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Improved seam carving combining with 3D saliency for image retargeting

Yanxiang Chen*, Yifei Pan, Minglong Song, Meng Wang

School of Computer & Information, Hefei University of Technology, Hefei 230009, China

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ABSTRACT

Seam carving is a content-aware image retargeting algorithm that removes the pixels with less energy values during resizing process to preserve important parts. Though many researchers have improved this algorithm by different ways, it is still a difficult problem to determine the energy function for removing task. Most existing approaches only use 2D features, and no single energy function performs well across all kinds of images so far. In this paper, we introduce a novel method that combine conventional $L-1$ norm of gradient with depth-aware saliency (3D saliency) to obtain energy map. Due to the different characteristics of these two operators in image analysis, our energy function contains both local and global information, which is proven to be effective in seam carving. The experimental results demonstrate the advantage of our method compared to conventional seam carving techniques.

1. Introduction

As mobile devices such as cell phones, tablet PCs are becoming increasingly popular, people would like to share their moments with their friends or relatives. They will use mobile terminal to upload photos to social networks, and their friends also get these data through the mobile portable displays. How to display the image on different terminal screens without distortion has become increasingly urgent need, but there are still many challenges to be accomplished.

Lots of papers have devoted to solving this problem, and some classical methods are available, such as scaling, cropping, etc. Scaling is the most direct and least desirable method. It achieves different resolutions display through stretching and interpolation, which will lead to a serious distortion of image content and structure.

Cropping is another traditional method, in which the most important step is to establish saliency map [1,2] and find the ROI (Region of Interest) of images, and then directly cropping the corresponding portion of the ROI according to different display screens [3,4]. But this will result in the loss of a large number of image backgrounds, and the results are not satisfactory when there are many ROIs in the source image. An approach [5] has been proposed to solve the problem, especially when the set of ROIs cannot contain all the important regions. They remove the important regions from the image and the resulting holes are filled using inpainting. Then, the background is resized to fit the display specification, and the important regions are pasted back onto the updated background. This approach also results in the distortion of the background. In short, cropping images to fit the different display mediums inevitably discards information, including backgrounds, structure, etc.

Recently, content-aware methods such as non-uniform warping [6,7] and seam carving [8] are proposed to supplement these traditional methods. Content-aware image retargeting achieves to change image into arbitrary aspect ratios while preserving visually prominent features, such as image structure. It relies on an importance map to retain the important parts of the picture at the expense of these less-important parts. Generally, the importance map (or energy function) can be generated by image gradients, saliency or entropy.

Warping is a special method of content ware methods. It puts a grid mesh onto the original image and then computes a new geometry for this mesh, so that boundaries adapt to the new size of the desired image and the quad faces covering important image regions remain unchanged at the expense of larger distortion to the other quads. Unfortunately, this method will fail if the size of prominent objects is larger than the desired image size.

Seam carving is a simple image operator which supports content-aware image resizing for both reduction and expansion. It delimits the importance of pixels using an energy function. A seam is an optimal 8-connected path of pixels on a single image from top to bottom, or left to right. By repeatedly carving out or inserting seams in one direction, the aspect ratio of an image can

* Corresponding author. Tel.: +86 13966668160.
E-mail address: chenyx@hfut.edu.cn (Y. Chen).

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be changed. By applying these operators in both directions, the image can be retargeted to different sizes. Compared to the conventional methods, seam carving has great advantages. For image reduction, seam selection ensures to preserve the image structure by removing more low-energy pixels and fewer high-energy ones. For image enlarging, the order of seam insertion ensures a balance between the inserted pixels and the original image content. However, the grayscale intensity gradient maps generating the energy function have higher value only at edges of objects and are sensitive to noise, which may result in deforming the salient objects in the image.

From the above description, we know that different methods have their advantages, and the disadvantages are also obvious. Michael Rubinstein [9] defines the resizing space as a conceptual multi-dimensional space, combining several retargeting operators, including scaling, cropping, warping, seam carving, etc. They point that using several operators can potentially get better results for retargeting than using a single operator, and give an algorithm for finding an optimal multi-operator retargeting sequence under some assumptions.

Meanwhile, Achanta and Susstrunk [10] revise the definition of the energy function, and get an efficient, noise robust retargeting method based on seam carving by using saliency maps to assign higher importance to visually prominent whole regions (not just edges). There are many references contributed to obtaining saliency maps [11,12]. Itti model [1] is the most classical method that generates the saliency map by choosing orientation, intensity and color information as features, and combining these features' maps into a global saliency map. Besides, there are some other models proposed in recent years, including GAFFE [13] (Gaze-Attentive Fixation Finding Engine) model, the saliency model based on frequency-tuned detection [14,15] and the model based on inverse Fourier transform and phase spectrum [16]. Furthermore, some high-level features such as face-detection [14,17], are also taken into account to generate the more accurate saliency map.

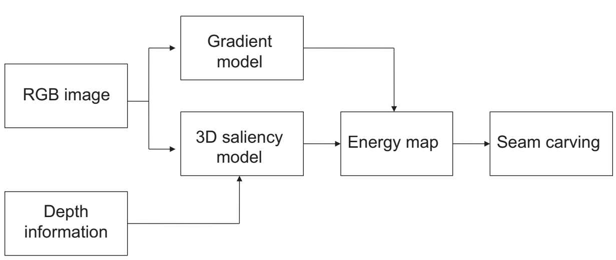

Fig. 1. Flow chart of our method. We obtain 3D saliency map from 2D features in RGB image and the depth information captured by 3D camera. Then we combine 3D saliency with gradient information coming from RGB image to guide seam carving algorithm.

With the development of technology, 3D information is accessible, i.e., kinect developed by Microsoft [28]. 3D information can help computer to understand the structure of image, which may be fail only by 2D features. Thus depth information [18–20] in 3D images is also taken into consideration in image retargeting recently. Shen [21] has applied the depth information into seam carving, and developed an efficient JND-based significant computation approach using the multi-scale graph cut based energy optimization. Lin [22] also notices the depth effect in seam carving, and obtains depth-based importance map automatically.

In this paper, we introduce saliency map into seam carving method. In other word, we use gradient information and saliency map together to determine the importance of each pixel. Moreover, we also use the depth information to update conventional 2D saliency into 3D saliency. Experimental results show that the proposed method does generate more desirable resized images than conventional seam carving algorithm.

2. Image retargeting using seam carving combining with 3D saliency

Seam carving is an image operator that supports content-aware image retargeting. The target of seam carving is to protect important information during resizing to make the processing unperceivable. The conventional seam carving method generally produce satisfactory results for only a class of images and it always suffering from distortion since the content of image has a variety of structure, and no single energy function performs well across all images. In this paper, we introduce a method which combine $L-1$ norm of gradient and 3D saliency to represent energy map. Due to the different characteristics of $L-1$ norm of gradient and 3D saliency in describing image, performance of seam carving using our method is more satisfactory than the state of the art approaches. Fig. 1 shows the flow chart of our method and more details are discussed in the following sections.

2.1. Seam carving with L−1 norm of gradient

Seam carving was first described in [8], as a content-aware algorithm for resizing image. It is an effective resizing approach by removing seams with less energy from image. Each seam is an 8-connected path of pixels on image from one side to the opposite. Suppose an $n \times m$ image $\boldsymbol{I}$ and a vertical seam can be defined as:

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

where x is a mapping $x: [1, \dots, n] \rightarrow [1, \dots, m]$, ensure each seam a 8-connected path of pixels, containing one, and only one pixel in each row. Similarly, if y is a mapping: $y: [1, \dots, m] \rightarrow [1, \dots, n]$, a

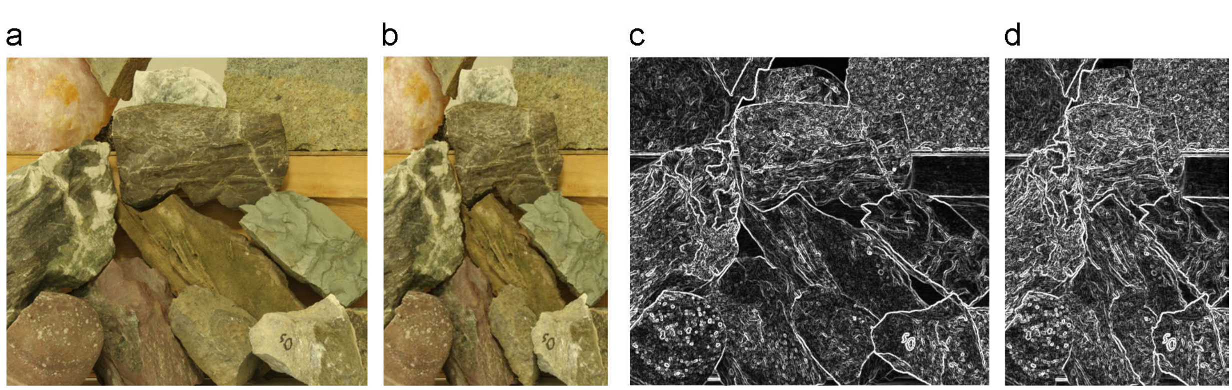

Fig. 2. $L-1$ norm of gradient performs well in seam carving. Due to the characteristic of gradient information, we can see that from (c) and (d), frame of image is preserved completely and the blanks between edges are removed in retargeting process.