Seam Carving for Content-Aware Image Resizing

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***Abstract*—The resizing of an image that comes stock to most devices capable of using images is typically accomplished through the use of scaling. Scaling has different methods of execution but essentially averages the pixel values along each dimension when shrinking, or interpolates when enlarging in a grid-like manner. This works well when maintaining aspect ratio, however, content of interest within the image becomes elongated or squashed if the aspect ratio changes. The idea of seam carving is to repeat the process of drawing a line from one edge of a provided image to the opposing edge of the image; that would contain a single pixel in each row, if starting from the top, that would be least noticeable if it was removed or cloned. This results in an image that can be a completely different aspect ratio without having a perceivable difference in its more important content upon viewing. For example, moving the buildings across a skyline closer to each other as opposed to changing their size to match the new aspect ratio.**

1. Introduction

The seam carving method applied in this paper allows for images to be resized while maintaining the proportion and size of the important content within the image. The foundation of this method relies on the idea that there exist in an image a seam of pixels that can be removed without being noticed. If that is executed successfully it can be done in succession until a desired target size for the image is reached; this is called seam removal. The reverse can also be applied it is possible to find a seam within an image that can be doubled without being noticed in order to enlarge an image instead. The "noticeability" of a seam can be quantified through the use of an energy map. The energy map serves as a high frequency/contrast detector that increases the "energy" of a pixel relative to its difference from neighboring pixels, therefore a seams energy is equal to the sum of the pixels that make it up. The lower the energy of a seam, the less noticeable it is and vice versa. Manipulating this energy map also allows us to extend the purpose of seam carving to act as a tool for content amplification and object removal highlighted in the upcoming sections.

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2. Method

2.1. Background

Figure 1: Energy Map

2.1.1. Energy Map. An energy map is the representation of change in the image and in this implementation is found using a gradient approach by performing a convolution with two kernels; kernel that provides the vertical gradient and a kernel that provides the horizontal gradient of each pixel in the image have their results summed to produce the energy map. Represented by the following equation.

$$e(I) = |\frac{\partial I}{\partial x}| + |\frac{\partial I}{\partial y}| \tag{1}$$

$$\begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix}$$

$$\begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix}$$

(2)

Figure 2: Energy Map with Vertical Seam

2.1.2. Definition of a seam. A seam is a line drawn through the energy map that takes the path of least energy Fig.2. This algorithm observes a seam that starts from every column and row index, originating from the top and left side of the image. The seam travels by observing the neighboring 3 pixels in the row directly below the current pixel for the case of a vertical seam. This process is repeated until the seam has reached the bottom of the image. The energy of the seam is calculated by the sum of all pixels energy in that seam and the minimum is the ideal for removal/insertion.

2.2. Image Resizing

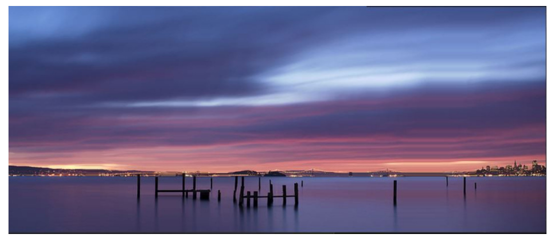
(a) Original Skyline

(b) 50% Width Reduction With Seam Carving

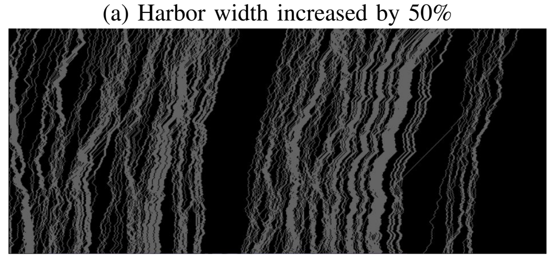
(c) 50% Width Reduction With Scaling

Figure 3: Scaling vs Seam Carving

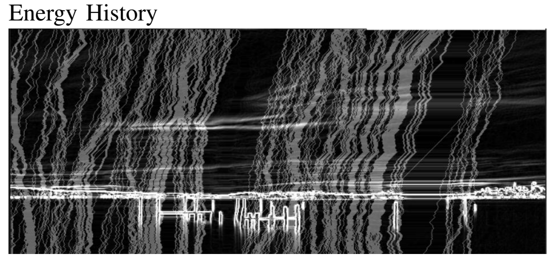
2.2.1. Seam Removal. Seam removal is the process of removing the ideal minimum seam once found. Fig.3 shows the comparison between an original image of a skyline (3a), a resized image using seam carving (3b) and a resized image using scaling (3c). It is apparent that seam carving maintained the size of the buildings by shift them closer together in order to preserve the image content as opposed to producing slimmed buildings in the scaled alternative. During execution the energy map has the same removed every time the image has a seam removed in order to maintain spatial consistency between the map and the image. A new minimum energy seam is searched for and the process is repeated.



(a) Harbor width increased by 50%



(b) Harbor width increased by 50% Energy Map + Energy History

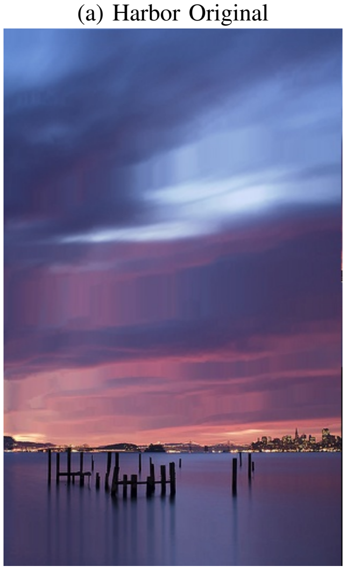


(c) Energy History

Figure 4: Seam Insertion.

2.2.2. Seam Insertion. Seam Insertion is the alternative to removal in which the seam adds more pixels to the image as the average of the adjacent pixels. Different rules apply to the seam insertion compared to removal due to the the newly added seem naturally being the new minimum when calculating the energy map. This produces a stretching artifact due to the same being selected infinitely or until the target size is reached. To counter this a matrix was created to store the data of previously selected seams (4b). This is then added to the energy map (4c). This step however only stops selection of the newly created seam, in order to select a seam other than the original a counter stores the amount of seam that have already benn added and skips that many minimum values to find the (n)-th least energy seam.

(a) Harbor Original



(b) Harbor Aspect Ratio Flipped

Figure 5: Simultaneous Resizing Order

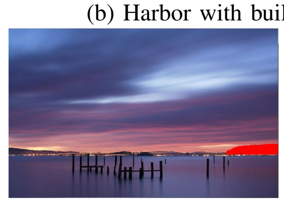
2.2.3. Simultaneous Resizing Order. In order to use Seam Insertion/Resizing simultaneously to perform a task such as an aspect ratio flip, the minimum seem is calculated for both the columns and rows simultaneously to determine which action would be least noticeable to get to the target size automatically. Fig.5.

2.3. Object Removal

Seam carving can be used to remove objects from an image by declaring a region to attract all the seams to. This method was performed allowing the user to select a region to remove and then subtracting that area from the energy map (6a), however, the seams in some images were able to go around the selected area due to the area being a to small and being surrounded by other possible paths. This was fixed by applying a large gaussian blur to the image in order to spread the influence of the selection region while also keeping the selected region as the largest absolute value in the blur, essentially like applying a magnet over the area of interest (6d).

(a) Original Harbor

(b) Harbor with buildings on the right removed



(c) Removal Selection Area

(d) Gaussian Blur

Figure 6: Object Removal

2.4. Content Specification

It is also possible to specify an object to make exempt from removal by adding energy to areas that the user selects (7b) in the image to the energy map (7f). Content aware resizing can misinterpret what the human visual system finds important if the background of an image is filled with high frequency and contrast like the pattern along the textile in the original image (7a). This can result in artifacts like squashed facial features(7c), but masking the energy map can prevent this entirely resulting in an image (7d) where the user set parameters and guides for the algorithm.

3. Conclusion

In conclusion seam carving provides an alternative to traditional scaling that can be used in conjunction with one another depending on the application in order to view an image in the most optimal proportion. Some limitations include usage for closeups and people, however, this shortcoming is made up for with content specification. It works best on wide shots and landscapes, but can fail in terms of enlargement

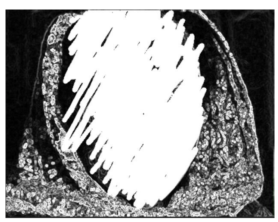
(a) Original Face

(b) Preservation mask

(c) Resizing without mask

(d) Resizing with mask

(e) Energy Map without no mask



(f) Energy Map with mask

Figure 7: Content Specification

for high frequency images due to the nature of even the least noticeable seam having high energy.This algorithm performs well for object removal if a clear focus is given

References

[1] Shai Avidan and Ariel Shamir, *Seam Carving for Content-Aware Image Resizing*, ACM Transactions on Graphics, Vol. 26, No. 3, Article 10 Publication date: July 2007.