Image Up-scaling: Based on Self Similarity and Local Information

Xin Zheng
College of Information Science and Technology
Beijing Normal University
Beijing, P.R.China
zhengxin@bnu.edu.cn

Chenlei Lv
College of Information Science and Technology
Beijing Normal University
Beijing, P.R.China
vvvwo@qq.com

Qingqing Xu
College of Information Science and Technology
Beijing Normal University
Beijing, P.R.China
xuqingqing101@163.com

Ping Guo
College of Information Science and Technology
Beijing Normal University
Beijing, P.R.China
pguo@bnu.edu.cn

Abstract—Most of the currently used image up-scaling algorithms are based on interpolation method. As the structural information is ignored, the result image will be blurred while sharp edges are interpolated smoothly. In our paper, we proposed a fast and local structure based algorithm, combined with improvement on up-sampling techniques, to enhance up-scaling image quality. The up-scaling process are guided through the self similarity computing. The structural information of image is retained effectively in this process. Experiments prove that our method has an obvious improvement on quality of result images, especially for details of texture rendering.

Keywords- Image upscaling; image sampling; self similarity

I. INTRODUCTION

As one of the most elementary image operations, image resizing or resampling has been used for many purposes and is supported by almost all image editing software and hardware. Some image sampling algorithms have been used to change or improve the resolution. Such as use the proper linear pre-filtering method can obtain satisfactory downsampling images. But for up-sampling it is not the same case.

Widely used interpolation methods are usually difficult to achieve a balance of speed and quality. Such as bilinear interpolation method don’t need high computing capacity requirement but there will be an obvious aliasing distortion. The other optimized linear interpolation algorithm to increase the number of operations for the region pixels and the establishment of the complex equation of matching to improve image quality, which will undoubtedly increase the processing time, reduce practicality. Because of lack the needed information during up-sampling, the result images usually lack small-scale texture-related features and the sharp edges become blurry, original pixel grids are still noticeable. Although many interpolation-based up-sampling methods have been proposed, the quality of result images is not satisfactory.

In our paper, we proposed an improvement sampling approach for the low resolution images which can both reserve high and low frequency information of images; it also can give us the result images faster and more clear than others sampling algorithms. Our method has a good use of the down-sampling technology to build a complex match. Based on some appropriate modify for native up-sampling method, we consider both up-sampling and down-sampling for original image to find the relationship about the local structural information, then get a more accurate match guidance, without sacrifice for compute time. In Section 3 we will discuss how to achieve the better result from two samples match and show the new up-sampling method in section 4. We ensure the performance of the algorithm, and improve the image details upsampling performance. The last part of the experiment will clearly demonstrate the advantage of our method.

II. RELATED WORK

For image up-scaling technology, optimization model based on linear filtering are usually proposed by first. Linear filtering predicted the intermediate pixel values by linear interpolation, designed to smooth enlarged image information and intermittent areas. These principle algorithms have fast computing speed and good result for some unnatural images processing effects. However, in the natural image, some of the discontinuous information is usually necessary, and contained within a high-frequency and more complex texture area than the professional image, while using linear filtering algorithm is usually not a good performance of these complex area of natural images, often appear aliasing, fuzzy distortion. For the improvement of the linear interpolation algorithm, the local image information weights ideological be applied, through the establishment of a smooth function [2] and set control framework [3] to reduce the effect of distortion from enlarge image.

The idea of the texture synthesis model is proposed to improve the natural image details and texture appearance. The advantage of this method takes into account the local
correlation of the image texture, it is better than linear interpolation algorithm to show a nature picture. The initial texture synthesis models usually concern MRF (Markov Random Field) based on local texture. But look for the global image, these methods usually produce the interregional match results, losing overall texture structural of the original image, caused structural distortion.

Up-sampling Synthesized based on Joint Bilateral Filter algorithm is an improved texture synthesis method. The method finds the correlation exists in the degree of image by analysis the local image’s texture information, and the match is established. This method effectively shows the texture detail than simple linear filtering algorithm, it has been a marked improvement in the image upscaling quality and clarity. Because the model establishes the texture information by global analysis and improves the energy function, it has a better result to show the overall structure of the texture. However, due to the need to calculate the correlation of the image texture information, it is not good to play in the efficient image processing applications and the video stream processing performance advantages. Bayesian model is also used in up-sampling. It derives mathematical expressions for the calculation of the maximum a posteriori estimate of the high resolution image and the estimation of the parameters involved in the model.

Based local similar area from image itself [1] compared to the previous method provides a new way of up-sampling. As the presence of the local information is proportional to the characteristics of the local image, the method to establish a match between the original image and the sample image, use image similarity patch to guide sampling reconstruct the structural features of the image information. This method takes into account the characteristic of image upscaling structure. It can also be well rendering the textures in the image, as well as other mixing message characteristics.

Gilad Freedman [6] provides a good method to show structure information in image. Our method uses the similar thought from it. But Freedman’s up-sampling method is not suitable in this algorithm framework. In section 5 we will show our method’s improvement for Freedman’s.

Other idea find the same local image’s similar structural characteristics, by a similar structure model to reconstruction structure information, so that the result is able to render the structure of the original image characteristics. We have a different implement method to build the structural characteristics information in the picture. We use a mature down-sampling algorithm to create an image match to deal with uncertain in the image rather than to extract the information structure. It can avoid the distortion caused by structural imbalances.

III. FRAMEWORK OF OUR METHOD

A. Self Similarity

There is a region structurally similar characteristic in the original image, such as texture. We call such a structure similar characteristic to self-similarity. Image of the self-similar characteristic do not change no matter when the image after upscaling or downscaling. In other words, like the texture or periodic information’s structural characteristics in image should not be lost after the change of resolution. This is the problem that the original interpolation algorithm cannot solve.

The core idea of self-similar method is to find the similarity between the image region information to guide upscaling for image. For instance, in the classic Lena image, the back decorations of the hat are a regular image area. Ordinary linear interpolation method will make the area become blurred. Use the feature of regional similarity in image can save the structural characteristics of the area and have a better result. Figure 1 shows this self-similar feature.

![Figure 1. Self similarity information in the local image, it won’t be change after the upscaling.](image1)

B. The framework

In order to find such regularity exists in the local image information, the original image is sampled twice; upscaling for the original image and downscaling the result picture as follow. So we get three images: original image, upscaling image, downscaling image for the second. We build the relationship of these pictures through block matching. Specific steps show in figure 2.

![Figure 2. Self similarity method combined with two sampling](image2)
p3. With the compute of b1, b2, b3 (b2 - b3 + b1), we get the new block b and instead b1 in p2. At last, we repeat the step of generate b one by one. We get the result protect the detail of texture and structure of image, without additional time cost.

IV. Up-Sampling Algorithm

Our method should combine with an appropriate upsampling algorithm. We use our previous work [11]; synthesize the goal point value from the 9 pixel values. We divide nine pixels in the original image into two types of sampling point and non-sampling points. Threshold judge function can eliminate the non-sampling points. It has two advantages: First, non-sampling points usually mean there has the borders of the image, if add these points into fit compute would make the image boundary blurred; followed by removal of non-sampling points can reduce the amount of computation and accelerate the speed of the algorithm.

The biquadrate method’s speed is quicker than cubic interpolation, quality is better than the bilinearity interpolation, therefore from the time and the effect overall evaluation, it is the best method.

\[
g_{x'y'} = \frac{\sum_{i=1}^{9} p_i g_i}{\sum_{i=1}^{9} p_i} \quad \quad (1)
\]

Where, \(g_{x'y'}\) is the output pixel value, \(g_i\) is the input pixel value, \(p_i\) is the pixel weight (\(p_i = 1/d_i\), \(d_i\) is the distance between two consecutive points).

In figure 3, we show two examples for our methods. The figure 3 has four points: 1, 2, 3 and 4. In order to facilitate the calculation, we simplify the pixel weight, we assume the length of the pixel is 1, the distance between the center original points to the projection point is 0.5, and the distance between each peak to the projection points \(\sqrt{2} \approx 1.4\), the distance between the mid-points of the edge to the projection point is 1.0. So the corresponding weights of points 1, 2, 3 and 4 are as follows: \(1/1.4 = 0.7, 1/1 = 1, 1/1.4 = 0.7, 1/0.5 = 2\). Equivalent to about: 1, 2, 1, 4. Thus we get the formula (2) corresponding to the edge situation in figure 3(a). In figure 3(b) shows another situation, the formula (3) is corresponding to it.

\[
g_{x'y'} = (g_1 + g_3 + (g_2 * 2) + (g_4 * 4)) * 0.125 \quad \quad (2)
\]

\[
g_{x'y'} = (g_1 + (g_2 * 2) + g_3 + (g_4 * 4) + (g_5 * 2) + g_6) * 0.09 \quad \quad (3)
\]

Thus we established the whole templates for the upsampling. We try to change the weight of every pixel in the template to find the best result, such as 3, 4, 3, 8 and 4, 5, 4, 10, we obtained very similar results, but the operation time is increased. So we retain the original weight in the template. We also carried out experiments to adjust the pixel boundary threshold parameter and adjustment effect into the best condition.

V. Result

Here we compare three different effect of the algorithm in figure 4 in order to prove the advantages of our algorithm presented in texture performance and details. We selected three different bitmap comparison, characters, vehicles, landscape as subjects. In particular, we will optimize the upsampling algorithm independent to participate in the experimental comparison.

It can be clearly seen that after the upsampling, our method have a good effect of the original picture; especially to details have a more precise and natural result. The image remained original appearance, the structure of the texture is preserved, there was no obvious blurring and basically maintained the previous method of the advantages of the smoothed image.

Taking into account the future, this technology may be applied to up frequency of the video image, so processing time is very important. After testing, we found our method without self similarity part has a good performance, combined with the adaptive method of treatment is still faster than the bi-cubic interpolation method. Table 1 show our test result.

<table>
<thead>
<tr>
<th>Graphics</th>
<th>GILAD FREEDMAN's method</th>
<th>Bicubic(base on GILAD FREEDMAN)</th>
<th>Our method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lena*1.25</td>
<td>219</td>
<td>624</td>
<td>187</td>
</tr>
<tr>
<td>Lena*1.6</td>
<td>327</td>
<td>982</td>
<td>312</td>
</tr>
<tr>
<td>Motorcycle*1.25</td>
<td>453</td>
<td>1138</td>
<td>531</td>
</tr>
<tr>
<td>Motorcycle*1.6</td>
<td>686</td>
<td>1731</td>
<td>811</td>
</tr>
<tr>
<td>Landscape*1.25</td>
<td>223</td>
<td>577</td>
<td>328</td>
</tr>
<tr>
<td>Landscape*1.6</td>
<td>312</td>
<td>858</td>
<td>483</td>
</tr>
</tbody>
</table>

VI. Conclusion

Bicubic and bilinear interpolation for the performance of complex textures usually present a variety of unknown distortion, such as ringing, confusion, blurred. Using our approach makes a good solution to this problem, it maintain the original image’s structure and make it more clear and...
natural after the upscaling. We have optimized the threshold parameter of the template, adjust each pixel weight in template, and then get a more reasonable result.

In experiments, we found that the detail of texture rendering and image smoothing requires a delicate balance. For some images with obvious texture features, the process of smooth transition will cause confusion, loss of performance of the texture details. For some special pictures, you need to show a natural sense of rough and grainy, use the original interpolation method and image smoothing method will lose the performance of these details.

Self similarity approach has more obvious advantages in video processing. Video frames need the guidance of self-similar, and thus make a more coherent frame upscaling. Taking into account the adjacent frame has a high similarity, using self-similarity method of processing after the video stream will be more natural. For the current method, we will improve it to make to adapt to the processing of the video stream file. We will further optimize the algorithm, and to improve the self-similarity for the inter-frame similarity guidance, smooth video stream processing.

At the same time, we take into account the GPU acceleration technology, we will consider developing a CUDA accelerated version, to improve the video processing speed. By parallel processing, so that our method is able to real-time processing of the video stream.

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REFERENCES

Figure 4. Results using different up-sampling methods. A. the original picture; B. GILAD FREEDMAN’s; C. Bicubic interpolation; D. our method; E. detail results in red circle of list B; F. detail results in red circle of list C; G. detail results in red circle of list D.