Content-Aware Image Rotation

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***Abstract*—We knew that image rotation will result in jagged edge and image blurry, especially for dominant structure images. Here we present a novel content-aware image rotation approach based on gradient map: first, compute the gradient map for the image which describes object structure of the image. Second, take gradient map into consideration, use our proposed weighting bilinear interpolation method to rotate image that combine the gradient value and the distance together to regulate interpolation when the pixel distribute in the sharpness region. Besides, a coefficient was used to eliminate the blurry caused by average operation on local areas. Compared to classic methods, our method is faster and will achieve better result in rotating images.**

***Index Terms*—Image rotation, gradient map, weighting bilinear interpolation, content-aware.**

I. Introduction

Geometric transformation is the most popular and commonly used operation in image processing, including translation, rotation and scaling, among which image rotation is the most complicated transformation and frequently used, so it is worth researching with higher quality and efficiency. Currently, there are three classic interpolation methods: nearest neighbor, bilinear and bi-cubic interpolation. It is known that image rotation is just a remapping for each pixel and the result fully depends on the interpolation method, so the interpolation method plays a key role in image rotation.

Nearest neighbor interpolation is the simplest and fastest method that selects the nearest pixel from the source image as the interpolated point, just have pixel replication. This method is efficient and easily to implement. However, it would lead to artifacts such as blurring and aliasing around edges due to pixels shifting. Bilinear interpolation is another commonly used method, which considers the closest 2×2 neighbour of known pixels surrounding the unknown pixel. The closer to the unknown pixel, the higher proportion will be applied to it, and the final interpolation value can be gained by weighted average for these 4 pixels. This method would produce smoothness image, but meanwhile, blurry effects and zigzagging edges would be induced. Better rotation image can be achieved by using bi-cubic interpolation, which considers the closest 4×4 neighbourhood around the unknown pixel. Bi-cubic is an approximation for the function of $\sin(x\times\pi)/x$, and x represents the distance between the selected and the unknown pixels. Bi-cubic would produce desirable results, but the excessive costing on time and memory is a major constraint for its application, especially for the device which has high demand on processing efficiency.

After several testing and observation, we found that the distortion mainly concentrated in border regions, so it is crucial to preserve the structure objects and reduce staircase effect along the object borders. A good rotation method should meet the following properties: Firstly, Low time complexity. Secondly, continuous and smooth object borders. Lastly, better result under several continuous rotations.

Aiming at the above problems, there have been many attempts to keep or highlight the image contours, in which the edge-directed interpolation algorithm [1]-[2] and gradient-based adaptive interpolation [3]-[5] were used by many researchers. But edge-directed approach would consume a great deal of resources on time and memory; in addition, it also has the drawbacks for introducing more noise to the rotation result. Until now, most of researchers have introduced the gradient map into image scale but never used on rotation, here we applied the gradient map on image rotation in a novel way.

In this paper, we present a weighting bilinear interpolation method that takes object texture into consideration. Here we use the gradient map to depict the object contours, and form a part weight for each pixel. Due to take into consideration on the texture regions our method will produce continuous and clearness result with high efficiency.

II. Content-Aware Image Rotation

Image rotation is an important and basic algorithm in digital image processing, the efficiency and accuracy play an important role in image processing, it can be realized in two steps: first, have a geometric transformation, second, compute the grey value for each pixel using known pixels, commonly referred as interpolation.

A. Weighting Bilinear Interpolation

Interpolation can be achieved by using known pixels to estimate values for the unknown points. It is recognized that the human visual system takes more attention on structural regions; the quality of the image mainly depends on the sharpness of the edge and the smoothness along it. The weighting bilinear interpolation method we proposed also known as content-aware which uses the gradient map to locate the sharpness regions. Assume that $(x^{'},y^{'})$ is the pixel on the outputted image $g(x^{'},y^{'})$, and the corresponding

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pixel on the original image $f(x,y)$ defines as (u,v) , as shown in Fig. 1.

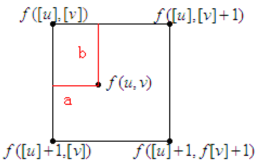


Fig. 1. The bi-linear interpolation diagram

The distance between $(u,\ v)$ and its around pixels can be described as: $a = u - [u]$, $b = v - [v]$.

The conventional bilinear interpolation method uses a and b to determine each proportion for these four pixels, but this will rise serious geometric distortion due to without taking into account the content of the image. In order to highlight and sharp the important regions, our method has a combination on the distance and gradient value for each pixel, that is, the bigger gradient value and closer distance, the more important we specified to this pixel. Gradient map which obtained through Sobel operator, here we use $G(i,j)$ to characterize it. Take pixel $([u],[v])$ for example, ("[ ]": rounding operation), the weight of which in the horizontal direction can be defined as: $W([u],[v]) = (1-a)$. If the pixels around $(u,\ v)$ distributes in the sharpness/important region, gradient value should be imposed on it to modulate its weight:

$$W([u],[v]) = (1-a)\begin{pmatrix} 2G([u],[v])/G([u],[v]+1) \\ +G([u]+1,[v]) \end{pmatrix} \qquad (1)$$

The pixel possessed high gradient value was considered as sharpness, and the threshold used to verify the characteristic of sharpness or smoothness was measured by averaging gradient values or specified a reasonable fixed value to it, in this paper, the threshold value was obtained by using the former approach and characterized as Ag. Before interpolation, normalized each weight for these 4 pixels from vertical and horizontal direction, represent as a_1, a_2 and b_1, b_2. Our interpolation operation can be obtained from two steps:

Firstly, interpolate from the vertical direction.

$$\begin{aligned} t_1 &= \lambda(a_1 v([u],[v]) + a_2 v([u]+1,[v])) \\ t_2 &= \lambda((1-a_1)v([u],[v]+1) + (1-a_2)v([u]+1,[v]+1)) \end{aligned} \qquad (2)$$

$V(i,j)$ is the R/G/B value of pixel $f(i,j)$, λ is the factor to eliminate the blurry caused by averaging on local area, typically, it is a value slightly less than 1.

Secondly, interpolate from horizontal direction:

$$g(x', y') = f(u,v) = b_1 t_1 + b_2 t_2 \qquad (3)$$

where, $b_1 = \lambda(b_1 + b_2)/2, b2 = \lambda(1-b_1)$. Due to the consideration on contour regions, our method can effectively protect the prominent domain from distortion, just as Fig. 2 (f) and Fig. 3 (e).

B. Continuous Rotations

We know that most of portable devices, such as mobile phones, pad, PSP are single document architecture, and in most cases, it is rarely possible to get the desirable result with only once rotation, so continuous rotation inevitably become the top choice for user-friendly. Continuous rotation can be described as taken the rotated image as the source one, and go through with the same operation until got the desirable result. Conventional continuous interpolation methods will rise serious aliasing effects and time costing. And worse of all, the more times running the more artefacts will leaded. Fortunately, our content-aware image interpolation approach can effectively reduce the degradation speed of the image's quality and would produce continuing and clearness result under several continuous rotations, just as Fig. 3.

C. Time Complexity Analysis

Suppose, the pixel number of image $f(i,j)$ is n . Nearest neighbor interpolation will need 2 rounding operations during interpolation, and bi-linear method will need 3 additional operations and 4 multiplication, while Bi-cubic interpolation, which considers the closest 4×4 neighbourhood, and the interpolation formula can be expressed as $\sum_{i=0}^{3}\sum_{j=0}^{3} a_{ij} x_i y_j$, 15 addition and 48 multiply operations were needed during interpolation. As described above our weighting bi-linear interpolation is an improvement for classical bi-linear, the time consuming of which is similar to bi-bilinear, only the sharpness regions of the image would use (6) expression, Table I demonstrated the above analysis. From all this, we concluded that our method is time saving compared to bi-cubic method.

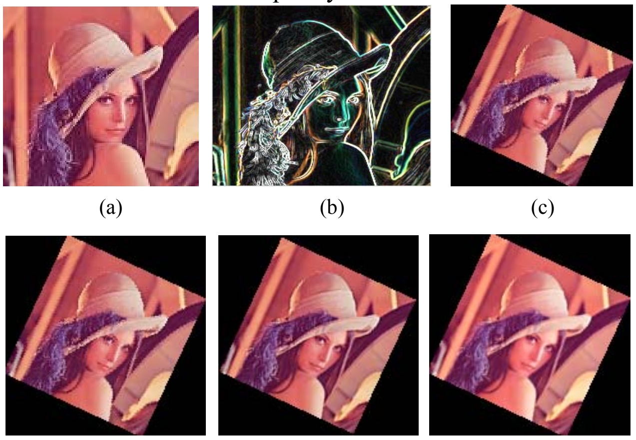
TABLE I: TIME CONSUMING WITH DIFFERENT INTERPOLATION METHODS.

Interpolation Method	Nearest N eighbor	Bilinear Method	Bi-cubic Method	Our Met hod
Lena	0.015s	0.032s	0.641s	0.079s
Lotus	0.078s	0.266s	5.469s	0.750s

III. RESULTS AND DISCUSSIONS

This content-aware interpolation method uses the gradient map to remove these jagged and obtain more smoothness edges in appearance. In this paper, we use VC++ to implement our algorithm on a computer with 2.00GHz Core Duo CPU and 1G RAM.

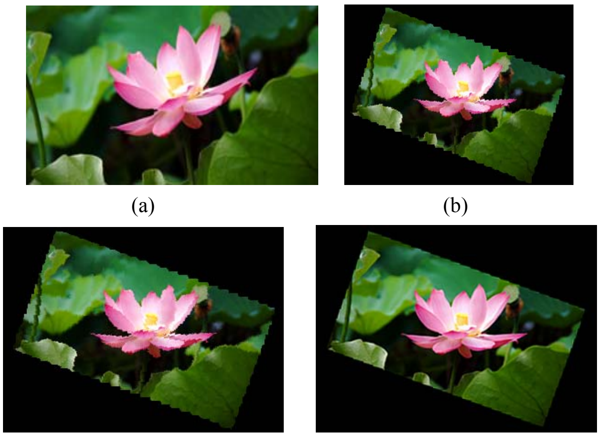
Examples are provided to show our algorithm is effective and has better results. We compared the rotation results of nearest neighbour, bi-linear, bi-cubic and our method, it can be observed that nearest neighbour and bi-linear interpolation is efficient but they will inevitably cause serious distortion and produce noticeable zigzag on structure objects just as Fig. 2 (c) and Fig. 2 (d), bi-cubic method which would produce desirable result while the high time consuming is a major restriction for its application. The time expense of nearest neighbour, bi-linear, bi-cubic and our method was listed in Table I. Take Fig. 3 for example, our proposed method removes these jagged and achieves continuous and smoothness looking edges. By comprehensive consideration, our method has an ideal combination on time and quality.



(a) (b) (c)

(d) (e) (f)

Fig. 2. Experimental results using different methods: (a) original image, (b) gradient map, (c) nearest neighbor interpolation, (d) bilinear interpolation, e) bi-cubic interpolation, and (f) our method.



(a) (b)

(c) (d)

(e)

Fig. 3. Images after four times rotation, and 5 degrees for each rotation: (a) original image, (b) continuous rotation by using nearest bilinear interpolation, (c) continuous rotation by using neighbor interpolation, (d) continuous rotation by using bilinear interpolation, and (e) continuous rotation with our method.

IV. Conclusion and Future Work

Compared with previous similar methods, our method would produce desirable quality images with high efficiency, and would keep object's boundary with smoothness transition due to take gradient into consideration.

Future research will focus on extending this approach to image resizing and portable equipment applications. It is necessary to design content-aware interpolation method to obtain desirable rotation images.

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