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Combined local and global image enhancement algorithm

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Abstract

We present a new image enhancement algorithm based on combined local and global image processing. The basic idea is to apply α-rooting image enhancement approach for different image blocks. For this purpose, we split image in moving windows on disjoint blocks with different size (8 by 8, 16 by 16, 32 by 32 and, i.e.). The parameter alfa for every block driven through optimization of measure of enhancement (EME). The resulting image is a weighted mean of all processing blocks. This strategy for image enhancement allows getting more contrast image with the following properties: irregular lighting and brightness gradient. Some experimental results are presented to illustrate the performance of the proposed algorithm.

Introduction

Many images like medical images, satellite images, aerial images and even real-life photographs may suffer from the following degradations: poor contrast due to poor illumination or finite sensitivity of the imaging device and electronic sensor noise or atmospheric disturbances leading to broad band noise.

Image enhancement is the image processing that the results are more suitable for display or further image analysis. So, the image enhancement is a problem-oriented procedure for improving the visual appearance of the image or to provide "better" transform for future automated image processing (analysis, detection, segmentation, and recognition).

Many methods proposed to enhance image are based on gray-level histogram modification, other methods are based on the local contrast transformation and edge analysis, or the "global" entropy transformation [1]. That is due to the absence of a general standard of the image quality, which could be served as a design criterion for image enhancement algorithms. It is a fact that there is no general unifying theory of the image enhancement.

The basic advantages of the transformed image enhancement techniques are: (a) a low complexity of computations; (b) an important role of the orthogonal transforms in digital signal/image processing applications (c) they are easy to view and manipulate.

The alpha-rooting method motivated by the human visual response. The analysis of the existing transform-based image enhancement techniques shows that it is difficult to select optimal processing parameters, and no effective measure can be served as a building criterion for image enhancement [2].

The solution of the last task is very important when image enhancement procedure is used as a preprocessing step for other image processing techniques such as the detection, recognition, and visualization.

This paper presents new image enhancement algorithm based on combined local and global image processing. The basic idea is to apply α-rooting image enhancement approach for different image blocks.

Related Work

Image enhancement algorithms can be classified regarding two properties: spatial and frequency domain methods [5]. The first group uses spatial domain image processing base on linear or nonlinear operations which directly manipulates the pixels. The shape of the histogram of an image does provide useful info about the possibility for contrast enhancement. Many spatial image enhancement methods are based on histogram analysis and modification: histogram equalization, histogram matching, contrast stretching, intensity adjustment, etc. [1, 3-7].

One of the most popular image enhancement methods is histogram equalization. It is a global processing approach, so the entire tone of the image has been changed like more bright or dark image. In many cases, these methods extend the dynamic range of an image in local regions, leading to artifacts and overall tonal change of the image.

The frequency domain enhancement group use transformation in the frequency domain through modification magnitudes and altering the frequency content of the image. These enhancement techniques use frequency transform such as DCT, Fourier, and following types of processing: alfa rooting, frequency filtering, homomorphic filtering, etc. [1, 8-11].

Adaptive histogram equalization (AHE) is an image processing technique used to improve contrast in images [12, 13]. An adaptive version of this algorithm called contrast limited adaptive histogram equalization (CLAHE) [14].

Alpha rooting is one of the more popular enhancement method [1, 8, 15-17]. The basic limitation of this method as global processing that it cannot simultaneously enhance all parts of the image very well, and it is difficult to automate the image enhancement procedure [18].

Each of these methods has strong and weak points. Hence, the combination of the above methods is used to enhance the image through transform histogram mapping technique [19].

So, the weaknesses of traditional methods are:

- extremely sensitive to parameters;
- fails to enhancement irregular lighting and brightness gradient;
- for point processing spatial information completely lost;
- a global processing approach has been changing the entire tone of the image like more bright or dark image;
- extend the dynamic range of an image in local regions, what leading to artifacts and overall tonal change of the image;
- frequency domain methods introduce certain artifacts which called "objectionable blocking effects and they cannot simultaneously enhance all parts of the image very well.

The objective of our work is to develop a new image enhancement algorithm based on combined local and global image processing.

Proposed enhancement algorithm

This paper presents a new image enhancement algorithm based on combined local and global image processing (Fig. 1). The block diagram of the proposed enhancement algorithm is shown in figure 2.

The procedure for the proposed algorithm is expressed as following steps:

Input: Original image.
Step 1: Image splitting.
Step 2: Enhancement processing.
Step 3: The measure of image enhancement (EME) calculation.
Step 4: Weighted average.
Output: Enhanced image.

The basic idea is to apply α-rooting image enhancement approach for different image blocks. For this purpose, we split image in moving windows on disjoint blocks with different size (8 by 8, 16 by 16, 32 by 32 and, i.e.).

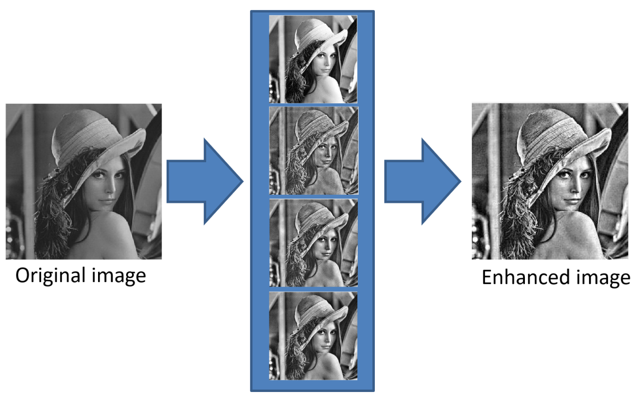

Figure 1. Combined local and global image enhancement

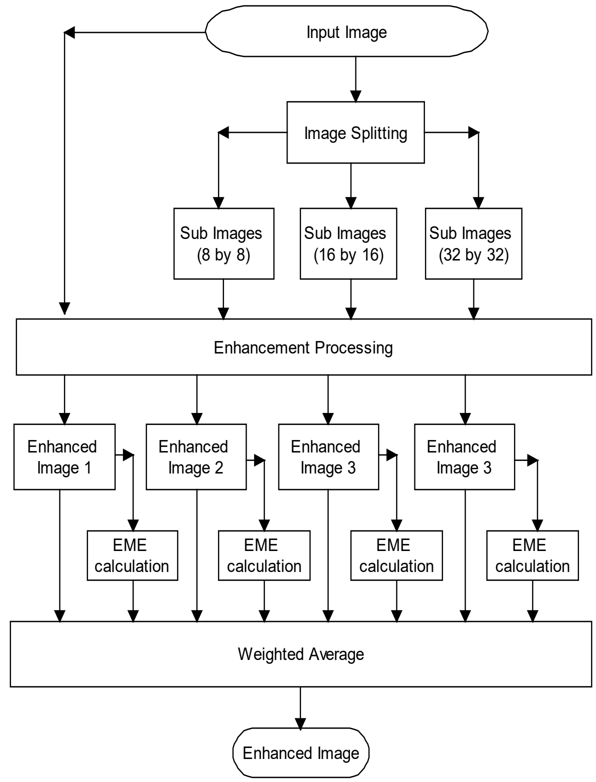

Figure 2. Block diagrams of the proposed algorithm

For proposed image enhancement method, we use the frequency domain. One simply performs the transform of the image to be enhanced, then manipulated the transform coefficient, and then perform the inverse orthogonal transform. Image transforms give the spectral information about an image, by decomposition of the image into spectral coefficients that can be modified (linearly or non-linearly), for enhancement and visualization. So, transform-based enhancement algorithm base on the α-rooting and magnitude reduction method.

For every block, we use transform-based enhancement algorithm base on the α-rooting and magnitude reduction method [16]:

$$\hat{X}(p,s) = X(p,s) \times |X(p,s)|^{\alpha-1} = |X(p,s)|^{\alpha} \times e^{i\theta(p,s)},$$

where $X(p,s)$ is the transform coefficients of the image,
α is a user defined operating parameter,
$\theta(p,s)$ is the phase of the transform coefficients.

There are several methods introduced as a measure of image enhancement [18]. To measure the quality (or contrast) of images and select the optimal processing parameters, we use the following quantitative measure of image enhancement.

The α-rooting transform depends on the parameter α. We are choosing the best (optimal) enhancement image through optimization of measure enhancement (EME) introduced by Agaian [20]:

$$EME_{k_1,k_2} = max\left(\frac{1}{k_1 \times k_2} \times \sum_{l=1}^{k_1} \sum_{k=1}^{k_2} 20 \times log \frac{X^{\omega}_{max;k,l}}{X^{\omega}_{min;k,l}}\right),$$

where $X^{\omega}_{max;k,l}$ and $X^{\omega}_{min;k,l}$ respectively are the minimum and maximum of the image $x(n,m)$ inside the block $\omega_{k,l}$.

For every patch of the image, we apply α-rooting algorithm with the value of alpha that maximizes the value of EME.

We calculate EME for every enhanced image:

- for enhanced image 1 (all image) is $EME^{\tilde{X}_1}$;
- for enhanced image 2 (blocks 8 by 8) is $EME^{\tilde{X}_2}$;;
- for enhanced image 3 (blocks 16 by 16) is $EME^{\tilde{X}_3}$;;
- for enhanced image 4 (blocks 32 by 32) is $EME^{\tilde{X}_4}$;.

These values allow to calculate weights, as follow:

$$W^{\tilde{X}_1} = EME^{\tilde{X}_1}/sum(EME),$$

$$W^{\tilde{X}_2} = EME^{\tilde{X}_2}/sum(EME),$$

$$W^{\tilde{X}_3} = EME^{\tilde{X}_3}/sum(EME),$$

$$W^{\tilde{X}_4} = EME^{\tilde{X}_4}/sum(EME),$$

$$sum(EME) = EME^{\tilde{X}_1} + EME^{\tilde{X}_2} + EME^{\tilde{X}_3} + EME^{\tilde{X}_4}.$$

The resulting image is a weighted mean of all processing blocks:

$$\tilde{X} = \tilde{X}_1 \times W^{\tilde{X}_1} + \tilde{X}_2 \times W^{\tilde{X}_2} + \tilde{X}_3 \times W^{\tilde{X}_3} + \tilde{X}_4 \times W^{\tilde{X}_4}.$$

Experiments

We compare the classical well-known algorithms histogram equalization and CLAHE and proposed. Figures 3-6 demonstrate the image enhancement results obtained by various algorithms respectively (a – original image; b - the enhanced image by the histogram equalization; c - the enhanced image by the CLAHE; d - the enhanced image by the proposed method).

The examples demonstrate the effectiveness of proposed image enhancement algorithm on different images with a qualitative opinion in a human observer study. These images have visually more contrast and details.

Figure 3. Examples of image enhancement «Sculpture»

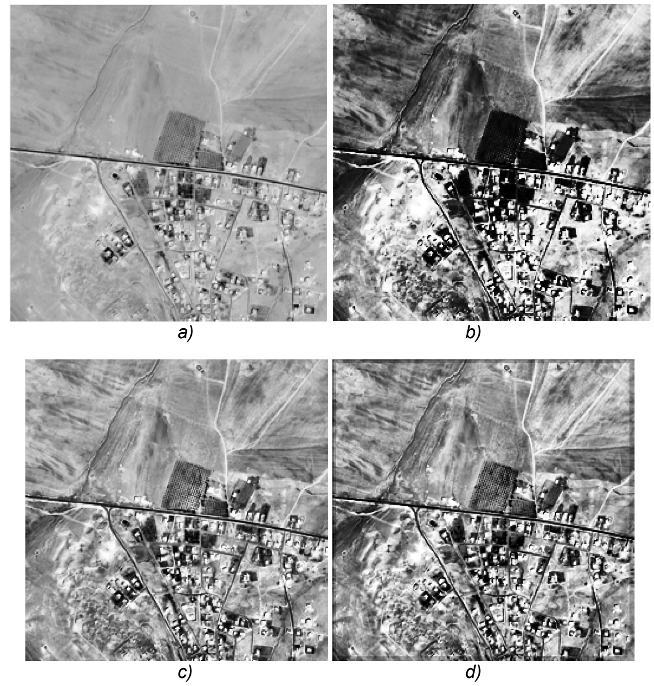

Figure 4. Examples of image enhancement «Map»

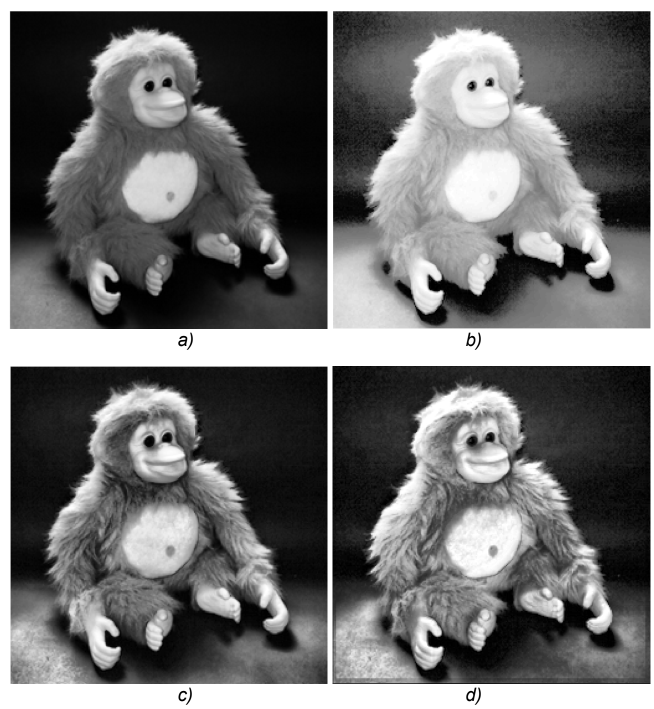

Figure 5. Examples of image enhancement «Monkey»

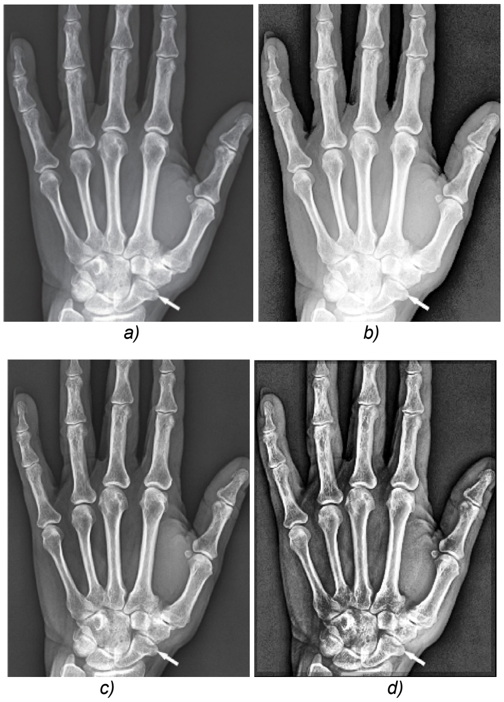

Figure 6. Examples of image enhancement «Hand»

The experimental results (table 1) show that the enhancement images by the proposed method have the highest EME. The new approach is better than the existing ones, because it combines their strengths and overcome their weaknesses.

Table 1. Comparison of resulting EME's of different enhancement methods

Images	***Original***	***Histogram equalization***	***CLAHE***	***Proposed method***
«Sculpture»	2,21	11,88	5,19	**14,17**
«Map»	3,34	18,12	8,21	**21,34**
«Monkey»	9,14	8,92	7,17	**13,75**
«Hand»	16,47	14,7	5,44	**18,59**

Conclusions

We present a novel image enhancement algorithm based on combined local and global image processing. The basic idea is to apply α-rooting image enhancement approach for blocks on the image with different size. For optimal alfa choosing, we calculate the measure of enhancement (EME). This strategy for image enhancement allows getting more contrast image with the following properties: irregular lighting and brightness gradient. The proposed image enhancement results compare favorably against other state-of-the-art approaches.

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Authors Biography

Viacheslav Voronin was born in Rostov (Russian Federation) in 1985. He received his BS in radio engineering from the South-Russian State University of Economics and Service (2006), his MS in radio engineering from the South-Russian State University of Economics and Service (2008) and his Ph.D. in technics from Southern Federal University (2009). Voronin V. is a member of Program Committee of conference SPIE. His research interests include image processing, inpainting, and computer vision.

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Sos Agaian (M'98–SM'00) is Distinguished Professor of Computer Sciences Department at CUNY Graduate Center, New York, USA. Dr. Agaian received the M.S. degree (summa cum laude) in mathematics and mechanics from Yerevan University, Armenia, the Ph.D. degree in math and physics from the Steklov Institute of Mathematics, Russian Academy of Sciences, and the Doctor of Engineering Sciences degree from the Institute of the Control System, Russian Academy of Sciences. He has authored more than 500 scientific papers, 7 books, and holds 14 patents. He is a Fellow of the International Society for Photo-Optical Instrumentations Engineers, a Fellow of the Society for Imaging Science and Technology(IS&T), and a Fellow of the Science Serving Society (AAAS). He also serves as a foreign member of the Armenian National Academy. He is the recipient of MAEStro Educator of the Year, sponsored by the Society of Mexican American Engineers and Scientists. The technologies he invented have been adopted across multiple disciplines, including the US government, and commercialized by industry. He is an Editorial Board Member of the Journal of Pattern Recognition and Image Analysis and an Associate Editor for several journals, including the Journal of Electronic Imaging (SPIE, IS&T) and the System Journal (IEEE). His research interests are Multimedia Processing, Imaging Systems, Information Security, Artificial Intelligent, Computer Vision, 3D Imaging Sensors, Signal and Information Processing in Finance and Economics, Biomedical and Health Informatics.