A Method of Ancient Manuscript Image Enhancement

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ABSTRACT

It is known that algorithms used for grayscale image enhancement can also be employed for color image enhancement where the image RGB components are transformed to YUV or the image RGB components are represented as three separate images, one for each primary color.

The paper introduces a color manuscripts' digital image enhancement method modified from grayscale image enhancement method introduced by S. Agaian [1]. The method is based on Quaternionic Fast Fourier Transform (QFFT) [2], [3], where the color image is not separated into components but is taken as a whole. A function of color manuscript image quality is offered [4], [5]. The effectiveness of the suggested method is considered for three cases, when the color image: (1) is presented in YUV components, (2) R,G,B components are taken separately, (3) is considered as a whole in form of quaternion matrix. As a result the latter case gives the best outcome.

Keywords

Quaternion, Quaternionic Fast Fourier Transform, color image enhancement, performance measure, manuscripts enhancement.

1. INTRODUCTION

One of the actual problems in digital image processing is the problem of enhancement. A number of grayscale image processing methods exist nowadays in contrast to the situation with color images. It should be noted that the main problem in color image enhancement process is the definition of a means to measure the quality of the enhanced image. This problem grows to be more apparent when the enhancement algorithm is parametric, as well as when a large quantity of images must be enhanced at once (video signal). In these cases, problems of choosing the best parameters and the best transform among class of unitary transforms as well as of automation of image enhancement procedures occur. For greyscale image enhancement purpose the parameters for modification of Fourier transform spectral components are chosen in a way that the function of the greyscale image enhancement measure [4],[5] reaches its local right-sided extremum value (minimum or maximum, depending on the function of choice).

2. METHOD OF COLOR IMAGE ENHANCMENT

Grayscale image enhancement is carried out in three stages: 1) the spectrum of the image relative to some orthogonal transformation is defined (Fourier, Hadamard, etc); 2) spectral components are modified; 3) inverse orthogonal transformation is applied. Color image enhancement is carried out in four stages. At first, image pixel components (Red, Green, Blue) are represented in form of pure quaternion $iR + jG + kB$, and only then the above described three stages are performed [2],[3].

Let R, G, B be the matrixes of color components of the image sized $N \times N$, where the formal description of the color image enhancement method has a form of:

1. Definition of quaternionic matrix $f = iR + jG + kB,$
2. Definition of quaternionic Fourier spectrum $F(p,s)$ (see [6]),
3. Modification of spectral components

$$F^{(3)}(p,s) = F(p,s)\,|F(p,s)|^{\alpha-1} \cdot \left[\lg\left(|F(p,s)|^{\lambda}+1\right)\right]^{\beta},$$

$$0 \le \alpha < 1, \beta \ge 0, \lambda > 0.$$

4. Return QFFT on the modified spectral matrix $F^{(3)}$.

3. IMAGE QUALITY MEASURES

One of the principal problems in image enhancement approach is to define a suitable image enhancement/contrast measure. However, it is impossible to develop a measure that may strictly define the quality of an image because quality itself is a subjective conception and there is no definition for the "best" quality of an image. Nevertheless, there are several measures defined in practice for grayscale images that use the image contrast for measuring the image quality [4],[5] such as Aghaian's measures of enhancement: EME, EMEE, AME, AMEE [1],[4]. The experiments in the framework of this paper showed that the AME (Accurate Measure of Enhancement) is the most effective one for the purpose of manuscript digital color image enhancement. AME is presented below:

$$AME_B(m,n) = \frac{20}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}\lg\frac{I_{\max}(B)-I_{\min}(B)}{I_{\max}(B)+I_{\min}(B)}$$

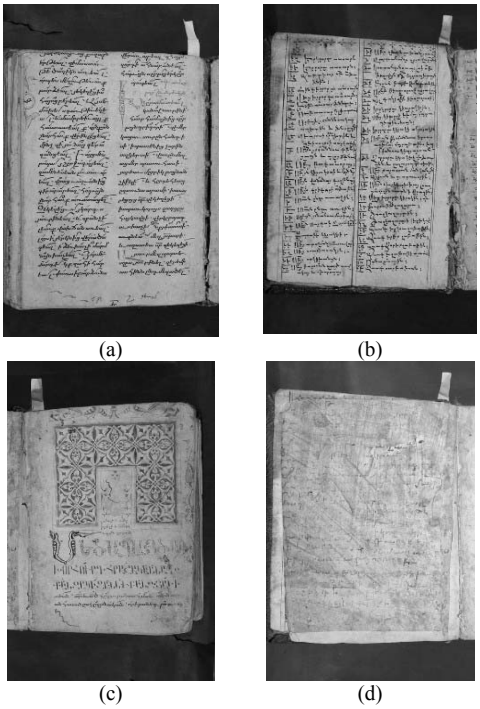
where B is an image sub block sized $m \times n$. For grayscale images $I_{\max}(B), I_{\min}(B) \in [0, 255]$ are maximal and minimal values of pixels contrast in B sub block.

As in the above described color image enhancement method the image is examined as a quaternion matrix, in quality measure formula AME in place of $I_{\max}(B), I_{\min}(B)$ for B sub block it is worthwhile to use quaternions with maximal and minimal $(R+G+B)/3$ value.

4. USING QUATERNIONIC FFT FOR ENHANCEMENT OF MANUSCRIPTS

Digital images of Matenadaran (Repository of Manuscripts in Armenia) are stored in a special laboratory. The outcome of the taken photographs largely depends on the model/functions of the camera, the brightness of the surroundings, dilapidation of manuscripts. The digitalization of manuscripts is a complicated and time consuming task, where each manuscript

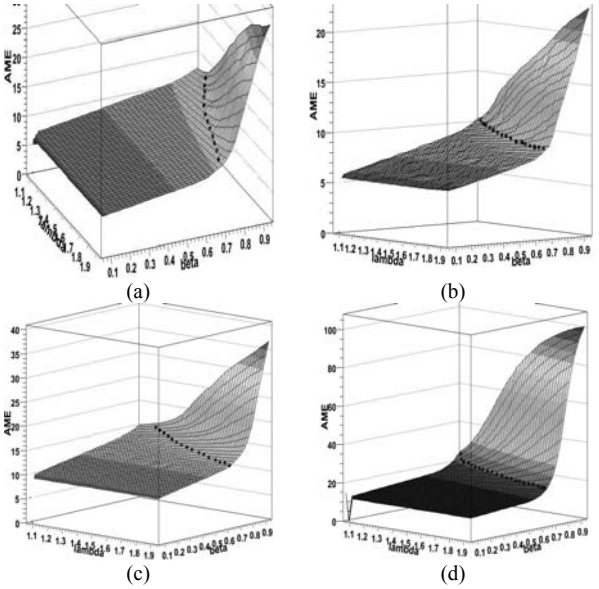
must be photographed one-by-one, and outcome image enhanced in case of need. A system is created to automate the enhancement procedure of large quantities of manuscript digital color images. The results of the attempt of color image enhancement are presented below (Pic. 1):



(a) (b) (c) (d)

Pic. 1. Original images

Applying the upper mentioned algorithm for color image enhancement and exploring the AME function of the image quality measure it is now possible to find the parameters, which can be used to achieve an image quality enhancement. The points in the below graphics (Graphic 1) highlighted with black color represent the breaking points. Any of AME breaking points can be used for searching the best parameters to apply for image quality enhancement.



(a) (b) (c) (d)

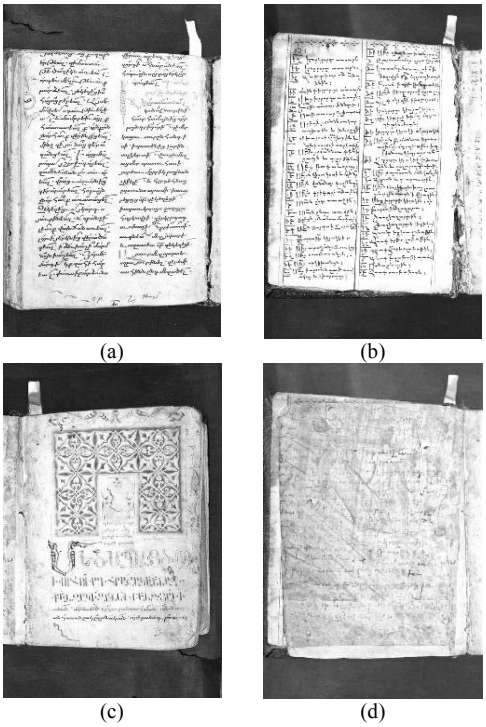
Graphic 1. AME (QFFT)

Graphic 1 shows the graphics of AME function variation corresponding to images presented in Pic. 1. Black dots represent the breaking points where AME function variates from its course. That very points show the optimal parameters for manuscript image enhancement.

The values of parameters corresponding to enhancement images from Pic.1 using QFFT are given in Table 1.

	α,λ,β	EME	PSNR
2(a)	α=0.9,λ=1.95,β=0.65	10.13	12.86
2(b)	α=0.9,λ=1.95,β=0.7	9.44	11.47
2(c)	α=0.9,λ=1.95,β=0.65	13.24	13.58
2(d)	α=0.9,λ=1.95,β=0.55	15.23	18.55

Table 1. Parameter values for Pic. 1 images

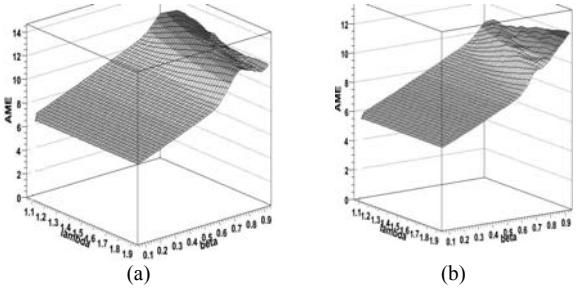


(a) (b) (c) (d)

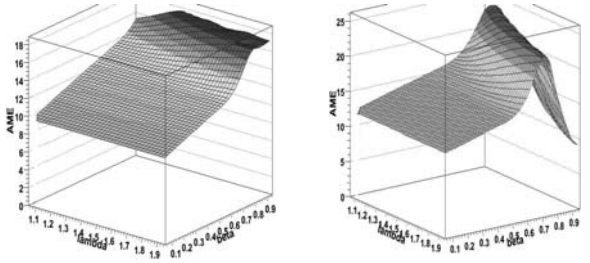
Pic. 2. Enhanced images (QFFT)

As a result of exploring a number of manuscripts we can say that manuscript image enhancement is noticed when $\alpha = 0.9,\quad \lambda = 1.95,\ 0.45 \le \beta \le 1$. Correspondingly, it is possible to automate and accelerate the manuscript image enhancement process setting $\alpha = 0.9,\quad \lambda = 1.95$ parameters and searching only for the best value for β.

An attempt was made to enhance color images presented in Pic. 1 using algorithm based on Fast Fourier Transform where the image RGB components are transformed to YUV and the image RGB components are represented as three separate images, one for each primary color. Here, using the corresponding parameters derived from the AME accurate measure function graphic breaking points image enhancement is not achieved (see Graphic 2).



(a) (b)



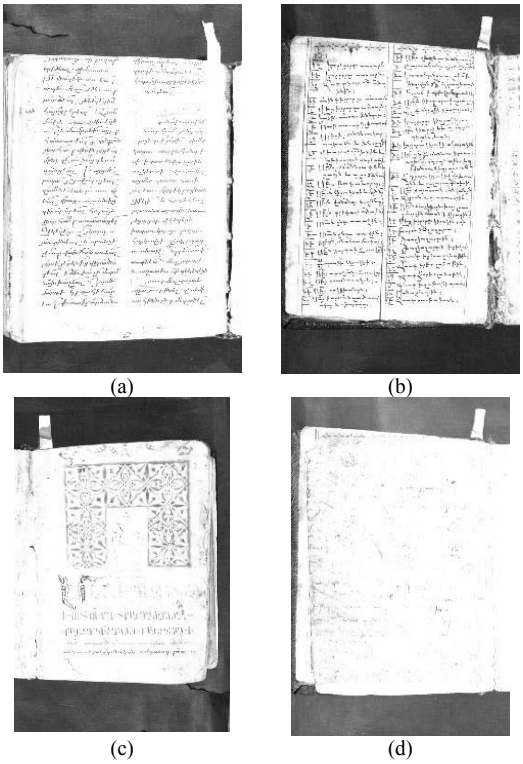
(c) (d)

Graphic. 2. AME (FFT (R,G,B))

The values of parameters corresponding to enhancement images from Pic.2 using FFT are given in Table 2.

Pic. 4	α,λ,β	EME	PSNR
(a)	α=0.9,λ=1.95,β=0.85	11.6	9.45
(b)	α=0.9,λ=1.95,β=0.75	9.95	10.51
(c)	α=0.9,λ=1.95,β=0.8	17.18	9.79
(d)	α=0.9,λ=1.95,β=0.7	22.8	11.57

Table 2. Parameter values for Pic. 2 images



(a) (b)

(c) (d)

Pic. 4. Enhanced Images (FFT (R,G,B))

CONCLUSION

Image enhancement using Quaternion Fourier Transform progressively develops. The paper introduced an algorithm based on QFT for the purpose of ancient manuscripts' digital image enhancement. The quality of outcome images was compared with the results received from the application of the image enhancement method using Fast Fourier Transform on the same images (more than 100). AME was researched to be a better quality measure function for manuscript enhancement among others. Comparison of QFT and FFT application results showed a noticeable difference in outcome images. QFT application outcome prevailed over the results received from the use of FFT on manuscripts' digital images. Moreover, the algorithm based on QFT allowed automating the enhancement of a large number of manuscript images at once.

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