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Flexible shape of seam for image retargeting with face detection

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Abstract

A new method is presented to prevent distortion around human faces for seam carving based image retargeting. For the pictures with many faces, a seam is preferable to go while avoiding faces, however the interspaces between faces are sometimes narrow. To solve the problem, a flexible seam which is not 8-connected but loosely connected is introduced. Since the flexible seam can bend acute angles, they pass through complicated interspaces.

A combination method of seam carving and face detection is also presented. Face regions are detected before seam carving, and given larger energy to be guarded.

Introduction

Seam carving is one of image retargeting algorithms [1]. For horizontal resizing, a vertical seam is defined as a polygonal line from upper end to lower end which passes through pixels whose energy is low. Similarly, a horizontal seam is defined as a polygonal line from left end to right end for vertical resizing. Image reduction is achieved by removing the seam iteratively. The shape of seam is subject to two restrictions: monotonicity and connectivity. Monotonicity means that a vertical seam must include only one pixel in each row. Connectivity restriction means that a seam must be 8-connected. The connectivity of seam is shown in Figure 1.

These two restrictions are considered simplest to form a seam, and bring simple shape of seam. Figure 2 shows all possible arrangements of consecutive three pixels in a vertical seam. There are 9 patterns of pixels. Under the above restrictions, a seam can bend at any of the following angles $\{\pi/2,\ \pi/4,\ 0,\ -\pi/4,\ -\pi/2\}$[rad]. The largest bending angle is $\pi/2$ (=1.57).

This paper focuses on image reduction for pictures including human faces, especially many human faces. It is known that unacceptable distortion is sometimes introduced in seam carving [2]. Such distortion is a common problem among various image retargeting algorithms, especially when the image is reduced drastically. Human faces are one of the most sensitive objects for distortion. In [1], it was described that a face detector is effective to get much better results in seam carving. However, the method of the combination of face detection and seam carving was not described.

For the pictures with many faces, a vertical seam is preferable to go from upper end to lower end while avoiding faces. In other word, a seam should pass through the interspace between faces. However, the interspaces are sometimes narrow in such pictures. Furthermore, the shape of interspaces is too complicated for seams to pass.

We propose a flexible seam which can bend acute angles so as to pass through narrow and complicated interspaces. The flexibility of seams achieved by easing the restriction of connectivity. In [3], discontinuous seam carving was introduced for resizing videos. The flexible seam is not discontinuous but restricted loosely connected. We also present a combination method of seam carving and face detection.

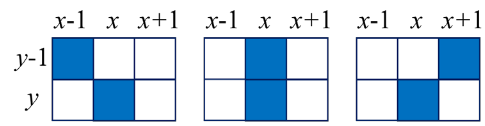


Figure 1. Connectivity of seam in the conventional seam carving. The previous pixel of (x,y) in a vertical seam should be selected among three pixels : (x-1,y-1), (x,y-1), (x+1,y-1).

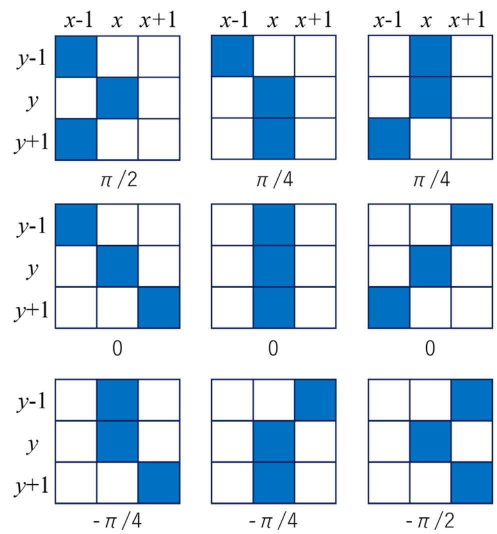


Figure 2. Possible bending angles of the conventional seam. Value presented below each diagram means the angle at the center pixel (x, y) which is formed between a line going from the pixel in y-1 to the center pixel (x, y) and a line going from the center pixel (x, y) to the pixel in y+1.

Related Works

There have been several works to consider external information such as saliency and location of objects in image retargeting based on seam carving. In [4], a saliency map that assigns visual importance to each pixels in terms of its global color and intensity contrast is introduced into seam carving to avoid artifacts. The saliency at a pixel is obtained by comparing the pixel value vector in Lab color space to the average of the whole image. In [3], the saliency cost is obtained using graph-based image segmentation. The energy function for seam carving is obtained by linearly combining the saliency cost with special and temporal coherence.

In [5], both a face map and a saliency map are considered in generating energy function. The face map indicates the position and the size of a face using a square. The saliency map is provided based on color, intensity and orientations. These two maps are linearly combined with the gradient based energy function.

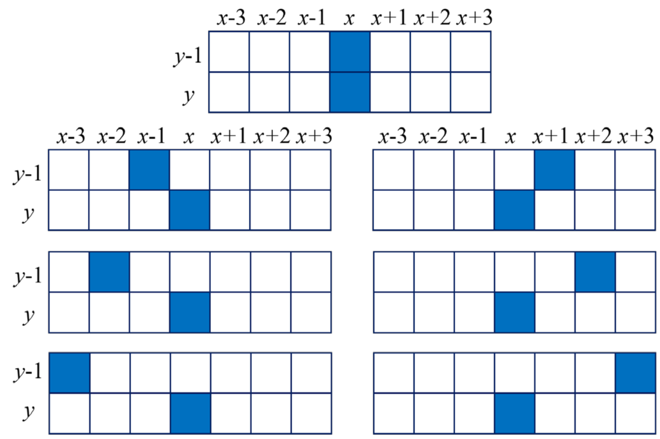


Figure 3. Flexible connectivity restriction in the proposed method. Two-pixel gap and one-pixel gap in horizontal direction are allowed. The previous pixel of (x,y) in a vertical seam should be selected among seven pixels : (x-3,y-1), (x-2,y-1), (x-1,y-1), (x,y-1), (x+1,y-1), (x+2,y-1), (x+3,y-1).

Proposed method

Flexible seam

A flexible seam which is not 8-connected but has small gaps is proposed. Figure 3 shows a scheme of the flexible seam. The top three patterns show 8-connected pairs. The next two patterns have one-pixel gap, and the bottom two patterns have two-pixel gap. In the flexible connectivity restriction, these 7 pairs are regarded as connected. A flexible seam is defined as a polygonal line which is connected using any of the 7 patterns.

The feature of the flexible seam is that it can bend at an acute angle. Figure 4 shows all possible arrangements of consecutive three pixels in a flexible vertical seam. There are 49 patterns of pixels in the consecutive three rows. Value presented below each diagram means the bending angle [rad] at the center pixel (x, y). A flexible seam can bend at an acute angle. It is noted that the largest bending angle is 2.50 in a flexible seam. The situation is the same in a horizontal seam.

Overall Procedures

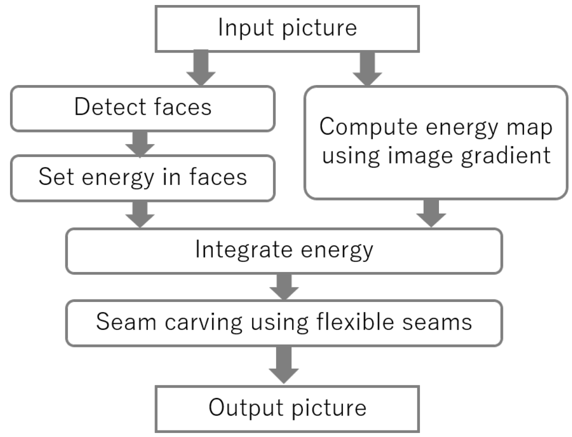


Figure 5. Overall procedures of proposed image resizing. A picture including many human faces is input.

Figure 5 shows a flow chart of overall procedures for the proposed image resizing. Face detection is combined with seam carving.

Detect faces

All human faces in the input picture are detected. We use Viola-Jones face detector [6] since it is fast and provides sufficient accuracy. The position and size of each face are obtained in this step.

Create face map

Energy for each pixel around faces is set in this step. By providing larger energy in faces than other areas, it is expected that seams do not go across faces.

First, a core area and an outer area are set for each face. Figure 6 shows an example of these two areas. The outer area is defined as a circle whose radius is twice the length of the face size and whose center is located at the center of the face. The core area is defined as an equilateral triangle inscribed in the circle.

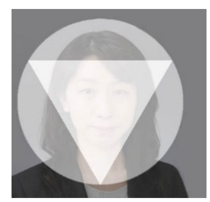


Figure 6. The core and outer areas for each detected face. The triangle on the face represents the core area. The circle around the face represents the outer area. The energy in the core area is replaced by a large constant value. The outer area is given the half as much energy as the core area.

Then, energy values are set in both areas. We give 4 and 2 as the energy for the core and outer areas, respectively. These values were determined on an empirical basis. The energy at each pixel is saved as a face map $F(x, y)$.

Compute energy map using image gradient

The energy map $E(x, y)$ is computed using the image gradient in a manner similar to the original seam carving [1]. The sum of color components (R, G, B) is used as the energy.

$$E(x,y) = \sum_{c=\{R,G,B\}} \left|\frac{\partial}{\partial x} I(x,y;c)\right| + \left|\frac{\partial}{\partial y} I(x,y;c)\right|, \qquad (1)$$

where $I(x, y)$ is the pixel value. The range of pixel value is [0, 1] in each color.

Integrate energy

An integrated energy map $G(x, y)$ is created from the face map $F(x, y)$ and the energy map $E(x, y)$ in this step. $G(x, y)$ is obtained by replacing the energy value in $E(x, y)$ with $F(x, y)$ around faces.

Seam carving using flexible seams

Seam carving based on the proposed flexible seam is performed using the integrated energy map. The flexible connectivity restriction is applied to find a flexible seam. Then the detected seam is removed. The set of processes (finding a seam and removing the seam) is repeated until the desired image size is obtained.

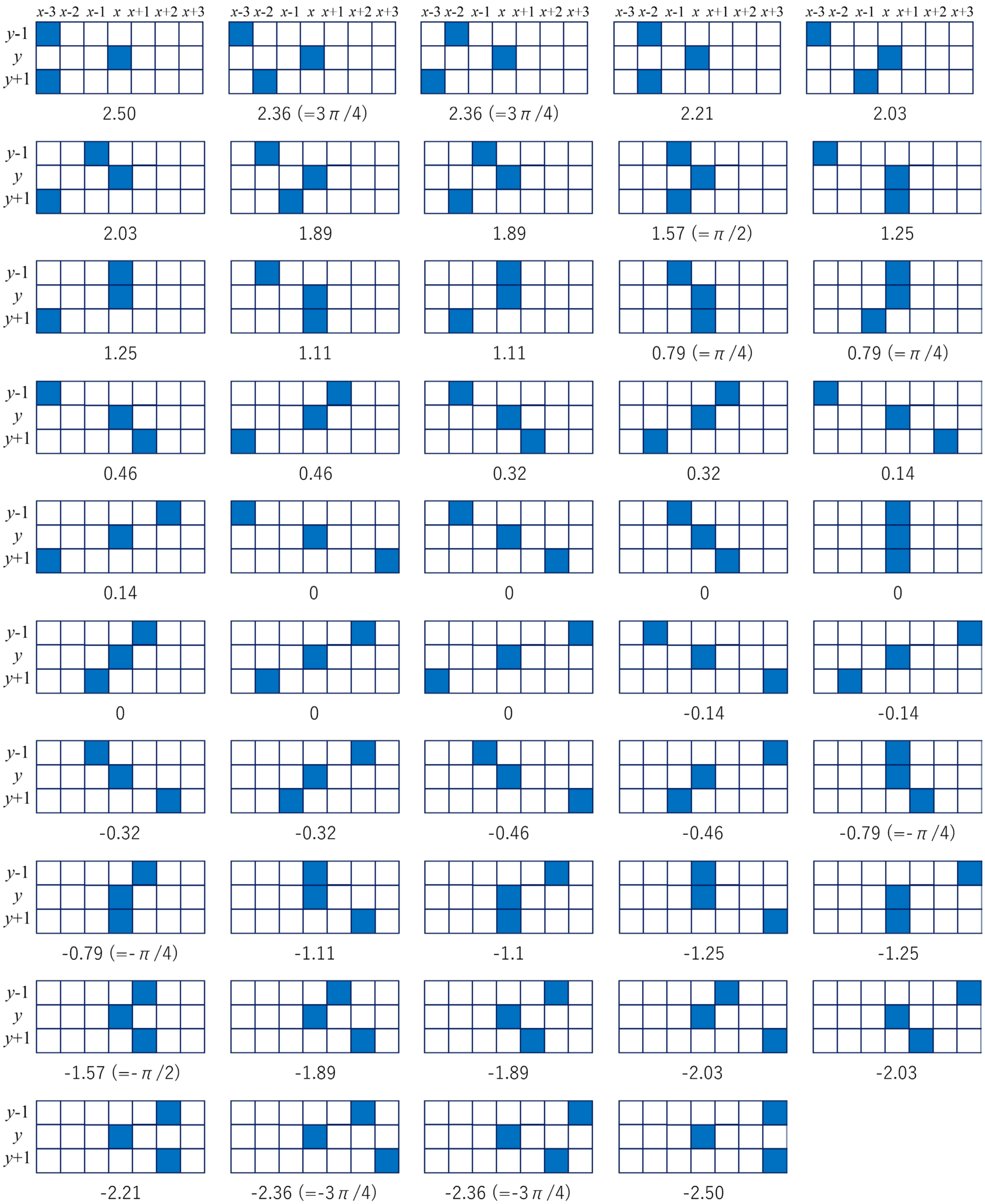
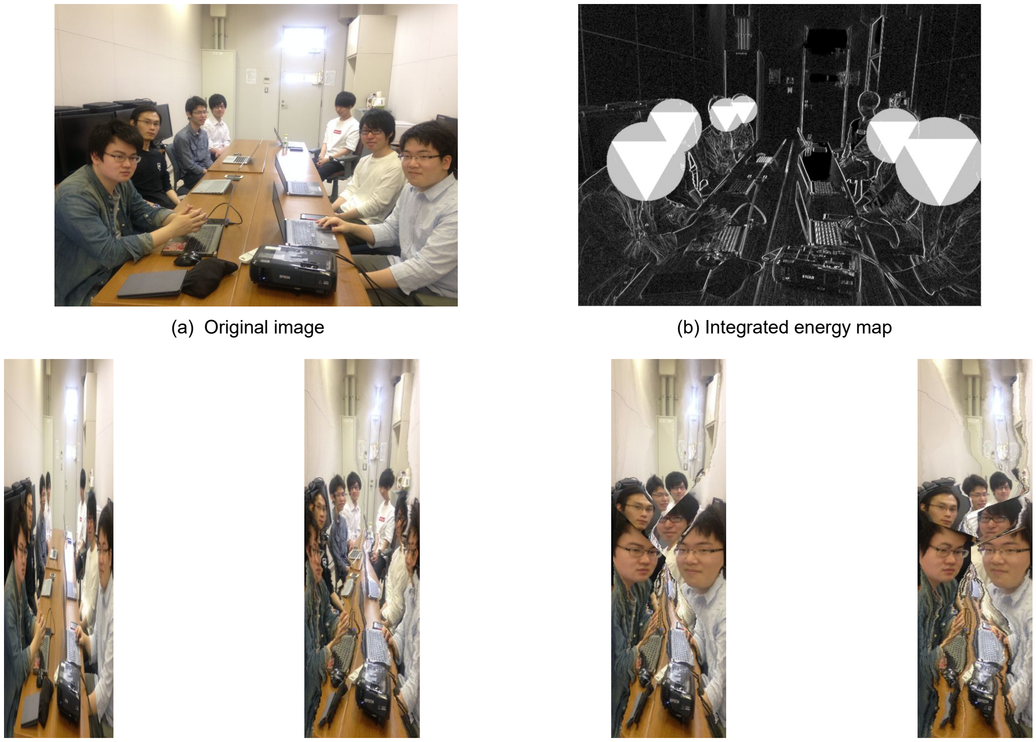


Figure 4. Possible bending angles of the flexible seam. Value presented below each diagram means the angle [rad] at the center pixel (x, y) which is formed between a line going from the pixel in y-1 to the center pixel (x, y) and a line going from the center pixel (x, y) to the pixel in y+1.



(a) Original image (b) Integrated energy map

(c) Bilinear (d) Conventional seam carving (e) 8-connected seam with face detection (f) Flexible seam with face detection

Figure 7. Experimental results of horizontal image resizing. The original image size is 816 x 612 pixels. The size of (c) – (f) is 185 x 612 pixels. The shape of faces is not preserved in (c) and (d). The distortion in faces is less in (f) than in (e).

Experiments

We tested the proposed method on a picture including seven human faces. Figure 7(a) shows the original image. (e) and (f) are results of image resizing by the procedures in figure 5. Horizontal image size is reduced by 22%. Faces were detected and integrated energy map was created. The integrated energy map is shown in (b). Six faces are detected and given extra energy. Since the faces are located close to each other, some circles are overlapped. The conventional 8-connected seams and the flexible seams were utilized for (e) and (f), respectively. As compared between (e) and (f), the shape of eyes is well preserved in (f).

(c) and (d) are also results of image resizing. (c) is obtained by bilinear interpolation. (d) is a result by the conventional seam carving in [1]. The shape of faces is not preserved in (c) and (d).

Conclusion

We introduced a flexible seam into seam carving for image resizing. An integrated energy map for combining seam carving and face detection was also introduced. It was confirmed that the method can diminish the distortion of faces when the percentage of face regions is high.

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Ikuko Tsubaki received her BS from Tokyo Institute of Technology (1995) and her PhD from the University of Tokyo (2004). She has worked in Tokyo University of Technology since 2016. Her research interest is image processing and computer vision.

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