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Learning to resize image

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ABSTRACT

Content-aware image resizing has been a promising theme in the communities of image processing and computer vision. To the best of our knowledge, most existing methods for image resizing are unsupervised. These unsupervised methods may either fail to protect the interesting regions or cause distortion of the image structure. This paper presents a novel learning based method for seam carving by incorporating the learned boundary of the important content. Specifically, a novel boundary model of the *region of interest* (ROI) is learned on a set of training images at first. Then the boundary of an input image is utilized as a key prior in performing seam carving to obtain the target image. The proposed method for image resizing can generate much less seams cutting through the ROI compared with previous efforts toward the same goal. Thus, the desirable regions can be preserved in the target image and the structural consistency of the input image is naturally maintained. Experiments on two publicly available data sets demonstrate the effectiveness of the proposed method.

1. Introduction

With the rapid development of multimedia technology, numerous digital images are frequently used in people's daily life. To better share and exchange information, a wide variety of display devices are developed, such as computer monitors, TV screens, and mobile phones. However, different display devices have distinct sizes and aspect ratios. If the examined image is not the same with the display device in aspect ratio, then it has to be distorted to adapt to the device. This will unsatisfactorily lead to a poor visual experience. To avoid this undesirable effect, the images are expected to be automatically adapted for different display devices, which is referred to as *image resizing*. Image resizing [1] has been a promising theme in computer vision. The main goal of image resizing is to adaptively resize the images for optimal display under different conditions [2,3]. Fig. 1 shows some examples of image resizing.

Studies in psychology and cognition have found that human visual system can quickly focus on one or several interesting contents of an image at first glance. These contents are generally called *region of interest* (ROI) [4–7]. The ROI and the background of an image constitute the image structure. Effective image resizing techniques should preserve the ROI as much as possible and reduce the distortion of the image structure to maintain the harmony of the image, which is called *content-aware* [8]. In order to protect the ROI in image resizing, some guiding information, which is able to distinguish the ROI from background, should be extracted. Traditional methods utilize image clues such as color and brightness contrast to infer the ROI. However, these low-level information are far less expressive for the ROI. The resulting resized images are usually distorted. In order to improve this situation, a novel method based on machine learning is developed by incorporating a high-level boundary feature of the ROI as prior information. Fig. 1 shows two typical examples of the proposed method compared with traditional nonuniform scaling. Naturally, in the two images, the boy and the flower usually attract people's eyes at first glance. The proposed method can well protect these two objects, while the traditional nonuniform scaling causes distortion of them.

The main contribution of this paper is a novel framework for image resizing by adopting supervised learning of high-level image information. We believe that the incorporation of learned high-level clue is the key point to greatly improve the performance of seam carving. For this purpose, boundary is first taken as an example to illustrate the effectiveness of the proposed method.

The rest of the paper is organized as follows. Section 2 briefly reviews the related work. Section 3 presents the proposed resizing method incorporated with detected boundary information. To verify the effectiveness and robustness of the proposed method, the experimental results are shown in Section 4. Discussion is presented in Section 5 and conclusion is made in Section 6.

2. Related work

Traditional straightforward methods for image resizing, such as *scaling* and *cropping*, cannot generate satisfactory results. This is

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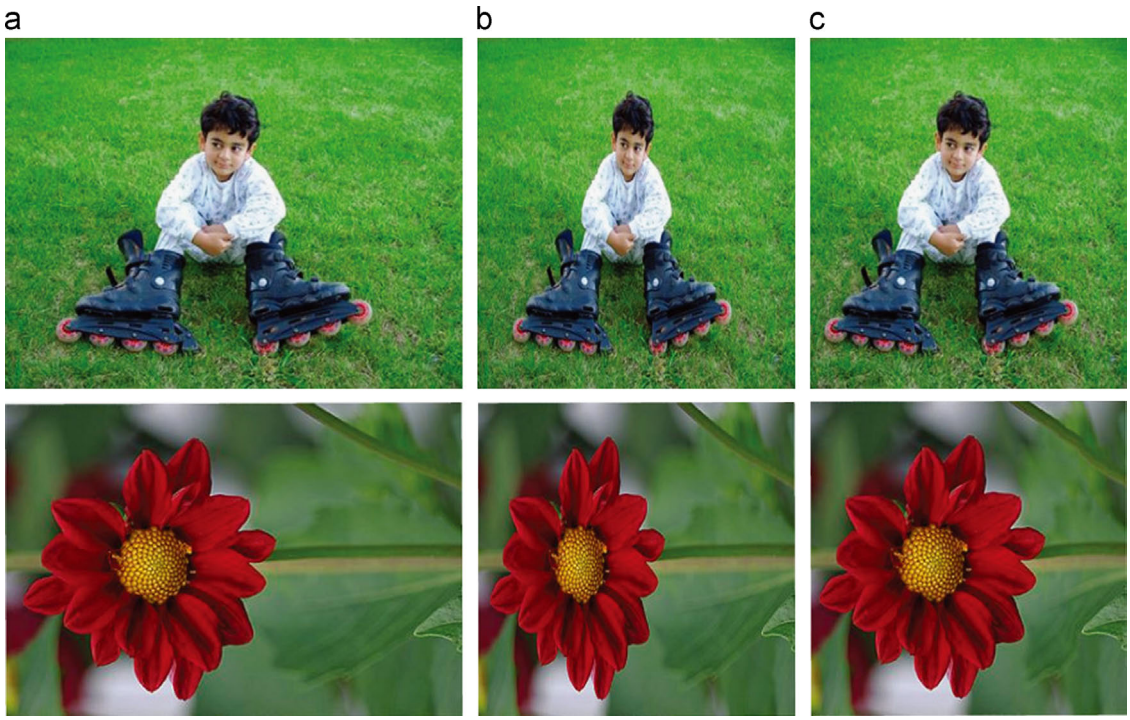

Fig. 1. Examples for image resizing. (a) Original input images. Results of (b) traditional nonuniform scaling and (c) the proposed method. The proposed method maintains the ROI while the traditional nonuniform scaling distorts it.

because they only consider the constraint of display space, but ignore the image content. To be specific, scaling may lead to distortions and produce artifacts when the aspect ratio of the image changes, while cropping may remove interesting areas in the result owing to an unjustified criterion. To overcome these limitations, a number of content-aware image resizing methods have been developed to preserve the ROI and avoid distortion when modifying the image's size and aspect ratio. According to the mechanism and the used methodology, these methods can be roughly classified into four categories. They are based on *content-aware cropping*, *segmentation*, *warping*, and *seam carving*.

Content-aware cropping methods [9–12] are important improvements of the original cropping method. There are two main steps for this kind of methods, detecting the salient portions and cropping them by fixed windows. However, these methods can only be applied to specific images (containing human faces or other priorly defined objects) instead of natural images, which limits their applicability. *Segmentation based methods* [9,13–15] present a way to address the image resizing problem with segmentation techniques. The ROI is segmented from an image at first. Then the background is resized to the desired size. In the end, the segmented ROI is inpainted to the renewal background. Nevertheless, these methods rely on accurate segmentation of ROI. The inaccurate segmentation may lead to distortions of ROI. *Warping-based methods* [16–19] seek to find a warping function mapping the original image grid to the target image. The local distortions of important areas are constrained to be as small as possible, while unimportant regions are allowed to distort more. However, this type of methods strongly depend on the definition of the warping function, as well as the corresponding parameter selection, which is often difficult to be satisfied in practice because different images have distinct warping requirement. *Seam carving based methods* try to obtain satisfactory resizing result by removing seams of minimal importance. A seam is defined as a path of 8-connected pixels that contains only one pixel per row or column in Avidan and Shamir [20]. The image resizing problem is actually an energy optimization problem and the dynamic programming is utilized to gracefully remove unimportant (low energy) seams in the image. After that, an improved seam carving method is developed in the work of Rubinstein et al. [21] by replacing the previous dynamic programming technique with graph cuts. Alternatively, an importance diffusion scheme is introduced by Cho et al. [22], aiming at emphasizing the pixels adjacent to the removed seams since the seams also contained context information. Although the existing seam carving based methods can have good performance in some cases, they may also produce seams cutting through important areas, which causes distortion and creates serious artifacts.

Though many methods have been developed to get an improved resizing result, the critical point remains unchanged, which is how to find the objects that should be maintained in the resizing process. Traditional attempts try to utilize low-level clues. However, these information have limited ability to guide the determination of important objects. Based on this consideration, saliency based clues [23–26], which exhibit certain kind of high-level semantic meaning and indicate human attention, are favored recently. These clues can infer the probable salient regions and protect them from distortion. In this paper, the proposed method also employs the high-level clue, but in an alternative manner. We consider the semantic boundary of an image, which can capture the main structure of important objects instead. Detailed introduction is followed in the next section.

3. The proposed method

3.1. Overview

In this paper, a novel method based on machine learning is developed by incorporating high-level information of the ROI. It aims to overcome the distortion of the ROI in image resizing. Though the seam carving framework is taken as an example to illustrate the proposed idea, it can be straightforwardly extended to other resizing prototypes, such as warping and segmentation based ones.