Analysis of Seam Carving Techniques for Image and Video Retargeting

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ABSTRACT
This paper describes that how we can implement various techniques using "**Seam Carving for Image and Video Retargeting**" which would solve many problems that arise during the displaying, scaling, resizing of the various images and videos [1,2,3]. In this paper you will go through many techniques and their implementations that have been proposed by many authors using Seam Carving for Image and Video Retargeting. Seam carving that is also known as image retargeting, scaling, liquid resizing, or liquid rescaling; is generally an algorithm for image resizing that was developed and introduced by Shai Avidan, of the Mitsubishi Electric Research Laboratories (MERL), and Ariel Shamir, of the Interdisciplinary Center and MERL[1]. As per the algorithm suggested by the author, you have to establish number of seams in the selected image and further automatically remove seams to reduce the size of the image. The same approach is adopted for video retargeting except the fact that you use video frames instead of objects in the image. The paper discusses various approaches that have been adopted by various authors in this respect.

General Terms
Seam Carving, Resizing, Image Retargeting, Video Retargeting

Keywords
Graphics, Image Processing, HTML, Web Layouts, Picture Contents, Cropping, Distorts, Stretching, Seam Carving, Video Retargeting, Liquid Rescaling, Content-Aware Scaling

1. INTRODUCTION
In this era of technology, where you have so many ideas and ways for the technical implications in the field of graphics or image processing, you still need something that is much definitive and which includes something called 'quality' in itself. We need something that doesn't just erratically perform action but which performs it with a balance in hand with the situation.

Talking about various standards present in the world today, like HTML and others, you can hold an opinion that although these standards are capable of providing different alternatives to the user but somehow not perfect in it. Using them you can perform many operations on the images and other section of a web page like the web layouts, picture contents, but the way it handles the changes made in the images, doesn't satisfy the user completely.

You cannot even suggest that cropping or stretching is appropriate for image resizing; as cropping reduces the image content and stretching distorts the image.

The issues related to displaying problems using varieties of display devices usually arrive with most of the gadgets or the display devices. However, to improve this you can make use of a better technique called Seam Carving, which was introduced by Shai Avidan, of Mitsubishi Electrical Research Laboratories (MERL), and Ariel Shamir, of the Interdisciplinary Center and MERL in 2007; it helps the user in the resizing of a particular image by simply elimination and the insertion of the pixels in the image [1,5,6,23,27].

You can say that seam carving is basically an algorithm that is used for image resizing. In this algorithm you can establish number of seams in the selected image and further on the basis of our choice, if you want the size of the image to be increased then the seams are added, on the contrary if you want the size of the image to be reduced we decrease the number of seams. Using this algorithm you can display images without distortions on various Medias.

"Seam carving" can be considered as the general superior method for the image targeting. At a high level it is an algorithm that preserves the sizes and shapes of "important" objects, while resizing "less important" parts of the image. In seam carving, you can refer to image content a lot and not just stick to the geometry of that particular image [1, 2, 3, 4, 5, 6].

1.1 Seam
The word *seam* about which you have been listening for so long has different meanings and has been described in different ways by different authors; but generally it means, a path of collected low energy pixels [1,6,23,24,25,26,27].

Seams can be both vertical and they could be horizontal [4]. A seam that is vertical in an image is vertical path of connected pixels, with one pixel in each row. Same way you can define a horizontal seam, the case being that it has one exception i.e. here the connection is from left to right [7].

- Assume m x n→m x n' , n'<n (summarization)
- The basic idea is to remove those pixels that are not important from the image.
- Pixels that are not important mean the pixels with less energy.

$$E_1(\mathbf{I}) = |\frac{\partial}{\partial x}\mathbf{I}| + |\frac{\partial}{\partial y}\mathbf{I}|.$$

Here we must preserve the contours and since the vision of humans is very sensitive to edges so it would be better if you could remove that specific content from smooth areas.

- Seam is generally considered to be a connected path of pixels from top to bottom or left to right (one in each row).

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

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

The optimal seam:

E(I)=| (∂/∂x) I| + | (∂/∂y) I|

The recursion relation is given by: M(i,j)=E(i,j)+min(M(i-1,j-1), M(i-1,j),M(i-1,j+1))

Could be further resolved efficiently using Dynamic Programming in O (s·n·m) where s=3 in the original algorithm [1, 7].

1.1.1 Computation

Once the seams have been established, you need to compute them. As per the algorithm described by the author. For computing seams you first need to find the minimum path of distance from one to another side of the image. To achieve this you can use any of the following: Dijkstra's algorithm, dynamic programming or graph cuts. Seam carving enables the change in the size of an image by carrying out modifications in the least noticeable pixel. To perform this action, a one-pixel wide path is chosen or found out in the image from the top to bottom and if the pixels in the path are similar to the surrounding pixels then they can be removed.

In seam carving, you simply use an energy function and you can simply enlarge and reduce the size of the image in both the directions by simply adding or eliminating the seam. In both the cases you must ensure to maintain the image structure. While preserving this image structure and enlarging the image, more low energy pixels are removed; and while enlarging the image you should make sure that there is a balance between the original image and the pixels that are artificially added to the selected image.

1.1.2 The Process

When you reduce the size of an image, you often remove the pixels that will go unnoticed. To find these respective pixels you need to first find the path across the image with the lowest total energy. In order to make an image one pixel narrower, further one pixel in each row of the image is removed; which reduces the image's width by one pixel.

Every pixel in the path is removed from the image, so that an over all reduction in the width of the image can occur. If further, you wish to reduce more width of the image then you need to remove the pixels from the next path of lowest energy.

This process can be continued until the width, which is desired, is reached.

1.1.3 The Way To Proceed

The process of resizing the image includes the process of assigning energies to each pixel and further finding the path across the image that minimizes the total energy [1, 27]. In this method the process of assigning energies to pixels, is difficult as the definitions of the energies used may lead to unexpected results.

1.1.3 Assigning Energy To Each Pixel

Each pixel possesses some energy and that energy is based on the sum of the 'x' and the 'y' derivatives at those points. The derivatives are further calculated by taking the finite divided difference between the pixel and its neighbors. Each color channel's energies are calculated and then added up for the overall complete energy of the pixel. Therefore, finding an appropriate energy function can affect the results drastically. But, there is one problem with this energy function i.e. it doesn't take into account the vertical lines that occur in the image.

$s^* = \arg\min_s E(s)$

This method works very well for the interior pixels, but those pixels, which lie along the edge, may not receive proper values since the central finite divided difference is not appropriate. For improvising the results, the image size is expanded by the reflecting pixels near the edge and across the edge and further cropping out the expanded region after convolution. By using this, the unrealistic energies near the edges can be removed without adding much calculation.

1.2 Energy Map Modification

When you start with a Seam Carving algorithm, you first calculate the energy value for every pixel depending on what value the gradient holds. Then you have to create an energy map that adds an offset value to every gradient. The value of this energy map is then initialized with zero.

Based on these energy values, all the seams are calculated and the optimal seam selection also takes place using this method. Now, along this optimal seam the points of intersection between the seam and the detected lines are marked and offset energy map is incremented in the locality of these points. When the next optimal seam is calculated the values carried by the offset energy map is further added to the gradient value.

The point of intersection i.e. the offset energy map is incremented by 200 and the adjacent pixels in an area of 7x7 pixels are increased as per the Gaussian distribution. Once the offset energy map is further changed the pixels covered by the optimal seam is removed from the image as well the offset energy map [1,2,3,4,5,6,7,12,13,15].

Once you have removed sufficient number of seams to reach the target image size, the algorithm is terminated.

2. PROBLEM WITH IMAGE RETARGETING

If you want to represent a digital image of size m x n, then you can use a 2D discrete grid that is made of pixels with m rows and n columns. Here each pixel will be having a value that encodes its respective color or intensity information. Taking the example of RGB images, every pixel has a triplet [R,G,B] stating its corresponding color channels i.e. Red, Green, Blue.

On the other hand the pictures that include pixels in gray accepts only one value that describes the intensity level. Now the problem that arises can be stated as follows.

As also pointed by Shamir and Sorkine (2009), there is no clear definition or measure to date as to the quality of I' being a good representative of I.

In loose terms, they define the three main objectives for retargeting as:

1. The important content of I should be preserved in I'.

2. The important structure of I should be preserved in I'.

3. I' should be free of visual artifacts.

This problem is pretty much challenging due to a number of reasons. Real-world scenes acquire tremendous variability and the discovered techniques are expected to handle different kinds of imagery, such as barren landscapes.

3. DYNAMIC PROGRAMMING

Dynamic programming stores the computed result of sub calculations in order to simplify the calculations of tricky and vague results and it is used for computing the seams.

When you wish to calculate the value of a vertical seam with lowest energy for each pixel in a row, you compute the energy of the present pixel in addition to the energy of one of the three pixels on top of that. Have a look at the picture shown below.

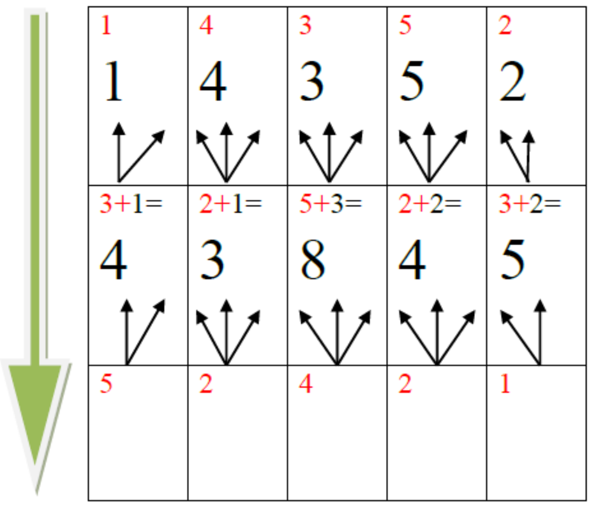


Figure 3.1 The green arrow alongside shows the algorithm's direction:

Here every square represents a pixel, and the top-left value in red represents the energy value of that said pixel. The value in black represents the cumulative sum of energies leading up to and including that pixel.

In the picture shown above, there are no rows present above the first row therefore the sum (in black) is just the same as the energy value of the current pixel.

Now look at the second row and the second pixel, whose energy value is 2. It has three possible values of the pixels i.e. 1, 4, 3 (black). Since the minimum value amongst them is 1, therefore you have to add 1 to the current energy value i.e. 2 plus 1. Ignore the rest of the values.

After the above operation is carried out, the table would appear like this:

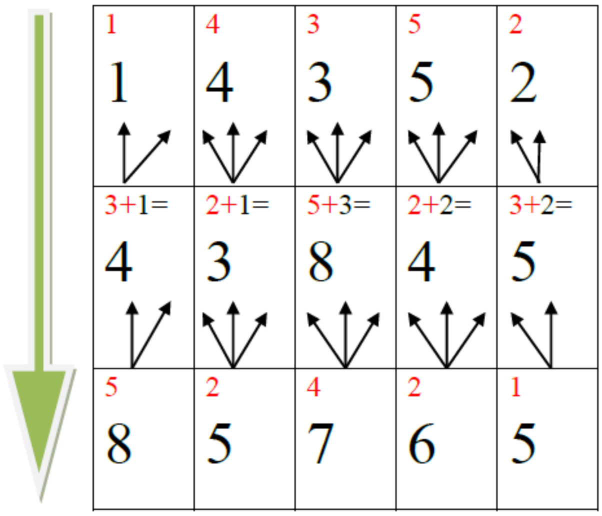


Figure 3.2 The table after carrying out the respective operation.

As proposed by the author you should repeat the same process with the remaining rows also. Here the lowest value or the values are the seams with the lowest energies

3.1 Calculation of Minimum Path Using Dynamic Programming

The task of finding the path of minimum total energy is called the direct implementation of Dynamic Programming. When the width of the image is to be reduced then the path will travel from top to bottom and the total number of pixels in the path will equal the height of the image. Further you will find the minimum path by storing the optimal path to find each pixel in the cost table

4. DIJKSTRA'S ALGORITHM

Dijkstra's algorithm was introduced by the computer scientist Edsger Dijkstra in 1956 and was published in 1959.
In this algorithm, if you are provided with a particular node or vertex in the graph, the algorithm will find the path with the lowest cost (i.e. with the shortest path) between that particular vertex and every other vertex through that [2,3,4].

For example, suppose if you have number of tasks to be accomplished and there are different procedures available for accomplishing it, then this Dijkstra's algorithm will help you to find the path with the shortest procedure or the procedure having the lowest number of steps; where the tasks are representing the nodes and the procedures with specific number of steps are representing the paths.

Hence, this algorithm is widely used in network routing protocols like, IS-IS AND OSPF (Open Shortest Path First).

However the Dijkstra's original algorithm does not use a min-priority queue and runs in time $O(|V|^2)$ (where |V| is the number of vertices.

As proposed by the author, the implementation based on a min-priority queue implemented by a Fibonacci heap and running in O (|E|+|V|log|V|) (where |E| is the number of edges) [5, 6, 7, 27]. This is asymptotically the fastest known single source shortest path algorithm for arbitrary directed graphs with unbounded non-negative weights.

5. THE MODIFIED SEAM CARVING ALGORITHM

The algorithm proposed by the author makes use of seam carving and prevents the distortion of considerable amount of straight lines. This is usually done through prevention of the removal of adjacent pixels lying on such a line [7, 27].

5.1 How The Algorithm Works

In many images the optimal seam crosses more than one object and hence deforms the straight line somehow. Here your goal is not to make the optimal seam to shift, but to make changes in it so that the effects due to the errors are not very much visible and the user does not recognizes the distortions in the image [23,24]. The point to be considered mandatory is that, the seam does not pass through a straight line in relatively adjacent pixel position.

Every time a seam crosses a line, the energy present in a certain radius from the point of intersection is increased, in order to decrement the chance that the other seams pass over the line in adjacent pixel positions.

In this algorithm you will make use of the *Canny edge detector* for the identification of the significant edges, then the edge pixels are further changed to *Hough space* so that the pixels on the straight line can be locate [1, 2, 7, 17, 19].

The key requirement in this modified Seam Carving algorithm is to change the calculation of the energy map.

5.1.1 How The Straight Lines Are Detected

Using the Canny edge detector where as parameters do this, a Gaussian mask of size 3 is used. It helps in the noise reduction. The upper and lower threshold of the hysteresis is given by T (up)=100 and T(low)=20[7].

Each pixel is transformed into Hough space. Now from the maximum value in the Hough space, a threshold

$T\ (Hough) = 0.6.\max\{I_H\}$ is derived.

Further the number of edge pixels located on this line is counted. Edge pixel is said to be a line pixel when the distance between the edge pixel and the line is below a threshold value T_{dist}=0.5 pixels, and if the line segment's line is at least T_{length}=10 pixels. Moreover all the small gaps created due to the seam removal are filled up (T_{up}=30) [15].

6. COMPARISON WITH THE REGULAR SEAM CARVING ALGORITHM

When compared with the regular seam carving algorithm, it was found that this algorithm provides much better results and proves to be significant. The distortion caused because of the curved lines is also very less obvious. A limitation also exists for this algorithm, i.e. this algorithm can avoid the straight lines only if enough space is there to move the seams across the image. Besides this if an image contains lots of straight lines or structures, then there lies a possibility that this algorithm may not be able to reduce these distortions or the unwanted bending of straight lines.

Otherwise, this modified algorithm provides us with excellent results and is much significant as compared to the regular Seam Carving algorithm.

7. VIDEO RETARGETING

Seam carving has been proved to be an effective technique for content aware image resizing; and you can even use it to test the video retargeting capabilities. It is a good idea to put efforts for the establishments of such techniques because videos are something that is displayed on televisions, mobiles and various other devices.

In this process every video frame is treated as an individual image and we resize it independently. Here you treat videos like a 3D cube and then extend seam carving with 1D paths on 2D images to 2D manifolds in a 3D volume [2,3,21].

While you are working on the video retargeting technique, the dynamic approach of programming for resizing the images is not applicable all the time. This is because you need to build a 2D connected manifold and that cannot be done just by the usual approaches for image resizing.

The idea is to create a new formulation of seam carving using graph cuts. But, these graph cuts could not be simple. These graph cuts should be monotonic and there should be only one pixel in every row (or column) and connected [22]. Since the process might take much longer time than expected, you will be putting some light on how the multi-resolution technique can be used to reduce the computation time.

Instead of so much correction and improved techniques there might be some limitations because of which our videos may appear irregular or vague. The spatial artifacts could be highlighted and augmented by the temporal ones at the same time. Even for this you define a novel seam carving criterion that would protect the salient spatial and the temporal issues thereby improving the quality of the images and the videos. As factors or parameters it takes the energy inserted into the image or video at the time of retargeting.

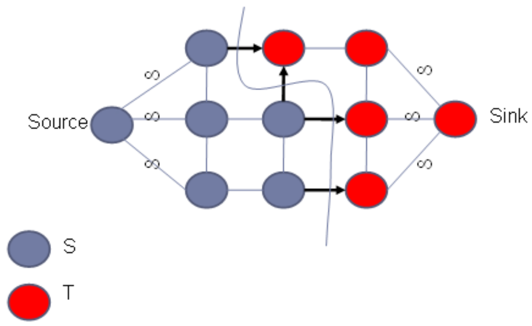
7.1 Seam Carving Using Graph Cut Method

You will have to refer to the vertical seams in the image rather than the horizontal seams in the image because they can be referred via the same method with variations in the rotations [2, 3, 22, 26]. You will refer to the graph edges as arcs so that you can distinguish them from the graphs in the images. Here you will be constructing a grid like graph from the image and in that grid every node will be representing a pixel and further connects to its neighboring pixel.

Two virtual nodes are created, Source (S) and the Sink (T) and they are connected with infinite weight arcs with all pixels to the leftmost and the rightmost columns. An S / T cut (or simply a cut) C on such a graph is defined as a partitioning of the nodes in the graph into two disjoint subsets S and T such that s € S and t € T. The cost of a cut C = {S, T} is defined as the sum of the cost of the 'boundary' arcs (p; q) where p € S and q € T.

Note that a cut cost is directed as it sums up the weights of directed arcs specifically from S to T. Further you can say that the arcs in the opposite direction do not affect the cost.

To define a seam from a cut, you have to consistently choose the pixels to the left of the cut arcs. The most talked about optimal seam is defined by the minimum cut which is the cut that has the minimum cost among all valid cuts.



7.2 Further Describing Graph Cuts for Videos

Here, you will be assuming that we are searching for a vertical seam and consider that X x Y planes in the video cube and use the same graph construction as in X x Y including backward diagonal infinity arcs for connectivity. Further the source and the sink nodes will be combined with both the left and the right columns of all the frames respectively. The manifold in the 3D domain is defined by the partitioning of the 3D video volume to the source and the sink using the graph cut method. This cut will be monotonic, optimal and restricted to each frame.

The figure above shows that how Seam carving creates optimal seams with different overtime.

The above figure shows the example of video retargeting of the image.

8. DISCUSSIONS AND OBSERVATIONS

No matter how beautifully and gracefully seam carving is helpful in image retargeting, there are still some parts where it needs to improvise.

Although the improved algorithm shows much better results but the run-time associated with it is pretty much longer (approximately 5times as long as the original algorithm). Besides this other operations like object elimination and object protection prove to be of quite a burden from the computation point of view which are not as much burdensome on the original algorithm. If these features could be turned off the run time would automatically improve somehow.

Another thing is that, the improved algorithm is capable of reducing the number of broken edges but it cannot eliminate them.

9. CONCLUSION AND FUTURE WORK

Going through the described techniques it could be said that a better seam carving operator can be provided for the video and the image retargeting process. It's very easy and quite a bit convenient to use graph cut method for this.

A new insight into the original seam carving operator has been presented in this paper and this paper tried to propose a forward-looking energy function that measures the effect of seam carving on the specific retargeted image.

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