Seam Carving
(COL783: Digital Image Processing)
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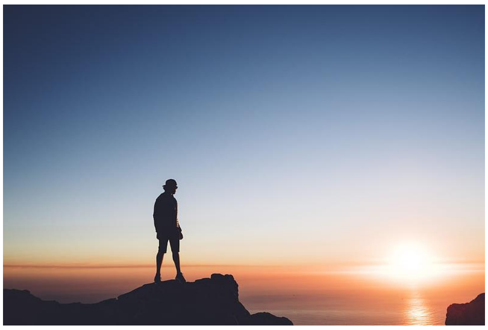
1 Introduction

Seam carving is a content-aware image resizing technique that removes or inserts pixels in a way that preserves the most important content of an image. Unlike traditional resizing methods (which scale an image uniformly), seam carving selectively adjusts the image dimensions by identifying and removing or adding "seams"—paths of pixels that represent the least significant parts of the image.

2 Implementation

2.1 Discrete Cosine Transform

The discrete cosine transform (DCT) and its partial derivatives were implemented from scratch. To compute the 2D DCT of an image, the 1D transform equation was applied sequentially to the rows and then the columns. The computational efficiency was improved by pre-calculating the transform matrix, enabling faster execution.



(a) Original Image (533, 800)

(b) Discrete Cosine Transform

2.1.1 Seam Insertion

2.2 Energy Function

The energy function is defined as the sum of the absolute values of the first-order partial derivatives of an image in the DCT domain. Rather than using the 8x8 cells, the entire length of the rows and columns was used to calculate the Fourier coefficients and partial derivatives. Visualizing this energy function provides the edge map of the image.

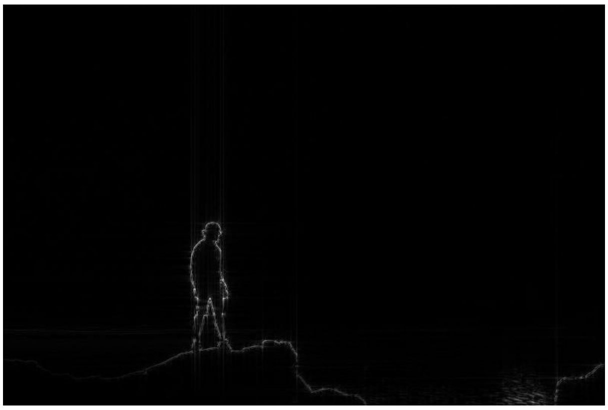


Figure 1: Energy Map

2.3 Cumulative Minimum Energy (CME)

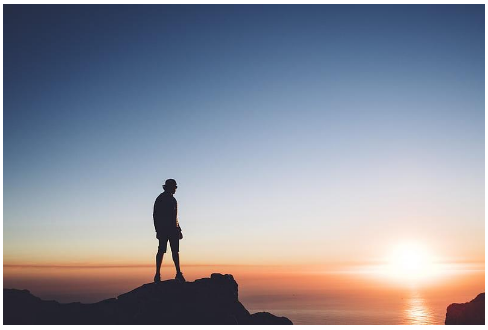
A dynamic programming approach was implemented to find the cumulative minimum energy (CME). Instead of starting from the top, the process began from the bottom, where the minimum cost of the connected pixel below a given pixel location was added to determine the minimum sum required to reach that location from the bottom. The cost of the globally minimum-energy path was identified as the lowest CME value found in the first row.

Figure 2: CMF

2.4 Seam Computation

2.4.1 Seam Removal

Traditionally, seams in the lowest cumulative minimum energy (CME) path are removed one by one to reduce the image size. However, this approach is computationally expensive, as recalculating the CME for each seam, even with dynamic programming, is slow. To address this, multiple seams were removed simultaneously by selecting those whose costs were within 10% of the standard deviation value of the first row in the CME controlled with variable α. This method maintained good results while significantly reducing the time complexity.



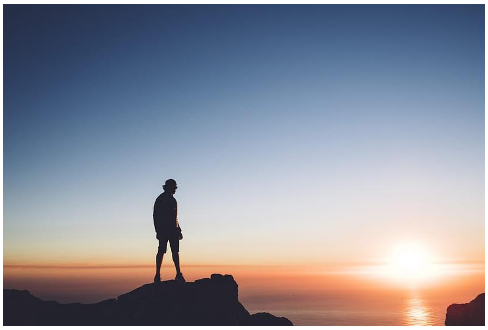
(a) Before Seam Removal (533, 800)

(b) After Seam Removal (383, 650)

Figure 3: Comparison of Images Before and After Seam Removal

2.4.2 Seam Insertion

Similar to the seam removal process, multiple seams are identified, and a new seam is inserted adjacent to these seams. The values of the new seam are obtained through bilinear interpolation from the surrounding pixels. This approach enhances the image's continuity and smoothness while preserving the overall visual quality.



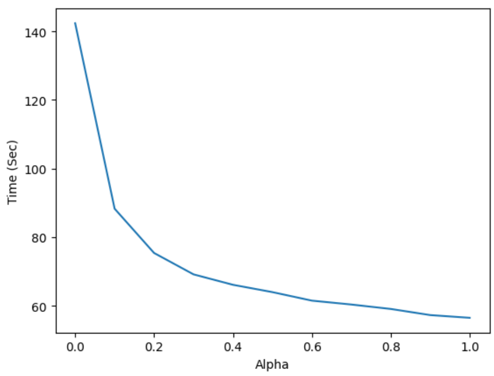
(a) Before Seam Insertion (533, 800)

(b) After Seam Insertion (683, 950)

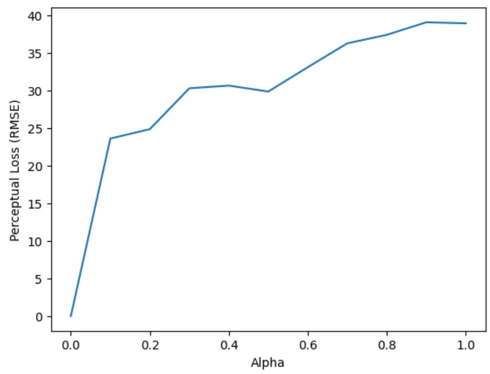
Figure 4: Comparison of Images Before and After Seam Insertion

2.4.3 Performance Improvement

By employing parallel seam removal using the standard deviation method, a 68% reduction in seam removal time is achieved. Furthermore, this resolution exhibits exponential characteristics, as illustrated in the graph below.



(a) Seam Removal Time Vs Alpha



(b) Perceptual Loss Vs Alpha

Figure 5: Seam Carved Images at different Alpha

3 Deep Seam Carving

Implemented using VGG16 based UNet architecture for the task and employed perceptual loss to improve quality of the produced images

Table 1: Architecture of the UNet Model

Layer	Type	Input Channels	Output Channels	Kernel Size	Stride
			Encoder		
1	Conv Layer	3 (or 4)	64	3x3	1
2	Conv Layer	64	64	3x3	1
3	Max Pooling	64	64	2x2	2
4	Conv Layer	64	128	3x3	1
5	Conv Layer	128	128	3x3	1
6	Max Pooling	128	128	2x2	2
7	Conv Layer	128	256	3x3	1
8	Conv Layer	256	256	3x3	1
9	Max Pooling	256	256	2x2	2
10	Conv Layer	256	512	3x3	1
11	Conv Layer	512	512	3x3	1
12	Max Pooling	512	512	2x2	2
13	Conv Layer	512	1024	3x3	1
14	Conv Layer	1024	1024	3x3	1
			Decoder		
15	UpConv Layer	1024	512	2x2	2
16	Conv Layer	512 + 512	512	3x3	1
17	UpConv Layer	512	256	2x2	2
18	Conv Layer	256 + 512	256	3x3	1
19	UpConv Layer	256	128	2x2	2
20	Conv Layer	128 + 256	128	3x3	1
21	UpConv Layer	128	64	2x2	2
22	Conv Layer	64 + 128	64	3x3	1
23	UpConv Layer	64	32	2x2	2
24	Conv Layer	32 + 64	32	3x3	1
25	Conv Layer	32	3	1x1	1

3.1 RESULTS

These are the results of the Deep Seam Carving model:

MRMS (Mean Root Mean Square): **0.0681**, Suggests that the model's predictions are generally close to the true values, which is a positive outcome.
SSIM (Structural Similarity Index Measure): **0.8186**, Indicates high degree of similarity between the predicted and ground truth images.
NMI (Normalized Mutual Information): **0.7055**, Reflects a moderate agreement between the model's predictions and the ground truth, indicating that while the model captures useful information, there is still room for improvement.

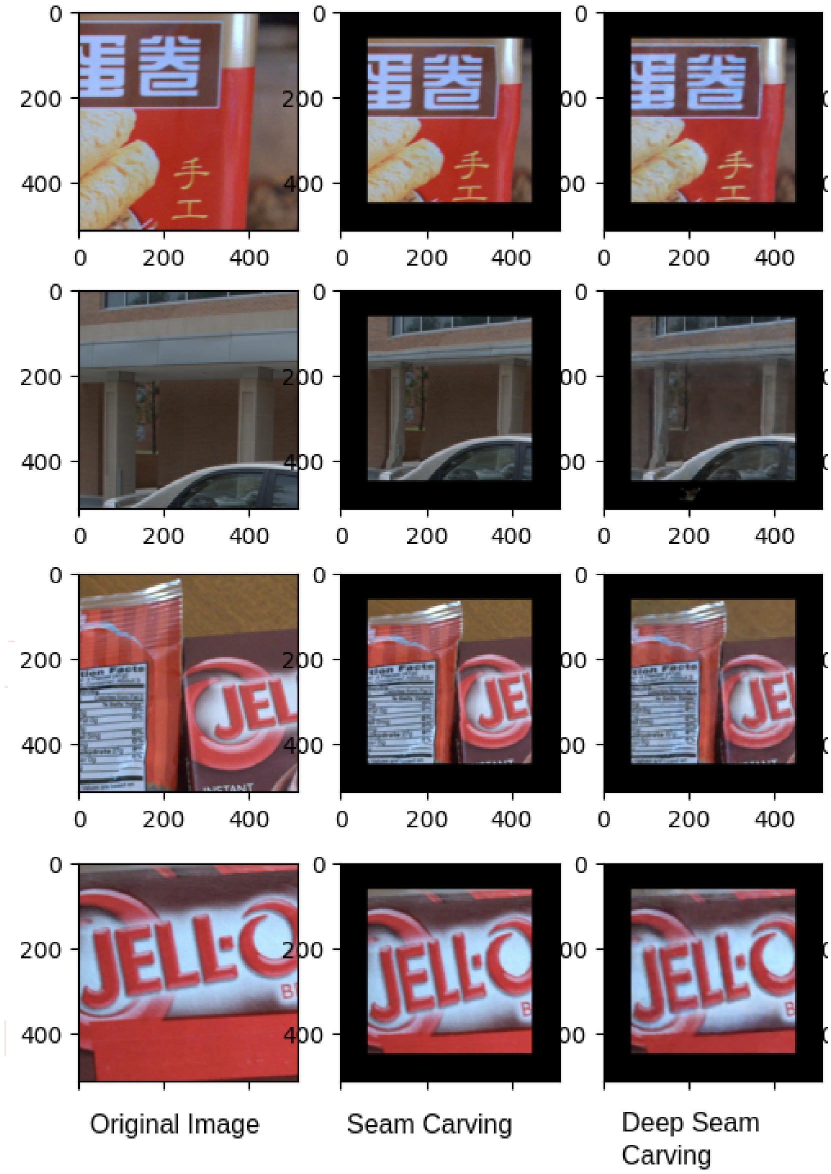


Figure 6: Results of the Deep Seam Carving Model