Project 2
Content-Aware Seam Carving

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I. Discussion of Algorithm

A. Inital Image Processing

Both the forward and backward algorithms are implemented by finding the lowest-energy path through an image as determined by a cumulative energy function. The initial processing of the cv.Mat image for both alogrithms is done by taking the horizontal and vertical Sobel gradients of the image. The absolute values of the gradients are added together element-wise then flattened, creating a 2-D array of energy values. In order to avoid edge indexing errors, a single-pixel edge of duplicate values was created using

```
cv2.copyMakeBorder(gradient,
 1,1,1,1,cv.BORDER_REPLICATE)
```

and the array was indexed from the second to the second-to-last column.

B. Backwards Energy Algorithm

The backward energy algorithm is implemented by looking "back" through the energy values; each cumulative value is determined by the value before it. The cumulative energy function loops through each row in the image from the top-down, beginning from the second row. Using the three neighboring pixels from the previous row, the function takes the lowest value of the three and adds it to the value of the current pixel. This process is repeated, using the values determined by the previous iteration, until the final row's values are determined.

C. Forwards Energy Algorithm

The forward energy algorithm is implemented by determining the "forward" looking energy values; the cumulative value of a pixel is determined by the lowest energy value that would result after a seam removal. By pre-emptively calculating the energy in each possible resulting image from the removed seam at each pixel, the function looks "forward" to the result instead of "back" at the original image. The absolute values of the differences between neighboring pixels are calculated, then the lowest result's value is assigned to the current pixel.

There are three possible seam removal patterns that can occur within a pixel with three neighboring pixels from the previous row. In conjunction with the current pixel, the upper left, the upper center, and the upper right pixel could also be removed. The difference values are calculated between the possible remaining pixels. Since the current pixel will be removed in all three possibilites, its forward value is given by the absolute value of the difference between the pixels directly to the left and right on the same row. This value is then added to each possibility. For removal of the upper right and the upper left values, the absolute value of the difference between the pixel directly below them (in the current row) and the upper center pixel is taken. For the upper center pixel, no additional value is calculated as the total is already incorporated by the previous iteration of the funtion. The lowest of these three calculated values is then assigned to the current pixel.

D. Seam Tracing

The seam is traced along the line of pixels with the lowest overall cumulative energy. Beginning at the lowest overall value in the last row of the cumulative energy array, the location of each lowest value from the three neighboring pixels above.

II. Comparative Metrics

A. Difference Images

To generate the difference image, the image generated by the algorithm was compared with a given comparison image from the original paper. The absolute value of the difference between the generated image and the comparison image was taken. This creates positive values of every difference in the image. Then the generated array was flattened and the values divided by the number of layers. This created a greyscale image of the average difference in each pixel of the images.

The benefits of generating a greyscale image are that it gives a clear visual indication of difference. Instead of creating indeterminate blends of of 16 million different colors, it scales values of black and white. Black indicates an absolute match to the original image data, and white is an absolute mismatch. This gives clear visual indications of areas and magnitude of difference without confusing the viewer with indistinguishable color information.

B. Quantitative Metrics

Answer Here; include equation A simple metric was used to give an easily understood overall measurement of the difference between images. The metric selected was the root sun squared deviation score (RSSD). This is a method of measuring the magnitude of the total differences between two images. By dividing the magnitude of the differences by the magnitude of the information from the comparison image, a measured difference in magnitude can be generated.

The equation describing the RSSD comparison is

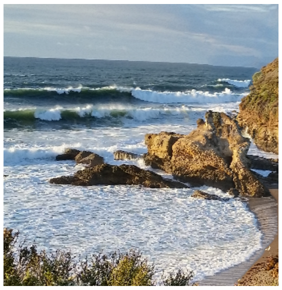
$$\sqrt{\sum (result - comparsion)^2} / \sqrt{\sum (comparsion)^2}$$

The RSSD is appropriate due to its being a measurement of differences between images that are very close to being identical. Comparison for similarity is best calculated by magnitude, as it always gives a positive value.

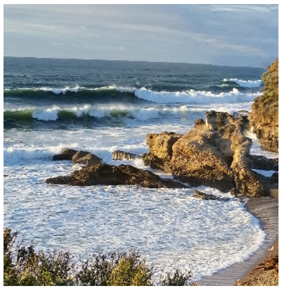
III. Replicated Images and Comparison of Results

A. Backwards Energy Seam Removal (2007): Beach

Comparison	Metric1
beach backward energy vs. comp	3.64



(a) Beach Comparison Image



(b) Beach Result Image

(c) Beach Difference Image

Fig. 1: Beach Backward Energy Seam Removal

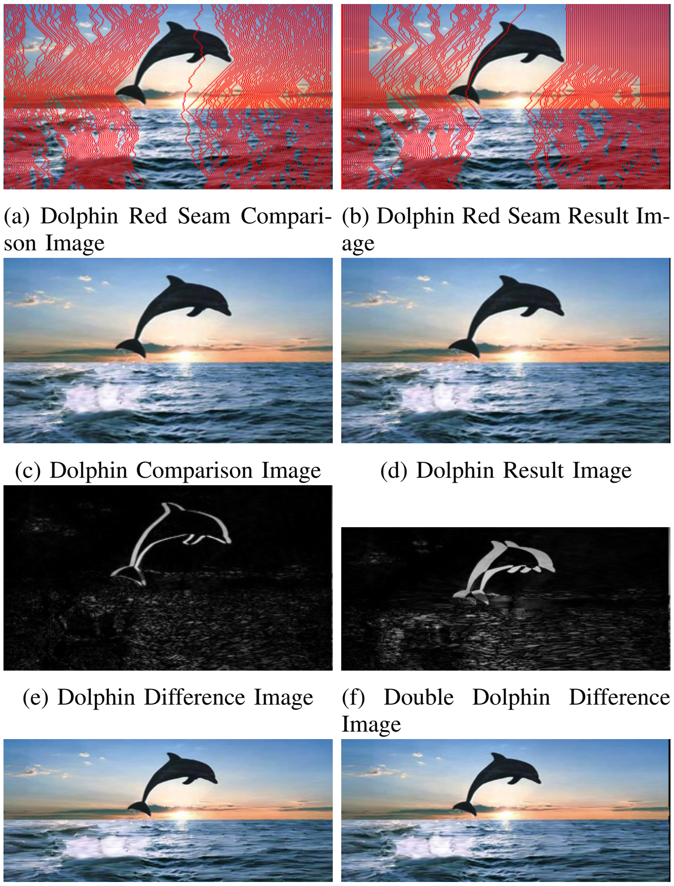
The visual similarities between the images is striking. Given the textures present in the image and its size, it is difficult to discern any difference with the naked eye. Several subtle differences become apparent on closer examination, such as the shape of the shoreline and the size of the bluff. These differences could be attributed to the energy function used. The HoG normalization in the original paper was not implemented in the project, and only the gradient information was utilized. This would have resulted in variations in seam selection.

The difference image makes these changes in shape more apparent. As it is a greyscale image of the differences in the image, it displays the magnitude of the change, and not merely which colors are different. From the white areas surrounding the bluff and the shoreline, it is apparent that image data differs most greatly here.

The selected metric shows that the images are distinctly similar in composition, with magnitudes of difference being negligible against the original image.

While the nu,mber of seams and the cumulative energy function were similar between the methods, the lack of histogram normalization in the gradient calculation was the deciding factor in the differences in structure of the images. Through slightly different seam selection criteria, the shape of the content of the image differed between the comparison and generated images. As the differences are slight, the energy function worked well in generating this image.

B. Backwards Energy Seam Insertion (2007): Fig. 8 Dolphin



(a) Dolphin Red Seam Comparison Image
(b) Dolphin Red Seam Result Image
(c) Dolphin Comparison Image
(d) Dolphin Result Image
(e) Dolphin Difference Image
(f) Double Dolphin Difference Image
(g) Double Dolphin Comparison Image
(h) Double Dolphin Result Image

Fig. 2: Dolphin Backward Energy Seam Insertion

Comparison	Metric1
res_dolphin_back_ins vs. comp	2.53
res_dolphin_back_double vs. comp	3.73

Visually, the differences between the comparison and generated images are minimal. The dolphin remains unstretched in both the single and double removal images, and the detail within the wave shapes are maintained. The size of major details are also well maintained and very similar betwene images.

The difference images make apparent the major differences between the two images. Despite similarity in shape, the location of the dolphin is not the same. This can be attributed to, again, using a different eengy function than the original paper. Though the shape of the dolphin is similar, its location can be affected by the location of the energy seams. The similarities in smaller detail, however, are illustrated well through the major areas of black space in the waves and sky.

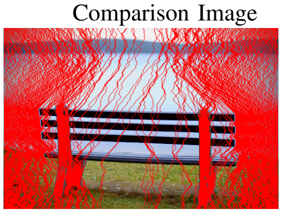
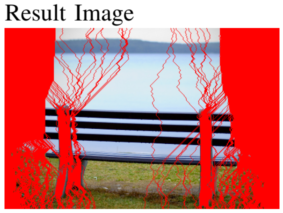
The similarity metric shows a close similarity between the comparison and generated images.

The most likely reason for the difference in the comparison and generated images are the differnet energy functions. Through not using the histogram normalization again, it changes the location of the lowest energy seams. This is especially illustrated in the differences in location between the single and double pass images, as the double pass image is offset twice as much as the single pass. Overall, these were very good energy methods for these images, with minimal visual aberration and maintenance of the shapes themselves.

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


(a) Bench Backward Comparison Image

(b) Bench Backward Result Image

(c) Bench Backward Red Seam Comparison Image

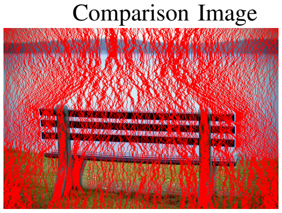
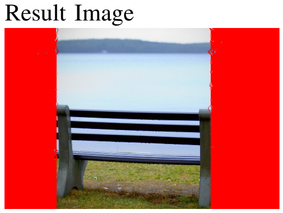
(d) Bench Backward Red Seam Result Image


(e) Bench Backward Difference Image

(f) Bench Forward Difference Image


(g) Bench Forward Comparison Image

(h) Bench Forward Result Image

(i) Bench Forward Red Seam Comparison Image

(j) Bench Forward Red Seam Result Image

Fig. 3: Bench Seam Removal with Backward and Forward Energy Functions

Comparison	Metric1
bench backward energy vs. comp	2.64
bench forward energy vs. comp	4.69

The visual presentation differs slightly between the comparison and generated backward images. While the posts are slimmed in a similar fashion, the dark diagonal areas are not apparent in the generated image. The post is also slightly bent in the generated image.

The backward difference image illustrates the major similarity between the two images. The dark space in the middle imdicates a near perfect similarity in those areas. The white areas indicate the areas of major difference already apparent in the visual comparison.

The backward metric is towards the lower end of the similarity metric results, and reflects the difference image's similarity illustration.

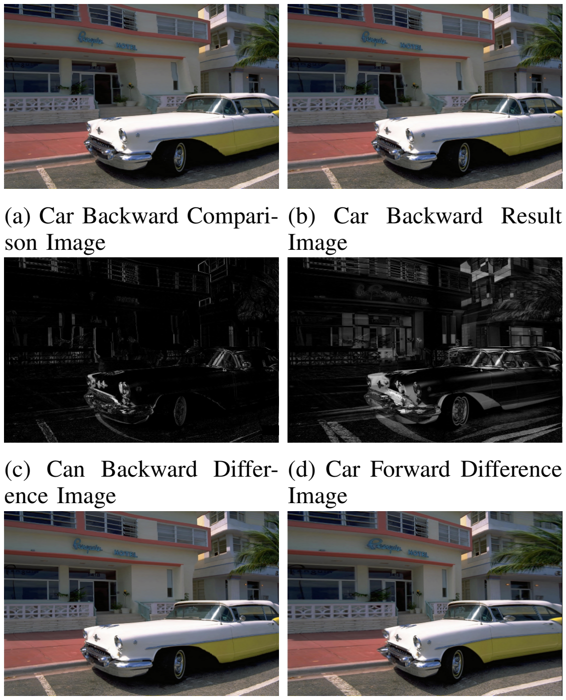
The forward energy presentation is greatly different. The middle of the bench remains unchanged, and the outer edges are missing. There is no real scaling of the content of the image, and the effect is more of a cropping of the original.

The forward difference image illustrates this edge-cropping very well, with major white areas at the ends of the bench where the information is lost or completely different. As the center of the image was least changed in the comparison image, the untouched center in the generated image is the most similar.

The results of the backward image differ due to, again, a lack of the histogram normalization used in the original paper. By only utilizing the gradient information, the seams will differ. The texture of the image could also be responsible for the differences, with a lack of detail in the water giving many different paths for the seams to run. This energy method was very effective in replicating the results of the paper.

The results of the forward image are distinctly different, with the seams in the generated image being pulled towards the edges. The lack of distribution of the seams throughout the image can be attributed to the lower amount of gradient information at the edges, and, again, a lack of histogram normalization. This energy method was not effective in replicating the results of the paper.

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



(a) Car Backward Comparison Image
(b) Car Backward Result Image
(c) Can Backward Difference Image
(d) Car Forward Difference Image
(e) Car Forward Comparison Image
(f) Car Forward Result Image

Fig. 4: 1955 Oldsmobile Seam Insertion with Backward and Forward Energy Functions

Comparison	Metric1
car backward energy vs. comp	1.92
car forward energy vs. comp	3.98

The visible differences between the backward energy seam insertion functions are nearly undetectable. The aberrations in the window line, the stretch of the fender, and the maintenance of small detail are all done very well. There is a small difference in the concrete railing next to the stairs, but overall the images are nearly identical.

The backward difference image illustrates the similarities well. Though there is some small difference in location of the small details, the majority of the image is black, indicating an overall high similarity between the two.

The backward comparison metric is the lowest out of any other images in the report, illustrating the high level of similarity between the two images.

The forward images are drastically different. The stretching of the roofline, as opposed to the hood, and the lack of aberration in the window line show a drastic difference that is immediately apparent.

The forward difference image also illustrates this well, with large white areas located throughout the image. This indicates a high level of difference between the two, with major features being in entirely different locations.

The forward similarity metric also shows a great difference in the images, with a very high value comparatively to the others in the report

The similarities in the backward comparison and generated images show very close results between the paper and the report. The difference in location can, again, be related to differences in the gradient

The forward images show the same tendency of the previous forward energy images, with the seams tending to be inserted toward the outside. This could be attributed to lower energy towards the edges, but it is more like that a bug in the function that causes the outer edge to be selected every time the seam is traced, with the cumulative value weighted toward the lack of information at the edge.

IV. Ambiguities and Issues

The first ambiguity that hindered progress was the lack of clear description in the seam removal process. While the original equation was meant to find a global minimum, it did not describe how to remove many seams at once. It was implied in the paper that all of the seams were removed at once. However, by removing seams one at a time, then finding the cumulative energy and finding a new global minimum, the seams could be removed until the entire image was gone without fault. A lot of time was spent trying to find ways to not have seams cross over, or to distribute seams without grouping. Seams travelling across many columns resulted in closed-off portions of the image. By realizing that each seam should be removed one at a time, the process became much easier.

The second ambiguity that raised issues was the description of seam addition. While the time analogy used to describe the process could be interpreted in the way they meant, the actual process of first removing seams, then adding them back, was ambiguous. A descriptive paragraph or a pseudocode algorithm would have been much more useful than a vague technical description using a time analogy in a function without a time dimension. Realizing that the time dimension was actually iterations, then expanding the iterated found seams to fit the original image, was instrumental in creating expanded images.

The third ambiguity was in the description of the connections as "8-bin" in section 3.2 of the original paper. This was not an accurate descriptor, as only 3 pixels were used in cumulative energy calculation. This was a source of early consternation as the seams could not have two pixels in the same row. The mathematical description of the seam tracing algorithms clarified the issue. Using the definition of 'n-bin' and describing the pixels used in that manner would have been more accurate.

References

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