Image Resizing Using Seam Carving Algorithm

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***Abstract*—Content-aware image resizing is the technique for resizing an image while trying to preserve the most salient features in it. The most popular approach is seam carving, which reduces the image size by identifying and removing low-energy seams from it. This paper presents an implementation of the seam carving algorithm based on dynamic programming. It first computes an energy map of the image, then builds a cumulative energy map on which it finds the lowest energy seam that needs to be removed. The paper discusses both time and space complexity of the algorithm and a method for backtracking in retrieving the optimal seam. Experimental results have shown the efficiency of the seam carving technique in saving mainly the key features of an image while resizing.**

I. Introduction

Resizing of an image is one such basic task in many applications of image processing, ranging from web design to photo editing, video processing. Most traditional resizing methods, like cropping and scaling, distort major features of an image and hence are aesthetically undesirable. Content-aware resizing can indeed change the size of an image while keeping significant features of it intact with minimal distortion.

A very popular method presented by Avidan and Shamir for content-aware image resizing is seams carving. This method detects and removes seams characterized by low energy, namely the paths of connected pixels moving from top to bottom or left to right. Through this, the image can be resized in a manner that helps in maintaining important objects due to removal of these seams and therefore improves the visual quality of resized images.

The proposed paper presents an efficient implementation of the seam carving algorithm using dynamic programming, though roughly divided into four main steps, namely: construction of the energy map, derivation of the cumulative energy map, identification of the optimal seam, and removal of such a seam from the image. The paper also includes analysis of the time and space complexity of the algorithm and gives a discussion on some backtracking methods for retrieving the optimal seam.

II. Seam Carving Algorithm

This algorithm has to be iteratively called several times. In the first call, one computes an energy map. In each iteration, there is building a cumulative energy map, searching for a seam to be removed, and removing that. Every one of these steps is explained in more detail in the following subparts.

A. Energy Map Computation

The energy map, therefore, represents the importance of each pixel in an image. This is typically approximated by gradient magnitude, which in turn is the rate of change in pixel intensity. For a given pixel, the gradient magnitude would be the sum of both horizontal and vertical gradients. The higher the gradient, the more "important" the pixel will be, and it will not be removed in the resizing process.

In this implementation, we use the gradient magnitude of each pixel to generate the energy map. The energy of a pixel $E(x, y)$ is calculated as:

$$E(x, y) = \sqrt{(I_x(x, y))^2 + (I_y(x, y))^2}$$

where I_x and I_y are the gradients in the horizontal and vertical directions, respectively.

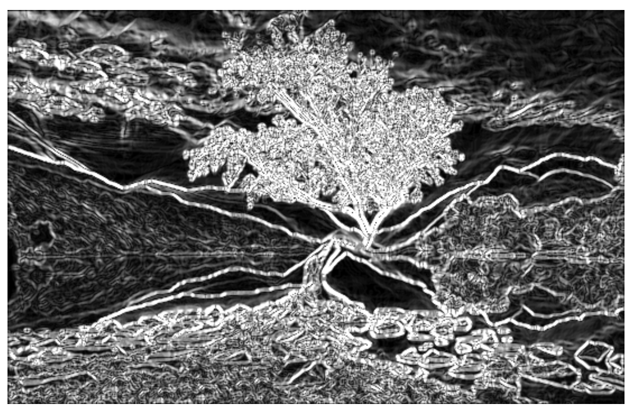

Fig. 1. Illustration of the energy map computation and cumulative energy map construction for seam carving.

B. Cumulative Energy Map Construction

This cumulative energy map now traces out the minimum energy path from top to every pixel in the image. We ensure to track the seam with the lowest energy. The cumulative energy at any pixel is computed by summing the current energy of that pixel to the lowest energy of these three pixels which are immediately above it: direct, left-diagonal, and right-diagonal. This approach is implemented using dynamic programming.

The value at a given pixel (x, y) in the cumulative energy map $C(x, y)$ is given by:

$$C(x,y) = E(x,y) + \min(C(x-1,y-1), C(x-1,y), C(x-1,y+1))$$

where $C(x-1,y-1)$, $C(x-1,y)$, and $C(x-1,y+1)$ represent the neighboring pixels in the previous row.

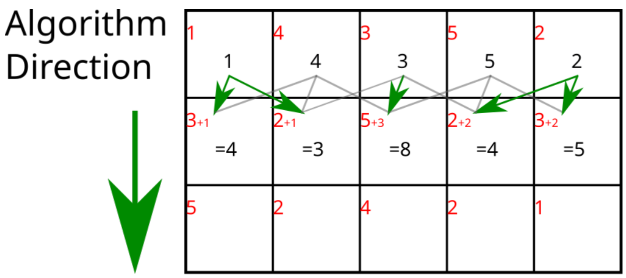

Fig. 2. Illustration of the cumulative energy map construction for seam carving.

C. Optimal Seam Identification

From now on, the minimal energy seam becomes computable given the pixel of minimum energy in the last row, then backward through the whole image up to the top. The backtrack path of pixels follows the lowest cumulative energy paths that correspond to the lowest-energy seam.

We start scanning from the last row, then drop down to find the minimum cumulative energy pixel, then move up in the opposite seam direction by one row of every one of the three neighboring pixels for the previous row-this is actually the approach used in generating the cumulative energy map-and trace back to recover the full path of the seam.

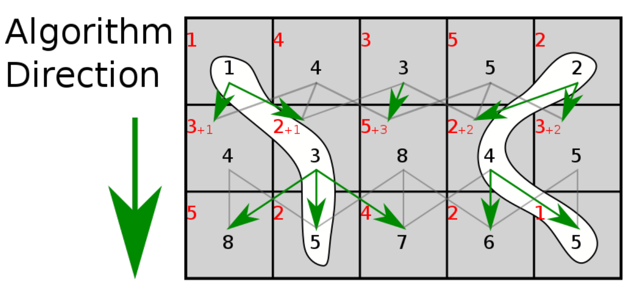

Fig. 3. Illustration of the dynamic programming path for optimal seam identification.

D. Seam Removal

Once the best seam is identified, it is removed from the image. The pixels on the right side of the seam or below it are moved horizontally or vertically to fill in the resulting space left by removal of that seam. This process iteratively repeats for each seam till the required size of the image is achieved.

III. Implementation and Results

The implementation of the seam carving algorithm is carried out in C++ using the OpenCV library. The primary steps include computing the energy map, constructing the cumulative energy map, backtracking to identify the optimal seam, and removing the seam from the image.

The performance of the algorithm was evaluated on several images, with the results indicating that the algorithm effectively preserves important visual features while resizing. The images resized using seam carving show less distortion compared to traditional resizing methods, which often crop or stretch images indiscriminately.

Fig. 4. Original Image (626x418)

Fig. 5. Resized Image (550x350) Using Seam Carving

The results shown in Figure 4 and 5 illustrate the successful resizing of an image using seam carving. The resized image retains its important features, such as the object in the center, while reducing its overall size.

IV. Conclusion

In this paper, we developed in detail a seam carving algorithm that has the capability of content-aware image resizing without losing essential features while scaling. In this paper, the stages involved in the algorithm are discussed, including computation of an energy map, constructing the cumulative energy map, identifying a seam, and removing the seam.

Experimental results show that our implementation proves seam carving can indeed be a very powerful technique, yet efficient in resizing images, besides maintaining the strong integrity of important visual features, which cannot be achieved using traditional resizing techniques. Possible optimizations in energy map computation and extending this method towards video and other formats of multi-media are future research.

References

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