Neurocomputing 140 (2014) 162–171

Contents lists available at ScienceDirect

Neurocomputing

journal homepage: www.elsevier.com/locate/neucom

Shrink image by feature matrix decomposition

Qi Wang [a], Xuelong Li [b,*]

[a] Center for OPTical IMagery Analysis and Learning (OPTIMAL), Northwestern Polytechnical University, Xi'an 710072, Shaanxi, PR China
[b] Center for OPTical IMagery Analysis and Learning (OPTIMAL), State Key Laboratory of Transient Optics and Photonics, Xi'an Institute of Optics and Precision Mechanics, Chinese Academy of Sciences, Xi'an 710119, Shaanxi, PR China

A R T I C L E I N F O

Article history:
Received 4 August 2013
Received in revised form
22 December 2013
Accepted 5 March 2014
Communicated by Mingli Song
Available online 13 April 2014

Keywords:
Computer vision
Machine learning
Image resizing
Seam carving
Low-rank representation
Sparse coding

A B S T R A C T

With the development of multimedia technology, image resizing has been raised as a question when the aspect ratio of an examined image should be displayed on a device with a different aspect ratio. Traditional nonuniform scaling for tackling this problem will lead to distortion. Therefore, content-aware consideration is mostly incorporated in the designing procedure. Such methods generally defines an energy function indicating the importance level of image content. The more important regions would be retained in the resizing procedure and distortion could be avoided consequently. The definition of the related energy function is thus the critical factor that directly influences the resizing results. In this work, we explore the definition of energy function from another aspect, matrix decomposition of *Low-rank Representation*. In our processing, a feature matrix that reflects the texture prior of object contour is firstly constructed. Then the matrix is decomposed into a low-rank one and sparse one. The energy function for resizing is then inferred from the sparse one. We illustrate the proposed method through seam carving framework and image shrinkage operation. Experiments on a dataset containing 1000 images demonstrate the effectiveness and robustness of the proposed method.

1. Introduction

With the widespread growth of digital images, a variety of display devices are developed. For example, laptop, cell phone, iPad, and TV screen are the most popular ones. When images are displayed on these devices, it is desirable that they could be automatically adapted to the different sizes of display devices. This technique of adjusting images for optimal display is named as *image resizing*.

Because of its actual usefulness, image resizing has been extensively studied in computer vision and graphics. Earlier and straightforward work towards this problem is nonuniform scaling and cropping. However, transforming the image isotropically or merely cropping a fixed portion will lead to distortion and unbalance of image content. Trying to keep the interesting objects unaffected and compatible with the background is thus the main focus of recent research [1,2]. According to the techniques employed, these content-aware methods can be categorized into *segmentation* based, *warping* based and *seam carving* based.

For segmentation based method [3,4], the region of interest (ROI) [5–7] is firstly segmented from the background. Then the remaining background is scaled to the desired output size. In the end, the cropped foreground object is placed back to the resized image. Warping based method [8] treats the image as a group of grids and stretches each grid individually according to its distinctive property. The interesting objects are less affected and the background absorbs most distortions. As for seam carving based method [9], seams representing the minimum energy paths are removed or added in the image. In this way, the desired output dimension is obtained.

In this work, however, we are not intent on covering all the three aspects. The focus is mainly related to the seam carving paradigm [9]. As a comprehensive method, it contains several challenging issues, such as feature selection, energy definition and minimum cost path search. But the critical point is to define a suitable energy function to guide the seam searching process. Unfortunately, existing definitions are mostly restricted to local intensity gradients. The global statistics are not considered. This makes the extracted seams suboptimal in describing the interesting objects. Take Fig. 1 for example. Original seam carving method emphasizes on the edges in an image, due to its gradient based nature. Since the seams crossing the ROI might have smaller energy (because the inside of ROI has no variations), the important objects are not protected well in the produced results [10]. Therefore, a more feasible energy needs to distinguish the foreground with background [11,12]. Motivated by this deficiency

* Corresponding author.
E-mail addresses: crabwq@nwpu.edu.cn (Q. Wang), xuelong_li@opt.ac.cn (X. Li).

http://dx.doi.org/10.1016/j.neucom.2014.03.025
0925-2312/

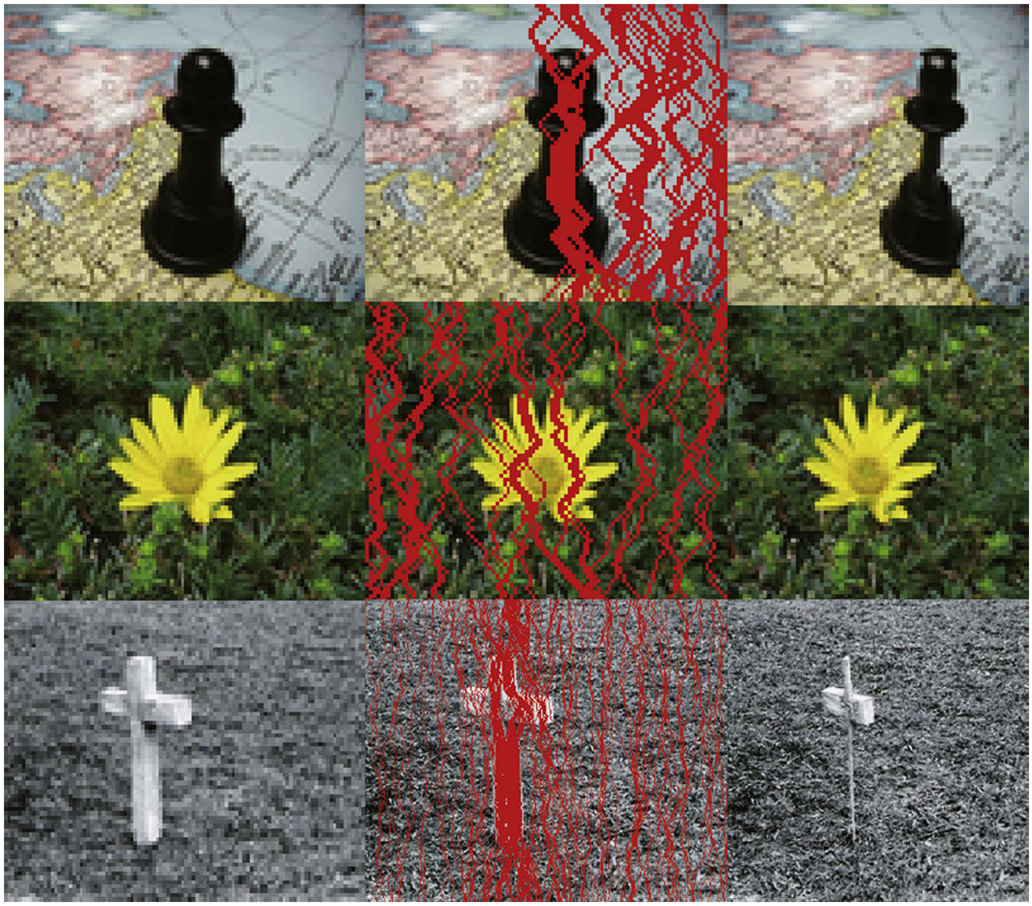

Fig. 1. Examples for image resizing by Avidan and Shamir [9]. The first column is the original images, the second column is the removed seams, and the third column is the final resized results.

and inspired by [13], a novel energy definition is introduced in this paper. We propose to decompose the feature matrix into a low-rank one and sparse one. Then the sparse matrix is considered to be reflecting the ROI information. This decomposition treats the image as a whole in the first place and then splits it into two parts of different properties. It integrates the local and global statistics at the same time. Therefore, it is assumed to be more reasonable and effective.

1.1. Related work

Seam carving is one type of resizing methods that has achieved great popularity in recent years. It was proposed by Avidan and Shamir [9] and extended by many other researchers. Since the proposed method mainly focuses on the redefinition of the energy function for seam carving, the review is only restricted on the energy related literatures. A thorough survey can be found in [11].

There are many proposed methods for the modified energy function in the framework of seam carving. For ease of presentation, we classify them into three categories, which are respectively *straightforward* seam carving, *human detection* based seam carving and *saliency* based seam carving.

Straightforward seam carving is the direct improvements of the seminal work by Avidan and Shamir [9]. Rubinstein et al. [14] defined a new energy function, which is called forward energy in the process of graph-cut. The new definition protects the interesting content better than the original backward energy in [9]. Han et al. [15] modified the energy function by weighing wavelet subband components. Conger et al. [16] generalized seam carving under the perspective of filter banks and redefined the backward energy and forward energy in the framework of the filter banks. Besides the redefined energy function, there are other ways to directly extend seam carving. For example, utilizing multi-operator [17] instead of single operator is a typical improvement. Rubinstein et al. [18] combined scaling, cropping, and seam carving together to resize images. Dong et al. [19] also combined seam carving with scaling by modifying the measure of image distance. However, these improved methods still result in aliasing [10] and the multi-operator ordering is difficult to determine either.

Human detection based seam carving is a transitional stage between the straightforward seam carving and the saliency based seam carving. The main operation is to extract human related features first such as face and gesture, and then to treat it as the ROI content that should be retained. Kopf et al. [20] proposed a method to pay more attention to objects, faces, and texts in images. In order to protect those regions, most of them are detected at first. Then the seams are ensured to round these regions. Subramanian et al. [21] employed neural network to detect the skin as the sign of human occurrence. Then the subsequent carving can avoid the possible human related region. However, not all images have a human related region. As for the images without human faces or gestures, this kind of method seems to be ill-suited. Thus more universal features expressing the salient region are needed.

Saliency based seam carving directly utilizes the output of saliency detection [22,23] and treat it as the guidance to conduct seam carving. Achanta and Susstrunk [24] presented an efficient seam carving method by utilizing saliency map. The employed saliency map, which is computed by intensity and color features, can be used to prevent seams passing through the ROI. Later after