Image Retargeting in Compressed Domain

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Abstract

A simple algorithm for image retargeting in the compressed domain is proposed. Most existing retargeting algorithms work directly in the spatial domain of the raw image. Here, we work on the DCT coefficients of a JPEG-compressed image to generate a gradient map that serves as an importance map to help identify those parts in the image that need to be retained during the retargeting process. Each 8×8 *block of DCT coefficients is scaled based on the least importance value. Retargeting can be done both in the horizontal and vertical directions with the same framework. We also illustrate image enlargement using the same method. Experimental results show that the proposed algorithm produces less distortion in the retargeted image compared to some other algorithms reported recently.*

1. Introduction

Image retargeting refers to the resizing of an image according to its content as opposed to blindly scaling or cropping an image. With the availability of display devices having a wide variety of display sizes and aspect ratios, images have to be retargeted to particular specifications so that the 'important' parts of an image are retained resulting in a more pleasing visual experience for the user. Thus, the way an image is adapted for display on a PDA might be different from that on a handphone due to the difference in real estate on these devices.

Image retargeting has attracted a lot of attention recently due to the success of several algorithms. What is noticeable, though, is the fact that all the methods developed so far work on images in the raw uncompressed format. However, it is well known that images are mostly stored in the compressed format such as JPEG and a natural question that should be asked is whether retargeting can be done in the compressed domain itself. In this paper, we present a very simple algorithm for image retargeting in the compressed domain, i.e., using DCT coefficients in a JPEG image. This will eliminate the need to decompress the image to retarget in the spatial domain. Experimental results show that the proposed method is effective for reducing the size (both vertically as well as horizontally) and also for image enlargement.

2. Related Work

Several retargeting algorithms have been proposed recently to resize images and videos in a content-aware manner. Liu and Gleicher [7] proposed an image retargeting algorithm using fish-eye view warping. Their algorithm detects a region of interest (ROI) based on a saliency map and on results from face detection, and then warps the region outside the ROI while preserving the ROI. It is simple but causes distortions in the warped region, yielding unnatural images. Avidan and Shamir [1] proposed the popular seam carving algorithm, which finds a monotonic and connective path with minimum perceptual energy called a seam. The seams are removed using a dynamic programming approach. When a target size is too small, important objects are carved out and the image becomes distorted. This problem is addressed in [5] in which a hybrid algorithm which switches modes between seam carving and the conventional scaling is developed. A wavelet-based seam carving method is proposed in [4]. In [9], completeness and coherence constraints are imposed in the redistribution process. A structure preserving retargeting algorithm is presented in [10], while multiple operators are integrated to obtain optimally retargeted images in [8]. Recently, Kim et al. [6] proposed a retargeting algorithm based on Fourier analysis. It divides an image into strips according to image contents and then, scales each strip differently to minimize the sum of distortions, which are modeled in the frequency domain.

All the above methods are performed on the spatial domain of raw images. As digital images stored in computers are increasingly in discrete cosine transform (DCT)-based compressed format [2], image processing in the compressed domain is a necessity and several algorithms in this respect have been proposed . These relate to edge extraction, detecting line features, segmentation and watermarking, to cite a few. In this paper, we

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describe a very simple algorithm for image retargeting in the DCT-based compressed domain like the popular JPEG format. Here retargeting involves both reducing the size of the image as well as enlargement.

3. Proposed Algorithm

As noted earlier, retargeting to reduce image size involves removing pixels that do not result in distortion of the original image. In this paper, the 'unimportant' pixels are identified through an importance map that is derived from the DCT coefficients. Specifically, the gradient map of the image that is obtained from the DCT coefficients serves as the importance map. The importance map is divided into strips and each of the strips is scaled according to a scaling factor, i.e. the widths of the strips are reduced so that the retargeted image is of the desired size.

3.1 Importance Map

The importance map I is basically the gradient map of the compressed image obtained from the dequantized DCT coefficients of each 8×8 block of pixels. The 8x8 inverse DCT is [3]

$$f(x,y) = \sum_{u=0}^{7} \sum_{v=0}^{7} C(x,u)C(y,v)F(u,v) \quad (1)$$

where $C(x,u) = C(u)\cos\frac{(2x+1)u\pi}{16}$ and $C(u) = \frac{1}{\sqrt{8}}$ if $u = 0$ and $\sqrt{\frac{2}{8}}$ if $u \neq 0$. The importance map $I(x,y)$ is given by

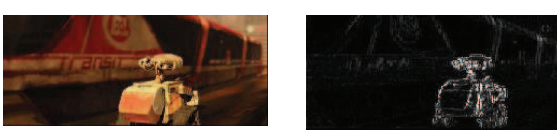
$$I(x,y) = \left|\frac{\partial f(x,y)}{\partial x}\right| + \left|\frac{\partial f(x,y)}{\partial y}\right| \quad (2)$$

where

$$\frac{\partial f(x,y)}{\partial x} = \sum_{u=0}^{7} \sum_{v=0}^{7} C'(x,u)C(y,v)F(u,v),$$

$$\frac{\partial f(x,y)}{\partial y} = \sum_{u=0}^{7} \sum_{v=0}^{7} C(x,u)C'(y,v)F(u,v)$$

and $C'(x,u) = -\frac{u\pi}{8}\sin\frac{(2x+1)u\pi}{16}$. Figure 1 illustrates an example of the importance map in which Fig. 1(a) is the original image and Fig. 1(b) is the importance map obtained from the derivative of the DCT coefficients. As is evident, the foreground object has been correctly identified as the 'important' region while most of the homogeneous background region is considered relatively 'unimportant'.



(a) (b)

Figure 1. (a) Original image, (b) importance map.

3.2 Scaling factors for retargeting

As noted, JPEG compression is initiated with the DCT of an 8×8 block of pixels. Thus the importance map is essentially made up of gradients within each 8×8 block. For an image of size $W_{in} \times H$, consider vertical strips each of width 8 pixels wide in the importance map, so that there are a total of $n = \frac{W_{in}}{8}$ strips. It is required to reduce the widths of selected vertical strips so that the retargeted image is of the desired size. We now describe the selection of the scaling factor s_j by which the strip j needs to be reduced.

First, the top 10% of the importance values for each column in the importance map are added. The complexity array consisting of these importance values reflects the presence of strong edges which should be retained during the retargeting process. Since the weak importance values do not support the presence of a strong edge, we ignore these and retain only the top 10%.

The importance values obtained for each column is then arranged in ascending order. If the width of the retargeted image is W_{out}, which is less than W_{in}, our objective will be to remove $P = W_{out} - W_{in}$ columns so as to obtain an image of size $W_{out} \times H$. These P columns will be those with the lowest importance values since they indicate columns without strong edges and hence the absence of an object that could get distorted during retargeting. For each vertical strip of width 8 pixels, the columns corresponding to the lowest importance values are removed. However, the constraint is that none of the vertical strips is completely removed since we wish to retain all information in the original image to some degree. If this constraint is not imposed, it could be that the retargeted image is simply a cropped image. Thus, the scaling factor s_j for each vertical strip is simply the number of columns that need to be removed from strip j. We illustrate this procedure through an example in Fig 2 which shows 3 vertical strips each having 8 pixels and the importance values for each column. The importance values are sorted in ascending order in Fig 2(b) and the retargeted data after removing 1 pixel is shown in Fig 2(c). Note that the column with importance value 0.1 from the first vertical strip was removed. After removing 5 columns, the retargeted data is shown in Fig. 2(d) and Fig 2(e) shows the result when 10 columns are removed where the constraint for each strip to contain at least 2 columns is imposed.

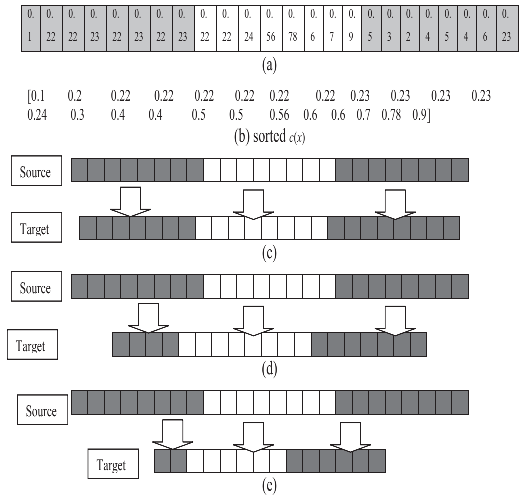


Figure 2. (a) Complexity array $c(x)$ (b) sorted $c(x)$; Strips reduced by factors of (c) 1 (d) 5 (e) 10

Let r_j be the number of columns remaining in strip j after the required number of columns in the importance map is removed. Then the $r_j \times 8$-point inverse DCT is taken for each block to obtain the retargeted image. Clearly, this type of retargeting can also be used to reduce the vertical size of the image. Here, the only difference is that the 8-pixel wide strips are now horizontal. In the experiments, we show results for both horizontal as well as vertical resizing.

3.3 Image enlargement

The framework that has been described for image size reduction is versatile to be extended for image enlargement operations. The image enlargement operation is carried out by duplicating once, the columns with P least importance value until the required size is obtained. This in effect is a duplication of the least important P columns that are removed in the image size reduction operation. The results of image enlargement using our proposed algorithm is shown in Fig 7. Note that while the image is enlarged, it does not increase its resolution.

4 Results and Discussion

Figure 3 compares the proposed algorithm with blind scaling. The proposed algorithm protects the shapes of the building and the tower more faithfully than scaling.

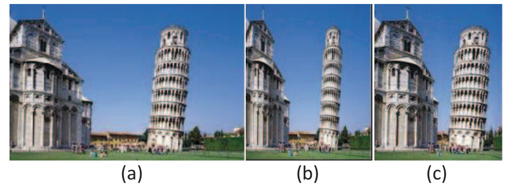


Figure 3. (a) Original image; Retargeting by (b) blind scaling and (c) the proposed algorithm

Figure 4 compares the proposed algorithm with the popular seam carving method [1] and the bidirectional similarity method [9]. The sloping roof is severely distorted in Fig. 4(b) and Fig. 4(c), while the proposed method retains its shape. In the dolphin image, seam carving produces just a cropped-like image (Fig. 4(c)) and the horizon and ocean is severely distorted and one of the windows of the house is lost as a result of the retarget operation in Fig. 4(b). Both these aspects are absent in the proposed method shown in Fig. 4(d). Fig. 5 shows the effect of retargeting by 50% in the vertical direction (right, bottom) and compares it to blind scaling (right, top). The distortion in the latter is clearly visible while the proposed method retains the shape of the butterfly. Fig. 6 illustrates the effect when retargeting is done both in the vertical and the horizontal direction. The image size is reduced by 50% and it is evident that in blind scaling all the regions in the image have been reduced equally (right, top) while using the proposed algorithm (right, bottom), the important region, viz, the opera house has been scaled less. As mentioned earlier, this simple framework can also be used to enlarge images. Fig. 7 (a) shows an original image which is enlarged in both directions by 50% by blind scaling (fig. 7(b)) and using the proposed method (fig. 7(c)). Columns and rows in the gradient image are

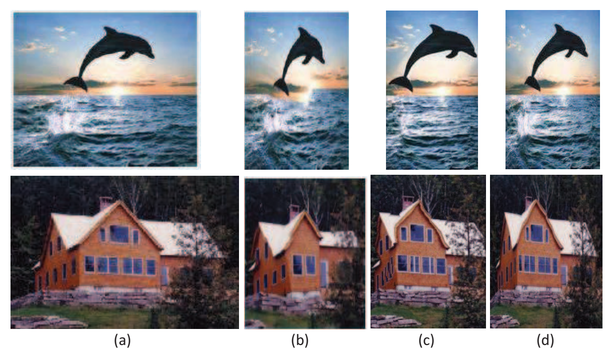


Figure 4. (a) Original image; Retargeting by (b) bidirectional similarity [9](c) seam carving[1] and (d) proposed method.

Figure 5. Image reduction by 50% along vertical direction (Left) Original image; (Right: Top) Blind scaling and (Right: Bottom) proposed method.

Figure 6. Image reduction by 50% along both directions (Left) Original image; (Right: Top) Blind scaling and (Right: Bottom) proposed method.

inserted based on the few least importance values in the original image. The simplicity of the proposed algo-

Figure 7. (a) Original Image; 50% enlarged image by (b) blind scaling (c) proposed method.

rithm is noteworthy especially since it works directly in the compressed domain. Every step of the algorithm including the computation of the importance map, ranking of the importance values and scaling of each strip has negligible computational complexity. The computation times using a PC running Matlab on a 32-bit Inter Core 2 Duo 2.66 GHz processor, with a 2 GB RAM are shown in table 1. In seam carving, the order of the seams have to be stored to create multi-size images for real-time retargeting.

Table 1. Computation times

Image	Original Size	Time (sec)
Pisa(Fig 3)	199x301	3.385
House(Fig 4)	200x300	3.067
Butterfly(Fig 5)	291x193	3.30
Opera(Fig 6)	175x263	1.99
Golf(Fig 7)	508x382	6.53

5. Conclusion

We have proposed a simple and efficient algorithm for image retargeting. The proposed algorithm is performed in the compressed domain directly using DCT coefficients. Simulation results demonstrated that the proposed algorithm provides high quality retargeted images even when the target size is very small. The framework can be used for both reducing as well as incrasing the size of the image.

Acknowledgements

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