dune points over the total number of dune points detected.

The TP and FP rates are shown in table 1. The results shown in figure 4 visually overlaps the ground truth with the dune detected.

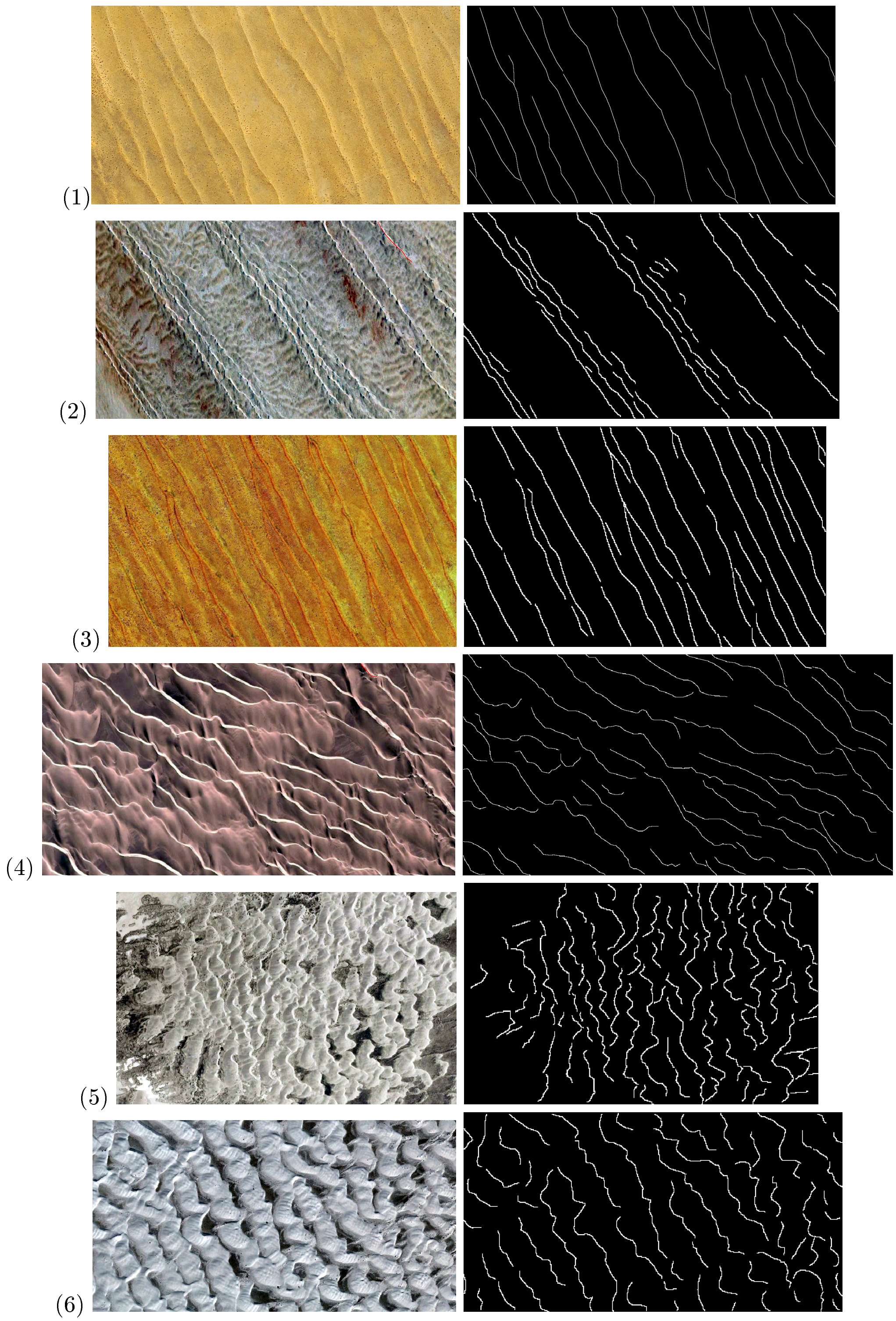

Figure 3: Dune dataset with corresponding dune crest line ground truth map. The images are labeled as (1) Kalahari, (2) Namib, (3) Simpson, (4) Skeleton Coast, (5) WDC, and (6) White Sands.

Images	TP	FP
Kalahari	0.7094	0.2178
Namib	0.7493	0.6026
Simpson	0.1364	0.6512
Skeleton Coast	0.8033	0.3253
WDC	0.5581	0.3731
White Sands	0.2614	0.6926

Table 1: Results of the dune segment detection algorithm for the benchmark dataset using a value of $e = 5$ pixels.

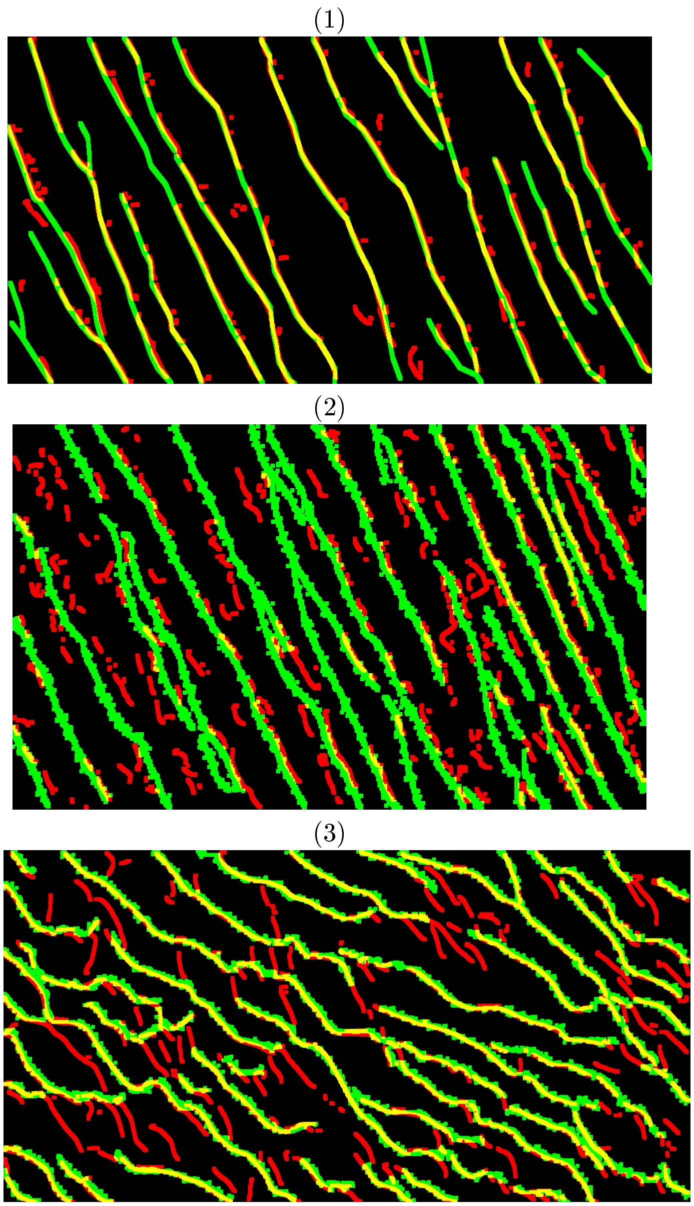

Figure 4: Dune detection results (red) compared to the ground truth (green), overall is shown in yellow. Shown are results for (1) Kalahari, (2) Simpson, and (3) Skeleton Coast benchmark images

6 Conclusion

TODO.

References