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Image resizing with minimum distortion

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ABSTRACT

Displays became cheap and were combined with many devices, like camera, mobile, and so on…, so there has been an increased interest on resizing methods to make the image suitable and fill any screen size. Common and known methods like cropping or resampling can cause undesirable effects such as: losses in information or distortion in perception. Recently, content-aware image resizing methods have been proposed to get rid of these problems and produce exceptional results. Seam-carving produced by Avidan and Shamir has gained attention as an effective solution. This paper discussed about this method and used it to resize (minimize and maximize) four colored images vertically and horizontally respectively, and maintained the main features of the images by deleting or repeating only the uninfluenced features. The energy map was calculated that described the basic and influential details of the image using energy function. But instead of gradient function (as in Avidan and Shamir) entropy function was used to compute the energy of the images. A vertical or a horizontal seam of pixels with minimum energy values was either deleted or inserted to resize the image. Good results were obtained especially when the image contains spaces within its details. The work was programmed using Matlab2018a.

Keywords: Content aware, Energy function, Image resizing, Minimum distortion, Seam carving

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1. Introduction

Now display devices vary and different, like computer screen, camera, and mobile so the image must be resized to suit the optimal display. Therefore, a lot of interest appears in changing the image size. Many methods have emerged in this area and the most common are cropping and scaling.

1-Cropping:

One of the traditional resizing method is cropping. It uses a rectangular window, deletes all image details outside the window and keeps the inside one. The main drawback of this method is that it loses some important portions of the image to maintain other parts [1], [2], [3].

2-Scaling:

The second common method used to resize images is scaling. By stretching or shrinking, the image until it reaches the optimal size. Image content is unchanged, modifications may be only on pixels or colors, so this method produces distortion [4].

3- Seam Carving:

This method, discussed in [5], enlarges or reduces the image size by adding or removing image information that has less influence on the content of the image.

Among these techniques of image resizing, seam carving (with entropy calculation) was chosen in this paper to change the size of several tested images. It is obvious from the results that, after resizing, the images preserved their key details, while changes were made only to the parts of the images with low details.

The paper includes five sections. Section 1 is the introduction. Section 2, represented by the background, contains brief paragraphs of the previous works that are related with the research. An overview of the original seam carving method is displayed in section 3. While section 4 contains the explanation of the method, the flowchart and the functions used in the research. Resulted resized images compared with the original one is also displayed in this section. Finally, section 5 briefly presents the discussions and the conclusions of the work.

2. Background

A great deal of attention has been paid to the subject of image resizing with its various types. Below is an abbreviation of some related works:

- Cropping has been widely investigated [1],[6],[7],[8] and [9] where the required area of a video or an image is determined using a visual saliency model. In all manners, the cropping method has a drawback of losing video or image details outside the used frame.
- Wolf L. et.al. [10], used a non-homogenous method for retargeting images. The original details of the image are kept unchanged while less useful details are shrunk to fit the desired display size.
- Wang YS. et. al. [11], produce a (scale_and_stretch) scaling method so the image is wrapped in both directions.
- Gal R. et. al. [12], descried a feature-aware texturing method.
- Seam carving can efficiently resize an image described first in [5] and [13] insert or delete uninfluenced seams until reaching the object size.
- David D. Conger et.al. [14], incorporated anti-aliasing and thresholding techniques to improve seam-carving algorithm.
- Gang P. et al. [15], considered a relationship between the insert and delete seam processes and presented an ameliorated energy function to minimize aliasing occurred with seam carving.
- Yongzhen K. et.al. [16], suggested the use of image similarity to detect the operation of seam carving.
- Ikuku T. et.al. [17], used a flexible seam to avoid face distortion.

Many of these resizing methods have been extended to video resizing:

- Deselaers T.et. al. [18], presented a video resizing model using cropping method.
- KrahenbuhlP.et. al. [19], described a video resizing system that uses temporal filtering of the per-frame saliency map to account for the camera and scene motion.
- Wang YS.et. al. [20], produced a motion-aware video resizing method that can better handle videos with significant object and camera motion.
- Rubinstein M.et. al. [21], presented a multi-operator media resizing method.
  More details can be found in [22], [23], [24] and [25].

3. Seam carving preview

Avidan and Shamir [5], presented seam carving method to resize an image first in 2003. The image is resized (enlarged or minimized) by inserting or deleting some connected pixels called a seam. A seam may be either vertical or horizontal depending on the resizing operation applied to the image.

They suggested that the removing must be to the least important and uninfluenced seam of pixels one by one until the image size is reduced to the desired one. The same is done for enlarging the image, uninfluenced seam is added between two unimportant paths of pixels. So, this method overrode many of drawbacks appeared with cropping and scaling methods [26].

Insertion or deletion of such a weak seam does not cause lots of effect on image visual. By repeatedly inserting or deleting seams, the image is changed to the desired size.

The energy function is used to calculate the (weight / energy) of image pixels and it is defined by eq.1:

$$e(I)=\left|\frac{\partial}{\partial x}I\right|+\left|\frac{\partial}{\partial y}I\right| \tag{1}$$

a vertical seam of an image I with size of nxm is defined as:

$$s^y=\{s_i^y\}_{i=1}^{n} = \{(y(i),i)\}_{i=1}^{n} \tag{2}$$

where $|y(i)-y(i-1)| \leq 1$, for all i and y: $[1, ..., n] \rightarrow [1,...,m]$

A horizontal seam is defined in a similar manner as:

$$S^x=\{s_j^x\}_{j=1}^{m}=\{(j,x(j))\}_{j=1}^{m} \tag{3}$$

where $|x(j)-x(j-1)| \leq 1$, for all j and x:$[1,...,m] \rightarrow [1,...,n]$

so, the seam energy equals to the summation of the energy of pixels that form the seam.

$$E(s)=E(Is)=\sum_{i=1}^{n} e(I(s_i)) \tag{4}$$

So, the ideal seam is found by using eq.5:

$$S*=min\ E(s)=min \sum e(I(s_i)) \tag{5}$$

The algorithm inserts or deletes low energy seam of pixels (either vertical or horizontal seam), and the process is repeated until the optimal image size is reached.

4. Practical work

4.1. Explanation

In this research, seam carving which is the method suggested by Avidan and Shamir in [5], is used to resize (minimize and maximize) four images vertically and horizontally respectively.

The main idea of seam carving is how to detect the optimal vertical or horizontal seam in order to remove or insert it (if the operation is minimizing or maximizing respectively). The seam with the lowest energy is determined as the optimal seam and Entropy function is used to compute the energy of the image, unlike the original method that used the gradient function. Entropy function can be defined mathematically as:

$$H(x) = -\sum_{i=1}^{n} P(xi)\, log_2\, P(xi) \qquad (6)$$

First, calculated the entropy for each pixel in the image. A function used to transform the original image to an energy matrix where each entry of the matrix corresponds to the corresponding pixel value in the image.

Second, the energy matrix is searched from the first row to the last row to calculate the minimum accumulated energy for each entry of the matrix and store the result in a new matrix.

Third, the new matrix is searched from the last row to the first one to determine the optimal seam.

Fourth, two separate functions are used either to delete or insert the seam with the lowest energy, so the image is resized.

Fifth, repeat the steps to find all the possible paths of the pixels which have the lowest energy.

the steps above were used to resize image width, the same steps can be used to resize image height after rotating the original image by 90.

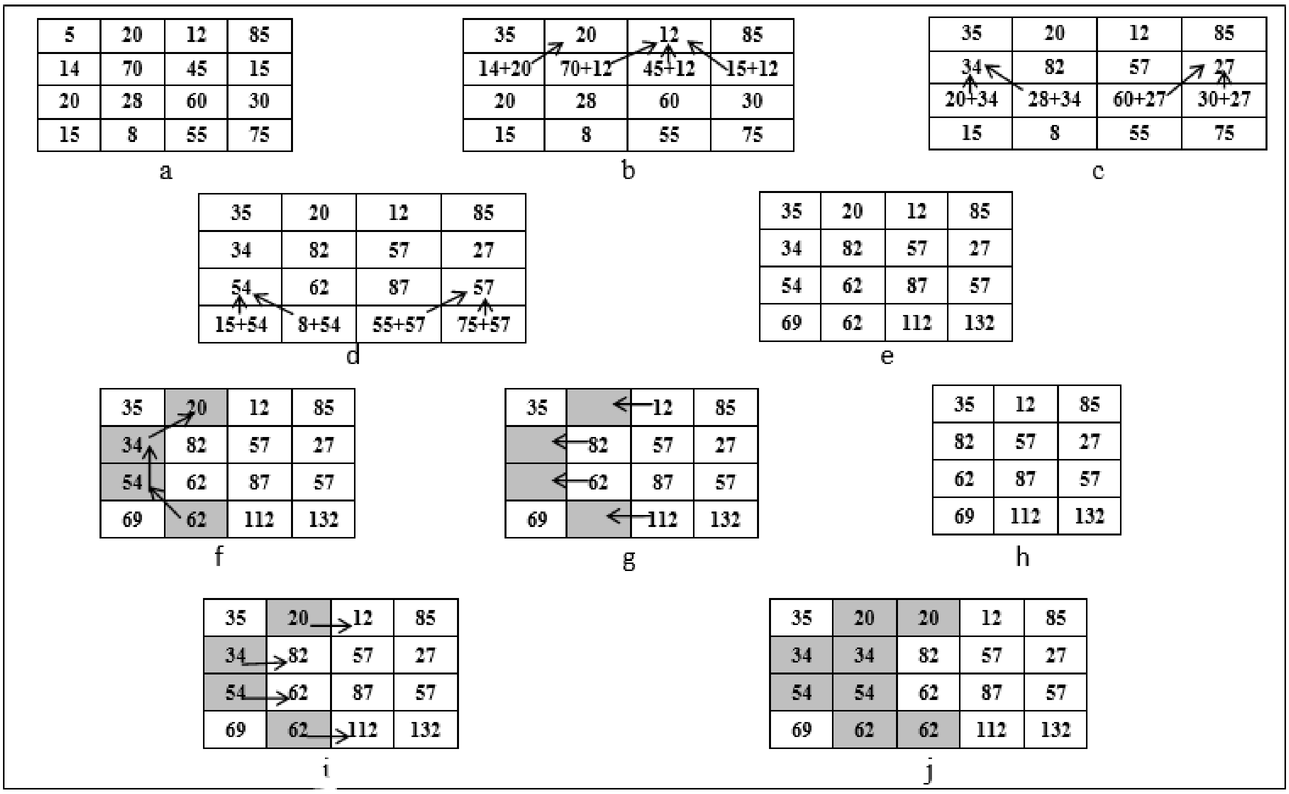


Figure 1. Simulation of optimal vertical seam finding process: a) Energy of the image; b,c,d,e) Calculate the accumulated energy; f) seam path; g) seam delete; h) matrix after deleting a seam; i) seam insertion; j) matrix after inserting a seam

4.2. Implementation functions

Below are several most important functions used in the work:

Energy: maps the image pixels into energy values.

Minenergy: calculates the accumulated energy matrix.
Optseam: finds vertical optimal seam.
Seamcar: removes a path of pixels with minimum energy.
Seamins: adds a path of pixels with minimum energy.
Imagrot: rotates image by 90 degrees.
The number of deduction/insertion (number of iteration) is determined by a counter (count in fig. 2)
First, the energy matrix is formed as in fig.1(a) (*Energy* function is used to do this). Then the minimum energy table is defined as in fig.1(e) (here *Minenergy* function is used), and the function works as follows: the first row of the energy matrix is copied to the table. The values for the rest of the table rows are calculated as the minimum value neighbor is added to the current pixel value. A comparison between the values of left, top, and right neighbors is done and the value of the smallest one between them is added to the current value. Pixels on the borders have only two upper neighbors, only top and left or right neighbors are compared to find their new corresponding value as in fig.1(c,d,e).
After the minimum energy table is determined, the table is searched from bottom to top and the minimum neighbor pixel value is selected in each row up until the first row of the table is reached, fig.1(f), to find the optimal seam using *Optseam* function. Seam values are removed fig.1(g) and other pixel values are shifted towards the removed pixels fig.1(h) so the image is reduced (by *Seamcar* function), or pixel values are shifted away from the optimal seam fig.1(i), then the seam values are inserted fig.1(j) , and the image is maximized.

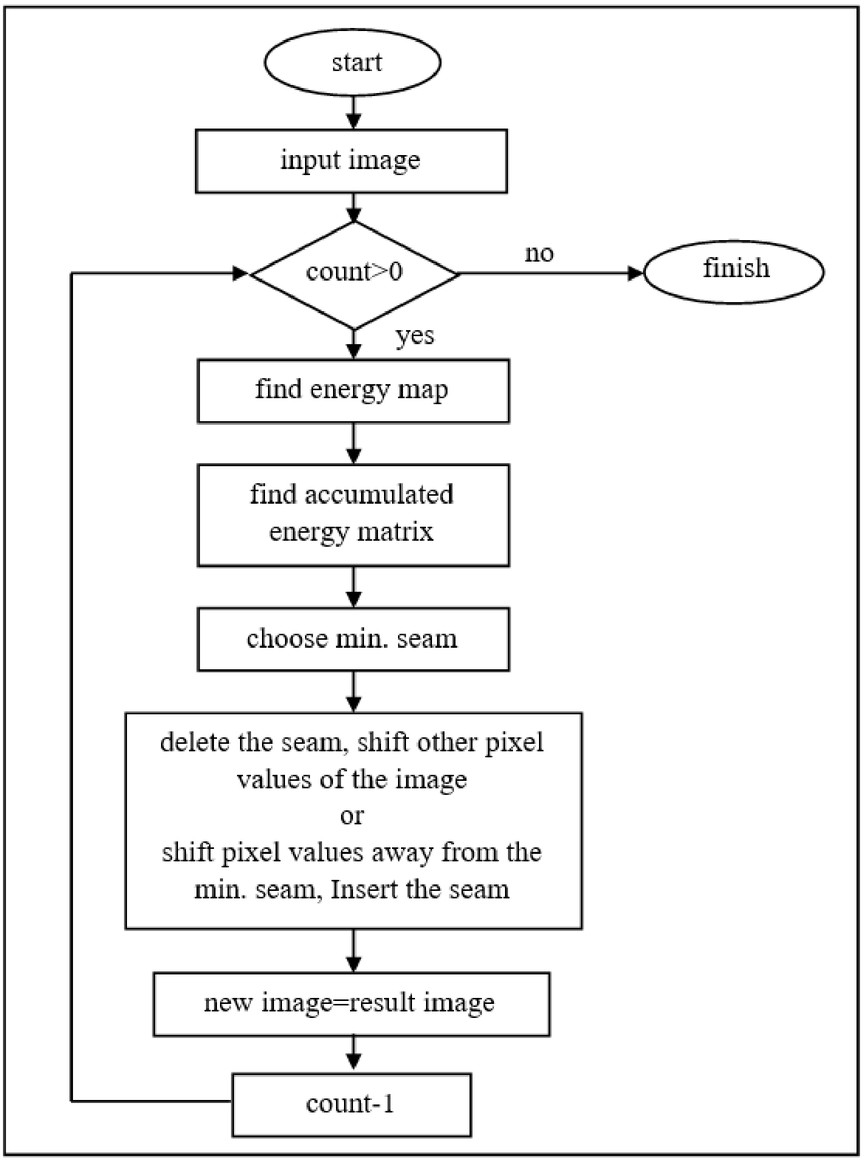


Figure 2. Practical work flowchart

4.3. Results

The functions are applied on four jpg images (img1, img2, img3 and img4) with different sizes.
The first image would be the original image. The second and the third images are the minimized ones (width compressed, and height compressed respectively). While the fourth and the fifth images are the maximized ones (with height expanded and width expanded respectively).

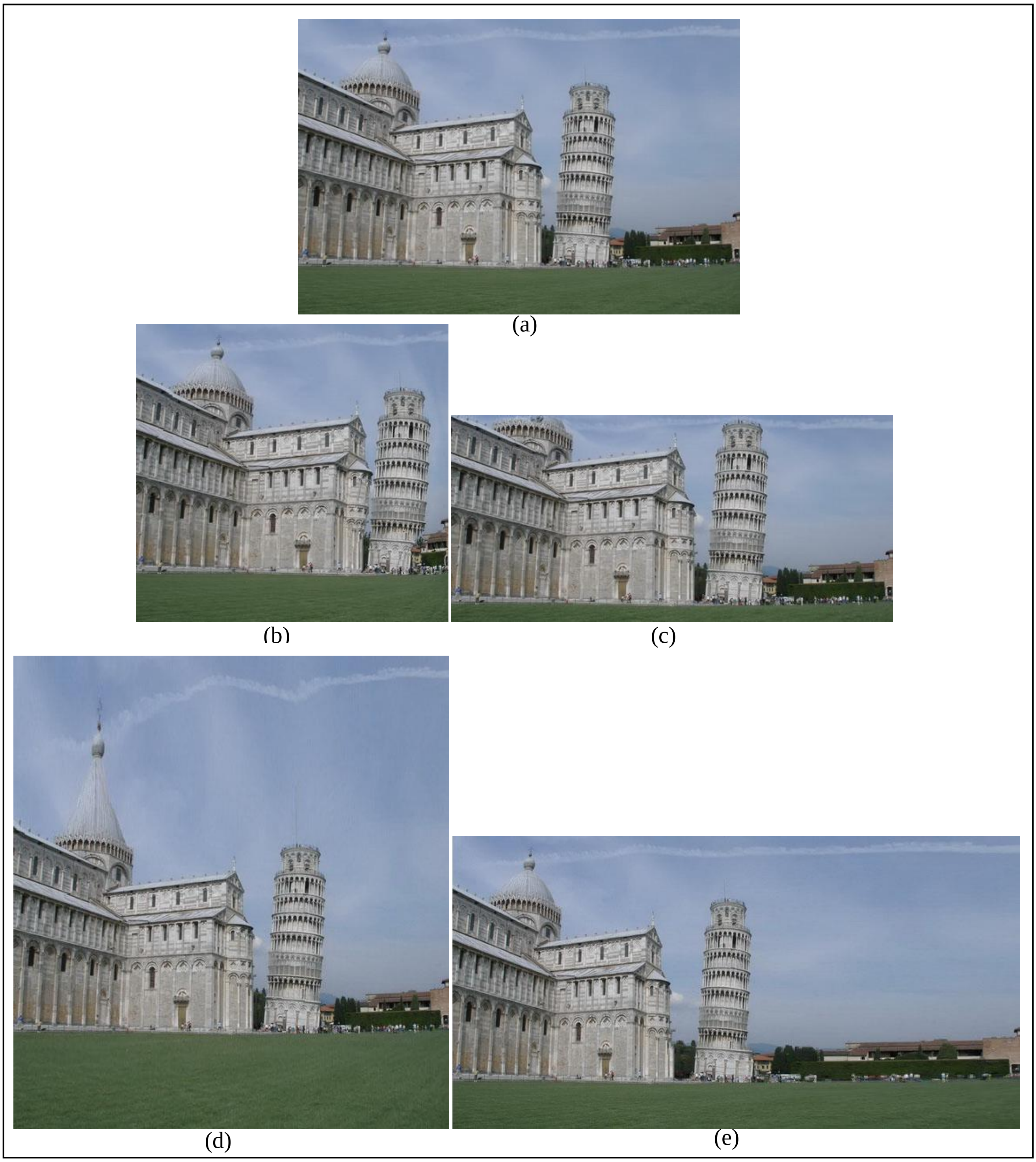
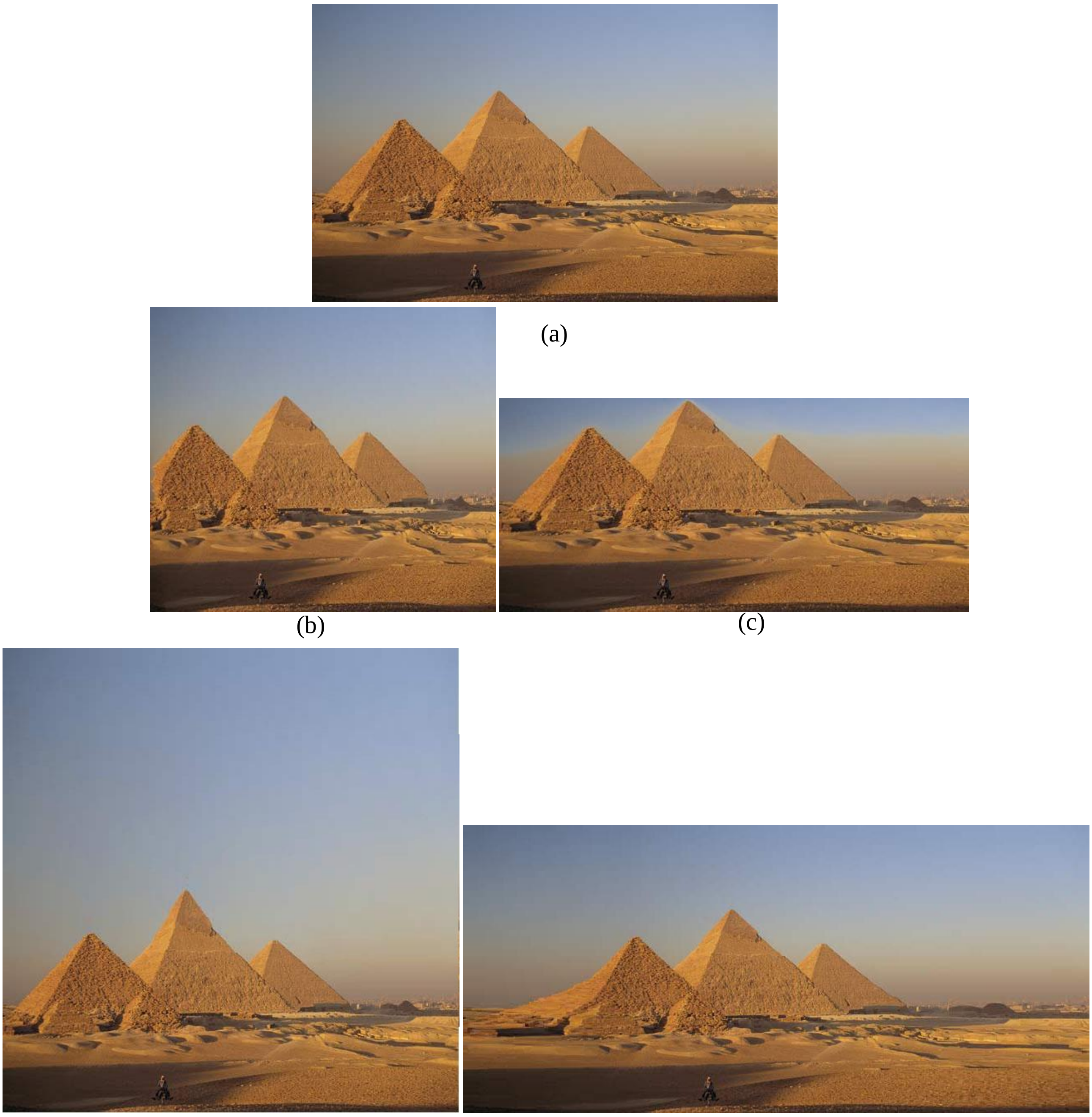


Figure 3. img1.jpg
a) Original size of image; b) Width deduction; c) Height deduction; d) Height expansion;
e) Width expansion



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

Figure 4. img2.jpg
a) Original size of image;
b) Width deduction;
c) Height deduction;
d) Height expansion;
e) Width expansion

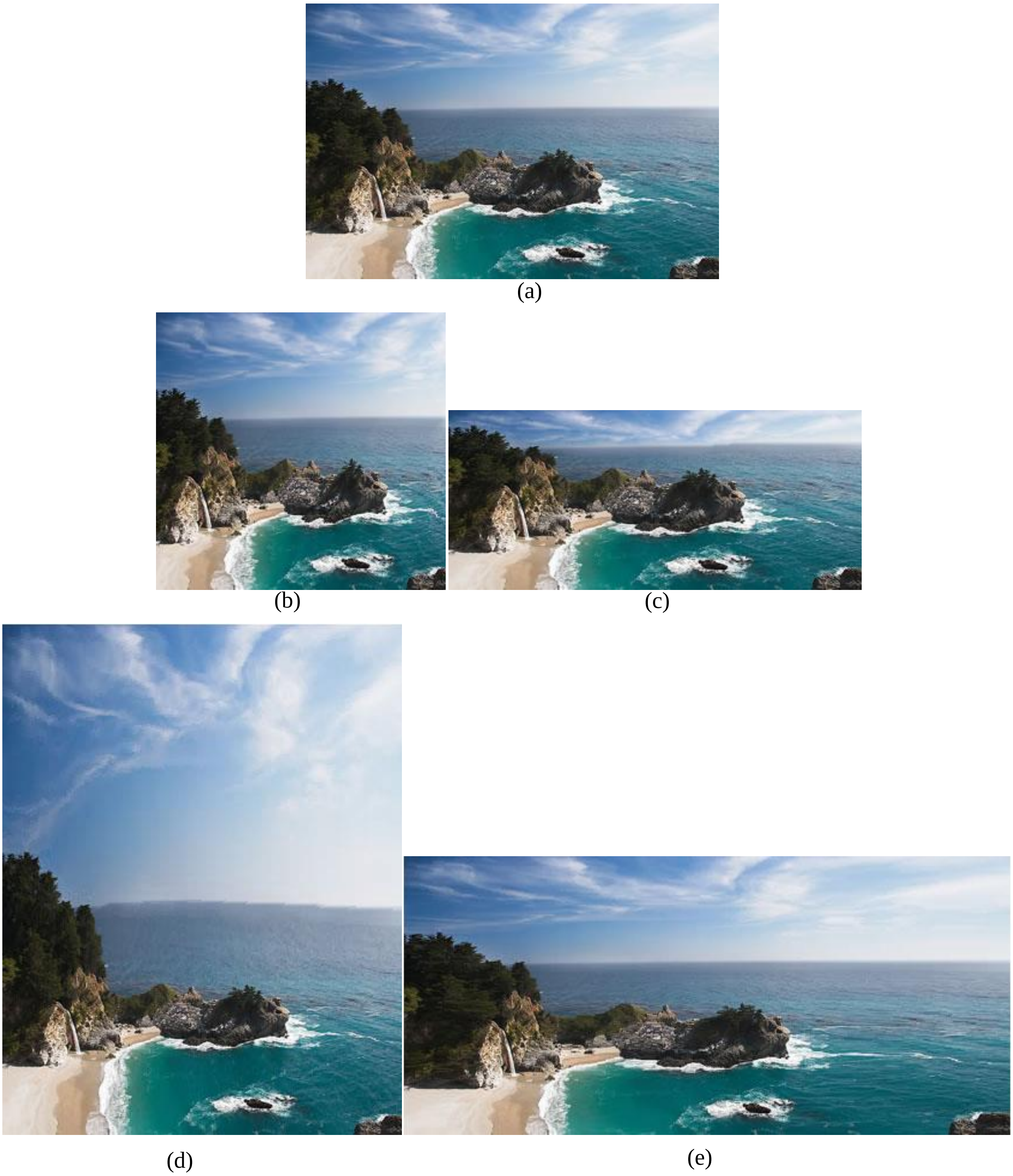


Figure 5. img3.jpg
a) Original size of image;
b) Width deduction;
c) Height deduction;
d) Height expansion;
e) Width expansion

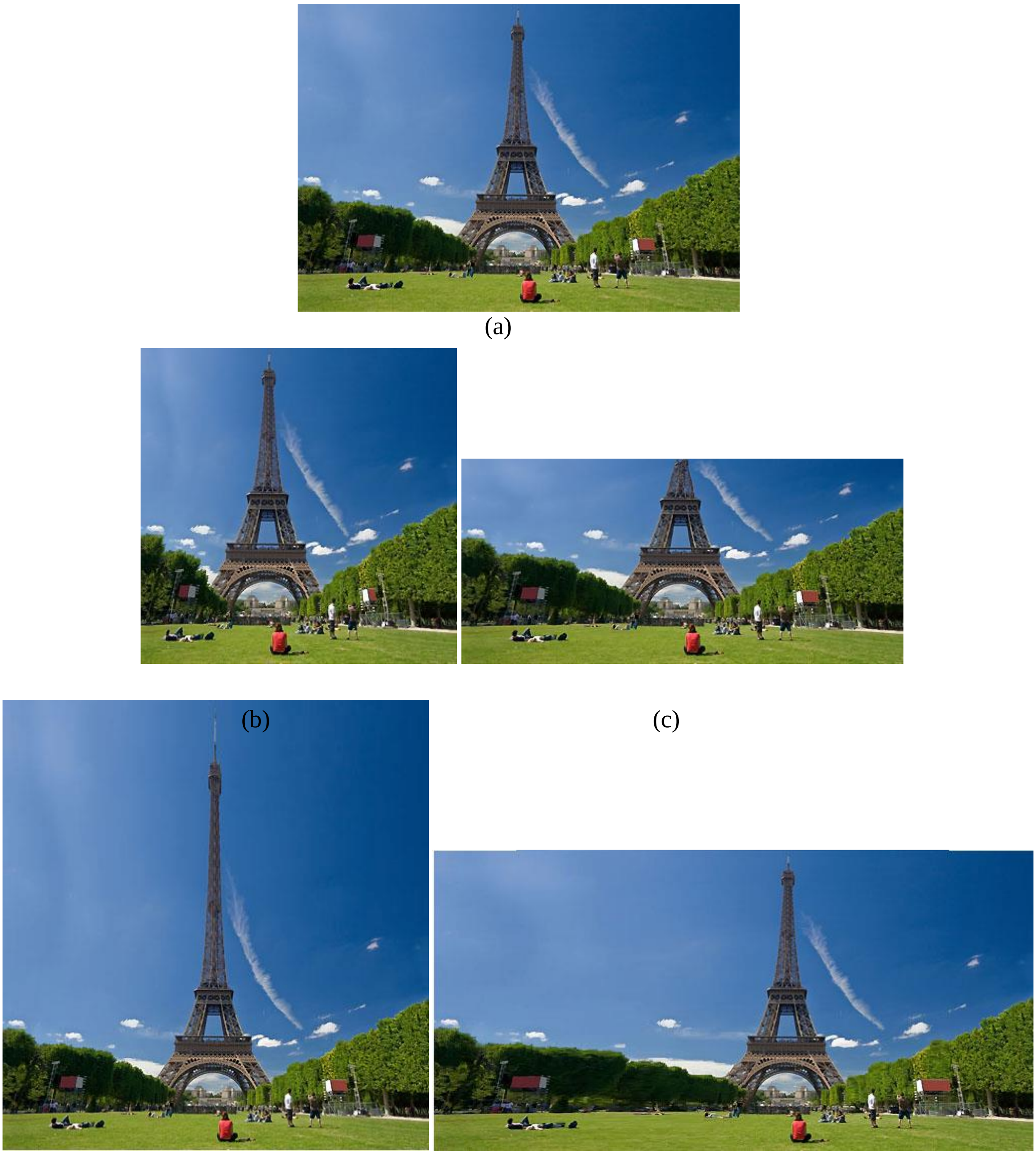


Figure 6. img4.jpg
a) Original size of image;
b) Width deduction;
c) Height deduction;
d) Height expansion;
e) Width expansion

5. Conclusion

- The main advantage of resizing the image by using seam carving is to maintain the main features of the image and delete or repeat only the not important and not influenced ones. As in fig.4 and fig.5, the algorithm maintains the details of the pyramid and the hill and removes or duplicate most of the sky pixels, so the resized image may lookalike a new photo taken from a different point, but it includes most important details of the original image.
- The algorithm works well with images contain spaces, so these spaces would be removed or expanded without distorting the original details of the image, like sea, sky, or desert images (as in fig. 3 to fig. 5).
- The algorithm does not always work well. As in fig. 6.c, causes deformation of the main features of the image as it cuts the upper parts of the Eiffel tower, while stretches the tower top as in fig.6.d, because of the very little details in this part of the photo.
- The algorithm is more complicated than other common resizing methods as it requires more calculations during resizing: establish the energy map, determine the optimal seam and pixels shifting. These processes are reiterated till the required size is obtained, so the algorithm consumes more time than other methods.

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