Seam Carving Using Forward Energy

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Abstract

Normally, there are lots of different ways of resizing an image, what imaging scientists call interpolation. The two most common type of interpolation is Near Neighbor Interpolation and Bilinear Interpolation. The nearest neighbor method takes the pixel that's nearest and copies that value over. However, this can result in blocky artifacts. For bilinear interpolation, after the pixels are spread apart and extrapolated, the nearest pixels are averaged in a linear fashion. This gives much better image quality overall. But none of the above methods prioritize the content of the image. This paper discusses the implementations, results, effectiveness and limitations of one such image operator that focuses not only on the geometric constraints but also the image content, called seam carving. Seam carving supports content aware resizing for both expansion and reduction. Seam is basically a connected path of pixel that extends left to right or top to bottom of the image. The seams with the lowest energy are removed to reduce the size of the image or doubled to expand the image. The algorithm utilizes the energy function to determine the optimal seams to be removed.

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Introduction

Seam carving is an image processing method that allows images to be reshaped without too much loss or distortion of important visual content. But why does this matter in modern society. Digital images are everywhere now, upwards of three hundred million pictures are posted regularly on Facebook alone. The human race crossed the one trillion photos mark in 2016. As the number of images increase, so are the number of contexts in which these images are presented. Photos are displayed and interacted in varied formats on social media, news media, on and offline backgrounds for websites and apps for desktop PCs, tablets and phones of all sizes and aspect ratios. Due to such varied approaches on how an image is presented, the ability to resize and reshape images is hugely important. To give an example, a Facebook cover photo is exactly eight hundred and fifty-one pixels wide by three hundred and fifteen pixels high. What happens when someone wants to upload a larger image? How can one fit an image to this size? The two most common strategies used by the Facebook algorithm are scaling and cropping. But this almost never are optimal solutions, as these methods lead to either image quality degradation or loss of data.
Seam Carving is an amazing solution to the above-mentioned issues. In this algorithm, we first calculate the energy of the image. Energy or edge of an image can be calculated using various methodologies. In this paper, a function for gradient magnitude was used to determine the energy of the image. Following that, we determine the seams using three possible techniques. In this paper we implement a backward energy function, forward energy function and lastly user inputted masks to determine the optimal seams for expansion or reduction of image size.

Related work

There are two common techniques for content-aware image retargeting: discrete and continuous. The discrete approach works on individual pixels and the continuous methods perform a complete mapping of the input image to the output image. Each method can utilize extra information and constraints to optimize their outputs (e.g. face detection, user supplied region selection, etc.). Well-known approaches are: Shift-mapping, energy-based deformation, nonhomogeneous warping, and scale-and-stretch. Each method suffers from some drawbacks and output better results on some tasks over others. [1]

The main inspiration for this paper was the “Seam Carving for Content-Aware Image Resizing” by Shai Avidan and Ariel Shamir. This implementation closely follows the above-mentioned paper. They did attempt to remove unwanted image content which was not addressed in this paper. [2]

The seam curving mentioned in the above paper was later improved by Mahdi Ahmadi, Nader Karimi and Shadrokh Samavi in their paper, “Image Seam-Carving by Controlling Positional Distribution of Seams”. The along with dynamic programming also implemented graph cut methodology, which further improves the results and reduces addition edges created in the method implemented in this paper.

Method

The seam carving algorithm first checks to see if the image downsize variable is true or false. If true the input image is reduced to the user inputted size. This is done to save computation power while creating example sets for the paper. If false the algorithm moves on to check if a mask is provided by the user, if not the algorithm converts the color image to greyscale and calculates the gradient magnitude of the image (ENERGY).

Backward Energy

Images are nothing but a three-dimensional matrix (for RGB, it is two dimensional for greyscale) of numbers. The output of the gradient magnitude is used to calculate the seam with the lowest energy. Seams are a connected path of pixels, extending from the top to the bottom or left to right of the image. The algorithm starts from one end of the image, calculating the minimum value of the first row. Following that, it looks at the three pixels in the second row directly below the minimum value in the first low. It then calculates the minimum value out of those three pixels and repeats the steps till it reaches the other end of the image. This process creates a chain of pixels extending from one end to the other. This process this repeated continuously until the desired number of pixels for extension or reduction are identified. Finally, it either removes those pixels to reduce the size of the image or doubles them to expand the image. Below, is the formula used to calculate the seam.

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

Formula 1: Seam Calculation using Backward Energy

Forward Energy

The backward energy approach can result in noticeable artifacts because it disregards the energy that is inserted into an image. The added energy a direct reason of the creation of edges that were not present in the original image. So, to tackle this issue, the forward energy is implemented. This approach selects the seam that inserts the least amount of energy into the image. To apply this technique using dynamic programming approach, we just need to modify our cost function. Here for each pixel considered for removal, its energy cost will be the difference between its neighbors. Therefore our cumulative energy matrix M now becomes:

$$M(i,j)=\min\{\ |M(i-1,j-1)+|I(i,j+1)-I(i,j-1)|+|I(i-1,j)-I(i,j-1)| \\ |M(i-1,j)+|I(i,j+1)-I(i,j-1)| \\ |M(i-1,j+1)+|I(i,j+1)-I(i,j-1)|+|I(i-1,j)-I(i,j+1)| \\ \}$$

Formula 2: Seam Calculation using Forward Energy

Masking

The masking technique is a much more computationally efficient method of performing seam curving, as no edge detection is required. Here the user defines the areas of high and low energy and the algorithm calculates the seams accordingly. This method works well for a limited number of images, as the user need to create and input the masks for each individual image. But in a real-life scenario, this becomes too taxing. It is always best practice to automate the entire process when it comes to large sets of data.

Results

Following are the results obtained using the developed algorithm.

Forward Energy results

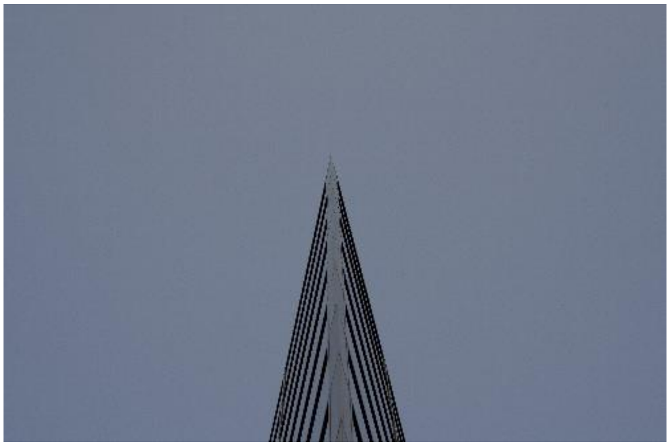

Figure 1: Original image of Cone resized

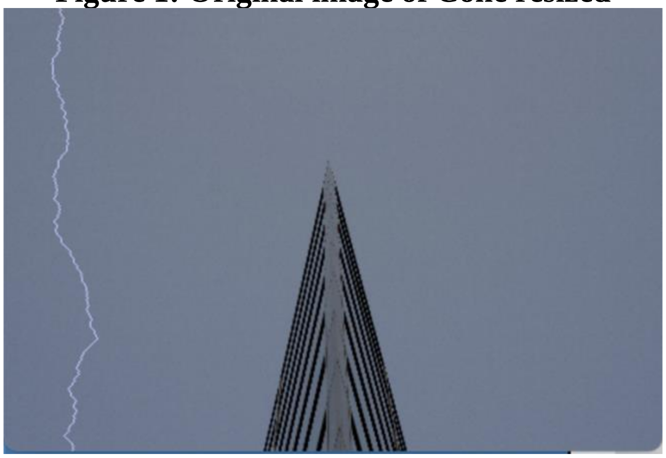

Figure 2: Seam Carving Being Applied to image of Cone

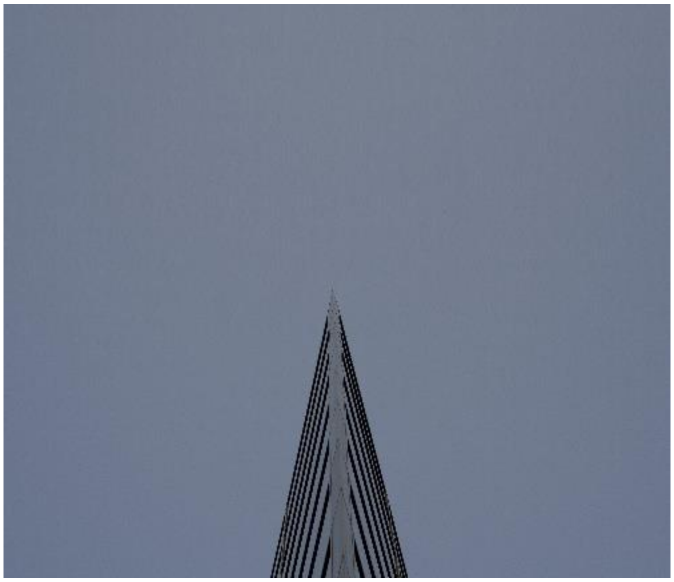

Figure 3: Image height increased by 100

Figure 4: Original image of Park resized

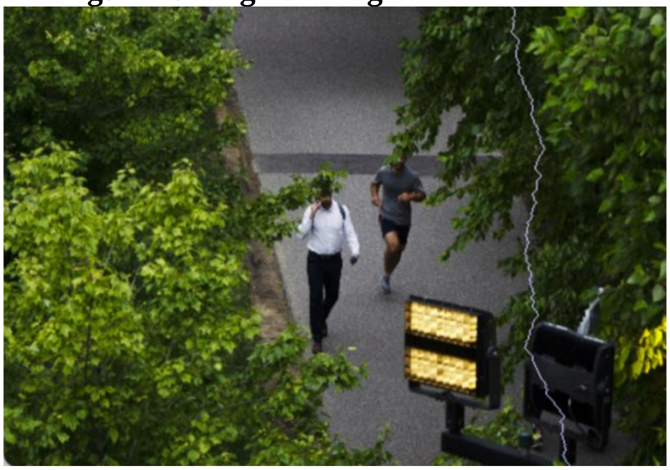

Figure 5: Seam Carving Being Applied to image of Park

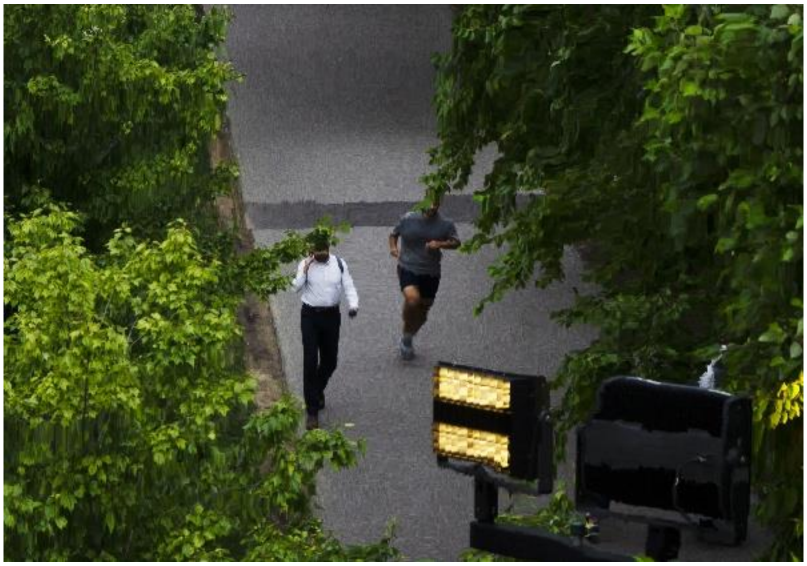

Figure 6: Park Image height increased by 100 and width increased by 100

Difference Between Using Masks and Forward Energy

Figure 7: Original image of Rata resized

Figure 8: The image on the left used forward energy and the image on the left used masking

As you see in the figure 8 both techniques have their drawbacks. In the forward energy technique, the Eiffel tower was extended beyond its normal size. Whereas, in the masked technique the landscape was distorted. The masked distortion can be fixed by including the landscape in the high energy region in the mask. The mask used for this image is given below in figure 9. The white regions are high energy and the black regions are low energy.

A readme file has been provided, describing the functions implemented and how to run the program from the terminal.

Figure 9: Mask used for the Rata image

Future Work

This paper only tackles the resizing of images, but seam carving can be implemented to perform a lot of other interesting tasks. In future iterations of the algorithm, I intend to create a function to remove unwanted content from the image. Below I have provided an image representation of such a method in action.

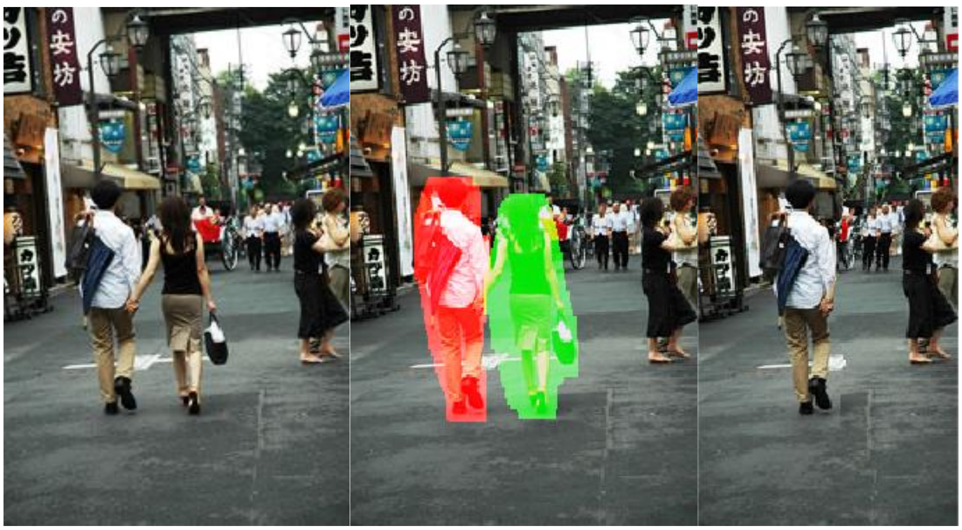

Figure 10: The first image in the row, is the original. The second image highlights the content to be removed in green. The third image shows the final result

The current iteration of the algorithm is run through the terminal. Another aspect of future work would be to develop a user-friendly graphical user interface.

References

[1] Rubinstein M., Gutierrez D., Sorkine O., Shamir A. A Comparative Study of Image Retargeting. (2010). http://people.csail.mit.edu/mrub/papers/retBenchmark.pdf

[2] Shai Avidan, Ariel Shamir. Seam Carving for Content-Aware Image Resizing .https://www.win.tue.nl/~wstahw/edu/2IV05/seamcarving.pdf

[3] Mahdi Ahmadi, Nader Karimi, Shadrokh Samavi. Image Seam-Carving by Controlling Positional Distribution of Seams. https://arxiv.org/pdf/1912.13214.pdf