1 Short answer problems

1. Consider an image I on which we want to apply the smoothing filter g first and then a derivative filter f. The naive way of computing would be $f * (g * I)$. Instead, we can use the associative property of convolution and compute $(f * g) * I$. The advantage of this is that $f * g$ can be precomputed and we need to convolve only one filter with the image instead of two.

$$\begin{aligned} T(g_{m\times n} * I_{M\times N}) &= mnMN \\ T(f * (g * I)) &= 2mnMN \\ T(f * g) &= m^2 n \\ T((f * g) * I) &= m^2 n + mnMN \\ \text{Since} m \ll M \text{ and } n \ll N & \\ m^2 n &\ll mnMN \\ m^2 n + mnMN &\ll 2mnMN \\ T((f * g) * I) &\ll T(f * (g * I)) \end{aligned}$$

2. $$\begin{aligned} I &= \begin{bmatrix} 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \end{bmatrix} \\ \text{After dilation } I' &= \begin{bmatrix} 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix} \end{aligned}$$

3. Assuming padding with zeroes, on the left and right

$$\begin{aligned} f' &= \begin{bmatrix} 0 & -1/2 & 0 & 1/2 & 0 \end{bmatrix} \\ f" &= f' * f' \\ &= \begin{bmatrix} 0 & 1/2 & 0 & -1/2 & 0 \end{bmatrix} \cdot \begin{bmatrix} 0 & -1/2 & 0 & 1/2 & 0 \end{bmatrix} \\ &= \begin{bmatrix} 1/4 & 0 & -1/2 & 0 & 1/4 \end{bmatrix} \end{aligned}$$

4. (a) Using a gaussian filter with larger sigma σ will smoothen the image and remove finer details.
   (b) Thresholding gradient with a higher value in non maximum suppression will remove small edges. During hysterisis thresholding also, starting with a higher threshold leads to an increase in the overall lower thresholds also.

5. There maybe other types of noise also due to lighting conditions, transmissions, etc. Assuming Gaussian may not be appropriate for these noises. Secondly, Gaussian filter being a low-pass filter does not preserve edges.

6. Consider, we have an templates for the correctly assembled part.
   (a) Downsampling of the video frames.
   (b) Create a binary image of the frame with thresholding on lower values.
   (c) Perform dilation on the image to fill holes within the object and then erosion to restore it to it's original size.
   (d) Calculate distance of the image from the template.
   (e) Classify based on distance as defective or not.

2 Programming problem

1. Reduced width image Prague

Figure 1

Reduced width image Mall

Figure 2

2. Reduced height image Prague

Figure 3

Reduced height image Mall

Figure 4

3. Energy map and cumulative energies in horizontal and vertical directions

Figure 5: Energy map in grayscale

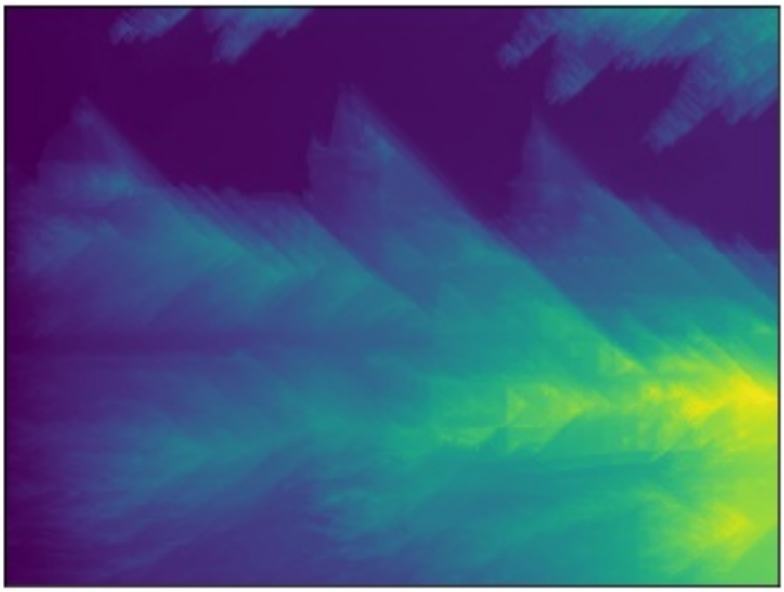

Figure 6: Horizontal cumulative energy map

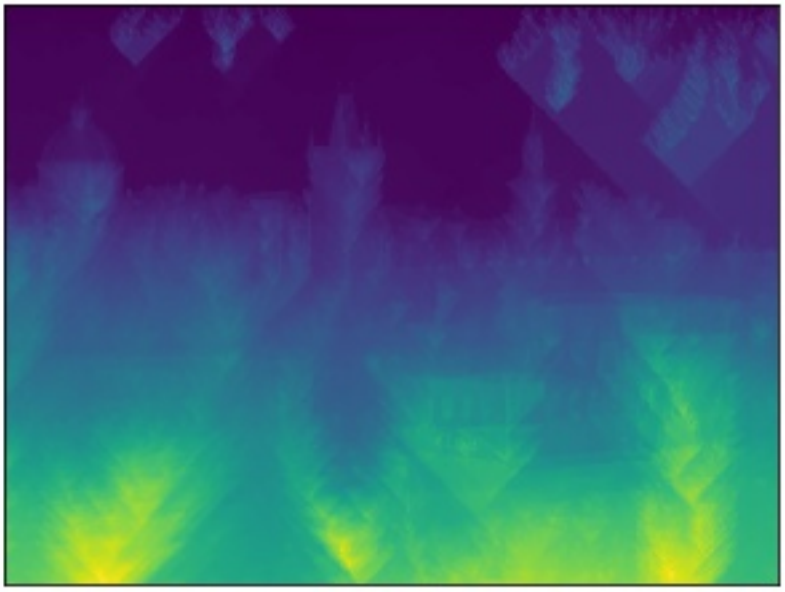

Figure 7: Vertical cumulative energy map

The energy in vertical map increases from top to bottom as we add up energies in top to bottom fashion in the algorithm. Similarly for horizontal cumulative map, the energies increase from left to right as expected. Also, we can see in the original image that since there is a lot of variation happening in the bottom right of the image due to the presence of boat's structure and it's reflection in the water. The cumulative energy maps in both the directions show higher energies towards bottom right. In addition, since there are no objects in the sky, implying low gradient, the energies are also relatively very low in the sky region.

4. Image with first vertical and first horizontal seam on next page.

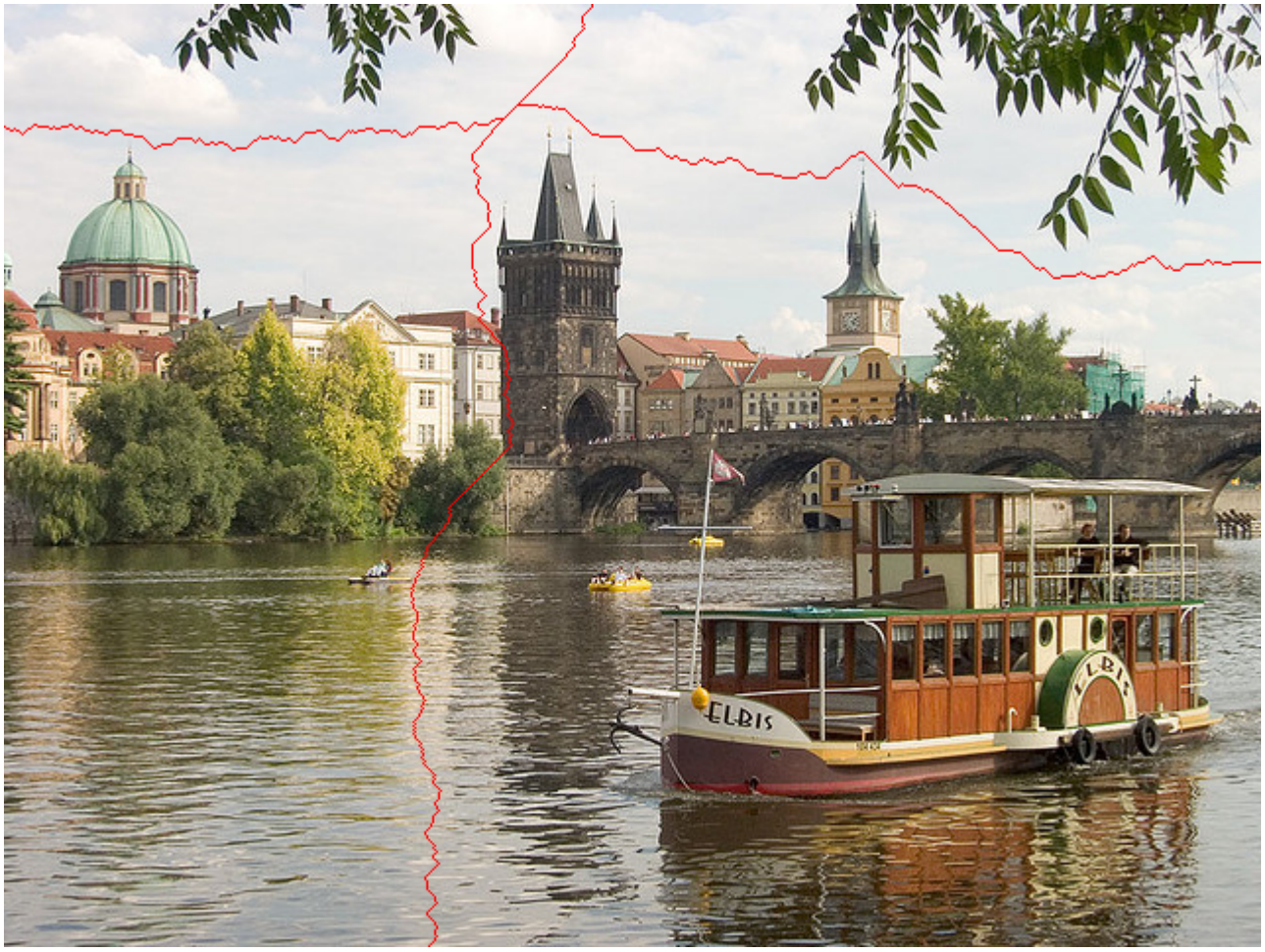

Figure 8: First vertical and horizontal seam

For vertical seam, we can see that the seam starts from bottom where the energy is lowest in cumulative energy map and follows the lowest energy path.
For horizontal seam, it is very evident from the cumulative map where the energies are the lowest (sky region). The first horizontal seam also starts from there.

5. Using Laplacian of Gaussian filter on Prague image with $\sigma = 2$.

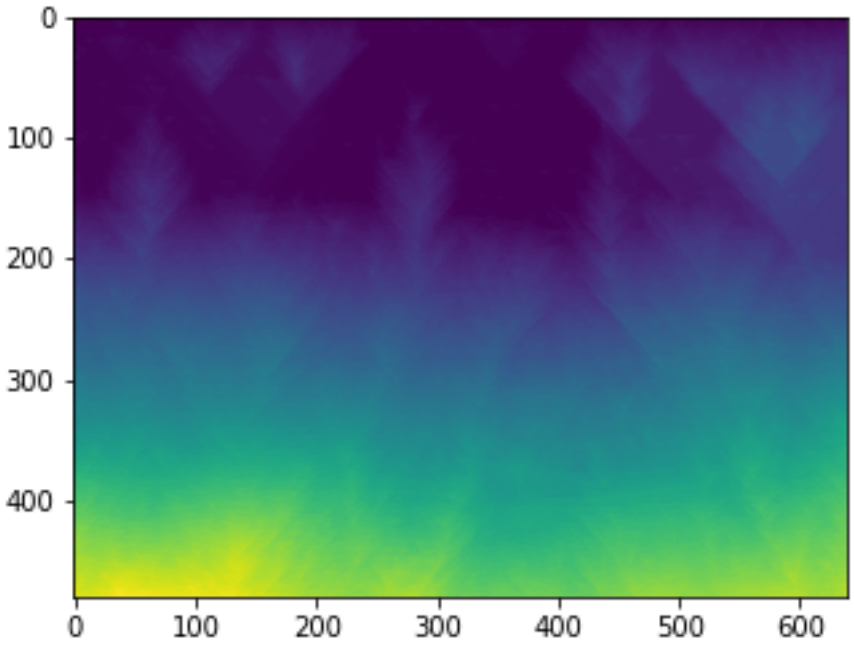

Figure 9: Vertical cumulative energy map

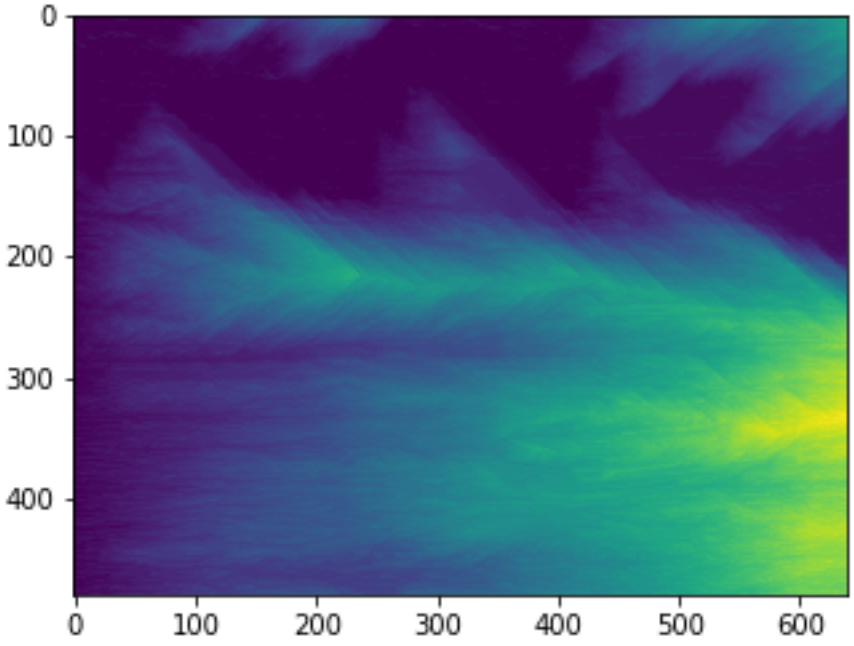

Figure 10: Horizontal cumulative energy map

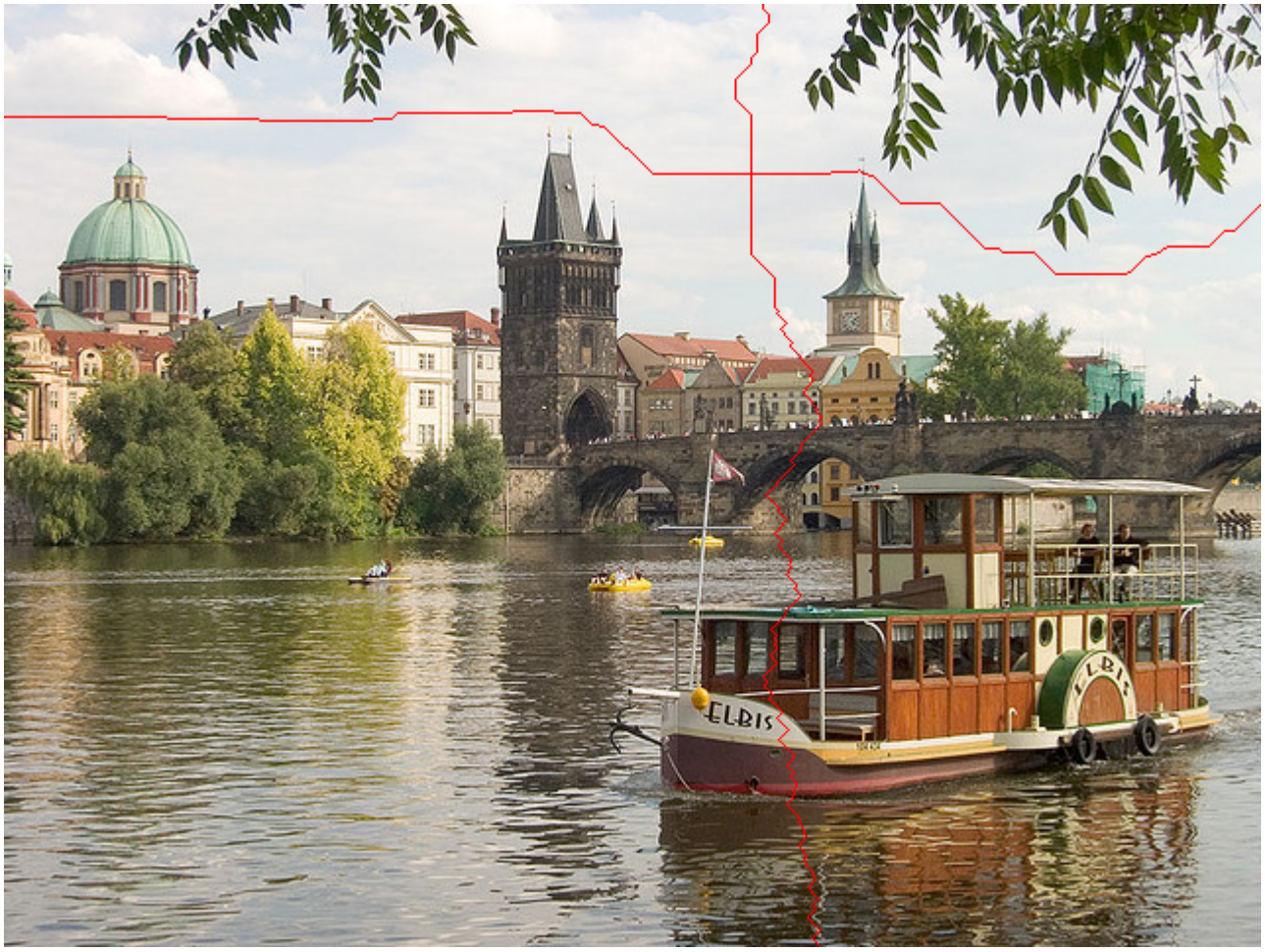

Figure 11: First vertical and horizontal seam

Since the LoG filter smoothens the image, we can see that both the vertical and horizontal seams are less fluctuating and have straight patches. Also, the vertical seam has shifted to the right, since the distribution of energies has been blurred in the bottom and shifted to the right.

6. All dimensions are in the format $H \times W$.
   Example 1

Figure 12: Original image 600×900

Figure 13: Resized image using seam carving 600×800

Figure 14: Resized image using Pillow resize 600×800

Input image : 600×900
Output image : 600×800
Operation: Reduced width by 100.
Explanation: The seam carving technique gives artifacts in this case. This is because the whole silhouette is black and low gradient. By algorithm the seam would pass through the girl and deshapes her image. On the contrary, simple resize technique performs well as it just squishes the girl's image and does not remove complete seams.

Example 2

Figure 15: Original image 177×284

Figure 16: Resized image using seam carving 177×177

Figure 17: Resized image using Pillow resize 177×177

Input image : 177×284
Output image : 177×177
Operation: Reduced width by 107.
Explanation: In this case also, seam carving gives artifacts. This is because the background is noisy and has a lot og edges while the squirrel image is smooth. Therefore, seams pass majorly through the squirrel and deshape it. The regular resize just thins the squirrel like everything else.

Example 3

Figure 18: Original image 415×738

Figure 19: Resized image using seam carving 415×473

Figure 20: Resized image using Pillow resize 415×473

Input image : 415×738
Output image : 415×473
Operation: Reduced width by 265.
Explanation: The seam carving gives a very good squarish image of this sunrise scene, keeping the sun intact. This is because there are gradients in the sun, while on the left side of the image there is not much variation. Regular resizing squishes the sun, as it would do in reducing width.

Example 4

Figure 21: Original image 683×1024

Figure 22: Resized image using seam carving 483×1024

Figure 23: Resized image using seam carving 483×1024

Input image : 683×1024
Output image : 483×1024
Operation: Reduced height by 200.
Explanation: In this image seam carving nicely removes the extra beach area on reducing height, starting seams from lower left corner where there is less variation. The regular resizing squishes the girl on reducing height.