Midterm Report
Content-Aware Seam Carving

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***Index Terms*—seam carving, content-aware, backward, forward, energy**

I. Discussion of Algorithm

In order to remove a seam, I created a boolean mask of the same shape as the input image and initialized it to all ones, which corresponds to True in a boolean mask. I then set the pixels which are part of the minimum seam to False in the mask. After that, I apply the mask to a copy of the passed-in image so as not to modify the input image. After that, it is essential to reshape the resulting masked image to be the same as the passed in image, albeit one column less, since one pixel from each row was removed, thus resulting in an image with one fewer column.

I split the insertion of a seam into two functions: a helper function and the main function which performs the seam insertion. The helper function first determines which seams to insert by calling the seam removal code and keeping a store of all seams removed, since these are the seams which will be inserted into an image to be expanded. This is because these are the seams with the lowest energy, or, in the case of forward energy, these are the seams which have been determined to result in the lowest cumulative energy after having removed that seam. Once the seams to insert have been determined, the main seam insertion function is called. To insert a seam, the average of the pixels to the left and to the right of the pixel which is part of the seam is calculated. Looping through the rows, the pixels in the current row are copied from the original image to the output image up until the index of the pixel which is part of the seam. The seam pixel is then inserted. Then, the rest of the pixels of the current row starting at the column directly to the right of the inserted pixel are copied from the original image, thus completing the insertion of a pixel of the seam for a particular row. This process is repeated for all the rows, since there will be one pixel inserted per row.

II. Comparison Metrics

In order to compare my resulting images with the comparison images from the paper, I decided to compare the energies of the images. Since one of the goals of seam carving is to retain as much energy as possible(since areas of high energy most likely contain important content), comparing the energies of the base images with the resulting images and comparison images seemed like one good metric for comparing the success of my seam carving pipeline.

III. Replicated Images and Comparison of Results

A. *Fig. 5 Waterfall (2007) Backward Energy Seam Removal*

The waterfall looks identical. There is a slight difference in the shoreline which is barely noticeable.

Fig. 1. $fig5\_07\_result.png$
Energy ratio of base to my result: 1.3949022 Energy ratio of my result to comparison: 1.0260503 Energy ratio of base to comparison: 1.43124

The result of the ratio between the base image and my resulting image (1.3949022) shows that the base image has about 40% more energy in it than my resulting image. The result of the ratio between my resulting image and the comparison image (1.0260503) shows that my resulting image has about the same amount of energy in it as the comparison image. The result of the ratio between the base image and the comparison image (1.43124) shows that the base image has about 40% more energy in it than the comparison image. These findings show that my resulting image is very similar in energy to the comparison image.

B. *Fig. 8 Dolphin (2007) Backward Energy Seam Insertion*

The dolphin seams image is pretty similar in general. The most important feature is that there should not be many seams going through the dolphin's body. This is the case in my result image, as most of the seams avoid the dolphin. There are a few areas where there are subtle differences; namely, the water on the right side is more stretched than in the comparison image. Also the white part of the water directly below the dolphin also appears more stretched. Other than that, the dolphin itself looks good, as do the sky and clouds. The clouds look a bit more stretched and warped in my resulting image than the comparison image. The sun and the large clump of clouds do not look like they are stretched as much as seen in the comparison image. The water on the left side of the dolphin, directly underneath it, looks more noticeably stretched than in the comparison images.

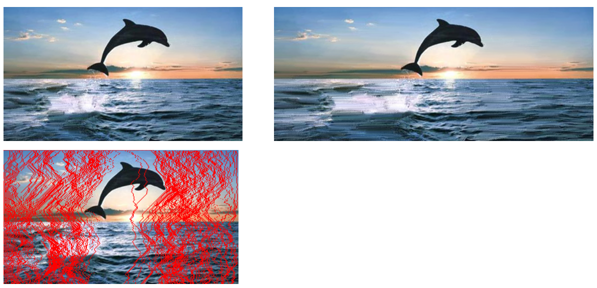

Fig. 2. Top Left: *fig8d_07_result.png* 50% Width Increase
Energy ratio of base to my result: 0.79619575 Energy ratio of my result to comparison: 0.9790657 Energy ratio of base to comparison: 0.77952796 Top Right: *fig8f_07_result.png* 2-Step 50% Width Increase
Energy ratio of base to my result: 0.6700197 Energy ratio of my result to comparison: 0.9803317 Energy ratio of base to comparison: 0.6568416 Bottom Left: *fig8c_07_result.png* dolphin image with red seams added to enlarge by 50%

For the top left image, the result of the ratio between the base image and my resulting image (0.79619575) shows that the base image has about 20% less energy in it than my resulting image. The result of the ratio between my resulting image and the comparison image (0.9790657) shows that my resulting image has about the same amount of energy in it as the comparison image. The result of the ratio between the base image and the comparison image (0.77952796) shows that the base image has about 23% less energy in it than the comparison image. These findings show that my resulting image is very similar in energy to the comparison image.

For the top right image, the result of the ratio between the base image and my resulting image (0.6700197) shows that the base image has about 30% less energy in it than my resulting image. The result of the ratio between my resulting image and the comparison image (0.9803317) shows that my resulting image has about the same amount of energy in it as the comparison image. The result of the ratio between the base image and the comparison image (0.6568416) shows that the base image has about 35% less energy in it than the comparison image. These findings show that my resulting image is very similar in energy to the comparison image.

C. Fig. 8 Bench (2008) Seam Removal by Two Methods

The seams for the forward energy of the bench looks quite different from the comparison image. In mine, the seams do not clump at the edges like they do in the comparison image. Additionally, they do not have the noticeable slant that is visible in the seams on the left and right of the bench. The seams for the bench using backward energy do have the overall general shape of the seams in the comparison image, however, they are not as clumped as the seams in the comparison image. The slant in the seams trajectory on the left and right of the bench is visible in my resulting images, though nor as much as it is visible in the comparison image. The bench using forward energy: My resulting image looks just slightly skinnier than the bench in the comparison image. Also there is a visible difference on the bottom of the right leg of the bench in my resulting image compared with the comparison image. Other than that, the image as a whole looks very similar. The bench using backward energy: My resulting image looks very similar to the comparison image. The benches look to be of similar width and there is a visible gradient shift near the left and right sides of the bench, which is visible in both my resulting image and the comparison image. There are visible differences on the legs of the benches, but other than that, my resulting image looks very similar to the comparison image.

Fig. 3. Top Left: *fig8_08_backward_result.png* 50% Backward Energy Width decrease
Energy ratio of base to my result : 1.4287444 Energy ratio of my result to comparison: 1.0248531 Energy ratio of base to comparison: 1.4642532 Top Right: *fig8_08_forward_result.png* 50% Forward Energy Width decrease Energy ratio of base to my result : 1.7071985 Energy ratio of my result to comparison: 1.0799495 Energy ratio of base to comparison: 1.8436881 Bottom Left: *fig8_08_back_seam_result.png* Bench with red seams to be removed by backward energy Bottom Right: *fig8_08_forward_seam_result.png* Bench with red seams to be removed by forward energy

The result of the ratio between the base image and my resulting image (1.4287444) shows that the base image has about 40% more energy in it than my resulting image. The result of the ratio between my resulting image and the comparison image (1.0248531) shows that my resulting image has about the same amount of energy in it as the comparison image. The result of the ratio between the base image and the comparison image (1.4642532) shows that the base image has about 45% more energy in it than the comparison image. These findings show that my resulting image is very similar in energy to the comparison image.

The result of the ratio between the base image and my resulting image (1.7071985) shows that the base image has about 70% more energy in it than my resulting image. The result of the ratio between my resulting image and the comparison image (1.0799495) shows that my resulting image has about the same amount of energy in it as the comparison image. The result of the ratio between the base image and the comparison image (1.8436881) shows that the base image has about 85% more energy in it than the comparison image. These findings show that my resulting image is somewhat similar in energy to the comparison image.

D. Fig. 9 Car (2008) Seam Insertion by Two Methods

In the image of the car using backward energy, there are quite a few visible differences between my image and the comparison image. The most notable differences are on the gate of the hotel and on the wall directly to the right of the gate. Additionally, the front wheel of the car is very noticeably misshapen as compared to the comparison image. Similar to the image of the car using backward energy, the image of the car using forward energy also has notable differences at the gate, the wall directly to the right of the gate, and the front wheel of the car.

Fig. 4. Left: $fig9\_08\_backward\_result.png$ 50% Backward Energy Width Increase
Energy ratio of base to my result : 0.8064615 Energy ratio of my result to comparison: 0.9903106 Energy ratio of base to comparison: 0.7986474 Right: $fig9\_08\_forward\_result.png$ Forward Energy 50% Width Increase
Energy ratio of base to my result : 0.78192455 Energy ratio of my result to comparison: 1.0125195 Energy ratio of base to comparison: 0.79171383

The result of the ratio between the base image and my resulting image (0.8064615) shows that the base image has about 20% less energy in it than my resulting image. The result of the ratio between my resulting image and the comparison image (0.9903106) shows that my resulting image has about the same amount of energy in it as the comparison image. The result of the ratio between the base image and the comparison image (0.7986474) shows that the base image has about 20% less energy in it than the comparison image. These findings show that my resulting image is very similar in energy to the comparison image.

The result of the ratio between the base image and my resulting image (0.78192455) shows that the base image has about 20% less energy in it than my resulting image. The result of the ratio between my resulting image and the comparison image (1.0125195) shows that my resulting image has about the same amount of energy in it as the comparison image. The result of the ratio between the base image and the comparison image (0.79171383) shows that the base image has about 20% less energy in it than the comparison image. These findings show that my resulting image is very similar in energy to the comparison image.

IV. Ambiguities and Issues

In the 2007 paper, there was not a lot of discussion on an appropriate energy function. They gave the high-level equation for an energy function, but did not go into much detail on how to calculate the energy function. Based on what they gave, it looked like a simple energy function is to use edge detection by taking the partial derivatives of an image in both the x and y directions. In order to do that, I used a Sobel filter. I created a kernel for both the x and y directions and then convolved both with the input image. After that, I took the sum of the absolute values of the results.

Also in the 2007 paper, there was not a sufficient discussion on edge cases while performing seam carving. In other words, there was not enough discussion on what needs to happen near the top, left, bottom, and right edges of an image during the seam carving process, both for seam removal and seam insertion. In my implementation, anytime during the pipeline that I had to deal with the edges of an image, I created an if-else block to handle those cases separately. For example, if the column I was currently dealing with happened to be an edge column, then I would need to be careful about which nearby columns I would be attempting to access, otherwise I would get index out of bounds errors.

In the 2008 paper, when the authors were discussing forward energy with dynamic programming, they did not go into much detail about the significance of the P(i, j) term in the calculation of the cost in the cumulative energy matrix. In my implementation, I left that term out as it seemed that it was just an additional term that could optionally be used as a heuristic in the calculation of the cost of a pixel.

V. Video Presentation

Here you can see my presentation of this report and some of the work I did in a visual format: https://youtu.be/H4Xo38D0Igc

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