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Research Article

An Algorithm for Amplified Image Enhancement based on Image Interpolation

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Abstract: An magnified image enhancement algorithm is presented in this study. Image interpolation is an important image magnification tool, but the magnified image has not been changed by the traditional image interpolation methods even if the magnified image is not satisfaction. Basically, the interpolating surface is determined uniquely for the given interpolating data. Namely the interpolating surface (magnified image) is fixed when the interpolating data (gray value of original image) is given. If the magnified image needs to be enhanced, another enhancement method must be chosen after image magnifying. The image magnification and enhancement are separated. The image natural attribute will be effected. To overcome the disadvantages of the traditional methods, a new method which combined the image magnification and enhancement is proposed. A bivariate rational interpolation with parameters is used in the algorithm. The value of the interpolating function at any point in the interpolating region can be modified under the condition that the interpolating data are not changed by selecting the suitable parameters. Using the surface control, the enlarged image enhancement is implemented. The experiment shows that the algorithm is efficient.

Keywords: Bivariate rational interpolation, image enhancement, image magnification

INTRODUCTION

Producing visually natural images or transforming the image such as to enhance the visual information within, is a primary requirement for almost all vision and image processing tasks. Methods that implement such transformations are called image enhancement techniques. The aim of image enhancement is to improve the interpretability or perception of information in images for human viewers. The task of image enhancement is a difficult one considering the fact that there is no general unifying theory of image enhancement (Munteanu and Rosa, 2004).

Image magnification (Interpolation) is an important research topic in the area of image processing. The focus of image magnification problem is how to keep good visual resolution and definition. Popular methods, as commonly used in image/video software and hardware products, are nearest-neighbor interpolation, bilinear interpolation, cubic convolution interpolation and cubicspline interpolation (Castleman, 1998; Keys, 1981). In order to enlarge the image, the polynomial interpolation functions usually is used in traditional methods. The unpleasing blocky appearance could be produced easily using the traditional algorithm. In recent years, people's visual perception is nonlinear interpolation (Carrato and Tenze, 2000; Malgouyres and Guichard, 2001; Yoshimitsu and Takeshi, 2007). Comparing with the traditional method, the effect of image magnification have been improved highly. But the reproduction quality of any image interpolation algorithm primarily depends on its adaptability to varying pixel structures across an image. In fact, modeling of nonstationarity of image signals is a common challenge facing many image processing tasks, such as compression, restoration, denoising and enhancement. Thus, when the local magnification effect is not satisfying such as changing the local average gray level, decreasing the image contrast and so on. The enlarged image has not been enhanced for the image local when those methods are adopted.

A bivariate rational interpolation has been constructed and studied (Duan *et al*., 2006a; Zhang *et al*., 2007). The bivariate rational interpolating function which based on function values has piecewise explicit rational mathematical representation. The expression is piece wised and each piece has its parameters for adjusting. Namely the interpolating data is controlled through selecting the suitable parameters. Using the image data to get interpolation surface, resampling the gray value on the magnified interpolating surface with an magnification scale, the magnified image based on resampling can be obtained. The gray value can be modified when the magnified image is not satisfaction. The magnified image can be enhanced though the gray value modification to increase the image contrast. The experiments show the interpolating surface control and the effect of the enhanced image.

Problem statement and preliminaries:

Interpolation function:
Let Ω: [a, b; c, d] be the plane region, $\{(x_i, y_j, f_{ij}), i = 1, 2, \ldots, n, n+1; j = 1, 2, \ldots, m, m+1\}$ are the given set of data points. For any point (x, y)$\epsilon[x_i, x_{i+1};\ y_j, y_{j+1}]$ in the xy−plane, let $h_i = x_{i+1} - x_i, \theta = \frac{x-x_i}{h_i}$ and $l_j = y_{j+1} - y_j, \eta = \frac{y-y_j}{l_j}$. For each pair (i, j), i = 1, 2, …, n−1 and j = 1, 2, …, m−1, define the bivariate rational interpolating function $P_{i,j}(x, y)$ on $[x_i, x_{i+1}; y_j, y_{j+1}]$ as follows:

$$P_{i,j}(x,y) = \sum_{r=0}^{2}\sum_{s=0}^{2}\omega_{rs}(\theta,\alpha_i;\eta,\beta_j) f_{i+r,j+s} \tag{1}$$

Surface control: For the interpolation defined by (1), since there are parameters, when the parameters vary, the interpolating function can be changed under the condition that the interpolation data are not changed. Thus, the interpolating surface vary as the parameters vary. Based on this, the shape of the interpolating surface can be modified by selecting the suitable parameters.

For any point (x, y) in the interpolating region $[x_i, x_{i+1}; y_j, y_{i+1}]$. The question is that if the practical design requires the value of the interpolating function at the point (x, y) be equal to a real number M. Namely:

$$P_{i,j}(x,y) = \sum_{r=0}^{2}\sum_{s=0}^{2}\omega_{rs}(\theta,\alpha_i;\eta,\beta_j) f_{i+r,j+s} = M. \tag{2}$$

If there exist parameters α_i and β_i which satisfy (2), then the problems are solved. Following a complex series of steps, Eq. (2) becomes the following Eq. (3). It is called control equation (Duan *et al*., 2006b):

$$X_0\alpha_i\beta_j + X_1\alpha_i + X_2\beta_j + X_3 = 0 \tag{3}$$

Theorem 1: Let $P_{i,j}$ (x, y) be the interpolating function defined by (1) and let the point (x, y)$\epsilon[x_i, x_{i+1};\ y_j, y_{j+1}]$ in the xy−plane, M is a real number, then the sufficient condition for the value of the interpolating function $P_{i,j}$ (x, y) at the point (x, y) to be equal to a real number M, is that there exist positive parameters α_i, β_i such that the Eq. (3) holds.

For any given real number M, from (3), there are varied expressions, so manifold control scheme can be derived.

Image resizing and local enhance: Given a $m \times n$ image $I_{m,n}$. Let $f_{i,j}(0 \le i \le m-1, 0 \le j \le n-1)$ be the gray value of the i line and the j row of $I_{m,n}$. The pixel coordinate is (i, j). Denote $I_{m,n}$ as a two-dimension discrete signal which sample at integer points. Let the gray value of each pixel as data point. The continuous interpolating surface can be constructed based on bivariate rational interpolation for discrete image. How to construct the surface $P_{i,j}$ (x, y) using the points $f_{i,j}$, $i,j = 0, 1, \ldots, n-1$. Firstly, matrix $f_1 = \{f_{i,j}, 0 \le i \le m-1, 0 \le j \le n-1\}$ is expanded into $f_2 = \{f_{i,j}, 0 \le i \le m, 0 \le j \le n\}$. Thus, the values of $f_{i,j}$ (i = m, j = n) are added.

Let $f_{m,j} = 2f_{m-1,j} - f_{m-2,j}$ $(0 \le j \le n-1)$, $f_{i,n} = 2f_{i,n-1} - f_{i,n-2}$ $(0 \le i \le m-1)$. Then expand f_2 to $f_3 = \{f_{i,j}, -\le i \le m, -1 \le j \le n\}$ which is similar to expand f_1. The last number of $M \times N$ as 3×3 interpolation surface $P_{i,j}$ (x, y) is constructed based on f_3. On each interval $[x_i, x_{i+1}] \times [y_j, y_{j+1}]$, i, j = 0, 1, …, n-2. The interpolating function have $f_{k,l}$ and parameters α_i, β_j, k = i, i + l, l = j, j+1. Let $f_{k,l}$ as the gray value of the pixel. All patch are put together to form the surface P(x, y) with C^1 continuation. In fact, resampling the gray value is to enlarge the discrete image. From above, bivariate rational interpolating spline surface P(x, y) is constructed based on image data. Resample progress is acted on the enlarged interpolation surface with an enlargement scale, then image magnification can be obtained.

A m'×n' digital image I'(x', y') is interpolated from a $m \times n$ digital image I(x, y). The enlargement multiples at i and j direction are $x_{scale} = \frac{n'}{n}, y_{scale} = \frac{m'}{m}$. Then the location of resample point I'(i', j') corresponding to the original image I(x, y). Namely, $x_0 = \frac{i'}{x_{scale}}, y_0 = \frac{j'}{y_{scale}}$. Let the sign of this resample point for original image as i = int(x), j = int(y) where int() is the integer function.

Substituting x_0, y_0 into $P_{i,j}$ (x, y) the gray value of the new interpolating pixel can be derived. If the effect of enlarged image is not ideal, it can be adjusted through selecting the suitable parameters. It is the basic principle to modify the interpolation surface using the parameters. Thus the gray of enlarged image is modified, until the satisfactory results are obtained.

MAIN RESULTS

- Using the property of the surface control, the local enhancement of the enlarged image is implemented successfully.
- The results show that this algorithm is effective for the enlarged image enhancement.
- Comparing with the traditional algorithms, this algorithm has small quantity of calculation and strong robustness.

EXPERIMENTS

Surface control: Let Ω: [0, 2; 0, 2] be the plane region. The interpolating function defined by (2) can be constructed in [0, 1; 0, 1] for the given positive parameters α_i and β_j. The following interpolation data are given $f_{i,j} = 2.0$, $f_{i,j+1} = 1.0$, $f_{i,j+2} = 3.0$, $f_{i+1,j} = 4.0$, $f_{i+1,j+1} = 3.0$, $f_{i+1,j+2} = 2.0$, $f_{i+2,j} = 3.0$, $f_{i+2,j+1} = 2.0$,

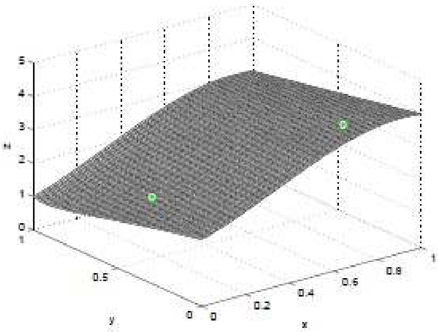

Fig. 1: $\alpha_i = 0.02$; $\beta_j = 24$

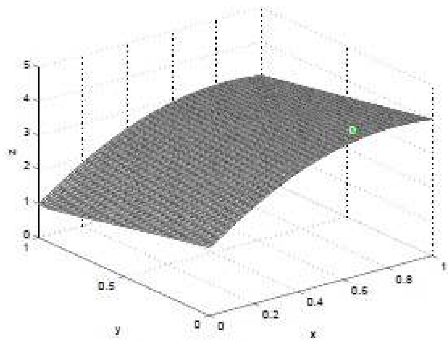

Fig. 2: $\alpha_i = 0.02$; $\beta_j = 24$

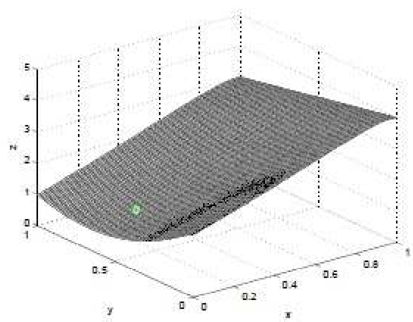

Fig. 3: $\alpha_i = 8.0$; $\beta_j = 0.04$

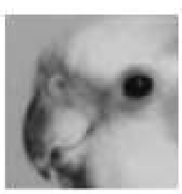

Fig. 4: original

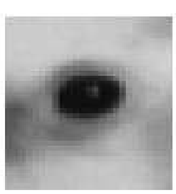

Fig. 5: Local

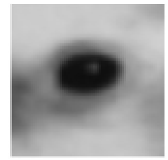

Fig. 6: Bilinear interpolation

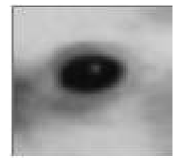

Fig. 7: Bivariate interpolation

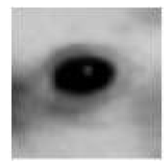

Fig. 8: Enhancement

$f_{i+2,\ j+2} = 1.0$. Let $\alpha_1 = 1.0$, $\beta_1 = 8.0$. Figure 1 shows surface $P_1(x, y)$.

In this case, the point $P_1(0.8, 1.0; 0.1, 8.0) = 3.88$ and $P_1(0.3, 1.0; 0.7, 8.0) = 2.0$. From the point control equation, the point value can be control through parameters modification. Then the surface can be constrained to be "down" or "up". From (3) the control equation of point $P_1(0.8, 0.1)$ is derived as follow:

$$-0.0640\alpha_i\beta_j - 0.5018\alpha_i + 0.0032\beta_j - 0.0364 = 0$$

It is easy to get a solution of above equation $\alpha_i = 0.02$, $\beta_j = 24.0$. Figure 2 shows the graph of the rational interpolation surface $P_2(x, y)$. $P_2(0.8, 0.02; 0.1, 24.0) = 4.0$. The point $P(0.8, 0.1)$ is modified through control equation. Then the shape of the surface becomes "up". As the same, Fig. 3 shows the graph of the rational interpolation surface $P_3(x, y)$. In this case, $P_3(0.3, 8.0; 0.7, 0.04) = 1.5$. The point $P(0.3, 0.7)$ is constrained. Then the shape of the surface becomes "down".

Amplified image enhancement: To test the performance of our methodology, the traditional algorithm, bivariate rational interpolation algorithm and the enhancement algorithm which based on surface control are all used. Figure 4 is the original image eagle. Figure 5 is the local region of the original image. In accordance with the human visual habits, the eagle-eye is the very important region for this image magnification. The image is enlarged to 4 times in the local region using bilinear interpolation algorithm, as Fig. 6 shows. Figure 7 is enlarged to the same times using bivariate rational interpolation algorithm. From the figure showing, obviously the latter is more effect than the former. But the contrast is not very satisfactory. Through selecting suitable parameters to enhance the contrast in the region of the eagle-eye, the more effective result is obtained as Fig. 8 shows.

CONCLUSION

The bivariate rational interpolation with parameters as the image magnification method has enhancing function for enlarged image. When the parameters vary, the interpolating function can be changed under the condition that the gray value of the original image (interpolation point) is not changed. But the gray value of the enlarged image (interpolating surface) vary as the parameters vary. Namely, the interpolating function has a variety of forms according to the different parameters. Comparing with the traditional algorithm, the image magnification is adjustable using this algorithm. According to an individual's visual habits, people can select different image magnification effect.

There are still several questions that remain unclear. Up to now, it is very difficult to select the optimal solution of the control equation and to determine the optimal effect. We are currently working on these problems.

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