

Fuzzy Controlled Fractal Interpolation Method for Image Resolution Enhancement

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Abstract

A fuzzy controlled fractal interpolation method for image resolution enhancement is proposed. In the method, local structures in an image are interpolated by global structures in the image based on a fractal self-similarity which is used to implement a fractal filter. The fractal filter parameters are controlled by a fuzzy reasoning. Experimental results have shown that the image quality by our method is better than the existing method.

1. Introduction

This paper describes an interpolation method for image resolution enhancement. In general, digital camera images are low resolution, and resolution enhancement techniques are essential to high resolution photographic printer output.

We propose a fuzzy controlled fractal interpolation method for image resolution enhancement. In the method, local structures in an image are interpolated by global structures in the image based on a fractal self-similarity which is used to implement a fractal filter. The fractal filter parameters are controlled by a fuzzy reasoning which is based on human subjective evaluation.

Experimental results have shown that the image quality by our method is better than the existing method.

2. Existing Methods

The most generally used frameworks are the linear interpolation, second or third order interpolation.[1,2] The defect of these methods is appearance of blur in the interpolated images because of lack of high frequency components.

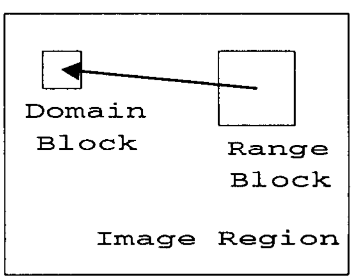

Figure 1. Illustration of the block self-similarity extraction.

Other framework is based on a fractal self-similarity. The fractal data compression method[3] can be directly applied to the image resolution enhancement problem. In the method, an image is divided into square blocks (domain block), and for each domain block, a self similar block (range block) which is larger than the domain block is searched in the image as illustrated in figure 1. By replacing domain blocks by range blocks, an resolution enhanced image is obtained. The defects of the method is appearance of block distortion.

3. Fuzzy Controlled Fractal Interpolation

From the view point of the sampling theorem, only low frequency components can be recovered by a low order interpolation. Hence, high frequency components should be estimated by employing any model which is based on a image domain or a frequency domain.

In the opposed method, low frequency components are interpolated by a low order interpolation in a image domain, and high frequency components are estimated and compensated by using a fractal self-similarity model framework in a image domain. The fractal self-similarity is used to implement a fractal filter which compensate high frequency components into a low order interpolated image. In the model, global geometrical structures in an image are utilized for the compensation of high frequency components.

Figure 2 shows the procedure of the proposed method. An image is divided into BN ($1<BN$) numbers of square blocks. In the procedure, the bi-cubic interpolation of L ($1<L$) times enlargement is employed, and the interpolated image is filtered by a fractal filter which is applied for each interpolated domain block. For each domain block, the range block which is L times larger than the domain block and the most similar to the domain block is searched in the image to be resolution enhanced. Before the calculation of the similarity, the average of intensity in a range block is normalized to the average of intensity in a domain block. The procedure of figure 2 is applied h times recursively for $L*h*100$ (%) resolution enhancement.

Figure 3 shows the block diagram of the fractal filter. The inputs of the filter are an domain block image by the bi-cubic interpolation and an fractal range block signal. The output of the filter is the fractal filtered image. The fuzzy parameter is a control signal to the fractal filter.

The fractal filtering is performed by the following equation :

$$I'(x,y)= I(x,y)+w(x,y)*(I_F(x,y)- I(x,y))$$

where,

$I(x,y)$: Intensity of an bi-cubic interpolated image, and (x,y) indicates image coordinate,
$I_F(x,y)$: Fractal signal of range block,
$w(x,y)$: Weighting function,
$I'(x,y)$: Modified intensity.

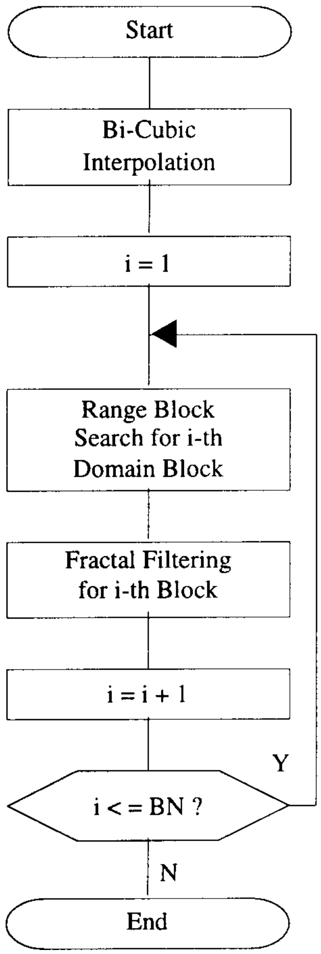

Figure 2. Procedure of the proposed method.

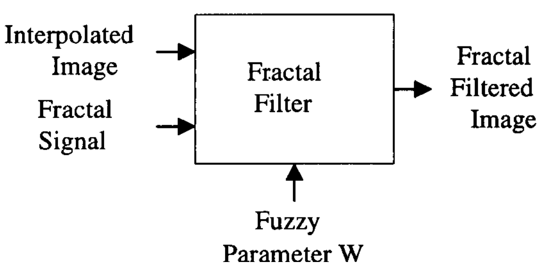

Figure 3. Block diagram of the fractal filter.

In the equation, a weighted fractal signal around $I(x,y)$ is a modification signal against $I(x,y)$. The fuzzy membership function is defined depending on the absolute difference of $|I_F(x,y)-I(x,y)|$. Where the relation between the membership function f and the weighting function w is $f=1-w$, and the smaller the membership function the larger the weighting function for the modification term. The membership function is based on human subjective evaluation.

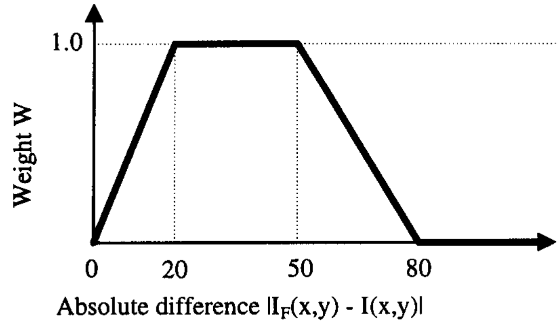

Figure 4. Weighting function based on afuzzy membership.

4. Experiments

Experiments have been performed to show the efficiency of the proposed method.

In the experiments, the parameters $L=2$, $h=4$, and the weighting function based on the fuzzy membership shown in figure 4 is used. The original images shown in Figure 5, 1(a), 2(a), 3(a) are used. Under the assumption, 1600% resolution enhanced images are generated.

Figure 5, 1(b), 2(b), 3(b) show resolution enhanced images by the bi-cubic method, and figure 5, 1(c), 2(c), 3(c) show resolution enhanced images by the proposed method. By using the bi-cubic interpolation, smooth tone images are generated, but entirely blurred. Compared with these images, smooth tone and sharp image which represents details of the corresponding resolution is generated by the proposed method. These results show the efficiency of the proposed method.

5. Conclusions

The fuzzy controlled fractal interpolation method for image resolution enhancement has been described.

In the proposed method, low frequency components are interpolated by a low order interpolation in a image domain, and high frequency components are estimated and compensated by using a fractal self-similarity model framework in an image domain. The fractal self-similarity is used to implement a fractal filter which compensate high frequency components into a low order interpolated image. In the model, global geometrical structures in an image are utilized for the compensation of high frequency components. The fractal filter is controlled by fuzzy reasoning in order to modeling and consider the characteristics of human visual system.

Experimental results by using various photographic images have shown the efficiency of the proposed method.

Hereafter, we will perform exact subjective evaluation including over 1600% resolution enhancement.

References

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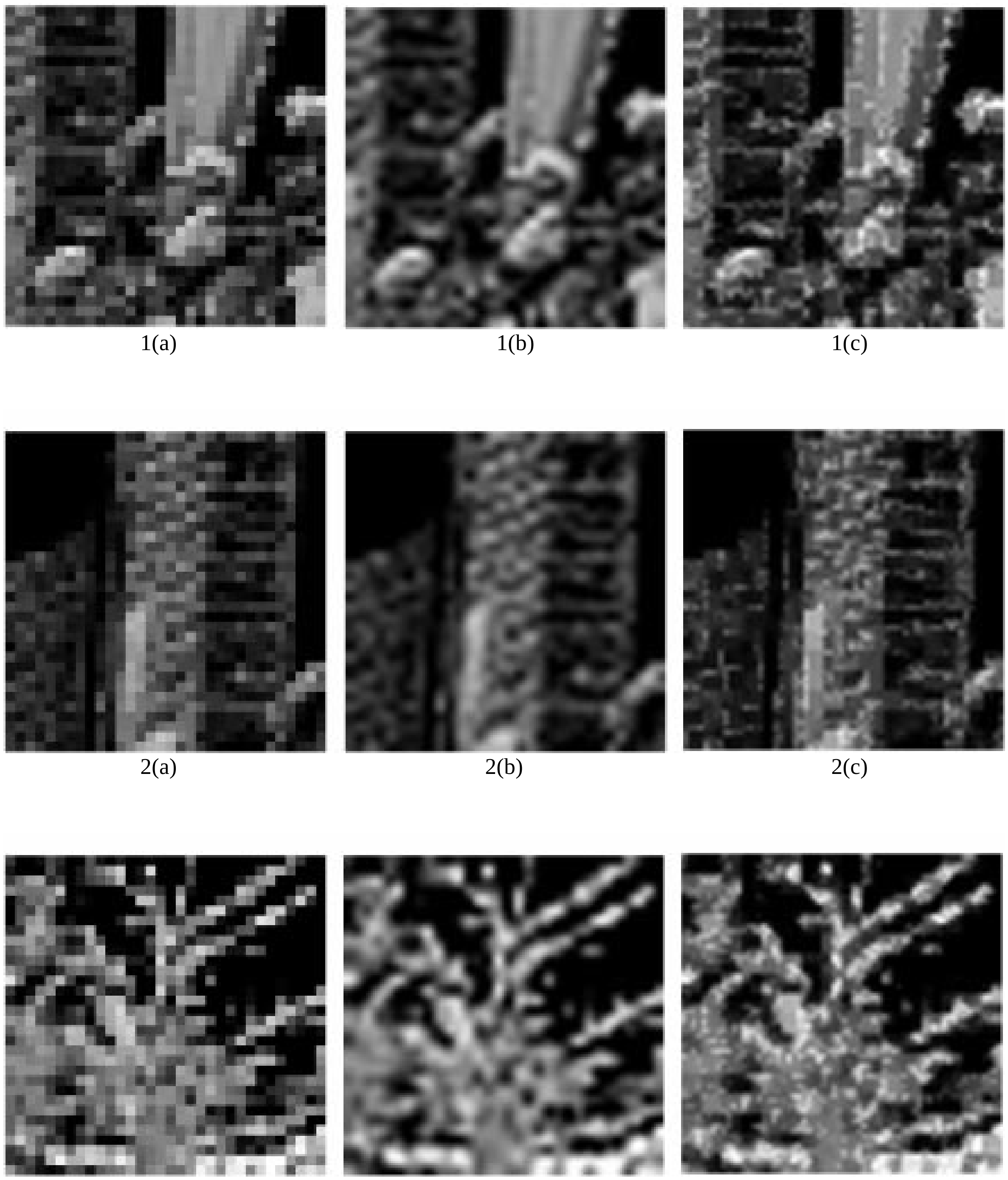

Figure 5 Photographic images of the experiments. (a) (32*32pixel) : The original images, (b) (512*512pixel) : The bi-cubic interpolated images, (c) (512*512pixel) : The interpolated images by the proposed method.