Assignment 5

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1 Overview

In this assignment, we perform seam carving to resize the image. This technique selectively removes parts of the image that are less important, while maintaining the aspect ratio of the most important objects.

2 Main Task - Seam Carving

2.1 Approach

Here, we demonstrate the approach to finding the vertical seam to remove in order to reduce the width. To find a horizontal seam to reduce the height, we can first rotate the image by 90 degrees clockwise and perform the same operations. The only difference is that the output should then be rotated counter-clockwise back.

Step 1 To perform seam carving, we first have to convert the RGB image to grayscale and compute the energy matrix. Here, the energy function is defined as the sum of absolute gradients in x and y directions. Assume our image grayscale image is I and we use the Sobel filter G_x and G_y where:

$$G_x = \begin{bmatrix} -1, 0, 1 \\ -2, 0, 2 \\ -1, 0, 1 \end{bmatrix}, \quad G_y = \begin{bmatrix} 1, 2, 1 \\ 0, 0, 0 \\ -1, -2, -1 \end{bmatrix}$$

The energy matrix is calculated as:

$$E = |I * G_x| + |I * G_y|$$

Step 2 Next, we can find the seam with the energy using dynamic programming. We first define the score matrix M to be the same as the energy matrix. We start from the top row of the score matrix and iterate through the rows. At row $i > 1$, we find the score at $M[i, j]$ based on:

$$M[i, j] = \begin{cases} E[i, j] + \min\{M[i-1, j], M[i-1, j+1]\}, & \text{if } j = 1 \\ E[i, j] + \min\{M[i-1, j-1], M[i-1, j]\}, & \text{else if } j = I.width \\ E[i, j] + \min\{M[i-1, j-1], M[i-1, j], M[i-1, j+1]\} & \text{otherwise} \end{cases} \tag{1}$$

Step 3 After finding the score matrix M, we perform backtracking to find the seam S. We start from the bottom where $i = I.height$ and $S[i]$ stores the column at the bottom of M that has the minimum value. We iterate the rows from the bottom to the top where:

$$S[i-1] = \begin{cases} S[i] + \text{argmin}\{M[i-1,j], M[i-1,j+1]\}, & \text{if } j = 1 \\ S[i] - 1 + \text{argmin}\{M[i-1,j-1], M[i-1,j]\}, & \text{else if } j = I.width \\ S[i] - 1 + \text{argmin}\{M[i-1,j-1], M[i-1,j], M[i-1,j+1]\} & \text{otherwise} \end{cases} \tag{2}$$

Step 4 We remove the pixel at $I[i, S[i]]$ for all i. Since we remove one pixel in each row, the width of the image will be reduced by 1.

We keep repeating Step 1 to Step 4 until we reach the target size we want.

2.2 Results

In this section, we show the results of reducing the width and height by a factor of 2, respectively. As we can see from Figures 1, 2, and 3, we successfully reduced the image dimensions by removing parts deemed less important, as determined by the energy function. This effect is best observed in Figure 2, where the distance between the left and right crowds was significantly reduced. This reduction occurred because the points in between, considered less important, were removed.

Figure 1: Example 1

Figure 2: Example 2

Figure 3: Example 3

However, for Figures 4 and 5, we can see that the seam carving does not perform as well as in the previous examples. In 4, when we reduced the width, it is clearly visible that part of the person's face was removed. The results are even worse in Example 5 (Figure 5), where the person is almost entirely removed and unrecognizable.

One reason for the poor results may be a complex background with high energy values similar to those of important image elements, leading the algorithm to mistakenly remove significant content. In this case, the algorithm selects a suboptimal seam because it lacks a higher-level understanding of the image content. To improve the results, we can use a mask to indicate which parts of the image should be preserved. This part will further be demonstrated in the next section.

Figure 4: Example 4

Figure 5: My Own Example

3 Extra Credit - Seam Carving with Mask

In this section, we use a mask to provide a higher-level understanding of the image content about the important part that should be preserved.

3.1 Approach

The approach mirrors basic seam carving, with a key distinction in the first step of calculating the energy function. Rather than relying solely on gradient values, we increase the energy of the pixels within the mask by adding a substantial constant, 10^9 in our implementation, after the gradient computation. This adjustment significantly increases the energy of the masked region, thereby protecting it from removal during the construction of the score matrix.

$$E[i,j] = \begin{cases} E[i,j] + 10^9, & \text{if } (i,j) \in \Omega \\ E[i,j], & \text{otherwise} \end{cases} \tag{3}$$

, where Ω represents the area in the mask (where value$=1$). Additionally, in step 4, when removing pixels, we must also ensure that pixels within the mask are removed correspondingly.

3.2 Results

Here, we demonstrate that by incorporating a mask into the seam carving method, we can successfully preserve the parts we consider important, such as the faces of the two people in this example.

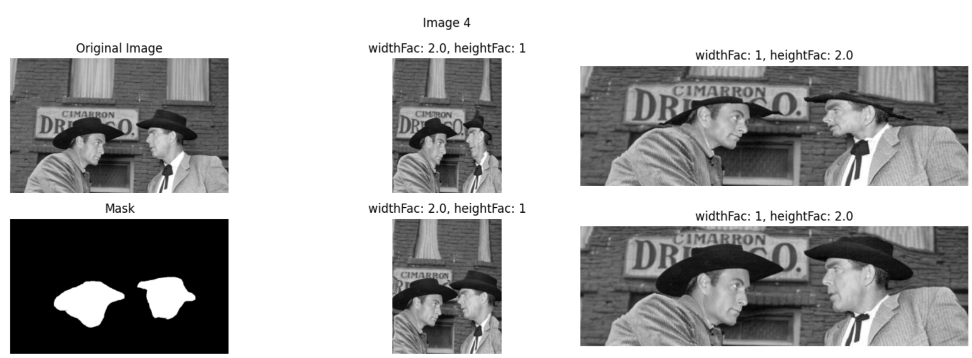

Figure 6: Comparison of results using a mask versus without. The top row shows results without a mask constraint, while the bottom row includes the mask constraint.