Seam carving

1 Introduction

The original paper can be found here `http://www.faculty.idc.ac.il/arik/papers/imret.pdf`.

Seam carving is a content-aware approach to resize images. Content-awareness means that it reduces images, but retaining the interesting parts on them. Figure 1 shows an demo for seam carving.

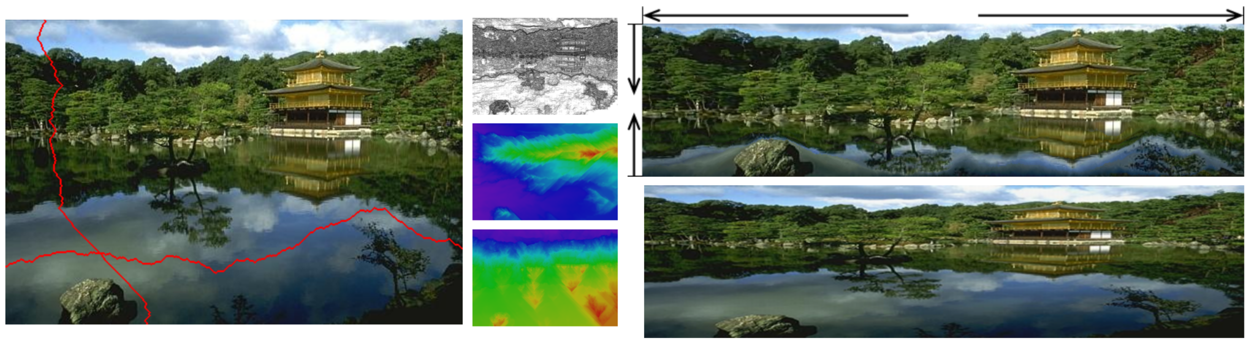

Figure 1: A demo for content-aware image resizing: the left image is the original image with a horizontal seam and a vertical seam. The top right is the image resized with seam-carving method. Bottom right shows the image resized with extension. Notice that important contents are preserved with seam carving.

Seam carving works in 3 steps.

- Compute the 'energy' of each pixel. The energy is defined to be features we would like to retain in images.
- Use dynamic programming to compute the optimal seam (the one with lowest energy).
- To reduce that image, simply remove the optimal seam.

If we would like to remove multiple seams of the image, simply repeat the procedure above several times. We are now going to details of the seam-carving algorithm.

1.1 Energy computation

It is natural that large uniform areas in an image contain less information. We can define the energy to be the difference of a certain pixel with surrounding pixels. Here we introduce a simple gradient-based method to compute the energy of pixels. Let $I(i, j)$ denote the color of pixel (i, j). The energy $E(i, j)$ is defined as:

$$E(i, j) = |I(i, j) - I(i, j + 1)| + |I(i, j) - I(i + 1, j)| + |I(i, j) - I(i + 1, j + 1)| \tag{1}$$

The sequential algorithm for energy computation is shown in Algorithm 1.

Algorithm 1 Sequential algorithm for energy computation.

Input: $R \times C$ image.
for $i = 1 \ldots R$ **do**
  for $j = 1 \ldots C$ **do**
    $E(i,j) = |I(i,j) - I(i,j+1)| + |I(i,j) - I(i+1,j)| + |I(i,j) - I(i+1,j+1)|$
Output: E - $R \times C$ energy map.

1.2 Finding a seam

In this subsection, we are going to find the optimal seam, which is the seam with the least energy. The seam must be connected. (i.e. Each pixel in the seam must be be touched by the pixel in the next row either via an edge or corner.)

We use dynamic programming here. Once we have found the energy of every pixel, we start at the bottom of the image and go up row by row, setting each element in the row to the energy of the corresponding pixel plus the minimum energy of the 3 possibly path pixels "below" (the pixel directly below and the lower left and right diagonal). Thus, we have to traverse the image from the bottom row to the first row and compute the cumulative minimum energy M for all possible connected seams for each pixel (i,j):

$$M(i,j) = E(i,j) + \min(M(i+1,j-1), M(i+1,j), M(i+1,j+1)) \quad (2)$$

Algorithm 2 shows the sequential algorithm for cumulative energy calculation.

Algorithm 2 Sequential algorithm for cumulative energy calculation.

Input: E - $R \times C$ energy map.
for $i = 1 \ldots R$ **do**
  $M(R,j) = E(R,j)$
for $i = 1 \ldots R$ **do**
  for $j = 1 \ldots C$ **do**
    $M(i,j) = E(i,j) + \min(M(i+1,j-1), M(i+1,j), M(i+1,j+1))$
Output: M - $R \times C$ cumulative energy map

1.3 Resizing the image

Once we have selected which pixels we want to remove, all that we have to do is go through and copy the remaining pixels on the right side of the seam from right to left and the image will be one pixel narrower. A sequential algorithm for seam removal is given in Algorithm 7.

2 Parallel algorithm for seam carving

This is the requirements for homework. Please parallelize the seam-carving algorithms above, and implement in MPI. Submit with pseudocode, raw code, and show the running time of the algorithm.

Algorithm 3 Sequential algorithm to remove a seam from the image.

Input: I - $R \times C$ original image.
Input: M - $R \times C$ cumulative energy map
min $= M(1,1)$
col $= 1$
for $j = 2 \ldots C$ **do**
    if $M(1,j) <$ min **then**
        min $= M(1,j)$
        col$= j$
for $i = 1 \ldots R$ **do**
    for $j = 1 \ldots C$ **do**
        $I(i,j) = I(i,j+1)$
    if $M(i+1, col-1) < M(i+1, col)$ **then**
        $col = col - 1$
    if $M(i+1, col+1) < M(i+1, col-1)$ **then**
        $col = col + 1$
Output: I - $R \times C$ resized image