Image Retargeting using Seam Carving

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1 Introduction

Seam carving (or liquid rescaling) is an algorithm for content-aware image resizing, developed by Shai Avidan, of Mitsubishi Electric Research Laboratories (MERL), and Ariel Shamir, of the Interdisciplinary Center and MERL. It functions by establishing a number of seams (paths of least importance) in an image and automatically removes seams to reduce image size or inserts seams to extend it. The purpose of the algorithm is image retargeting, which is the problem of displaying images without distortion on media of various sizes.[1]

The main photo that will be used for testing will be:

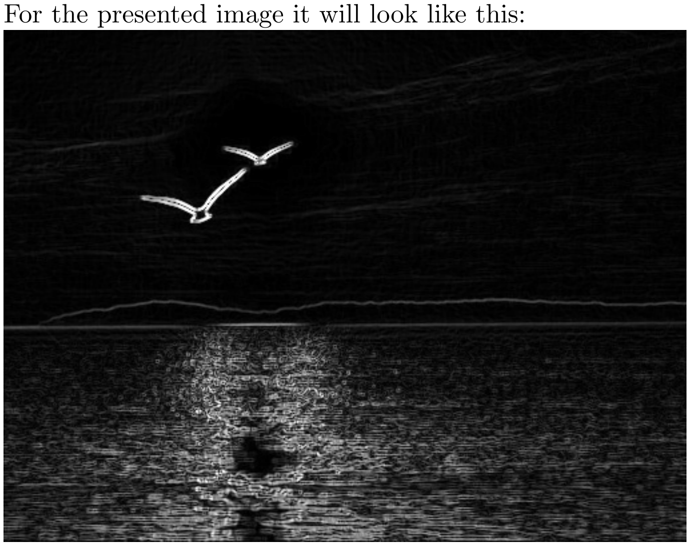
2 Algorithm

2.1 Energy Function

Our goal is to remove unnoticeable pixels that blend with their surroundings. This leads to the following simple energy function presented in the article [2]:

$$e_1(I) = \left|\frac{\partial I}{\partial x}\right| + \left|\frac{\partial I}{\partial y}\right|$$

The energy function is applied to the grayscale conversion of the image.
For the presented image it will look like this:



2.2 Optimal Seam

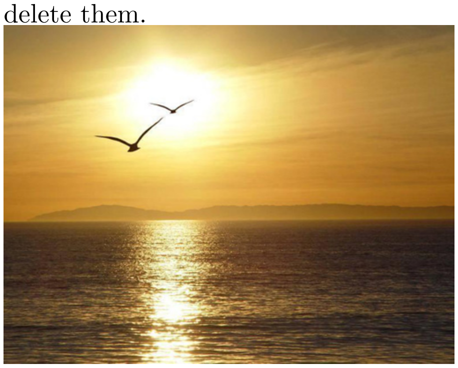
We want to find a vertical seam with the lowest energy and remove it. Recall that a seam is simply an 8-connected path of pixels that is either vertical (top-to-bottom) or horizontal (left-to-right) in an image.[3] The optimal seam can be found using dynamic programming. The first step is to traverse the image from the second row to the last row and compute the cumulative minimum energy M for all possible connected seams for each entry (i, j):

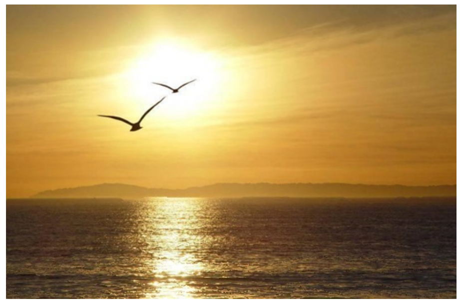
$$M(i, j) = e(i, j) + min(M(i - 1, j - 1), M(i - 1, j), M(i - 1, j + 1))$$

At the end of this process, the minimum value of the last row in M will indicate the end of the minimal connected vertical seam. Hence, in the second step we backtrack from this minimum entry on M to find the path of the optimal seam. A simpler explanation would be that after filling the matrix M, finding the optimal seam is a simple traversal of this matrix starting from the bottom row and moving upwards.

2.3 Shrinking

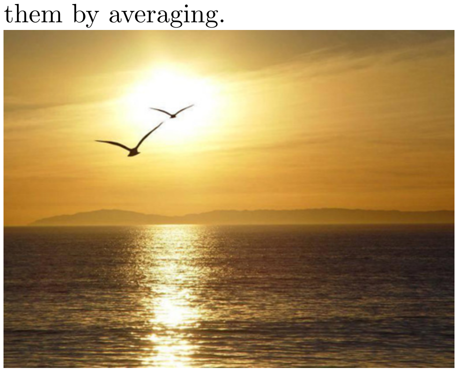
Shrinking is done by traversing the image and when we find a pixel that is on the seam, we overwrite the pixels on that row from that point on with their right neighbours and then we resize the image to have one less column. To decrease the size by more than one, we just identify the k optimal seams for removal and delete them.

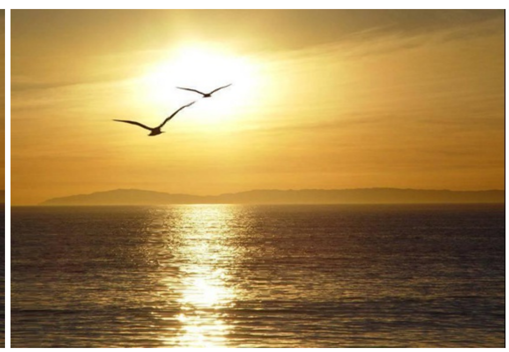




2.4 Enlarging

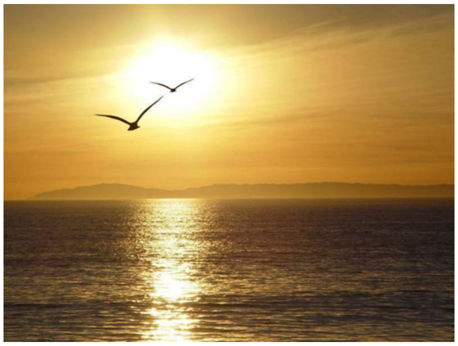
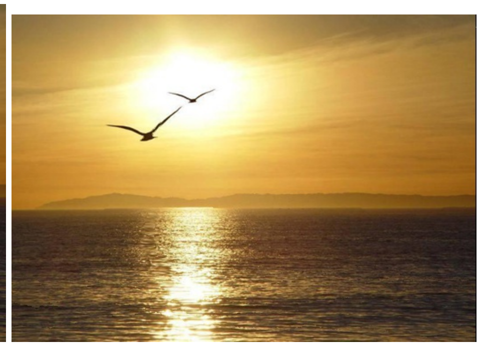
Consider the case where we would like to increase the width or height by one. First we identify the optimal seam as discussed above (vertical or horizontal). Then we duplicate this seam by averaging the left duplicate with its left neighbour and the right duplicate with its right neighbor. To increase the size by more than one, we just identify the k optimal seams for removal and duplicate them by averaging.





2.5 Resizing

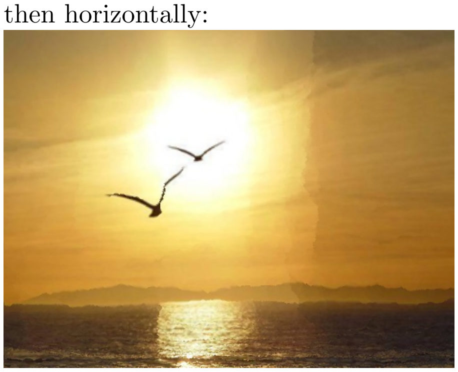
Resizing of the image is done, using the 2 previously presented operations, for example if you have an image of 1000 x 500 and you want to make it 800x600 you will use the enlarging on columns(vertical seams) by 100 and shrinking on rows(horizontal seams) by 200.
The original image is 384x512 and it will be resized to 400x500:

2.6 Content Amplification

Instead of enlarging the size of the image, seam carving can be used to amplify the content of the image while preserving its size. This can be achieved by combining seam carving and scaling. To preserve the image content as much as possible, we first use standard scaling(done using the resize function) to enlarge the image and only then apply seam carving on the larger image to carve the image back to its original size, usually this is done on a 50% scaling.

First, an example of what it looks if we shrink all at once first vertically and then horizontally:



Second, an example of what it looks like if we shrink one by one, one seam vertically and then one horizontally:

3 References

[1]Seam Carving on Wikipedia: https://en.wikipedia.org/wiki/Seam_carving
[2]Seam Carving for Content-Aware Image Resizing: http://graphics.cs.cmu.edu/courses/15-463/2007_fall/hw/proj2/imret.pdf
[3]Implementing Seam Carving for Image Resizing: http://pages.cs.wisc.edu/~moayad/cs766/download_files/alnammi_cs_766_final_report.pdf