

INTERPOLATION ALGORITHMS FOR IMAGE SCALING

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Nowadays, the tendency for image visualization is deviates, which have determined resolution, to be used more and more. Image resampling is essential for the purpose of correct image visualization. In this paper, parallel between different resampling algorithms is made, and as basis for this comparison are used three methods: Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR) and Subjective Evaluation (SE). In the present paper are given qualitative and quantitative results from the execution of the above algorithms upon special, designed for the purpose, vector graphics and selected photographs. The method offered is a useful tool for doing simple tests.

Keywords: Resizing, Scaling, Image Interpolation, MSE, PSNR

1. INTRODUCTION

Image resizing or scaling (magnification or reduction) is one of the main operations in image processing. It is done whenever resolution change has to be done. For example, in the last few years, for viewing images and video are used devices with fixed resolution, more and more, such as plasma panels and LCD displays. Digital resizing is also applied for scaling of video data of devices based on Digital Micromirror DeviceTM (DMDTM) technology, developed by Texas Instruments. DMD is in the core of Digital Light Processing (DLP) which is used in a large scale in the contemporary fully digital viewing systems. In the present moment such systems are produced in various forms: video projector, high definition displays, home theatre, standard TV etc. Essential in all of them is that the resolution is determined by the number of the mirrors in DMD. More and more popular become High Definition TV (HDTV) that also has fixed resolution, higher than that of DVD and films broadcasted at the TV channels. Different regimes of visualization – "panorama", "cinema", "preview" and so on, also demand resizing options as input data. When printing photographs taken by digital cameras, it is also needed an adapting of the input resolution to that of the printer to be done. The quality of the image of the devices mentioned above tends to depend more and more on the resizing techniques used.

The aim of the current paper is to create a methodology for comparison of some of the most common algorithms for image interpolation. The interpolation methods are compared via executing those algorithms upon three types of images: synthetic (vector) and two types of real photographs. The algorithms realized, the test images used and their characteristics are described in Section 2. Qualitative and quantitative results are presented in Section 3. Conclusions about the results and the properties of

these algorithms are presented in Section 4. We use two error metrics: the MSE and the PSNR in the RGB color space.

2. SCALING ALGORITHMS AND EVALUATION METHODS

In the present paper is made a comparison between the following algorithms: Box Algorithm (Nearest Neighbour - NN) [7]; Simple (Pixel) Interpolation (SI), Bilinear Interpolation (BI) [7]; Bicubic-Spline Interpolation (BSI) ($a = 0, -1/2, -1$) [1, 2]; Directional Interpolation (DI) [8]; Data Dependant Triangulation (DDT) [3]; “Marbella” [5] and Functional Interpolation (FI) [9] – sin and exp.

Especially, for the purpose of comparing the scaling algorithms were created 7 synthetic vector images (miras) (Fig. 1). These vector images are with four different resolutions: 256x256, 512x512, 800x800 and 1024x1024 pixels. For their creation is used the principle described in [4]. Except these 7 vector images, 14 photographs are tested too: 7 images from the Kodak test suite with resolution 768x512 pixels and 7 similar high quality photographs.

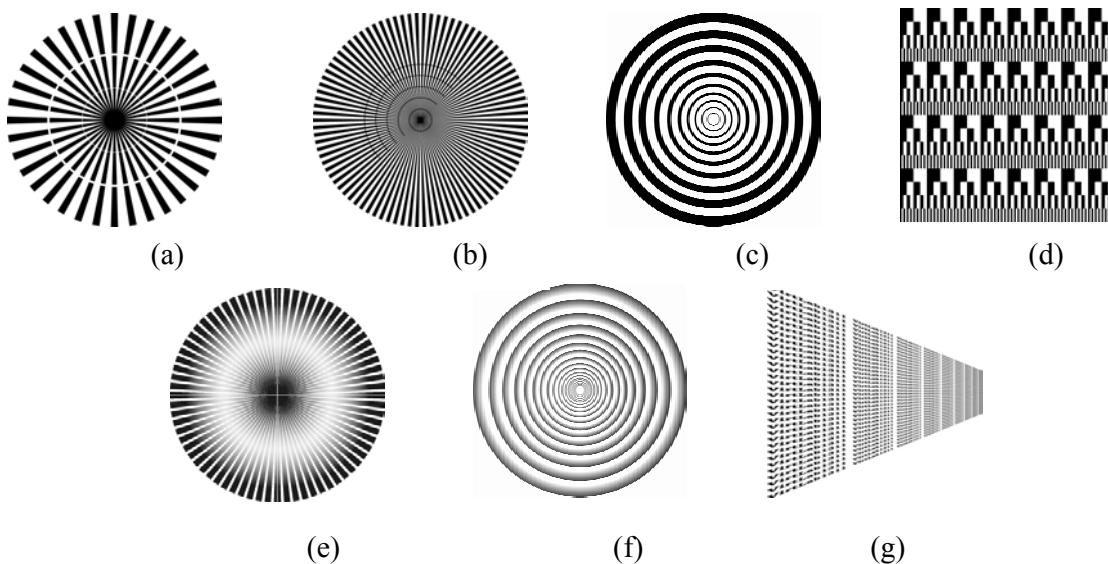


Fig. 1 Synthetic vector images (“miras”)

Images (a)-(d) are used for estimating the quality when transforming sharp edges; Images (a), (b), (e) and (f) – for estimating the systematic sub pixel shift in different parts of the image; Images (e) and (f) – for estimating the transformation of low contrast details; Image (g) – for estimating the conversion of tiny details; The last image is the label “VirtLab1311”, repeated several times and displayed in perspective.

The corresponding vector images are scaled up and down to suitable resolutions. The quality of the applied algorithm is estimated by comparing the result images with the original ones or with images got by third party algorithms (in the current case, for these purposes is used Photoshop 7.0 Bicubic algorithm – PB). Estimating the quality of the scaling process of the photographs is accomplished by following a strict succession of actions. These three steps are: scaling the image up or down using some of the tested algorithms, recovering the original resolution using the same methods

and measuring MSE and PSNR between the original and the final image. There is no limitation for the value of the scaling coefficient, such as being integer. It can be even a floating point number. Furthermore, scaling down can be done with one algorithm, and scaling up – with another (for estimating the quality of combinations of algorithms).

When processing the selected image, for obtaining the final resolution is formed a so called “Frame”, comprising of four images: the original one, the intermediate one – obtained at the first step of the processing (reduction or magnification); the final one – obtained at the second step of the processing (for one-step image processing the intermediate and the final images are identical) and another one – represents the visual (RGB) difference between the original and the final images. In the software is realized the possibility for creating more than one frames, when processing an image (vector or raster), in order to study the variation of the algorithm’s quality, for different scaling coefficients.

For objective estimate of the scaling algorithm’s quality is used the main approach in digital image processing, based on computing MSE and PSNR. MSE (1) represents the average square error (difference) in the intensities [$I(i; j)$ and $I'(i; j)$] of a given color of the corresponding pixels from the both images and it is dimensionless quantity. Because of its simplicity, it is the most common method of objectively measuring image quality given a reference image

$$MSE = \frac{1}{m \cdot n} \sum_{i=1, j=1}^{m, n} (I(i; j) - I'(i; j))^2 \quad (1)$$

PSNR (2) represents the square of the ratio between the maximum of the signal (the maximal possible value of color’s intensity (I_{max})) and the mean square error (difference) in the intensities [$I(i; j)$ and $I'(i; j)$] of a given color of the corresponding pixels from the both images and is measured in decibels (dB)

$$PSNR = 10 \lg \frac{I_{max}^2 \cdot m \cdot n}{\sum_{i=1, j=1}^{m, n} (I(i; j) - I'(i; j))^2} \quad dB \quad (2)$$

The estimate can be done by computing MSE and PSNR for every single color (Red, Green, Blue), as well as totally for the three of them.

3. RESULTS

For estimating the quality of each scaling algorithm, several experiments with different test images are competed. It is compared the results from execution of different algorithms upon one and the same image, as well as execution of one and the same algorithm upon different images. Combinations of algorithms executed upon one and the same image are tested too. The results got are compared in between and with pre-created images. Some of the images were resized, using Photoshop 7.0 Bicubic algorithm, and then compared with those got from the execution of this program.

The main artifacts in the images, that can be noted and determined as results of the scaling process, are:

1. Ringing (Fig. 2) – appearance of a single wave near a sharp edge in the image.
2. Overshooting (Fig. 2) – appearance of several such waves.

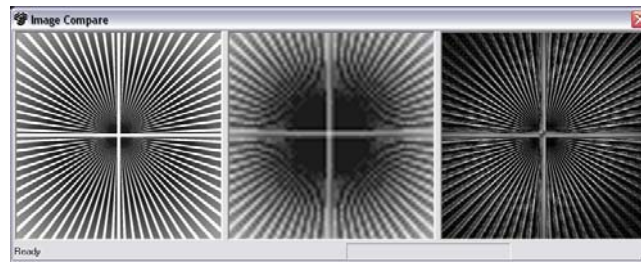


Fig. 2 Ringing, Overshooting and Sub-pixel shift

(a) – Original image 1024x1024 (detail); (b) – Bicubic-spline $a = -1$ ($256 \Rightarrow 1024$); (c) – Difference

3. Sub-pixel shift – translation of the image to some direction. It is relevant to special features of the algorithm’s realization. For the image from Fig. 1e (Fig. 2), the shift is up and left. Sometimes it has no influence over the visual quality of the image (Fig. 3), but has significant influence over the formal metrics.

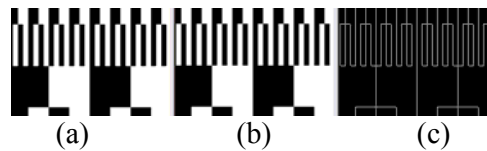


Fig. 3 Sub-pixel shift

(a) – Original image 1024x1024 (detail); (b) – Nearest Neighbour ($512 \Rightarrow 1024$); (c) – Difference

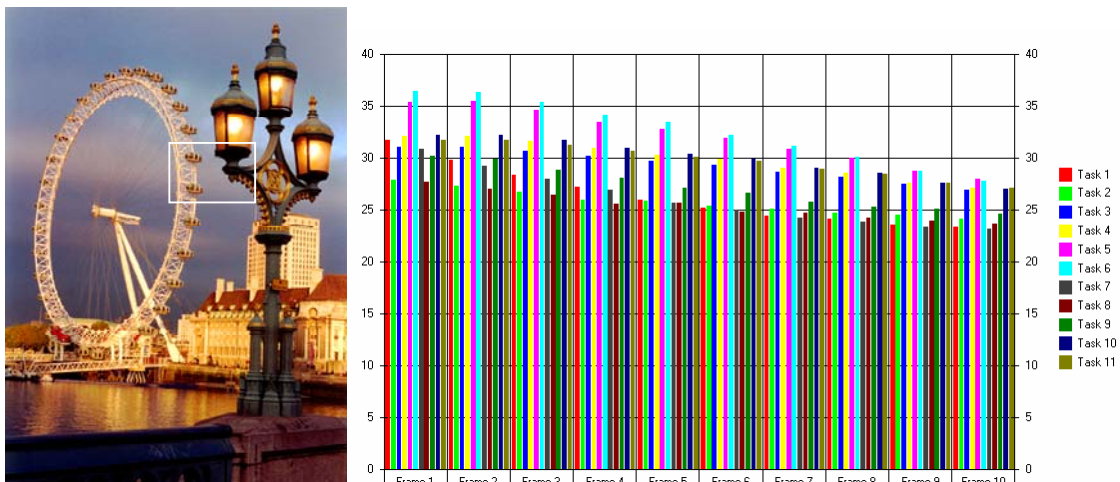


Fig. 4 Left: original “LondonEye” 496x700 with Region of Interest (ROI).

Right: tasks: (1) – NN; (2) – SI; (3) – BI; (4) – BSI $a = 0$; (5) – BSI $a = -0.5$; (6) – BSI $a = -1$; (7) – DI; (8) – DDT; (9) – Marbella; (10) – FI (sin); (11) – FI (exp). For each method the image is scaled

down twice and then scaled up to the original size again, as for Frame 1 the scaling is (100-95-100)%, for Frame 2 is (100-90-100)% and so on. For Frame 10 the scaling is (100-50-100)%.

4. Aliasing – so called “step effect” – irregularity of the sharp diagonal edges of the image. It emerges in the vector, as well as in the photographic images (Figs. 5,6). It is most noticeable in Nearest Neighbour, DI, DDT and somewhat in Marbella.

5. Blurring (Figs. 5c, 6c) – insignificant sharpness of the image after scaling. In fact it appears for all the interpolation algorithms, but is most distinctive for Simple Interpolation (SI). Boosting the sharpness increases the rest of the artifacts and vice versa – reducing the artifacts loses image's sharpness.

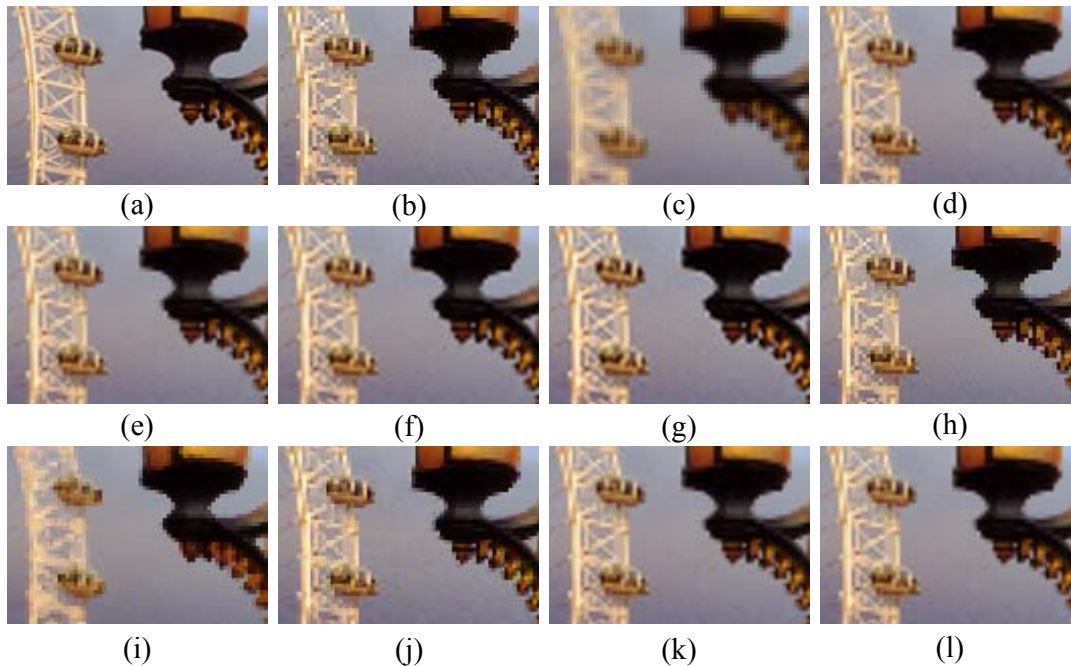


Fig. 5 ROIs

(a) – Original; (b) – NN; (c) – SI; (d) – BI; (e) – BSI $a = 0$; (f) – BSI $a = -0.5$; (g) – BSI $a = -1$; (h) – DI; (i) – DDT; (j) – Marbella; (k) – FI (sin); (l) – FI (exp).

For all images, especially for these with sharp and contrast edges, best of all the tested algorithms performs BSI-s (Figs 4, 5, 6), mainly with $a = -0.5$ and $a = -1$. When $a = -1$ around these edges appears a slight aureole (Fig. 5g), similar to Gibbs effect [6].



Fig. 6 From left to right: (a) – ROI on test image PineCone, (b) – NN, (c) – SI, (d) – BSI $a = -1$, (e) – DDT

Very good visual results and PSNR also give FI and BI, which besides have small computation complexity. Marbella rates just after them on the quality obtained. NN performs very well only with images, consisting of vertical and horizontal lines (Fig. 3). DI increases the visual contrast, but has worse quality when processing details with higher spatial frequency and has sub-pixel shift. DDT brings in much color aliasing and the tiny details are blurred (Fig. 6e).

4. CONCLUSIONS

The method for estimating the scaling algorithms offered in the paper is a convenient tool that allows implementing simple and efficient experiments with similar methods to be performed in order to improve their characteristics. The results achieved in this research, outline the directions for further tests and algorithm development.

For some methods, such as SI, DI and DDT it is not quite reasonable, attempts for improvements to be done, while for others (BSI-s, BI and FI) is recommended to be done efforts for improving the sharpness and the precision of the interpolation. Marbella also has potential for improving the quality. NN is suitable for image preview and for some specific applications.

The authors continue their work in the described direction as well as for developing a new adaptive image scaling algorithms, enabling more precise measurement of the interpolated images.

5. REFERENCES

- [1] Lancaster, D. *Using Cubic Spline Basis Functions for Image Pixel Interpolation*. www.tinaja.com/glib/basis.pdf.
- [2] Lee, C et al. *High-Quality Image Resizing Using Oblique Projection Operators*. IEEE Transaction on Image Processing, vol. 7, No. 5, May 1998.
- [3] Su, D. and Willis, P. *Image Interpolation by Pixel Level Data-Dependant Triangulation*. Computer Graphics Forum, No. 1, 2004.
- [4] Vatolin, D., S. Putilin. *Image scaling methods evaluation and comparative results between different methods*. Proceedings of Graphicon-2003, pp 202-207, Moscow, September 2003 (in Russian).
- [5] Battiato, S. et al. *A new edge-adaptive zooming algorithm for digital images*. Proceedings of Signal Processing and Communications SPC, pp 144-149, Marbella, Spain, 2000.
- [6] Radaelli-Snachez, R., R. Baraniuk. *Gibbs Phenomenon*. September 2003, www.cnx.rice.edu/content/m10092/latest/.
- [7] Goshtasby, A. *Image Resampling*. CVPR'04.
- [8] *Quick Image Scaling by 2*, www.compuphase.com
- [9] www.efg2.com/lab/library/Delphi/Graphics/LazikasoPontios_Resampling.txt