A Method for High Precision Enlargement of Pictures taken by Cellular Phone on Personal Computer

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ABSTRACT

In this paper, we propose a method to enlarge and display images of picture with high precision and scalability taken by cellular phone on personal computer without producing jaggy noises.

One of the major problems we face in image enlargement is the amplification of the jaggy edges. To deal with this problem, we first detect the edges, and approximate them using three kinds of functions including straight line, arc and quadratic curve. In addition, the color information of the enlarged image is determined by interpolation using quadratic Fluency DA function, which is subsequently merged with the edge information obtained earlier. This enables the construction of a high precision and scalable image that cannot be produced by conventional image coding method such as JPEG or MPEG. The proposed method is evaluated by applying to images taken by cellular phone equipped with CCD camera to demonstrate its effectiveness.

Keywords: High Precision Picture Enlargement, Fluency sampling functions, Cellular Phone

1 Introduction

Nowadays, communication with image data has become a part of human life. In Japan, more than 90and the tendency has spread in the world. Howerer, an image that is taken by the camera of a cellular phone is limited in resolution because of limit of memory or hardward, ete.. As a result, the enlargement technique of the digital image with high precision and scalability has been important subject.

As a enlargement technique, the interpolation process based on Bi-Cubic sampling function is one of the most popular method. The interpolation process is realized by convolution between the original data and the Bi-Cubic. Since the Bi-Cubic has infinity vibration, approximated function of Bi-Cubic is introduced in real calculation.

Recently, other approaches that use super resolution or wavelet analysis have been introduced. Since they require iterative processing, the calculation cost is longer when compared with methods based on the interpolation process.

The common problem of these methods which is appearance of the jaggy noise has been reported. Because digital images are consisted of discreted pixels, the common problem has been reconized as inevitable in enlarged image.

Since edges information is great influnce to quality of image, in order to improve the quality of an enlarged image, the problem has to be improved.

In this paper, we propose a method to enlarge the images with high precision and scalability. The proposed high precision and scalable coding method for digital images is largely consisted of two processes.

The first process is the encoding of edge information that exist boundary of objects. Specifically, it is the establishment of an edge extraction method by an application of the Fluency AD function system based on the Fluency information theory[1][2]. First, outlines in the digital image are detected by Laplacian approach that has served as the basis for edge detection[3] The detected edge is approximated by three kinds of functions that include straight line, arc and quadratic curve. Concretely, the theoretical basis of this process is the classification of the Fluency signal spaces based on the times of continuous differentiability.

A straight line is represented by Fluency DA function of degree 1. An arc is approximated by $m =$ class. A free curve is described by functions of degree 2 which means only one time continuously differentiable.

By using this method, edge lines contained in the image can be represented by three types of Fluency DA function.

- The straight lines : Functions of degree 1
- The free curve : Functions of degree 2
- The arcs : Functions of infinity

Next, the enlargement process is performed. The edge information that has been determined based on 3 kinds of functions. Also, the color information of an enlarged image is determined by using quadratic Fluency DA function[4], which is subsequently merged with the edge information. This enables the construction of a high precision and scalable image that cannot be realized by conventional coding method such as JPEG or MPEG.

The proposed method can obtain the result image which represent the boundaries of image clearer than the conventional methods as bi-linear method and bicubic interpolation.

In the case of sinc function used in the bi-cubic, the function show an infinite attenuation in the time domain. As a result, the problem that error was introduced due to truncation was unavoidable. However the Fluency DA function(we called it "C-type") is compactly supported. It means proposed function can avoid truncation error.

The proposed method is applied to the image taken by cellular phone equipped with a CCD camera, to demonstrate its effectiveness.

The remaining of this paper is organized as follows. We review the motivation of this paper in Section 2. Two-variables sampling function is transformed to fit the direction of the detected edges, will be presented in Section 3. This proposed method is implemented and is compared with the conventional methods in Section 4. The concluding remarks are given in Section 5.

2 Equipment

In Japan, a camera is attached to the cellular phone that has become the standard function of a cellular phone. To input a note, a drawing and a photograph in the PC, the scanner has mainly been used. A cellular phone equiped with a camera can be the basis for new input methods to replace a scanner. A photograph taken by a camera equipped cellular phone can be easily sent to a PC by attachi to a e-mail or by connecting and transmitting to PC. When enlarge the image using major conventional methods(nearest neighbor, bilinear interpolation and cubic convolution), edge of an image has jaggy noise or faded. In this paper, proposed method paid its attention to the edge of the image which was not being taken into consideration in the conventional method. The enlargement method of the picture which observed the form of an edge is proposed. In case enlargement a picture using conventional sampling function, due to the cut both ends, there make a problem of producing a truncation error. Then, by applying our original information theory, "Fluency Information Theory" make it possible to edit under high quality and scalable. The following chapter describes the concrete enlargement method

3 Fluency sampling function

3.1 Overview of Image Enlargement

There are largely two processes in our approach to enlarge and display pictures taken by cellular phone on personal computer. First, to chose an outline point is the digital picture using the gradient of the Laplacian approaches. We use Laplacian filter in order to extract the outline point where the slope changes more than the neighboring values. When an outline point exists 8-neighbor-connection, they are classified into one block. The blocks whose sizes are less than a fixed threshold may be noise or a texture and will be removed. Then, joint points between the different kinds of segments on the original image are extracted in three successive stages. In the first stage, right-angled corner points and end points of straight line are extracted based on the digital curvature. In the second stage, the sets of contour points extracted in the first stage are approximated with Fluency functions of degree 2. Based on the analog curvature computed along the approximated contour, joint points between arcs and straight lines are precisely extracted and added. In the third stage, joint points that are made redundant by the merging of two consecutive lines or arcs are removed.

3.2 Fluency sampling function for interpolation

According to the shannon's sampling theorem[4], restoration of band limited signals is guaranteed by the use of the sinc function. Therefore, sinc function has been used as the sampling function in general.

The conventional sampling theorem targets, however, shannon's sampling theorem deal with continuous signals as well as non-continuous one. This means a signal containing discontinuities, which often appear in image as edges, cannot be restored precisely by the sinc function. As such, it can be said that the sinc function is not always suitable function for applying to image representation. For this problem, one of the author proposed "Fluency Information Theory" in order to appropriately deal with actual signals. In this theory, signals are classified based on their continuous differentiability and the sampling function in each class. For example, discontinuous signals can be represented by using a sampling function that belongs signal space conposed rectangular function. Here, we will describe the sampling functions in Fluency information theory. Let, ${}^mS$ denotes the signal space composed by the function system $\{{}^m\psi\}_{l=-\infty}^{\infty}$ as follows,

$$ {}^mS \triangleq [{}^m\psi(t-l\tau)]_{l=-\infty}^{\infty}, {}^mS \subset L_2(\Re), m = 1, 2, ... $$

Where τ is the sampling interval. When $m \leq 2$, ${}^m\psi$ is represented as a piecewise polynormial of degree $(m-1)$ with $(m-2)$ times continuously differentiable. When $m = 1$, ${}^m\psi(t)$ is a rectangular function that is non-continuous but non-differentiable at $t = \pm\tau/2$. When $m = 2$, ${}^m\psi(t)$ is triangular function that is continuous but non-differentiable at $t = \pm\tau$.

We proposed Fluency sampling function(we called it "C-type") which can carry out high speed and high accuracy calculation. The sampling function with compact support is represented as linear combination of function systems composed of 2 degree. C-type function which are $m = 3$ class is denoted as follows:

$$ {}^3_{[c]}\psi(t) = -\frac{1}{2}{}^3\psi(t+1/2) + 2{}^3\psi(t) - \frac{1}{2}{}^3\psi(t-1/2) \qquad (1) $$

The Fluency DA sampling function with compact supported. The ${}^3_{[c]}\psi(t)$ has next features.

- The Fluency DA function has compact support which converges to 0 at the left and right 2_{nd} sample
  ${}^3_{[c]}\psi(t) = 0, for\ |t| \geq 2$
- The function is symmetrical on the center of $t = 0$.
  ${}^3_{[c]}\psi(t) = {}^3_{[c]}\psi(-t)$
- Only one time continuously differentiable

3.3 Interpolation using Fluency sampling function

Here, we will define a two-variables sampling function based on ${}^3\psi_k$ function to interpolate gray level data, which is distributed in two-variables plane.

Definition

We define a two-variables sampling function as follows:

$$ {}^3_{[S]}\zeta(x, y) = {}^3_{[S]}\psi(\sqrt{x^2 + y^2}) $$

Here, ${}^3_{[S]}\psi(t)$ is a two-variable sampling function described in the previous section. This way, a sample point will equally affect the points that are equidistantly located from it. The contour of this two-variables sampling function is shown in Fig.1.

4 Enlargement with adaptive sampling function

4.1 Transformation of Two Variables Compactly Supported Fluency Sampling Function

In this section, to remedy jaggy edge problem, we transform the two variables sampling function to fit along the direction of the edges as seen in Fig.2.

If the sampling function is correctly transformed along the edge direction, edges can be enlarged smoothly.

In order to apply the transformed sampling function to enlargement of general images, their edge direction

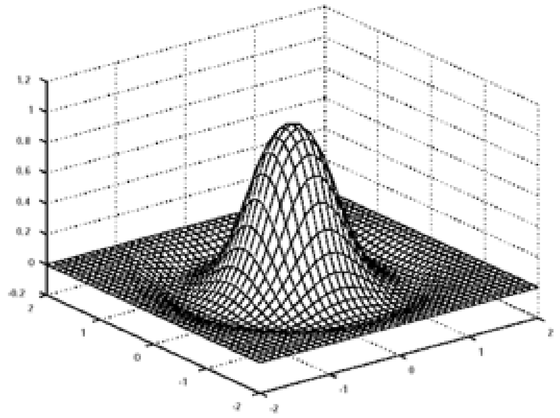

Figure 1: Two Variables Compactly Sapported Fluency Sampling Function

must be decided adaptively. In the next section, the process to decide the edge direction will be presented.

4.2 Decision of edge direction

In our method, the edge direction is decided mainly by using local information. The result is then optimized by employing global information.

4.3 Edge detection

The Laplacian filter is used to detect the edges. At an area where the edges are gathered and form complex shape, the jaggy edge is not noticeable. In contrast, the jaggy edge appears clearly at an area where the shape of the edge is smooth and continuous. Therefore, we will detect such areas and treat such edges specifically.

4.4 Local decision of edge direction

To find the edge direction, the least squares method based on the principal component analysis is used. The least squares method is a technique to find a line that the best fits to the given set of points. In other words, it gives a line whose sum of the distance from it each point is the least. This line is called a regression line. Here, we apply the least squares method to the edge pattern and assume that the direction of the regression line to be the direction of edge. First, the regression line is searched in 3×3 pixel neighborhood area. There are some cases where the regression line is not uniquely decided. In such cases, the direction is decided using additional global information of the neighboring edges, whose direction is already decided.

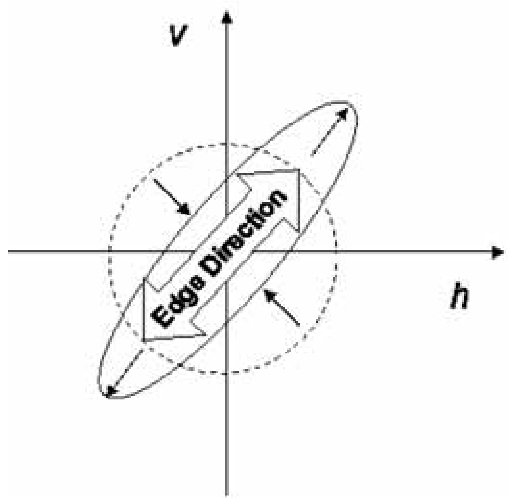

Figure 2: Transformation of Two Variables Fluency Sampling Function

The direction is expressed in a vector form and is called the direction vector.

4.5 Optimization of direction

We have explained in the previous section that the local information is used is deciding the edge direction. In this process, the global edge shape is not yet considered, and the decided direction does not always match the global edge shape. To solve this problem, the decided direction vector is employed. All decided direction vectors in a 5×5 pixel area, of which the center is the referenced edge, are added. Vectors of the edges, which are not connected to the referenced edge, are excluded. A weight which is inversely proportional to the distance from the center is given for each vector.

4.6 Adaptive sampling function

To elliptically transform a two variables sampling function, the ratio of the long axis to the shot axis is necessary. We call this ratio the shape coefficient. The shape coefficient is computed by using the information of the neighboring edge pattern. That is, if some edges exist in the direction of the referenced edge and if their direction match the referenced edge direction, the shape coefficient is set to make the transformation larger. In contrast, if there are no edges in the direction of the referenced edge, the coefficient is reduced to restrict the transformation.

Adaptive sampling functions are generated according to the determined edge direction and the shape coefficient. That is, if we let a_γ, be the shape coefficient and θ be the edge direction, the mapping of (x, y) to (x'', y'') is given as follows:

$$\begin{pmatrix} x'' \\ y'' \end{pmatrix} = \begin{pmatrix} cos\theta & sin\theta \\ -sin\theta & cos\theta \end{pmatrix} \begin{pmatrix} x' \\ y' \end{pmatrix}$$

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \frac{1}{\alpha} & 0 \\ 0 & \frac{1}{\beta} \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$

here, $\alpha = \sqrt{a_\gamma}, \beta = \frac{1}{\sqrt{a_\gamma}}$.

Two variables sampling function on this mapping plane is the required adaptive sampling function. Enlargement is executed by using adaptive sampling function generated for each edge pixel. A normal two-variables sampling function is used at a non-edge pixel.

5 Experimental results

The proposed method including adaptive sampling function is implemented and is applied to actual image data. The result is compared with images reconstructed by conventional methods: nearest neighbor, bilinear interpolation and cubic convolution.

Fig3-B, Fig3-C and Fig3-D are enlarged Fig.3-A by 20 times. Fig.3-B shows the diagonal jaggy edge of an image enlarged by the nearest neighbor method is conspicuous. As for Fig.3-C and Fig.3-D, edge of an image is blurred. On the other hand, the result of proposed method shown in Fig.3-D, reveals that the jaggy edge is not noticeable because of an edge is enlarged smoothly by an adaptively transformed sampling function.

According to this subjective evaluation, the proposed method is effective to reduce the influence of the jaggy edge.

6 Conclusion

We have proposed a method to enlarge and display images of picture with high precision and scalability taken by cellular phone on personal computer without producing jaggy noises. In this method, a one dimensional sampling function in the fluency theory was extended to two-variables to interpolate the image data. In order to remedy the jaggy edge problem, we proposed a two-variable sampling function that is transformed to fit the edge direction. To evaluate its effectiveness, the proposed method is implemented and applied to actual image data. The result shows that our method is effective to improve the quality of enlarged images. As for the future, more precise evaluation will be performed. Also, more intelligent process in deciding the edge direction will have to be developed to improve the effectiveness of the proposed enlargement method.

Figure 3-A: Original Image

Figure 3-B: Nearest Neigbor

Figure 3-C: Bi-linear

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Figure 3-D: Bi-cubic

Figure 3-E: Proposed method

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