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Multi-operator image retargeting with automatic integration of direct and indirect seam carving☆

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ABSTRACT

Multi-operator image resizing can preserve important objects and structure in an image by combining multiple image resizing operators. However, traditional multi-operator methods do not take both horizontal and vertical content-aware resizing potential into consideration, which essentially leads to squeeze/stretch effect in the resultant images. In this paper, we propose a new multi-operator scheme that addresses aforementioned issue by integrating direct and indirect seam carving. Compared with previous methods, the proposed scheme remarkably reduces the cost of deciding when to change operators, by employing a newly defined image artifact measure. Furthermore, we propose a novel seam carving enhancement, named ACcumulated Energy Seam Carving (*ACESC*), as a basic operator to improve global structure preservation. By combining horizontal and vertical seam carving, our scheme preserves the shapes of important objects well. We present typical results to demonstrate the effectiveness of our method. User study shows that our method has high user preference.

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1. Introduction

In recent years, content-aware image resizing (*a. k. a.*, retargeting) techniques, which can preserve visually important contents and maintain good perceptual invariance in an image when the size and aspect ratio are changed, have evoked a great deal of interests. Such techniques are especially meaningful for transforming images or video clips between multimedia devices with different resolutions.

The techniques can be coarsely divided into five major categories [7]: cropping methods, warping methods, seam carving methods, patch based methods and multi-operator retargeting methods. In cropping methods [8–11], an optimal sub-window of the target size, which contains visually important regions, is searched from the input image. However, a disadvantage is that such methods may discard a large part of essential regions when the important objects are near the image periphery. Warping methods resize images non-homogeneously [3,12–16]. By fixing a mesh on the image, they warp the designed mesh non-uniformly to reach the desired size based on a global optimization function. Patch based methods [17] achieve resizing by optimizing a patch-based similarity measure between the input and target image. One limitation of this method is its high computational cost, as pointed out in [6]. Seam carving (*SC*) methods [4,18] perform image retargeting by iteratively adding or removing the most unimportant curves (*i.e.*, seams) from the image. For images with large homogeneous region going across from its left to right (*e.g.*, the sky region in Fig. 1 going across the image from left to right), a better seam carving scheme, which is called indirect seam carving, first resizes the height by inserting/deleting the horizontal seams in order to achieve the target aspect ratio, and then scales the intermediate image to the target size [14,19]. The advantage of indirect seam carving is that the resizing is mostly done in the homogeneous region, resulting in less visual artifacts. Seam carving methods are especially suitable for images with sparsely distributed objects. It is prone to produce undesirable artifacts when resizing images with many prominent objects in them.

Multi-operator retargeting techniques [1,19] adaptively utilize multiple operators including scaling, seam carving and cropping in turn to achieve content-aware image resizing. Those techniques employ an objective similarity measure to select the best combination from all possible combinations of different operators. A recent survey [6] indicates that compared with most state-of-the-art algorithms, multi-operator frameworks can produce retargeted images highly preferred by people. However, a major quality limitation is that when the resizing task is mono-directional, such techniques neglect the warping potential in the other dimension and are prone to distort the object shape (see Fig. 1 MultiOp, the people are "narrowed"). Another problem is that the computational cost of evaluating the image similarity measures is high and exponentially depends on the number of operators used [20].

Considering the aforementioned pros and cons, we propose a simple yet effective multi-operator resizing scheme to exploit both horizontal and vertical content-aware resizing potential, which has not

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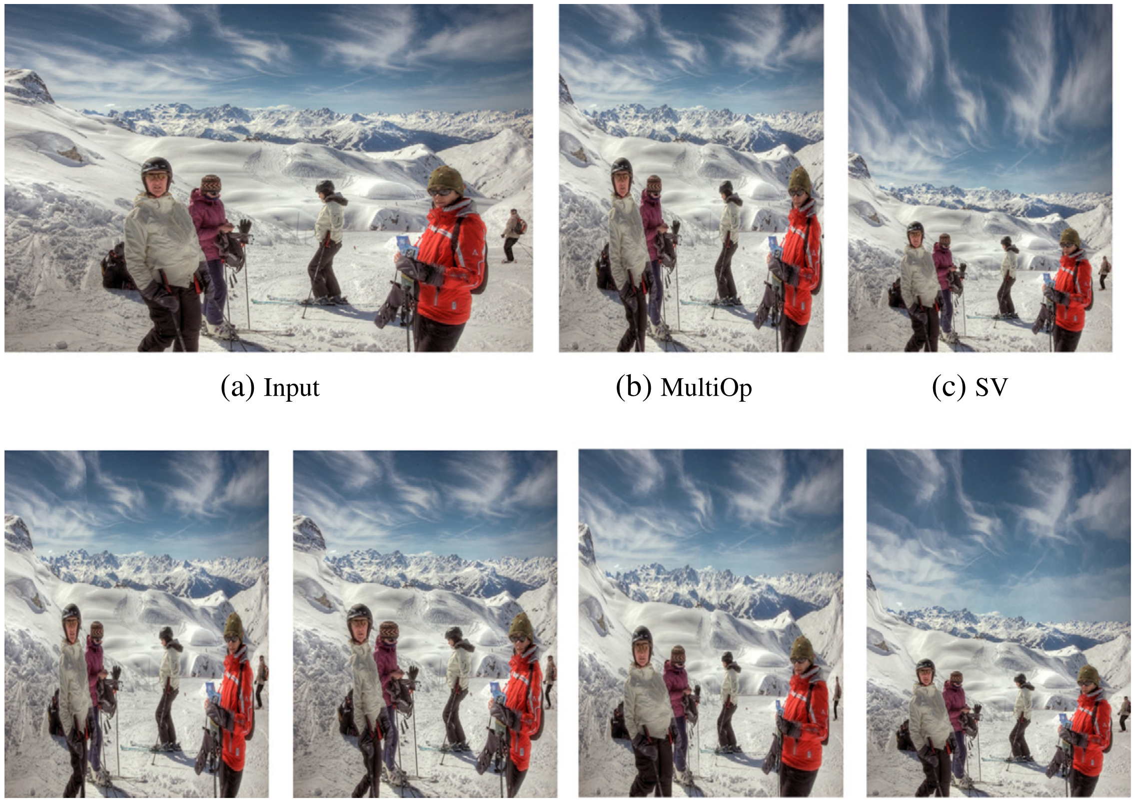

(a) Input (b) MultiOp (c) SV

(d) Warp (e) SC (f) LG (g) Ours

Fig. 1. Examples of retargeting the results of several state-of-the-art methods. (a) Input image; (b) multi-operator [1]; (c) streaming video retargeting [2]; (d) nonhomogeneous warping [3]; (e) seam carving [4]; (f) energy-based deformation [5]; (g) ours. The method notations follow RetargetMe dataset [6]. By exploiting the advantages of integration of direct and indirect *SC* with improved *SC* energy, our method generates better results in comparison with most other methods in terms of keeping the object aspect ratio.

been focused in previous multi-operator techniques [1,19]. The scheme automatically and effectively combines four simple resizing operators. In particular, direct and indirect seam carvings are first performed, and then a similarity transformation is employed to scale the image to a suitable size, followed by cropping the image to the target size. Although we believe that taking the global warping as a basic operator will enhance the ability to distribute distortions in multiple directions, we choose seam carving for its simplicity. Furthermore, we propose a seam artifacts measure to reduce the computational cost of selecting effective changing points among performing different operators. Moreover, we design a novel seam energy scheme for seam carving, named ACcumulated Energy Seam Carving (*ACESC*), to relieve the seam distortion significantly and eliminate the expansion ratio limit of seam carving for enlarging. Compared with several state-of-the-art image retargeting methods, experiments in a benchmark image retargeting dataset indicate that the proposed multi-operator scheme has comparable performance and user preference in preserving the global structure and the shapes of important objects. Its computational cost is remarkably lower than that of the previous multi-operator methods.

The remainder of the paper is organized as follows. In Section 2, we survey related works. In Section 3, we introduce some preliminary knowledge on image retargeting. Section 4 details the proposed multi-operator scheme. Experiment results are presented and discussed in Section 5. We conclude the paper in Section 6.

2. Related work

In this section, we give a brief survey on the content-aware image and video retargeting algorithms.

Among cropping methods, [21–24] constructed an optimal sub-window to preserve the prominent regions of the original image, which usually involves attention model extraction and object detection. With four psychological attributes (region of interest, attention value, minimal perceptible size, and minimal perceptible time), Liu et al. [8] employed an image attention model to extract main objects within an image. Santella et al. [10] used interactive eye tracking technique to locate important image contents to obtain optimal cropping window. Ciocca et al. [11] utilized different cropping methods to deal with different image types that are classified through a well-trained classifier.

The continuous methods [3,12–16,25] are to construct and optimize a warping function to retain the global structure of the images. Liu and Gleicher [5] employed a fisheye warping strategy to retain both details at regions of interest and context information in the resized image. With Laplacian editing techniques, Gal et al. [12] warped an image into various shapes to preserve the user-specified features. Wolf et al. [3] proposed an image and video retargeting method by utilizing local saliency, face detection [26] and motion detection (for video retargeting) to preserve the visually important pixels. Zhang et al. [13] incorporated a per-pixel cumulative shrinkability map with the random walk model to accelerate the computation and save storage space. Wang et al. [14] employed a significance map [27], which characterizes the visual attractiveness of each pixel, to guide the degree of image deformation. They constructed a warping mesh to distort homogeneous regions while preserving visually prominent regions. Guo et al. [16] combined the triangular mesh and important map as well as some structural constraints to preserve the shapes of important objects and minimize visual distortion. Karni et al. [25] presented a general approach to energy-based image retargeting and 2D shape deformation.

The patch based methods [17] achieve image retargeting based on image patches. Simakov et al. [17] defined a bi-directional similarity,

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