Seam Carving Algorithm Based on Saliency

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Abstract. This paper proposes a seam carving algorithm based on saliency. This algorithm makes saliency detection to the source image. Images are classified according to the gray-scale of saliency detection. Adding different energy protection methods, it can protect the foreground area of a subject and detailed areas of the edge. Then the cumulative energy map is calculated. According to the principle of deleting the minimum energy pixel, single pixel-wide carves chosen to be deleted or copied. The experimental result shows that the algorithm avoids image restoration caused by extracting too many pixels in saliency area and non equal-ratio scaling. It reduces the deformed structures caused by displacement of edge pixel and also improves the integrity of algorithm.

Keywords: Image resizing · Seam carving · Saliency · Classification · Pixel energy

1 Introduction

1.1 Background

Numerous digital images are frequently used in daily life with the rapid development of multimedia technology and display devices. Different display devices have distinct sizes and aspect ratios. The images will be resized and image resizing should keep the most important content as far as possible. Ordinary image resizing methods are nearest

J.-S. Pan et al. (eds.), *Advances in Smart Vehicular Technology, Transportation, Communication and Applications*, Smart Innovation, Systems and Technologies 86,
https://doi.org/10.1007/978-3-319-70730-3_34

neighbor interpolation and linear interpolation [1]. They are more suitable for the images which are same aspect ratios. Hence seam carving for content-aware image resizing is presented by Avidan et al.

1.2 Related Work

A seam is an optimal path of pixels on a single image from left to right, or top to bottom. The optimality of the seam is defined by energy function of the image. We change the aspect ratio of the image by carving out or inserting seams repeatedly. Seam caving supports both reduction and expansion for image [2]. After that, more research works about image resizing are conducted. Optimized image resizing using seam carving and scaling is presented by Dong et al. The method operates by joint use of seam carving and image scaling. It preserves both the important regions and the global visual effect [3]. Huang et al. present a real-time resizing method for content-aware image [4]. It reduces the time of looking for the seam. Liu et al. using saliency-based continuous seam carving to efficiently display images on small screens [5]. Frankovich and Wong via integration of energy gradient function to retain high image detail concentration [6]. Noh and Han proposes a new energy function for seam carving based on forward gradient differences to preserve regular structures in images [7]. Cao et al. improve the image quality and avoid removing the seams adjacently via strip constraints [8]. Wang and Akleman simply uses the original energy function of seam carving. They resize image with cuts in continuous domain [9]. Shen et al. presents a method which achieves a better seam carving performance by cutting the near objects less seams while removing distant objects more seams [10]. Yue et al. proposes improved seam carving for stereo image resizing. The method protects the important content, reduces the visual distortion and guaranteed the geometric consistency of resized stereo images [11]. Dekel et al. proposes a novel method for retargeting a pair of stereo images [12]. Wang and Yuan presents a high quality image resizing. It retains the details when stretching an image and a further extension on video enlargement is also presented as an example [13]. Seam carving is also used for media retargeting by Shamir and Avidan [14]. Zhang et al. proposes a method allows distortion to be diffused better in all directions, and important image edges are well-preserved [15]. Geometry seam carving is presented by Dekkers et al. The method enables the deformation of a given mesh in a way that causes stronger distortion in homogeneous mesh regions while salient features are preserved much better [16].

2 Overview

Biologic visual system research indicates that humans have a visual attention mechanism and it is selective. It is caused by the saliency of vision which is great different from the background and then selected according to the subjective consciousness of the observer [17].

Experimental results show that seam carving is effective to the images without visual focus. It uses the same energy map for all images. Hence the resizing result loses much important information about the visual focus if the image energy is concentrated and the seam goes through the salient area. It also loses much important information about edge if the image energy is scattered and it includes much slender vertical or horizontal region [18].

This paper proposes a seam carving algorithm based on saliency and classification. Images can be classified into two types according to visual sense. One is that having obvious visual focus and the image energy is concentrated, the other is that having no obvious visual focus and the image energy is scattered, using different methods to protect the image energy. When the image energy is concentrated, the salient area should be protected. When the image has no visual focus or there is something long or narrow, the information about edge should be protected. Hence visual focus and details can be obtained more. Then, seam carving is applied to resized the image.

3 Seam Carving Algorithm Based on Saliency

3.1 Saliency Detection

Image saliency refers to the difference between the salient object and the background in the image. It describes the ability of object to be prominent from the background. The purpose of saliency detection is to generate a saliency map as gray scale map. It shows the importance level by different gray scale. The gray scale is higher, the saliency is more obvious. And it has more possibility to belong to the saliency area [19].

By analyzing the log-spectrum of an input image, Hou and Zhang extracts the spectral residual of an image in spectral domain, and proposes a fast method to construct the corresponding saliency map in spatial domain [20]. Achanta et al. presents a method for salient region detection that outputs full resolution saliency maps with well-defined boundaries of salient objects [21]. Zhang et al. presents a bayesian framework for saliency using natural statistics [22]. Cheng et al. proposes regional contrast based saliency extraction algorithm, which simultaneously evaluates global contrast differences and spatial coherence. The proposed algorithm is simple, efficient, and yields full resolution saliency maps [23].

In this paper, the salient region is checked by the algorithm based on global contrast. Figure 1(b) is the saliency map of Fig. 1(a).

(a) Original Image (b) Saliency Map (c) Blocks

Fig. 1. Examples of saliency map and block partition

3.2 Image Classification

Images are classified into two types according to the saliency maps. Each of them uses different method to protect the image energy.

Global Objective Function. Suppose that the size of original image is n × m. Either m or n is divided by 10, the remainder is 0. The image S is divided into i × j blocks. The width of each block is parameter a. The blocks compose a set Z. As shown in the Fig. 1(c). The calculation procedure of target parameter λ will be shown.

1. Calculate the percentage of energy for each block.

$$EN(i,j) = Z(i,j) / \sum_{i=1}^{n} \sum_{j=1}^{m} S(n,m) \tag{1}$$

   Z (i, j) is the sum of energy of all the pixel in each block.
2. Calculate the average energy of each block.

$$AE = \sum_{i=1}^{n} \sum_{j=1}^{m} S(n,m) / (i \times j) \tag{2}$$

3. Calculate P. Iterate through EN, get the number of the block which energy is higher than verified ratio k × AE.
4. Calculate λ, which is the percentage of P.

$$\lambda = P / (i \times j) \tag{3}$$

5. The image is classified according to the weight W. W is got through a large number of experiments with different parameters. Analyze the results of λ and the subjective consciousness of vision.

Training Data. Some experimental data are listed below. NO. 1 and NO. 2 are the images without visual focus, NO. 3 and NO. 4 are the images with visual focus (Tables 1, 2 and 3).

Table 1. The result of k and λ when a = 10

λ \ k	1	1.5	1.6	1.7	1.8	1.9	2
1	0.383	0.229	0.220	0.162	0.025	0.018	0.009
2	0.423	0.114	0.097	0.073	0.066	0.064	0.061
3	0.228	0.183	0.178	0.173	0.169	0.167	0.163
4	0.275	0.215	0.211	0.207	0.196	0.186	0.181

Table 2. The result of k and λ when a = 15

λ \ k	1	1.5	1.6	1.7	1.8	1.9	2
1	0.217	0.190	0.185	0.179	0.176	0.173	0.173
2	0.231	0.201	0.201	0.190	0.190	0.183	0.176
3	0.442	0.238	0.210	0.183	0.165	0.153	0.139
4	0.449	0.217	0.186	0.163	0.123	0.080	0.069

Table 3. The result of k and λ when a = 20

λ \ k	1	1.5	1.6	1.7	1.8	1.9	2
1	0.224	0.188	0.182	0.182	0.172	0.167	0.167
2	0.250	0.188	0.188	0.181	0.181	0.169	0.169
3	0.436	0.158	0.127	0.115	0.103	0.079	0.073
4	0.439	0.139	0.114	0.075	0.068	0.057	0.036

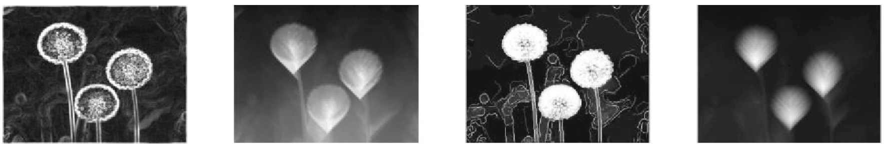
Compare the experimental data and the results of the subjective consciousness of vision, the accuracy of image classification is highest when a = 10, k = 1.9 and w = 1.5 are set.

3.3 Energy Protection

Protect the area which has great influence on human vision by increasing the energy of it in gradient map.

When λ > w, there is visual focus in the image, people pay more attention to the focus. The gradient map was got from the operator of Canny. Superposed the gradient map and saliency map, an updated gradient map is formed. It can protect the visual focus region, but it will pay a price of losing some pixel which is less concerned. After that, energy map with the updated gradient map is got.

Figure 2 shows the comparison before and after the saliency map is superposed. Figure 2(a) and (b) are the gradient maps and energy maps of seam carving. Figure 2(c) and (d) are the updated gradient maps and energy maps of new algorithm.



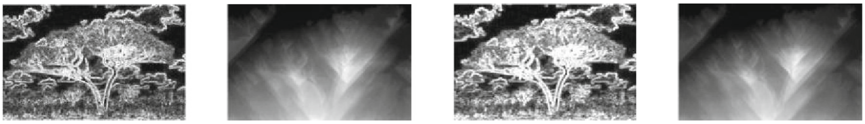
(a) (b) (c) (d)

Fig. 2. The comparison chart before and after protection

When λ ≤ w, seam carving is effective. But it is easy to loss details if there is high frequency and vertical region. We get the gradient map by the operator of Sobel. Get an updated gradient map by protecting the details of edge through dilation. After that, an energy map with the updated gradient map is got.

Linear structuring element is selected in this paper and the parameter is 3.

Figure 3 shows the comparison before and after dilation. Figure 3(a) and (b) are the gradient maps and energy maps of seam carving, Fig. 3(c) and (d) are the updated gradient maps and energy maps of new algorithm.



(a) (b) (c) (d)

Fig. 3. The comparison chart before and after dilation

3.4 Image Resizing

Let I (original image) be an n × m image and define a vertical seam to be:

$$s^x = \{s_j^x\}_{j=1}^n = \{(x(i), i)\}_{j=1}^n, s.t.\forall i, |x(i) - x(i-1)| \leq 1 \tag{4}$$

The horizontal seam to be:

$$s^y = \{s_j^y\}_{j=1}^m = \{(j, y(j))\}_{j=1}^m, s.t.\forall j, |y(j) - y(j-1)| \leq 1 \tag{5}$$

In order to resize the original image to n × k, it will delete m-k seams or insert k-m seams.

At first, get the saliency map S of original image then calculate the target parameter λ according to S. The gradient map is got through canny operator or Sobel operator according to λ and w. When the updated gradient map is formed, superposed saliency map or dilation according to λ and w. Finally, obtain energy map, removes low energy pixels and keeps the high energy ones by seam carving for content-aware image resizing.

4 Experiment

After comparing the result with the seam carving algorithm, the newly applied algorithm can be further validated. Parts of the result are shown as following.

4.1 Comparison of the Images with Visual Focus and the Energy Is Concentrated

Figure 4 is the original and resized images when λ > 0.15. Figure 4(a) is original images; Fig. 4(b) and (d) are the resized images by single seam carving; Fig. 4(c) and (e) are the resized images by the updated algorithm.

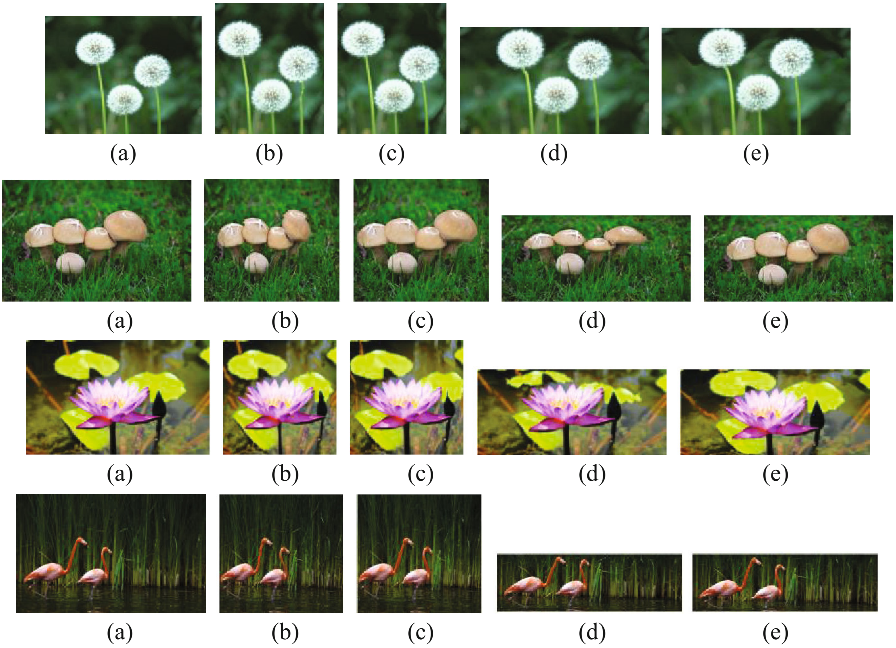


Fig. 4. Resized images by single seam carving and the updated algorithm

Mushrooms and lotus leaves are distorted and there are zigzag cracks on the stalks of dandelions and the necks of flamingos in the resized image by single seam carving because of the lost details. The updated algorithm protects the details and avoids the distortion effectively. Figure 5(a) is the details by single seam carving; Fig. 5(b) is the resized image by the updated algorithm.

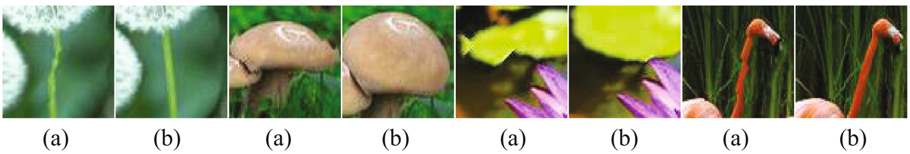


Fig. 5. Magnified image of details

4.2 Comparison of the Images Which the Energy Is Scattered

Figure 6 is the original and resized images when $\lambda \leq 0.15$. Figure 6(a) is original images; Fig. 6(b) and (d) are the resized images by single seam carving; Fig. 6(c) and (e) are the resized images by the updated algorithm.

The results of the updated algorithm retain more details about foreground and edge like the trunk and the bridge. It also proves that the updated algorithm retains more

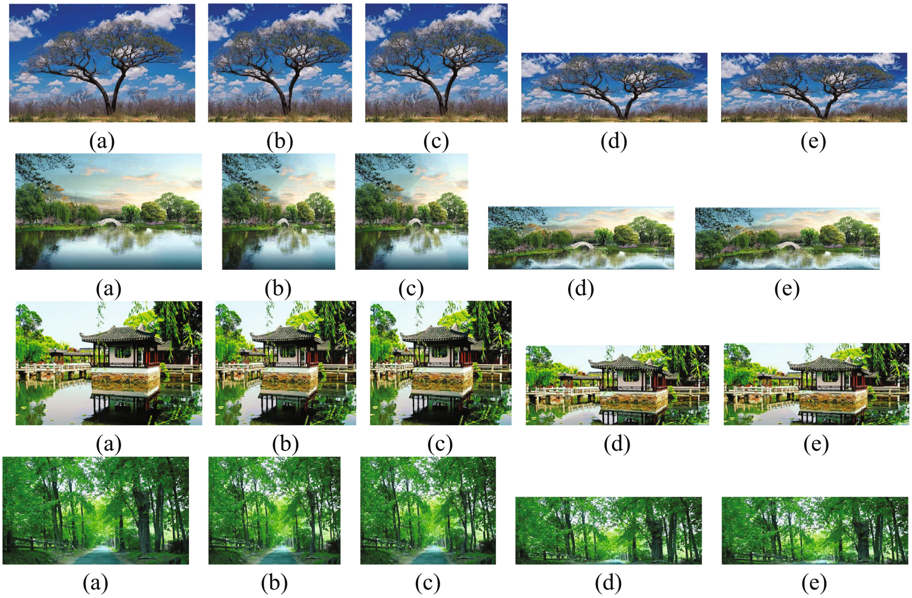


Fig. 6. Resized image by single seam carving and the updated algorithm

details and avoids the distortion effectively. Figure 7(a) is the details by single seam carving; Fig. 7(b) is the resized image by the updated algorithm.

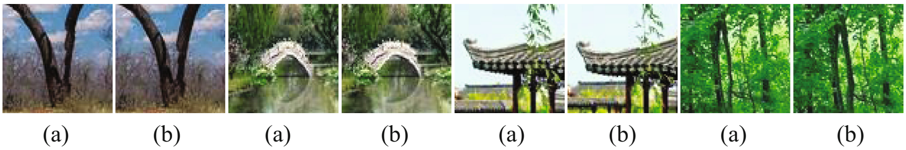


Fig. 7. Magnified image of details

4.3 Experimental Data

Different size of images are chosen randomly. Resize the images by using single seam carving and the updated algorithm. Compare the results to the subjective judgment of human mind. 7% of them do not meet the demand of human visual perception, and the effect of 16% improved ones is not obvious, 77% is effective.

4.4 Comparison of Running Time

Running time of image resizing by single seam carving and the updated algorithm is compared. The result shows that the running time of the updated algorithm can satisfy human's higher visual requirement. However, the average running time is 17.97% more than the original one. Figure 8 is the chart of the percentage of running time difference.

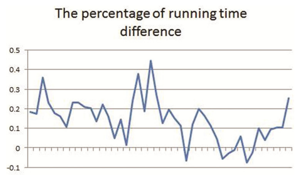
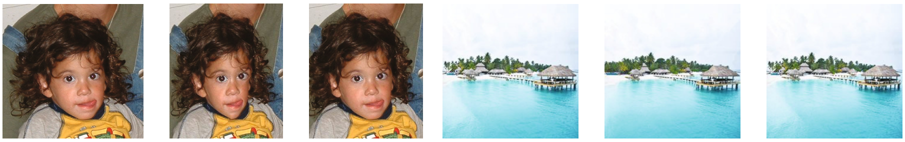


Fig. 8. The percentage of running time difference

4.5 Limitations

Figure 9 shows the images which improvement effect is not obvious.



(a1) (b1) (c1) (a2) (b2) (c2)

Fig. 9. The images which improvement effect is not obvious

The limitations of the new algorithm are caused by two reasons: (1) Classification error. Figure 9(a1) is an image with visual focus, but it is distinguished that the energy is scattered because the focus is too big. Figure 9(b1) is the result. If the classification is correct, Fig. 9(c1) will be got. (2) When the energy of the image concentrate in a narrow region, dilation is more suitable for the image. But if $\lambda > 0.15$ in the experiment, it superposed the gradient map and saliency map. Figure 9(b2) is the result. It loses many details about edge. If dilation is used to protect the image energy, more details of edge will be retained and get Fig. 9(c2).

5 Conclusions and Future Work

This paper presets a seam carving algorithm based on saliency. This algorithm makes saliency detection to the source image. Images are classified according to the gray-scale of saliency detection for the first time. Adding different energy protection methods, it can protect the foreground area of a subject and detailed areas of the edge. The results shows that the updated algorithm can avoid distortion and retain more details. But the algorithm still has limitations and the running time is longer than single seam carving.

In the future, the method of image classification will be improved in order to improve the classification accuracy, search for better energy protection methods and reduce the complexity of the algorithm to reduce the running time.

Acknowledgment. The paper is supported by the foundation of Technologies Research of the Education Department of Fujian Province No. JA15535. The work of Fuquan Zhang was supported by the Scientific Research Foundation of Minjiang University (No. MYK17021). Thanks to Pro. Shiming Hu and Dr. Mingming Chen.

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