SEAM CARVING FOR CONTENT-AWARE IMAGE RESIZING

Pabitra Bansal *Sumanyu Bhatia*

IIIT Delhi

ABSTRACT

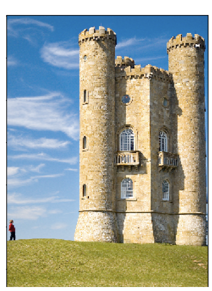
Advances in imaging technology have made the capture and display of digital images ubiquitous. A variety of displays are used to view them, and images often have to undergo changes in size and aspect ratio to adapt to different screens. Straightforward image resizing operators, such as scaling and cropping, often do not produce satisfactory results, since they are oblivious to image content. More effective resizing can only be achieved by considering the image content and not only geometric constraints. We propose to implement Shai Avidan and Ariel Shamir's [1] resizing of an image by carving-out different parts of the image. By successively removing seams, we can reduce the size of an image in both directions which, in effect,produces a content-aware resizing of images.

***Index Terms*—** pixels, energy function, seam, seam-carving, content-aware resizing

((a)) Original

((b)) Cropped

((c)) Scaled



((d)) Seam-Carved

Fig. 1: Tower Image resized using different techniques.

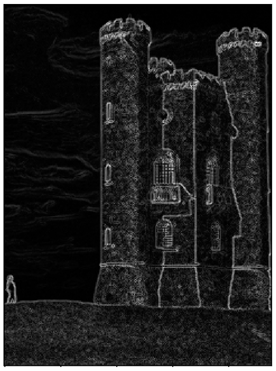
1. INTRODUCTION

With the recent advances in imaging technology, digital images have become an essential component of media distribution. Images are typically authored once but need to be adapted for consumption under varied conditions. For instance, a variety of displays can be used for image viewing, ranging from high-resolution computer monitors to TV screens and low-resolution mobile devices.

This diversity of image consumption conditions introduces a new problem: images must be resized optimally for different displays or use in various applications. The process, also known as image retargeting or image resizing, consists of modifying the image's aspect ratio and size to satisfy the new requirements best. Standard image scaling is not sufficient since it is oblivious to the image content and typically can be applied only uniformly. Cropping is limited since it can only remove pixels from the image periphery. More effective resizing can only be achieved by considering the image content and not only geometric constraints.

To overcome this limitation, a class of techniques attempt to resize the images in a content-aware fashion, i.e., taking the image content into consideration to preserve important regions and minimize distortions. This is a challenging problem, as it requires preserving the relevant information while maintaining an aesthetically pleasing image for the user.

We propose to implement a simple image operator, termed seam-carving by Shai Avidan and Ariel Shamir's [1], that can change the size of an image by gracefully carving-out pixels in different parts of the image. Seam carving uses an energy function defining the importance of pixels. A seam is a connected path of low energy pixels crossing the image from top to bottom, or from left to right. For image reduction, seam selection ensures that while preserving the image structure, we remove more of the low energy pixels and fewer of the high energy ones. By successively removing seams, we can accomplish the targeted resizing (Fig. 1).



((a)) Energy

((b)) Seam

Fig. 2: Tower Image resized using proposed methodology.

2. METHODOLOGY

The general idea is to decrease the image width (or height) one pixel at a time, by removing a seam of minimal importance. A seam is defined as an 8-connected path of pixels (from top to bottom, or from left to right of the image, depending on which dimension is being reduced) that contains only one pixel per row (or column). Intuitively, if the importance map is based on gradient energy, the first removed seam will be in a homogeneous area. The image is then readjusted by shifting pixels left or up to compensate for the removed seam, resulting in an image which is one pixel smaller, either on width or height. The image changes only at the seam region, while the other areas remain intact. The authors observe that using gradient energy as the importance map gives satisfactory results. The optimal seams are computed using dynamic programming, and an algorithm is implemented for resizing in both dimensions by choosing between optimal vertical or horizontal seams. The technique produces impressive results when there are enough low-importance seams to be removed, but creates distortions and artefacts when seams cut through essential areas.

2.1. Energy Function

The aim of content-aware image resizing is to remove unnoticeable pixels that blend with the surroundings. These pixels can be detected using the energy function used by Shai Avidan and Ariel Shamir's [1] :

$$e(\mathbf{I}) = |\frac{\partial \mathbf{I}}{\partial x}| + |\frac{\partial \mathbf{I}}{\partial y}| \tag{1}$$

The energy function used by them is the sum of magnitudes of the first derivatives of the image in horizontal and vertical direction. Using the energy found, an optimal seam is detected (Fig. 2(a)).

2.2. Optimal Seam Detection

Let $\mathbf{I}$ be an $n \times m$ image and we define a *vertical seam* to be:

$$\mathbf{s^x} = \{s_i^x\}_{i=1}^n = \{(x(i), i)\}_{i=1}^n, s.t.\forall i, |x(i) - x(i-1)| \leq 1 \tag{2}$$

where x is a mapping $x : [1, ..., n] \to [1, ..., m]$. Similarly, if y is a mapping $y : [1, ..., m] \to [1, ..., n]$, then a *horizontal seam* is defined as:

$$\mathbf{s^y} = \{s_j^y\}_{j=1}^m = \{(j, y(j))\}_{j=1}^m, s.t.\forall j, |y(j) - y(j-1)| \leq 1 \tag{3}$$

The pixels of the path of seam $\mathbf{s}$ (e.g. vertical seam $\{s_i\}$) will therefore be $\mathbf{I}_s = \mathbf{I}(s_i)_{i=1}^n = \mathbf{I}(x(i), i)_{i=1}^n$.

The optimal seam either vertical or horizontal is an 8-connected path of pixels in the image from top to bottom or from left to right, containing one, and only one, pixel in each row / column of the image having the lowest cumulative energy among all other possible seams (Fig. 2(b)). The optimal seam can be found using dynamic programming algorithm. The first step is to traverse the image from the second row to the last row and compute the cumulative minimum energy M for all possible connected seams for each entry *(i, j)*:

$$\begin{aligned} &M(i,j) = e(i,j) + \\ &min(M(i-1,j-1), M(i-1,j), M(i-1,j+1)) \end{aligned} \tag{4}$$

At the end of this process, the minimum value of the last row in M will indicate the end of the minimal connected vertical seam. Hence, in the second step we backtrack from this minimum entry on M to find the path of the optimal seam. The definition of M for horizontal seams is similar to the one defined for vertical seams.

2.3. Optimal Seam Removal Order

In this implementation image $\mathbf{I}$ of size $n \times m$ will be retargeted to size $n' \times m'$ such that $m' < m$ and $n' < n$. Let $r = m - m'$ and $c = n - n'$

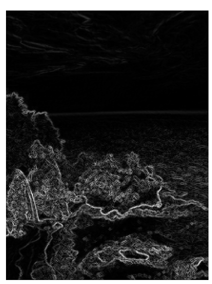
We find the optimal order using a transport map $\mathbf{T}$ that specifies, for each desired target image size $n' \times m'$, the cost of the optimal sequence of horizontal and vertical seam removal operations. That is, entry $T(r,c)$ holds the minimal cost needed to obtain an image of size $n-r \times m-c$. We compute **T** using dynamic programming. Starting at **T**(0,0) = 0 we fill each entry (r,c) choosing the best of two options - either removing a horizontal seam from an image of size $n-r \times m-c+1$ or removing a vertical seam from an image of size $n-r+1 \times m-c$:

$$\begin{aligned}&\mathbf{T}(r,c) = min(\mathbf{T}(r-1,c) + E(\mathbf{s^x}(\mathbf{I_{n\text{-}r\text{-}1\times m\text{-}c}})),\\ &\mathbf{T}(r,c-1) + E(\mathbf{s^y}(\mathbf{I_{n\text{-}r\times m\text{-}c\text{-}1}})))\end{aligned} \tag{5}$$

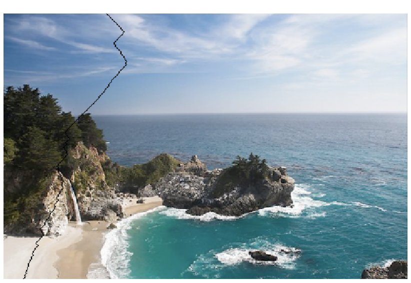
where $I_{n-r\times m-c}$ denotes an image of size $n-r\times m-c$, $E(\mathbf{s^x}(\mathbf{I}))$ and $E(\mathbf{s^y}(\mathbf{I}))$ are the cost of the respective seam removal operation.

We store a simple $n \times m$ 1-bit map which indicates which of the two options was chosen in each step of the dynamic programming algorithm. Choosing a left neighbor corresponds to a vertical seam removal while choosing the top neighbor corresponds to a horizontal seam removal. Given a target size $n' \times m'$ where $n' = n-r$ and $m' = m-c$, we backtrack from **T**(r, c) to **T**(0,0) and apply the corresponding removal operations.

((a)) Original



((b)) Energy



((c)) Seam

((d)) Seam-Carved

Fig. 3: Sea Image resized using proposed methodology.

3. LIMITATIONS

We can characterise two significant factors that limit the implemented seam carving approach. The first limitation is the amount of content in an image. If the image is too condensed, in the sense that it does not contain ‘less important’ areas, then any content-aware resizing strategy will not succeed as segregating and prioritising important regions from less important regions would become difficult which may lead to information loss. This may also result in creation of distortions and artefacts when seams are cut through essential areas. The second limitation is that other importance measures, such as saliency map, entropy, and histograms of oriented gradients, could be used for constructing the importance map which may perform better and produce better results.

4. CONCLUSIONS

We presented the implementation of an operator for content-aware resizing of images using seam carving. Seams are computed as the optimal, low energy paths on a single image and are removed from the image to generate the desired results (Fig.3). We were able to to produce content-aware resized images successfully, and look forward to make improvements and possible extensions to the work.

5. REFERENCES

[1] Shai Avidan and Ariel Shamir, “Seam carving for content-aware image resizing,” in *ACM SIGGRAPH 2007 Papers*, New York, NY, USA, 2007, SIGGRAPH ’07, p. 10–es, Association for Computing Machinery.