The performance of the modified AGC algorithm for the quality improvement of low-contrast images

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Abstract –**The first part of the paper analyzes the AGC algorithm for the improvement of the visual quality of low-contrast images. It has been shown that the quality of images with low luminance and low contrast, after AGC correction is good. However, the quality of images with high luminance and low contrast, after AGC correction is not good. In the second part of the paper, the author has modified the AGC algorithm (MAGC) to improve the visual quality of high-luminance images. The efficiency of the MAGC algorithm was tested experimentally. A comparative analysis of the statistical parameters of images corrected by the AGC and MAGC algorithms shows the effectiveness of the MAGC algorithm. All test images with high luminance and low contrast, after being corrected applying the MAGC algorithm, can be classified as good quality images (GQ images), according to statistical parameters.**

Keywords – **Gama correction, contrast improvement, AGC algorithm.**

I. Introduction

Digital image processing algorithms can, among other things, perform visual image quality improvement. Improved image quality includes image corrections, such as: luminance, color and saturation correction, sharpness, contrast enhancement, edge and contour emphasizing etc. A number of algorithms have been suggested for improving image contrast [1] - [3]. The algorithms are used intensively, where the corrections are performed by analyzing the histogram of the image, that is, histogram equalization (HE) [4]. HE algorithms have a small numerical complexity. However, HE algorithms do not always give satisfactory results, because they can cause excessive improvement in pixels with luminance intensities that are often repeated, which results in a decrease in contrast intensity with less frequent occurrence [3]. In order to alleviate the problems of excessive increase or decrease in contrast, the following algorithms have been proposed: a) BBHE (bi-histogram equalization algorithms), b) DSIHE (dualistic sub-image histogram equalization algorithms) [5], c) MMBEBHE (minimum mean brightness error bi-histogram equalization algorithms) [6].

In [7] a simple algorithm which uses image classification as well as an appropriate method for each type of image has been proposed. The main goal of the proposed algorithm is to transform the image into a visually high-quality image. This is achieved by: a) increasing contrast and b) correction of luminance. The algorithm is based on adaptive gamma correction (AGC), where the luminance transform function is dynamically determined depending on the input image feature (mean value μ, standard deviation σ).

In [8] the performance of the AGC algorithm for correcting low-contrast images has been determined. The quality of the test image before and after correction with the AGC algorithm was tested. The testing was performed by: a) objective and b) subjective methods. The objective methods (MSE, PSNR, AMBE and SSIM) included a comparative analysis of AGC corrected by good quality (GQ) images. In addition, the image contrasts were analyzed using the following measures: a) RMS (Root-Mean-Square) and b) Ed (Discrete entropy). The subjective picture quality scores were obtained using the MOS (Mean opinion score) method. A detailed analysis has shown that the quality of the AGC corrected images of low contrast and low luminance is good, while the quality of AGC corrected images of low contrast and high luminance is unsatisfactory.

In this paper, the authors have proposed a modification of the AGC algorithm (MAGC algorithm). The modification was performed in the part concerning the correction of high-luminance images ($\mu > 0.5$) and low contrast ($\sigma > 0.1$). The MAGC algorithm was described in detail. After that, an experiment was performed in order to test the efficiency of AGC and MAGC algorithms. An experimental data-base composed of high-luminance images, $\mu = \{0.6, 0.7, 0.8, 0.9\}$ and low-contrast images $\sigma = \{0.02, 0.08\}$ was created. The tables and graphs show the contrast measures (RMS, Ed) and the measures of comparison of MAGC corrected images and GQ images (MSE, PSNR, AMBE and SSIM). The detailed analysis of the results indicates the high quality of MAGC corrected images, which, according to the values of the statistical parameters (μ, σ), are classified as GQ images.

The paper is further organized as follows: Section II describes the AGC and MAGC algorithms; in Section III, the experimental results are presented and the comparative analysis is performed, Section IV is the conclusion.

II. Algorithms for Repairing a Visual Quality of the Image with a Small Contrast

A. AGC algorithm

In [7], the AGC algorithm for improving the visual image quality has been described. The AGC algorithm, based on the image histogram, determines the mean μ and standard deviation σ. The AGC algorithm first classified the dark ($\mu < 0.5$) and bright ($\mu \geq 0.5$) images. After that, a classification of low-contrast images ($\sigma \leq 1 / 3\tau$) and high-contrast images ($\sigma > 1 / 3\tau$) was performed, where $\tau = 3$ [7]. Finally, the parameter γ was calculated to improve the image quality using γ-correction: $I_{out} = c\, I^{\gamma}$, where I is a low-contrast image, I_{out} is γ-corrected image, and c is the transformation parameter. In [9], an

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experiment is described in which GQ images are determined by subjective methods (MOS test). The analysis of statistical histogram parameters for GQ images shows μ ≈ 0.5 and σ > 0.1. These results match the results from [7] for high-contrast images.

In [8], the performance of the AGC algorithm has been determined using a) objective and b) subjective measures. The objective testing was carried out using contrast measures (RMS and Ed), as well as the comparative analysis measures (MSE, PSNR, AMBE and SSIM). These measures were obtained by comparing the tested images with the GQ image. The subjective tests were carried out using the MOS test. Fig. 1.a presents test image Lena with low contrast (MOS = 1.364) and its histogram (fig.1.b) ($\mu = 0.2$, $\sigma = 0.02$). By applying the AGC algorithm to the test image (fig. 2.a), a corrected image was obtained (fig. 1.c), with MOS = 3.29, whose histogram is presented in fig. 1.d ($\mu = 0.4943$, $\sigma = 0.1351$). According to the statistical parameters and MOS scores, it has been concluded that the AGC corrected image belongs to the class of GQ images.

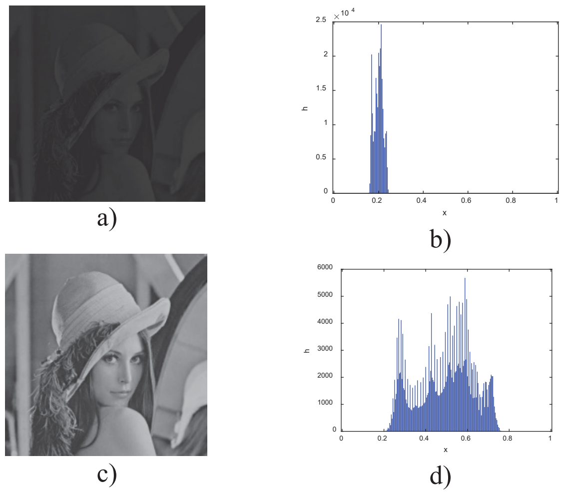


Fig. 1. a) Dark test image Lena with low contrast, b) histogram, c) AGC corrected image, and d) corrected image histogram.

Fig.2.a shows a bright test image Lena with low contrast (MOS = 1.148) and its histogram (fig.2.b) ($\mu = 0.7$, $\sigma = 0.02$). By applying the AGC algorithm to the test image (fig. 2.a), a corrected image was obtained (fig. 2.c), with MOS = 1.034, whose histogram is shown in fig.2.d (μ = 0.1350, $\sigma = 0.0216$). According to the statistical parameters and MOS scores, it has been concluded that the image corrected by AGC is poor in visual quality, and does not belong to the class of GQ images. The results from [8] show that AGC algorithm improved the dark images with low contrast very well, while the improvment of visual quality for bright, low-contrast images was poor. The efficiency, measured by subjective MOS scores, was higher in the dark images compared to the bright ones, and this was MOSdark / MOSbright = 1.4 times. According to the contrast analysis, as one of the objective measures, it could be concluded that the efficiency of the AGC algorithm for dark images was higher RMSdark / RMSbright = 3.74 times compared to the bright images.

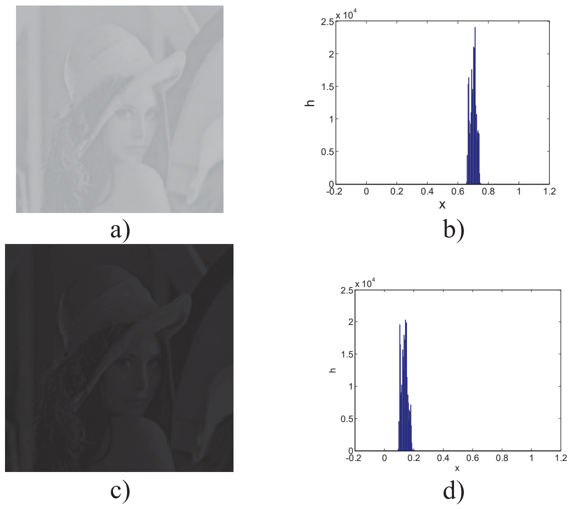


Fig. 2. a) Bright test image of Lena with low contrast, b) histogram, c) AGC corrected image, and d) corrected image histogram.

The authors of this paper have modified the AGC algorithm (MAGC) to repair the visual quality of the images with low contrast and high brightness.

B. MAGC algorithm

The modified AGC algorithm (MAGC) for visual improvement of the images with low contrasts is realized in the following steps:

Input: I_{MxN}
Output: Y_{MxN}
Step 1: Calculating the average brightness:

$$\mu = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j}^{N} I_{i,j} , \qquad (1)$$

Step 2: Calculating the standard deviation:

$$\sigma = \sqrt{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j}^{N}\left(I_{i,j}-\mu\right)^{2}} , \qquad (2)$$

Step 3: Calculating the γ-factor depending on the contrast:

$$\gamma = -\log_2(\sigma) , \qquad (3)$$

Step 4: Classifying the *I* image according to the brightness:

IF μ<0.5

Step 5: Transforming the dark image *I*:

$$Y = \frac{I^{\gamma}}{I^{\gamma}+(1-I^{\gamma})\times\mu^{\gamma}} , \qquad (4)$$

ELSE

Step 6: Transforming the bright picture *I:*

$$I = 1 - I, \qquad (5)$$

$$Y = \frac{I^{\gamma}}{I^{\gamma}+(1-I^{\gamma})\times\mu^{\gamma}} , \qquad (6)$$

$$Y = |1 - Y|. \qquad (7)$$

END

The MAGC modification in relation to the AGC algorithm is in step 6 (Eq-s. 5, 6, 7). A detailed verification of the efficiency of the MAGC algorithm was performed experimentally.

III. Experimental results and the analysis

In order to test the efficiency of the MAGC algorithm for improving the visual quality of bright low contrast images, an experiment was performed.

A. Experiment

The experiment was realized within an objective quality testing of low-contrast and high-luminance images was done. It was shown that the visual quality was increased by: a) AGC [7] and b) MAGC (Section II.B) algorithms. The visual quality improvement involved increasing the image contrast. The quality testing of MAGC corrected images was performed using a comparative analysis of the contrast measures (RMS and Ed) and objective measures (MSE, PSNR, AMBE and SSIM) with a) GQ image [9] and b) AGC corrected images [8].

B. Base

A database of the test images was created using the images obtained by modifying the luminance and contrast of the original image. The original test image Lena was used to create low-contrast images with high luminosity ($\mu > 0.5$): I_1 ($\mu = 0.9$, $\sigma = 0.02$), I_2 ($\mu = 0.9$, $\sigma = 0.08$), I_3 ($\mu = 0.8$, $\sigma = 0.02$), I_4 ($\mu = 0.8$, $\sigma = 0.08$), I_5 ($\mu = 0.7$, $\sigma = 0.02$), I_6 ($\mu = 0.7$, $\sigma = 0.08$), I_7 ($\mu = 0.6$, $\sigma = 0.02$) i I_8 ($\mu = 0.6$, $\sigma = 0.08$) (Table I).

C. Results

Table I presents the statistical parameters (μ, σ) and contrast measures (RMS, Ed) of the test images. Table II presents the parameters and contrast measures for the images after applying the AGC algorithm [8]. Table III presents the parameters and contrast measures for the images after applying the MAGC algorithm. The visual effect of applying AGC and MAGC algorithms on the test image I_5 is presented in fig. 3. Figure 4 presents the contrast measures RMS (fig. 4a) and Ed (fig. 4b). Figure 5 presents the objective measures MSE (fig. 5.a), PSNR (fig. 5.b), AMBE (fig. 5.c) and SSIM (fig. 5.d) graphically.

Table I

Statistical parameters and contrast measures of test images.

Image	μ	σ	Contrast	
			RMS	*Ed*
I_1	0.9	0.188	$4*10^{-4}$	4.2382
I_2	0.9	0.08	0.0064	5.7216
I_3	0.8	0.02	$4*10^{-4}$	4.2291
I_4	0.8	0.08	0.0064	6.1898
I_5	0.7	0.02	$4*10^{-4}$	4.2382
I_6	0.7	0.08	0.0064	6.1906
I_7	0.6	0.02	$4*10^{-4}$	4.2291
I_8	0.6	0.08	0.0064	6.1898

Table II

Statistical parameters and contrast measures of test images after applying AGC algorithm [8].

AGC Image	μ	σ	Contrast	
			RMS	*Ed*
Y_1	0.5553	0.0692	0.0048	5.9884
Y_2	0.7070	0.2230	0.0497	6.7687
Y_3	0.2861	0.0401	0.0016	5.2212
Y_4	0.4648	0.1640	0.0269	7.1261
Y_5	0.1350	0.0216	$4.6594*10^{-4}$	4.3377
Y_6	0.2897	0.1159	0.0134	6.6497
Y_7	0.0568	0.0106	$1.1172*10^{-4}$	3.3653
Y_8	0.1687	0.0779	0.0061	6.0793

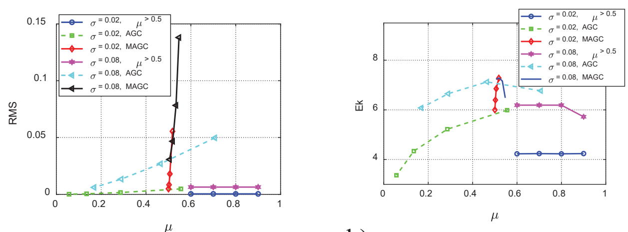
Table III

Statistical parameters and contrast measures of test images after applying MAGC algorithm.

MAGC Image	μ	σ	Contrast	
			RMS	*Ed*
Y_1	0.5181	0.2354	0.0554	7.2789
Y_2	0.5470	0.3714	0.1380	6.4852
Y_3	0.5063	0.1340	0.0180	6.8524
Y_4	0.5338	0.2797	0.0783	7.1644
Y_5	0.5027	0.0919	0.0084	6.3952
Y_6	0.5191	0.2161	0.0467	7.2841
Y_7	0.5003	0.0700	0.0049	6.0001
Y_8	0.5053	0.1751	0.0307	7.2307

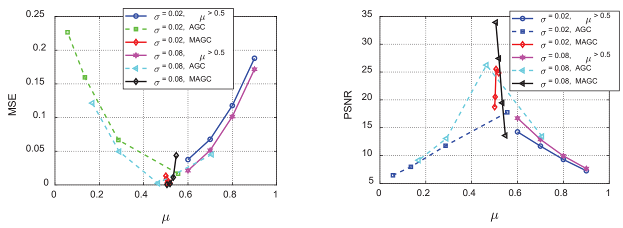
a) I_5 b) AGC I_5 c)MAGC I_5

Fig. 3. Examples of images from the test base (I_5): a) the original image, b) the image after AGC correction, and c) the image after MAGC correction.

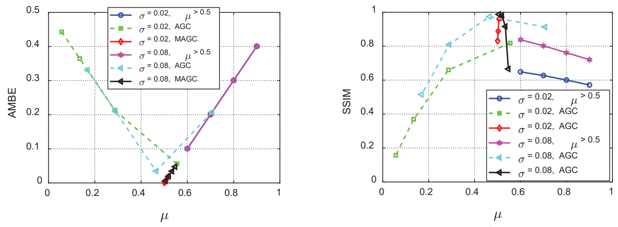


a) b)

Fig. 4. Contrast measures: a) RMS and b) E_d.



a) b)



c) d)

Fig. 5. Objective measures of the image quality: a) MSE, b) PSNR, c) AMBE and d) SSIM.

D. Analysis of the results

According to the results presented in Tables I, II and III and in Fig. 6 and 7, it has been concluded that:

1. for bright images (μ > 0.5, σ = 0.02 the increase of the objective parameters in the test images after applying MAGC algorithm: a) μ → 0.25 / 0.0068 = 36.7647, b) σ → 0.1328 / 0.02 = 6.64, c) MSE → 0.1028 / 0.0071 = 14.4789, d) PSNR → 10.6229 / 22.4012 = 0.4742, e) AMBE → 0.2506 /0.0075 = 33.622, f) SSIM → 0.6119 /0.9125 =0.6706, g) RMS → $4.0000*10^{-04}$ /0.0217 = 0.0185 i h) E_d → 4.2336 / 6.6316= 0.6384 times,

2. for bright images (μ > 0.5, σ = 0.02) the increase of the objective parameters after applying MAGC algorithm in relation to the applying of AGC [8] algorithm: μ → 0.2693 / 0.0068 = 39.015, b) σ → 0.1328 / 0.0354 = 3.7514, c), MSE → 0.1174 / 0.0071 = 16.5352, d) PSNR → 10.9832 /22.4012 = 0.4903, e) AMBE → 0.2691 / 0.0075 = 35.88, f) SSIM → 0.5015 / 0.9125 = 0.5496, g) RMS → 0.0017 / 0.0217 = 0.0783 i h) E_d → 4.7282 / 6.6316 = 0.71298 times,

3 for bright images (μ > 0.5, σ = 0.08) the increase of the objective parameters in the test images after applying MAGC algorithm: a) μ → 0.25 / 0.0263 = 9.5057, b) σ → 0.2606 / 0.08 = 3.257, c) MSE → 0.0865 / 0.0143 = 6.0489, d) PSNR → 11.7980 / 23.6075 = 0.4998, e) AMBE → 0.2506 / 0.0269 = 9.3073, f) SSIM → 0.7807 /0.8877 =0.8795, g) RMS → 0.0064 / 0.0734= 0.0872 i h) E_d → 6.0730 / 7.0411 = 0.8625 times,

4. for bright images (μ > 0.5, σ = 0.08) the increase of the objective parameters after applying MAGC algorithm in relation to the applying of AGC [8] algorithm: a) μ → 0.0199 / 0.0263 = 0.0757, b) σ → 0.2606 /0.1452 = 1.7948, c), MSE →0.0547 /0.0143 = 3.8252, d) PSNR → 15.4755 / 23.6075 =0.6555, e) AMBE → 0.1956 / 0.0269 = 7.2714, f) SSIM → 0.8030 / 0.8877 =0.9046, g) RMS → 0.0240 / 0.0734 = 0.32697 i h) E_d → 6.6559 / 7.0411 = 0.94529 times.

The obtained results indicate the high efficiency of the MAGC algorithm in relation to the AGC algorithm.

IV. Conclusion

The paper has been described the AGC algorithm for improving the quality of images with low contrast. A detailed analysis has shown that the quality of AGC corrected dark images with low contrast are of good quality, and that they can be classified as GQ images. However, the quality of the corrected bright images with low contrast is of unsatisfactory quality. The authors suggested the MAGC algorithm obtained by modifying the AGC algorithm. The experimental analysis of the application of the MAGC algorithm on the base of the high-brightness and low-contrast test images, showed that the visual quality of all images from the base, after MAGC correction, was excellent. According to the statistical contrast measures (RMS and E_d) and comparisons with GQ images (MSE, PSNR, AMBE and SSIM), the MAGC corrected images can be classified as GQ images.

Acknowledgement

The authors thank professor Slađana Živković for language support.

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