# Seam Carving

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***Abstract*—Most of digital images are viewed in different devices with a variety of resolutions. the shift of multiple device make the resolution of viewing images difficult because they usually are resized to shape limited space.Resizing an image's height and width can cause distortion if not using an effective algorithm. One such algorithm is seam carving which allows for resizing by still maintaining the important features of an image.This allows you to make carvings of the image but keep the most important features of the image during the resizing process. The purpose of seam carving algorithm is image retargeting, which is the issue in images displaying without deformation on media of various sizes such as cell phones, or projection screens. In this paper we will introduce multiple applications of seam craving algorithm, and discuss in deep the method about it.In addition, we will also shows a new energy criterion for improving the visual quality of retargeted images and videos. The original seam carving operator focuses on deleting seams with the least amount of energy while ignoring the energy put into the photos and video by applying the operator. To combat this, the new criterion for reducing seams will be to look forward. This method is referred as forward energy it predicts which pixels would be nearest after removing a seam and uses that data to suggest the optimum seam to eliminate. This is in contrast to the traditional approach's backward energy.**

***Keywords*— Forward energy, Backward energy, Image retargeting**

## I. Introduction

Digital images are powerful tool that have many useful applications from movies to magazines. However, there is always a potential problem in the resizing of images. Changing the heights and widths of an image can cause images to be stretched or compressed in ways that are distorted. This can lead to many real world problems. Computer and television screens today have a large variety of aspect ratios but just stretching and compressing images to fit the various types of screens will cause distortion. Newspapers and magazines have only a set amount of space they can fit on a page or between text sections and publishers need to find a way to include images that are smaller or larger than their required length. Any resizing algorithm would need to be able to maintain the proportions for important features to not allow noticeable distortions. One algorithm that does this is seam carving.

Seam carving modifies the size of an image by changing the pixels that are the least prominent.It is frequently used to minimize the size of a picture in one dimension. This can be accomplished by locating and eliminating one-pixel wide routes from the image's top to bottom. If the pixels along those paths are comparable to the pixels in the surrounding area. Then, their removal can go unnoticed. Increase the size of an image, change the size of an image in two dimensions, and even remove an object are some of the other seam carving uses.

The input image is converted to grayscale and the energy is calculated to remove seams. Using dynamic programming concepts, we calculate the minimum energy of a connected path from the image's top to each pixel.Energy is measured using one of two methods: backward-energy or forward-energy. Backward-energy is the method described in the original paper[1], where each pixel is given an energy, and the sum of the pixel energies in a path defines the path's cost.Forward energy aims to address this problem by reducing the energy introduced by removing a seam rather than reducing the energy of the seam.Forward-energy works well in general because it is designed to reduce common artifacts.However, there are a few instances where standard backward-energy appears to work better.This paper addresses these multiple application of seam carving and presents results for the base algorithm for reducing and increasing image height and width, Implementation of forward energy , and adding one novel energy adjustment to detect and remover object in image.

## II. Related work

Besides seam carving, there are numerous other algorithms that are used for image scaling. One type of algorithm are edge-directed interpolation which includes examples like the New Edge-Directed Interpolation by Xin Li and Michael T. Orchard[2]. These algorithms preserve edges in the image after scaling. These algorithms prevent the ”staircase” artifact that can be seen in curves or diagonal lines when scaled larger. However, for our purposes, we decided to focus on seam carving based on the paper by Shai Avidan and Ariel Shamir, **Seam Carving for Content-Aware Image Resizing**[1]. The operator from this paper uses a value called energy which represents the importance of a pixel by measuring the contrast of this pixel and its neighbors. The equation for energy for this paper is given as:

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

A new framework introduce by A. Mansfield, P. Gehler, L. Van Gool and C. Rother in **Visibility Maps for Improving Seam Carving** paper[3] to analyze, extend and improve seam carving itself called the visibility map, This map offers a natural description of methods that remove pixels from the input image in order to generate the output, enabling us to identify retargeting as a binary graph labeling problem. The authors describe an energy over a visibility map, which can still be optimized with seam carving operations.The visibility map algorithm generates generalized energy terms for seam carving operations, and forward energy seam carving terms are similar to it., but with a key difference: they pay only the new contact terms, and not the terms related to old contact.

In this paper we will implement the forward energy from **Improved Seam Carving for Video Retargeting** paper done by Rubinstein, Michael, et al.[4].Which work by eliminating low-energy seams from the image and replacing them with new energy.New edges are generated by previously non-adjacent pixels that become neighbors once the seam is erased, resulting in added energy. The gradient between the new neighbors can be used to measure this change.It compare the amount of energy inserted by each seam using this forward energy and lower it by selecting the seam that inserts the least amount of energy.

## III. Contribution/Method

### A. Algorithm for Reducing Image Height and Width

Part 1 of this project was to implement the base algorithm that reduces an images height and width. This process is done through seam removal and is based on the **Seam Carving for Content-Aware Image Resizing** paper[1]. This process begins by selecting an image. Then, you must calculate the energy of all the pixels based on the contrast of itself and its neighbors. From these energy calculations, you can create seams which are connected paths of low energy pixels. You must create a list of seams and remove the minimum (or the lowest energy) seams needed for the image reduction to get the final image.

A vertical seam is defined based on the **Seam Carving for Content-Aware Image Resizing** paper[1] by the following equation:

$$\mathbf{s}^{\mathbf{x}} = \{s_i^x\}_{i=1}^{n} = \{(x(i), i)\}_{i=1}^{n}, \text{ s.t. } \forall i, |x(i) - x(i-1)| \leq 1,$$

An image is defined by an n x m matrix and x is defined as a mapping of x : [1,...,n] → [1,...,m]. This means that a vertical seam is 8-connected paths of pixels from top to bottom where only one pixel is in each row of the image. We can define a horizontal seam in a similar way where y is the mapping of y : [1,...,m] → [1,...,n].

$$\mathbf{s}^{\mathbf{y}} = \{s_j^y\}_{j=1}^{m} = \{(j, y(j))\}_{j=1}^{m}, \text{ s.t. } \forall j |y(j) - y(j-1)| \leq 1$$

We can then use the energy function to calculate the cost of a seam and determine the the optimal seam that minimize the seam cost :

$$\mathbf{s}^{\mathbf{y}} = \{s_j^y\}_{j=1}^{m} = \{(j, y(j))\}_{j=1}^{m}, \text{ s.t. } \forall j |y(j) - y(j-1)| \leq 1$$

### B. Algorithm to Increase Image Height and Width

Part 2 of this project was to implement the ability to increase an image's height and width. This is based on the methodology from the "Seam Carving for Content-Aware Image Resizing" paper. To do image enlarging, you must first create the seams list in the same way as defined in part 1. However, instead of removing the seams with the lowest energy, you must compute a new seam where the minimum seam is by taking the average of the left and right neighbors of that seam. In order to avoid the stretching artifact that can be seen by choosing the same seam multiple times, you need to alternate between seams.

We cannot just duplicate all the seams in an image because this would be the same as standard scaling. Instead, in order to maintain important features of an image, we must enlarge the image a fraction of it size from the previous step. However, extreme enlarging will still cause visible distortion of the initial image that seam carving will not be able to prevent.

### C. Forward Energy

Part 3 implement forward energy algorithm.The goal of the original paper "Improved seam carving for video retargeting"[1] was to generalize the seam-carving algorithm. The main flaw with the original concept of energy was that it indicated which seams to remove but did not account for what happened afterward.(See Figure 1).Forward energy, on the other hand, anticipates which pixels will remain adjacent after a seam is removed and uses that information to propose the optimal seam to remove.This is in contrast to the backward energy.


Fig. 1. The comparison between backward energy seam carving and forward energy seam carving

When a low-energy seam is removed, pixels that were not adjacent are pushed together, resulting in a substantial increase in the image's total energy. We'll have to evaluate pixels that weren't adjacent previously but are now when a seam is erased.As a result, begin by establishing the concept of a color difference between two randomly selected pixels.Next, we must consider which pixels are pulled together when a pixel is removed. This is determined by whether the current pixel is connected to a top-left or top-right seam. (Figure 2).

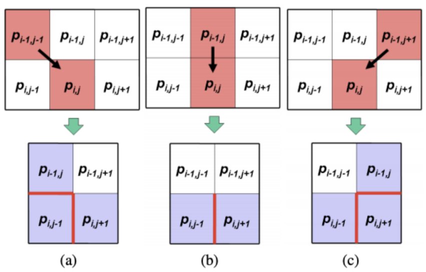


Fig. 2. As may be seen in the diagram,New neighbors appear when the seam is removed (in gray) and new pixel edges(red color) occur in the current row when the current pixel is removed by connecting to an earlier seam.Note that the new edges created in row i-1 were accounted for in the cost of the previous row pixel.

We compare the color difference between each pair of pixels since these two pairs of pixels will be connecting when the seam is removed.It's worth noting that we only evaluate new edges involving pixels in the current row, as the preceding row is taken into consideration when these calculations are done for the previous row.This represents, the new cost is the color difference between pixels (x-1,y) and (x+1,y) as well as the color difference between pixels (x,y1) and (x1,y) in the situation where we link to the top-left seam. $C_L$(x,y) is the name given to this cost. Furthermore, when connecting to the top seam, we have costs $C_U$(x,y), and when linking to the top-right seam we have costs $C_R$(x,y).As a result, rather than a single cost associated with each pixel, we now have three:

$$
\begin{aligned}
&(a)\ C_L(i,j) = |I(i,j+1) - I(i,j-1)| + |I(i-1,j) - I(i,j-1)| \\
&(b)\ C_U(i,j) = |I(i,j+1) - I(i,j-1)| \\
&(c)\ C_R(i,j) = |I(i,j+1) - I(i,j-1)| + |I(i-1,j) - I(i,j+1)|
\end{aligned}
$$

We adopt dynamic programming to determine the seams utilizing these prices in a new accumulative cost matrix M.The following rule is used to adjust each cost M(i, j) for vertical seams,where P(i, j) is an additional pixel based energy measure:

$$
M(i,j) = P(i,j) + \min \begin{cases} M(i-1,j-1) + C_L(i,j) \\ M(i-1,j) + C_U(i,j), \\ M(i-1,j+1) + C_R(i,j) \end{cases}
$$

*D. Object Removal*

Object removal can be accomplished using the seam carving algorithm. We modify the energy matrix to eliminate things from the image. For example, if we set the pixel energy to a very low level intentionally (i.e. using a mask), the Seam Carving method will eliminate the object. This can be accomplished by re weighting the energy matrix area in which the object appears (Figure 3).The user selects the object to be eliminated, and seams are removed from the image until all of the marked pixels are removed.The system will automatically determine which of the target removal region's in pixels and perform vertical or horizontal removals appropriately.


Fig. 3. Object Removal

In Photoshop, we simply generated a mask that picks the object's region.We had the computer read in the mask, and everytime a pixel on the mask is not white, the energy of that pixel is dropped to a negative value. As a result, any seams that pass across the pixels with the mask should have a negative cost( Figure 4).This strategy changes the entire image, unlike earlier object removal strategies [Drori et al. 2003; Criminisi et al. 2003; Bertalmio et al. 2003][5]. This may affect the size (or the content, if it is rescaled).This is due to the fact that both the removed and inserted seams may pass through the image at any point.

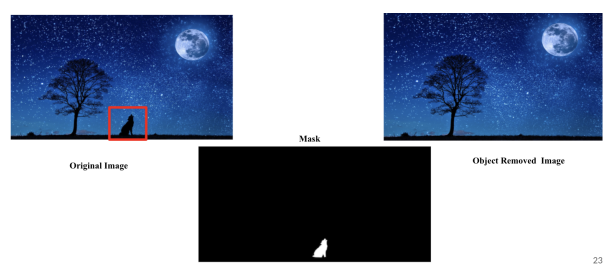


Fig. 4. In this case, we're going to use mask to choose the object (wolf) that has to be removed.The image was resized to its original dimensions. It's worth noting that employing in-painting or texture generation to get this result would be challenging.

## IV. Results

Here are the some results for Part 1, the base algorithm to reduce an image's height and width. (Figure 5 and 6). As seen by these examples of decreasing an image's width and height, we were able to showcase examples of seam removal without much distortion. This shows that seam carving can be used to reduce the height and width of an image.

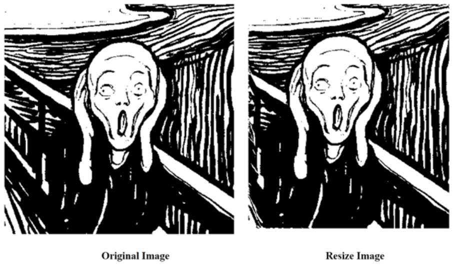


Fig. 5. From this Van Gogh scream rendition, 50 seams were removed from width and 10 seams from height.

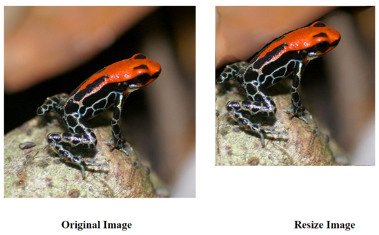


Fig. 6. From this image of a frog, 100 seams were removed from width and 100 seams from height.

Here are the some results for Part 2, giving an algorithm to increase an image's height and width (Figure 7 and 8). As seen by these examples of increasing an image's width and height, we were able to showcase examples of seam insertion. These results, however, do showcase some distortion. Not as much distortion was seen in Figure 3 compared to Figure 4, but both of these result showcase examples of some distortion. This shows that seams insertion can be used to increase the width and height of an image but there might be some distortion in the results.


Fig. 7. From this Van Gogh scream rendition, 10 seams were added to the width and 50 seams were added to the height.

Figure (9 and 10 ) illustrate the difference affects between forward energy and backward energy. New edges are generated by previously non-adjacent pixels that become neighbors once the seam is erased, resulting in inserted energy.The gradient between the new neighbors can be used to measure this change. We may compare the amount of energy entered by each seam using this forward energy and lower it by selecting the seam that inserts the least amount of energy.


Fig. 8. From this image of a frog, 100 seams were added to the width and 100 seams were added to height.

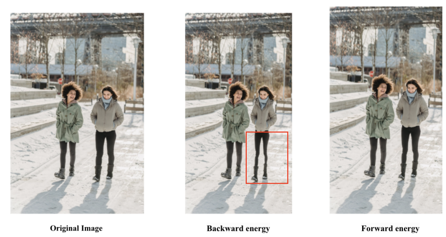


Fig. 9. Examples of Comparison for Energy Methods

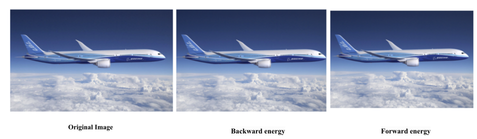


Fig. 10. Examples of Comparison for Energy Methods

Figure 11 illustrate the object removal technique. After the user has marked the target object to be deleted, seams are eliminated from the image until all of the designated pixels are gone.

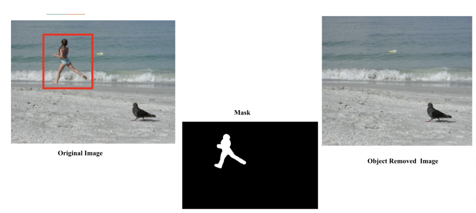


Fig. 11. Examples of Object Removal

## V. Limitations

Seam carving isn't always successful.It appears to perform best on landscapes and photos with a lot of little details. Distortions and other artifacts are much more evident when there are only a few significant features. For example, as you can see in Figure 12, the image it's look squeezed after the object(cone) is removed. Moreover, Figure 13 illustrate the same thing when removing the gun.

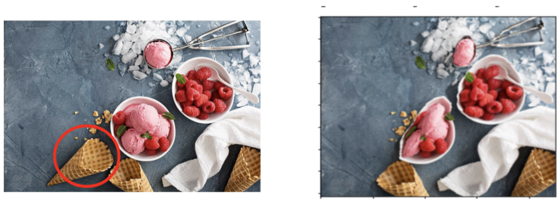


Fig. 12. Failure Image of Object Removal technique


Fig. 13. Failure Image of Object Removal technique

## VI. Conclusions and Future Work

Seam carving, also known as Content Aware Image-Resizing or Image retargeting, is a technique for resizing photographs ”smartly.”The approach essentially resizes photos based on the image’s content.Instead of considering the image’s present energy, forward energy considers the image’s energy after removing a seam.The original seam carving method has been simplified, resulting in more natural content-aware image scaling.Despite numerous academics have refined this technique in various ways, determining the energy function for job removal remains a difficult challenge.

In this paper we illustrate the implication of the base algorithm for reducing and increasing image height and width, Implementation of forward energy , and adding one novel energy adjustment to detect and remover object in image. This work could be expanded in a variety of ways.We’d like to expand our technique to other domains, starting with reducing heights and photos by removing seams. Seams don’t cause as many problems, but adding seams can cause distortion in some circumstances.Would be interesting to use a similar algorithm to change the shape of an image. Find a specific criteria when to use foreword energy , since in several case where standard backward-energy seems to work better.

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