

Improved Image Resizing using Seam Carving and scaling

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Abstract. Seam Carving, the popular content-aware image resizing technique, removes or inserts seams of low energy iteratively without sufficiently considering their impact on the global visual quality of the image. However, sometimes seams pass through the regions of interest (ROIs) with low energy and distort the geometric shapes of the important objects. In this paper, we propose an improved resizing method based on improved seam carving method that can prevent the seams going through the ROIs and better preserve the content of the image. With considering frequency-tuned saliency map and the distance to the image center for each pixel in the importance map, it can protect the ROIs when the image is resized to the target size. Moreover, a developed two-dimension search scheme for seam carving and an switching scheme between seam carving and scaling are also proposed to efficiently protect the global visual of the image. Experiments demonstrate that resizing results of the proposed method are more pleasant than those of cropping, uniform scaling and other several methods.

Keywords: image resizing · saliency map · center distance map · two-dimension search

1 Introduction

With the development of digital media technology, it is popular to browse images on the various display devices of different resolutions and sizes such as mobile phones, cameras, televisions. How can we provide as good as possible visual

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Fig. 1 Comparison of 4 different retargeting methods for retargeting to 50% width of original image: (a) Original image, (b) Cropping, (c) SNS[4], (d) ISC [2], (e) Our algorithm.

quality on these different devices? Traditional image resizing methods such as cropping and homogeneously scaling all are not sufficient since they only consider the display space limitation but not the image content. To address this problem, many content-aware resizing methods have been proposed such as seam carving [1,2] and non-homogeneous warping [3].

Seam carving is an efficient content-aware resizing method. It can carve out unimportant information by iteratively removing or inserting the seam with minimum cost guided by an importance map and protecting the important information. But the seams may still go through the regions of interest (ROIs) when the energy of the regions is low. The main drawbacks of seam carving is that it only considers the pixel information to make the image resizing unperceivable causing discontinuity artifacts. From Fig.1 (d) we can see that the shape of the six persons are severely damaged by seam carving when resizing the original image to 50% width. To improve the efficiency of seam carving, many attempts were made. Rubinstein et al. [2] introduced an improved seam carving method (ISC) using forward energy criteria to find the pixels in a seam. Saliency map [5,6,8] and other importance measures are used to measure the importance of the pixels in the image. Wang et al. [4] proposed a scale-and-stretch method (SNS). An importance map generated by multiplying the intensity gradient of the image with Itti's saliency map [5] was used to guide the warping process. However, these methods do not significantly alleviate the drawbacks of gradient map. It is because the saliency maps used by [4,5,6] determine local grayscale contrast using gradients that result in higher importance values for textured areas and edges, but lower values for smooth salient regions. To address this problem, Achanta et al. [7] proposed a frequency-tuned salient detection approach which is proved to outperform other saliency detection methods. This saliency detector was used in [8] to compute the importance value of the pixel replacing the gradient map for seam carving. Dong et al. [9] developed a fast multi-operator image resizing method (FMO) combining seam carving with scaling and cropping. The speed of algorithm is fast in a sense while the resizing results may be unsatisfactory.

In this paper, we propose a novel improved technique for content-aware image resizing based on seam carving method. Gradient magnitude, saliency map and center distance map are combined together to formulate the operator importance map. Moreover, a developed two-dimension search scheme is introduced to seam

carving. When only one dimension of the image is to be changed, the proposed method can change the image in both two dimensions instead of operating in a single dimension. Considering that single-operator methods might not work well in many cases, the seam carving is combined with homogeneous scaling. In addition, a switching scheme between seam carving and scaling are also proposed to protect the global visual of the image efficiently.

2 Improved Seam Carving and Scaling

In this section, we introduce our improved image resizing method using improved seam carving and scaling in detail. First of all, our method relies on the Improved Seam Carving algorithm [2] with the following improvements:

2.1 Optimized Importance Map

2.1.1 Frequency-tuned Saliency Map

In this paper, we choose the frequency-tuned salient detector to compute the saliency map of an image. When computing the saliency map, this detector operates on the original image without any down-sampling so that the generated saliency map is a full resolution saliency map. Moreover, this saliency map has uniformly highlighted salient regions with well-defined boundaries, demonstrating both higher precision and better recall than several other state-of-the-art methods. Moreover, high saliency values are assigned to the entire region, not just at the edge of the region. Once we know which pixels are less salient concerning the original image, we can remove them without having to re-compute their importance after each seam removal.

However, the frequency-tuned salient detector can outperform other saliency detector but may fail to detect the salient regions correctly. From Fig.2 we can see that the frequency-tuned salient detector may not work well alone and so does the gradient map. The saliency map from [7,8] didn't detect the club and the legs of the man on the right while the gradient map can. On the other hand, the gradient map cannot prevent the seams going through the body of the man on the left while the saliency map can. Therefore, we combine the gradient map and the frequency-tuned saliency map together to compute the importance map of each pixel in the image. The combination can merge the advantages of the two maps together to protect the ROIs efficiently. From Fig. 3 (d) and (g) we can see that the resizing results using our importance map are more satisfactory when downsizing or enlarging the image comparing with those of ISC and the methods in [7,8] .



Fig. 2 Comparison of 3 different energy maps for resizing the original images *golfrmen*. (a) Original image, (b) Gradient map, (c) Energy map of [7,8], (d) Our energy map.



Fig. 3 Image resizing comparison for 80% and 120% of original width: (a) Original image, (b) and (e) are the outputs of ISC [2], (c) and (f) are the outputs of [7,8], (d) and (g) are our results.

2.1.2 Center Distance Map

From the research of Judd T. et al. [10] we can conclude that when humans watch pictures they naturally frame an object of interest near the center of the image. For this reason, we include a feature which indicates the distance to the center for each pixel. In our algorithm, we define the distance from the center to the corner is 1. Then the distance of each pixel to the center can be normalized by the distance from the pixel to the center to a value between 0 and 1.

2.1.3 The Optimized Importance Map

In sum, instead of employing gradient magnitude, we use an optimized importance map combining the gradient image with saliency map and center distance map. Let I be an image and (x, y) be the coordinates of an arbitrary pixel, the function to calculate the importance of each pixels in the original image is modified as:

$$e_{opt}(I(x, y)) = \sqrt{\left| \frac{\partial}{\partial x} I(x, y) \right|^2 + \left| \frac{\partial}{\partial y} I(x, y) \right|^2} + \alpha \cdot saliency(x, y) + \beta \cdot center(x, y) \quad (3.1)$$

where the α and β are the weights of the saliency map and center distance map in turn. To determine the value of the two weights, a couple of experiments are needed. In this paper, we set $\alpha = 0.000255$ and $\beta = -1$. Note that, because the saliency map and center distance information are more related to the original image rather than the processed image, the function $saliency(x, y)$ and $center(x, y)$ are calculated only once, rather than re-computing when each seam is carved. As shown in Fig.2(d), the importance map achieved by our optimized importance map uniformly highlights the salient regions in the image. As showed in Fig.3(a), our importance map prevents the seams from passing through the two men.

2.2 Two-dimension Seam Search

When only a one-dimensional change is needed to retrieve the resized image, many approaches such as cropping and homogeneously scaling only operate on the image in one dimension. In the same case, SC algorithm only looks for seams in one direction which causes distortion in global visual. Therefore, we reason in terms of aspect ratios and not any more in terms of dimensions. We compare the aspect ratio of the input image with the target image. When the desired target ratio is smaller than the input ratio, vertical seams may be deleted for the image and horizontal seams may be added:

$$\frac{targetW}{targetH} = \frac{inputW - s_v}{inputH + s_h} \quad (3.2)$$

where s_v is the number of vertical seams to be deleted and s_h is the number of horizontal seams to be added. In the opposite case, vertical seams may be added to the image and horizontal seams may be deleted. At every step, we choose a vertical seam and a horizontal seam with least energy cost and select the seam with less cost between them to operate. Iterate this process until the desired aspect ratio is achieved. Then, we homogeneously rescale the image to the desired dimensions.

In order to avoid the introduction of noticeable artifacts to the image, our algorithm may switch from seam carving to scaling before the target aspect ratio is achieved. Formally, when the energy $e(s_{vl})$ of the last vertical seam satisfy the inequality

$$e(s_{vl}) > \frac{3}{4} \frac{e_{sum}}{inputW} \quad (3.3)$$

where e_{sum} is energy summation of the original image or the energy $e(s_{hl})$ of the last horizontal seam satisfy the inequality

$$e(s_{hl}) > \frac{3}{4} \frac{e_{sum}}{inputH} \quad (3.4)$$

the algorithm will terminate the seam carving process and homogeneously scale the image to the desired dimension. The criterion is tested empirically, the coefficient 3/4 may be justified.

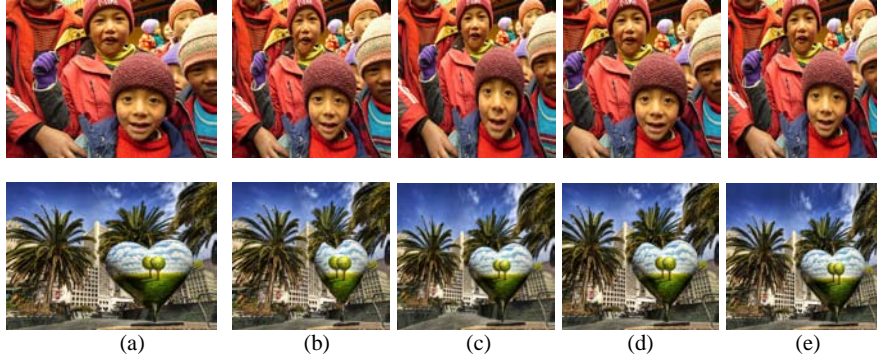


Fig. 4 Image resizing comparison between 4 different image resizing algorithms. The original image (a) is retargeted to 75% width using : (b) ISC [2],(c) SNS [4] ,(d) FMO [9] and (e) Our algorithm.

3 Results

The retargeted results obtained by our improved resizing method are compared against those of ISC [2], as well as those of [4,7,8,9]. Figures in this paper show that outputs of our algorithm are more pleasant in visual.

Fig.1 demonstrates that our algorithm keeps the feature of six persons better. When resizing the original image to 50% width, cropping lost half content of the image. The ISC method deleted hundreds of vertical seams to reduce the width of the image to half of the original width which leads to the terrible deformation of the persons, while our optimization scheme choose to delete less vertical seams and insert horizontal seams to achieve the target aspect ratio. Based on the results in Fig. 4, comparing the results of image downsizing to 75 % width of the original image, it is clear that our method preserves the global structure better than other three approaches including cropping, SNS [4] and FMO method[9].

4 Conclusions

We present an improved resizing algorithm using seam carving combining with scaling method for content-aware image resizing. The proposed method uses an optimized importance map including gradient map, Frequency-tuned saliency detector and center distance map to guide the seam carving process. This new importance map can efficiently detect the important regions in the image. The two-dimension searching operation prevent the resizing process from operating in a single direction of the image causing obvious visual deformation. And the integra-

tion of seam carving and homogeneous scaling with a switching scheme also effects the resizing results. This novel resizing scheme preserves the ROIs of the images and leads to more pleasant results when compared to several different image resizing algorithms.

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