Algorithm for Removal of Power Lines from Digital Photographs

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Abstract: Power lines are notoriously difficult to remove digitally from photographs, an algorithm[1] is presented which automates the removal of this specific artifact. The proposed method consists two steps: 1. Segmentation by use of matched filters and morphology, 2. Interpolation of the pixel values segmented as power lines. Successful segmentation of most power lines in an image is possible with this algorithm, and the interpolation method presented is light weight and robust.

Introduction

Power lines are the bane of a photographers existence, often ruining the perfect sunset or scenery. Commercially available image editing software can be used to retouch an image, but manually removing artifacts such as power lines in an image is laborious even in the most cutting edge applications.

To perform this kind of artifact repair the logical sequence is to mask the region that contains the artifact then decide what value the masked pixels should be. The proposed algorithm performs this process in two distinct steps: segmentation and interpolation, where the segmentation step decides which portions of the image are power lines, and the interpolation step infers what the value of the segmented pixels should be based on the contents of the local region. The algorithm contains a specifically designed matched filter for the detection of power lines, and interpolation is based on a mean nearest neighbor technique. Using matched filters for line detection has been used for detection of blood vessels in retinal images [2].

Method

The method developed consists of the following steps: segmentation and interpolation. Segmentation utilizes filters, thresholding and morphology to mask regions suspect of containing power lines. Interpolation uses an average filter to estimate what the contents of the segmented regions should be. Bellow is the original image that will be used in subsequent examples, taken using a Samsung S6 and cropped.

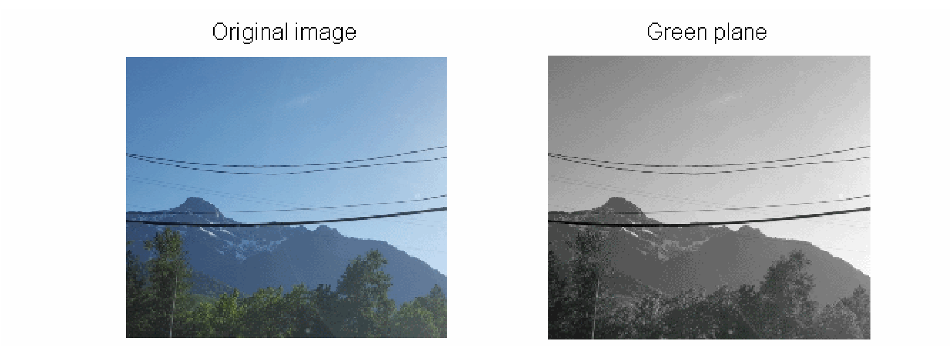

Fig 1. (left) Original image, (right) green plane used for segmentation

Segmentation

The segmentation process uses filters, thresholding and morphology to mask regions suspect of containing power lines, the green plane of the original image is used in this algorithm.

Matched Filter

A 42×42 kernel is used for the matched filter, the one filter is shown below.

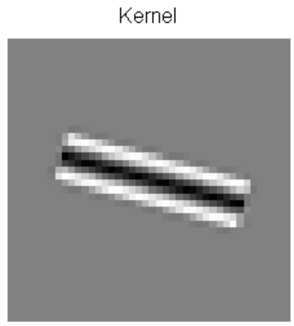

Fig 2. One example of the 12 orientations of the matched filter

There are a total of 12 filter kernels with orientations $\angle_n = 15n\frac{2\pi}{360}$ with $1 \leq n \leq 12$. For smaller resolution images a scaled down version of this kernel should be implored. The algorithm would benefit from a programmatic method to chose the matched filter kernel size. The algorithm applies the kernels to the contaminated image in the spatial domain via a two dimensional convolution, the combined filtered image is determined by the following equation:

$$f_c(x,y) = Max(f_1^+(x,y), f_1^-(x,y), ..., f_n^-(x,y))$$

Where the lhs is the value of the filtered image at coordinates (x,y), and the rhs is the maximum value of each filtered image at coordinates (x,y).

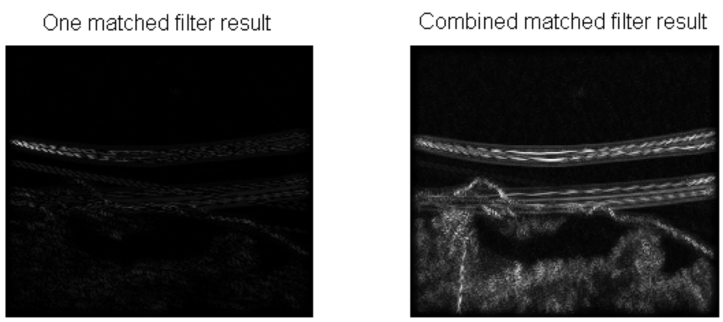

Fig 3. (left) One example of matched filter response, (right) combined response

Thresholding

The regions detected by the matched filter are segmented by use of an semi-automatically selected hard threshold. The threshold value is increased until a set number of pixels are detected as power lines. A starting point for this thresholding is chosen to be the maximum pixel count in the following histogram:

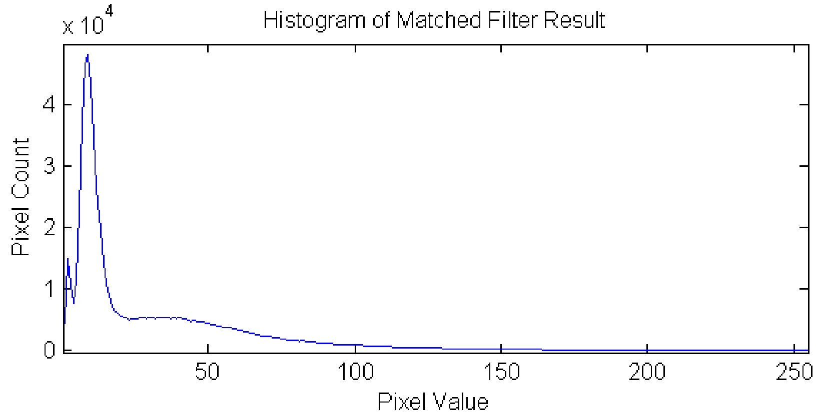

Fig 4. y = count(pixels with value x), the maximum value is used as a starting point for choosing the threshold

Thresholding is performed using Matlab's "im2bw" function.

Morphology

After thresholding is performed the binary image is subjected to morphological transforms. The binary image is first dilated with a disk structuring element to fill any holes that may exist along the power lines. Next the skeleton operation is applied using Matlab's "bwmorph" function, this function shrinks regions to a line. Finally the binary image is dilated again so that the region mask is approximately the width of the power lines in the original image.

The image is now segmented.

Fig 5. y = count(pixels with value x), the maximum value is used as a starting point for choosing the threshold

Interpolation

the preceding process has produced an image mask with a zero valued background and 255 values only where power lines are apparent in the original image. The original image is multiplied by $\frac{254}{255}$, and the mask is added to it and the masked image is padded. The masked image is iterated through, stopping at values of 255 to replace them with the average of a 5×5 region surrounding the coordinates in interest (pixels of value 255 are ignored in this averaging routine.)

Fig 6. Final image with power lines erased

Conclusion

The proposed algorithm provides a foundation for the development of a fully automated power line removal algorithm that could be implemented as a filter on mobile devices. The segmentation algorithm could benefit from applying filters in the frequency (FFT) domain, variable kernel size, and a verification routine to check for accurate segmentation. The interpolation algorithm could be improved for a more professional looking final image, one possible improvement is to replicate the texture of the surrounding regions. One limiting condition encountered is processing an image that has multiple diameters of power lines in it, multiple kernel sizes should be used to handle this case. As the code stands now some adjustment of parameters is needed before images can be successfully processed although the results are not up to the standards of professional photography.

References

[1] K. Cote. (2017). "Algorithm for Removal of Power Lines from Digital Photographs" [Repository]. Available: https://github.com/KrisCote/Power-Line-Removal-Algorithm

[2] S. Chaudhuri et al, "Detection of Blood Vessels in Retinal Images Using Two-Dimensional Matched Filters" IEEE Medical Imaging, Vol. 8, No. 3. Sept 1989