Grid-Based Image Resizing with User-Selected Constraint

Kazu MISHIBA and Masaaki IKEHARA
Keio University, Yokohama, Japan
E-mail: mishiba,ikehara@elec.keio.ac.jp

***Abstract*—We present a novel method for content-aware image resizing based on grid transformation. In our proposed method, an original image is projected onto a grid, and then the vertical and horizontal grid lines are moved to resize the image. For obtaining plausible results, our method preserves not only important regions but also aspect ratios of objects and shapes of lines. We define three distortion measures for achieving these preservations. Experimental results demonstrate that our proposed algorithm resizes images with less distortion than other resizing methods.**

I. Introduction

With the diversity of display device sizes and aspect ratios, image resizing has played an important role for optimal display. Traditional resizing techniques such as cropping and uniform scaling resize images with low computational cost. Cropping images, however, may be discard important content such as human faces and foreground objects, and scaling images may be distort important content when the aspect ratio is changed.

Recently, there have been many content-aware image resizing methods for overcoming these limitations. Seam carving [1], [2], [3] is one of approaches for content-aware image resizing. Seam carving methods change the size of an image by gracefully carving out or inserting seams, which are path of pixels. Warping methods [4], [5], [6] are other approaches for content-aware image resizing. They place a mesh grid onto the image, then deform the mesh by computing a new geometry for the mesh. Many content-aware image resizing methods focus on only preventing important content from distortion because keeping important content unchanged can reduce the possibility of making visually implausible images. However, if the target image width is smaller than the widths of important content on the original image, these methods fail to prevent important content from distortion. In addition these methods fail to preserve the shapes of prominent image lines. Line shapes, which are seen mainly in artificial objects, are prominent content on an image. For obtaining better resizing results, we need to solve these problems.

In this paper, we propose a new resizing method, which is classified into warping method. Fig. 1 shows the overview of our method. Our method preserves important regions, aspect ratios of objects, and shapes of lines. Preserving important regions is one of main purposes in image resizing. Depending on the target size, however, keeping important objects untouched fails. Thus our method permits the size change of the objects if their aspect ratios are preserved. Additionally our method prevents the shapes of lines from distortion. In our method, importance of pixels is measured by using saliency region detection method [7], and objects targeted for preserving their aspect ratios and lines targeted for preserving their shapes are selected by a user.

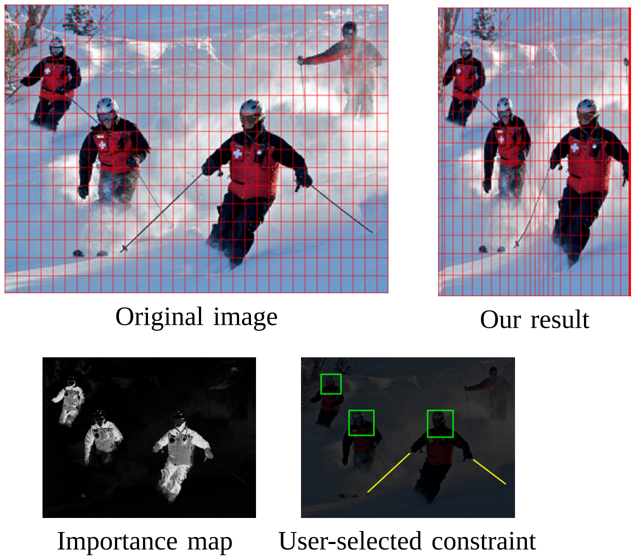


Fig. 1. An overview of our proposed method. An original image is deformed based on the transformed grid. An importance map is used for preserving important region. User-selected constraints are used for preserving the aspect ratios of objects and the shapes of lines. A green frame and a yellow line indicate selected objects and lines for preserving, respectively.

II. Proposed Method

In our proposed method, an image is projected onto a grid, and then the grid lines are moved to resize the image. Unlike [4] and [5], which move vertices on the grid for image resizing, our method moves vertical and horizontal grid lines. Vertical grid lines move horizontally, and horizontal grid lines moves vertically. Our method computes the optimal position of the grid lines to resize an image of $m \times n$ into an arbitrary size of $m' \times n'$ pixels with less distortion. Each initial grid face is scaled into the new size by a simple interpolation method such as bicubic interpolation. This transformation leads to distortion. We introduce three distortion measures, *content distortion*, *aspect distortion* and *proportion distortion*. Suppressing these distortions means preserving important region, preserving original aspect ratios of objects, and preventing line shapes from distortion, respectively. The details of these distortions are described in the following sections.

Let G be a grid consisting of w vertical grid lines and h horizontal grid lines, $V_x = \{v_{x,i} \mid 1 \leq i \leq w\}$ be a set of the x-coordinates of the initial positions of vertical grid lines, and $V_y = \{v_{y,j} \mid 1 \leq j \leq h\}$ be a set of the y-coordinates of the initial positions of horizontal grid lines. These positions satisfy $v_{x,i} \geq v_{x,i-1}$, $v_{y,j} \geq v_{y,j-1}$ and the boundary lines satisfy $v_{x,0} = 0, v_{x,w} = n$, $v_{y,0} = 0, v_{y,h} = m$. Our goal is to find the optimal positions $v'_{x,i}$ and $v'_{y,j}$ satisfying $v'_{x,i} \geq v'_{x,i-1}$, $v'_{y,j} \geq v'_{y,j-1}$ and the boundary constraint $v'_{x,0} = 0, v'_{x,w} = n'$, $v'_{y,0} = 0, v'_{y,h} = m'$. Let t_i be an interval index between grid lines v_i and v_{i+1}, $l_{t_i} = v_i - v_{i-1}$ be an interval distance. In our method, the quad faces in the same interval are transformed equally in a horizontal or vertical direction. Thus we compute three distortions for each interval.

A. Content Distortion

Content distortion represents the size change of an important region on an image. It is prefer that the important region remains unchanged through a resizing process. Therefore, our method preserves the important region from changing, like other resizing methods. Changing an interval distance distorts important region on the interval. We define *content distortion* as a function of the scaling rates of the intervals:

$$E_C = \sum_{t \in T} e_t \left(1 - \frac{l'_t}{l_t}\right)^2 \tag{1}$$

where T is a set of all intervals on the grid, e_t is the sum of importance of pixels on interval t, and l'_t is the interval distance after transforming the grid. Many methods to measure the importance of pixels have been proposed. Our method calculates the map of importance of pixels using Achanta's saliency region detection method [7], then normalizes the map between 0 and 1.

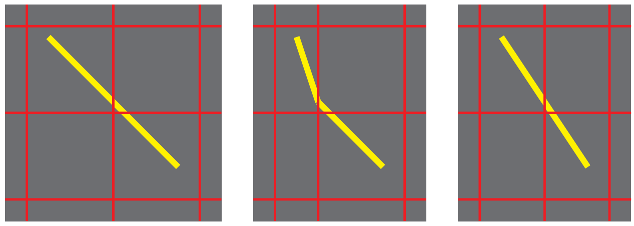
B. Aspect Distortion

Aspect distortion is defined for preserving the original aspect ratios of objects. The changing of the aspect ratio of an object, especially of human faces, appears strange. To prevent such distortion, our method penalizes the change of the aspect ratio of an object. In our resizing approach, the aspect ratio of the object changes when the scaling rates of the intervals containing the object change. *Aspect distortion* for object s is defined as a function which has a large value when the scaling rates of the intervals containing s differ:

$$E_A(s) = \sum_{t \in T_s} l_t \left(r_s - \frac{l'_t}{l_t}\right)^2 \tag{2}$$

where T_s is a set of the horizontal and vertical intervals containing object s, r_s is the average scaling rate of the intervals expressed by

$$r_s = \frac{1}{N(s)} \sum_{t \in T_s} \frac{l'_t}{l_t} \tag{3}$$



(a) (b) (c)

Fig. 2. Proportion distortion. (a) A line (yellow) on a grid (red). (b) The line shape is distorted in the case of scaling the horizontal intervals at different proportion. (c) Scaling at same proportion in horizontal direction keeps the line shape.

and $N(s)$ is the number of the intervals containing object s. The total *aspect distortion* is expressed by

$$E_A = \sum_{s \in S_A} E_A(s) \tag{4}$$

where S_A is a set of objects, which are selected by a user to preserve their aspect ratios.

C. Proportion Distortion

Proportion distortion is defined for preventing line shapes from distortion. Line shapes, which are seen mainly in artificial objects, are prominent content on an image. As mentioned in [4], however, conventional methods fail to preserve the shapes of prominent image lines. The reason the shape of the line is distorted through a resizing process is that each pixel on the line is mapped into a new image by different transformations. Unlike preserving aspect ratio, a line shape is preserved when the intervals containing the line are scaled at equal proportions in horizontal and vertical directions independently (see Fig. 2). *Proportion distortion* for line s is defined by

$$E_P(s) = \sum_{t \in T^x_s} l_t \left(r^x_s - \frac{l'_t}{l_t}\right)^2 + \sum_{t \in T^y_s} l_t \left(r^y_s - \frac{l'_t}{l_t}\right)^2 \tag{5}$$

where T^x_s and T^y_s are a set of the horizontal and vertical intervals containing line s, respectively, and r^x_s and r^y_s are the average scaling rates of the horizontal and vertical intervals containing s, respectively. The total *proportion distortion* is expressed by

$$E_P = \sum_{s \in S_P} E_P(s) \tag{6}$$

where S_P is a set of lines, which are selected by a user to prevent their shapes from distortion.

D. Total Energy Minimization

We wish to minimize the weighted sum of three distortions:

$$E = \lambda_C E_C + \lambda_A E_A + \lambda_P E_P \tag{7}$$

subject to $v'_{x,i} \geq v'_{x,i-1}$, $v'_{y,j} \geq v'_{y,j-1}$, $v'_{x,0} = 0, v'_{x,w} = n'$, $v'_{y,0} = 0, v'_{y,h} = m'$. Here, λ_C, λ_A and λ_P are the weight factors to *content distortion*, *aspect distortion*, and *proportion*

Fig. 3. Comparison of our method with other methods. Green frames and yellow lines on original images indicate user-selected objects and lines for preserving in our method.

distortion, respectively. If $v'_i < v'_{i-1}$, the resized grid has self-intersection. One way to eliminate self-intersection problem is to relax the grid. Thus we introduce the smoothing energy:

$$E_S = \sum_{t \in T} w_t l_t \left(1 - \frac{l'_t}{l_t}\right)^2 \tag{8}$$

where w_t is a smoothing weight to interval t and is set to 1. We modify the total enegy function to be

$$E = \lambda_C E_C + \lambda_A E_A + \lambda_P E_P + \lambda_S E_S \tag{9}$$

subject to $v'_{x,0} = 0, v'_{x,w} = n'$, $v'_{y,0} = 0, v'_{y,h} = m'$. Here, λ_S is the weight factor to the smoothing function. Using the smoothing function can prevent the grid from self-intersection. In some cases, however, self-intersection occurs when the grid size is greatly reduced through a resizing process. Hence, if a resized grid has self-intersection, the proposed method repeats increasing smoothing weight w_t and solving Eq. (9) until self-intersection is eliminated. In this iteration, smoothing weight w_{t_i} is updated by

$$w_{t_i}^{(k+1)} = \begin{cases} 2w_{t_i}^{(k)} & v'_{t_i} > v'_{t_i+1} \\ w_{t_i}^{(k)} & otherwise \end{cases} \tag{10}$$

where k is an iteration number.

III. Experimental Results

To evaluate our method, we have implemented the proposed method with MATLAB and tested it on a variety of images. We solved Eq. (9), which is a least squares optimization problem, using MATLAB function *mldivide*. In our experiments, we found that $\lambda_C = 0.1$, $\lambda_A = 10$, $\lambda_P = 10$ and $\lambda_S = 0.1$ produce sufficiently good results. We set $h = 17$ and $w = 33$, which means an initial grid was divided into 16×32 faces.

In Fig. 3, we compare some results of Rubinstein's seam carving method [2], Wang's warping method [4] and our method. As shown in this figure, the conventional methods distort prominent objects and lines. Comparing with other

Original image

Fig. 4. Resizing results in cases of significant changes of aspect ratio. Our method produces plausible results even in this situation.

methods, the proposed method can preserve the aspect ratios of objects and shapes of lines. Fig. 4 shows the resizing results using our method with the significant changes of the aspect ratio. Even in the severe conditions, our method produces plausible results.

IV. Conclusions

We proposed a novel method for content-aware image resizing based on grid transformation. Our method preserves important regions, aspect ratios of objects, and shapes of lines. For achieving these preservation, we defined three distortion measures. Experimental results demonstrate that our proposed algorithm resizes images with less distortion than other resizing methods.

Although our method can produce plausible resizing results, it requires user inputs for preserving aspect ratios of objects, and shapes of lines. Our future work is to choose objects and extract lines automatically for preserving.

Acknowledgment

We thank the following Flickr (http://www.flickr.com/) users for Creative Commons imagery: DennyMont(ski patrol), dmondark(Decorative vases), robholland(pumplin), Wouter Kiel(street).

This work was supported by Keio Gijuku Academic Development Funds.

References

[1] S. Avidan and A. Shamir, "Seam carving for content-aware image resizing," *ACM Trans. Graph.*, vol. 26, no. 3, pp. 10, 2007.

[2] M. Rubinstein, A. Shamir, and S. Avidan, "Improved seam carving for video retargeting," *ACM Trans. Graph.*, vol. 27, no. 3, pp. 1–9, 2008.

[3] M. Rubinstein, A. Shamir, and S. Avidan, "Multi-operator media retargeting," *ACM Trans. Graph.*, vol. 28, no. 3, pp. 1–11, 2009.

[4] Y.-S. Wang, C.-L. Tai, O. Sorkine, and T.-Y. Lee, "Optimized scale-and-stretch for image resizing," *ACM Trans. Graph.*, vol. 27, no. 5, pp. 118:1–118:8, 2008.

[5] R. Gal, O. Sorkine, and D. Cohen-Or, "Feature-aware texturing," in *Proc. Eurographics Symposium on Rendering*, 2006, pp. 297–303.

[6] L. Wolf, M. Guttmann, and D. Cohen-Or, "Non-homogeneous content-driven video-retargeting," in *Proc. IEEE int. Conf. Computer Vision*, 2007.

[7] R. Achanta, S. Hemami, F. Estrada, and S. Susstrunk, "Frequency-tuned salient region detection," in *Proc. IEEE Conf. Computer Vision and Pattern Recognition*, 2009.