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Adaptive Contrast Enhancement and White Balancing Integration for Image Enhancement Based on Non-linear Generalized Equalization Model

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Abstract: ***The digital image processing has introduced revolutionary developments in research fields like medicine, military, security, biometrics, robotics, satellite image processing, digital image compression, digital image enhancement, digital video processing, etc. Image enhancement is the predominant fundamental step in the image processing and digital image enhancement creates an image which is perceived by human visual system (HVS) in pleasant way. Although tremendous progress has been made in the past years on digital image enhancement process but still digital image enhancement is area of concern in the field of digital image processing. In the proposed method a non-linear generalized equalization model for image enhancement has proposed by integrating the non linear contrast enhancement and white balancing to form a unified algorithm based on the different parameter configurations into considerations. An adaptive image enhancement algorithm has been derived which yields good theoretical results based on two important histogram transform properties namely contrast gain and non linearity. Finally experimental results shows proposed method achieves good performance and low complexity over traditional state of art methods and proposed model is successful in achieving better efficiency in terms of tone correction as well as white balancing.***

Keywords: Image enhancement, white balancing, non-linear contrast enhancement, transformation, non linearity

1. Introduction

The invention of the computers is the pillar for the modern science and technology and digital image is the predominant area is also a technology based on computer. Digital image processing supports wide range of applications ranging from daily needs like mobiles, laptops, photography to high level research fields like medicine, satellites, radars, remote sensing, Etc. Digital image processing has ability to process the information visualized by human visual system (HVS) and daily trillions of new images are generated which needs automatic processing, manipulation.

Acquiring the sensory information using the digital sensors is called as digital images, mostly all image acquisition devices namely satellites, radars, cameras has one thing in common i.e. sensors. As shown in following figure 1.1 the acquisition of the object by digital sensors is the initial step in the image processing and then digital sensors acquired with great speed results in the abnormal content in some scenarios which needs processing to perceive the visual content by th human visual system in pleasant way.

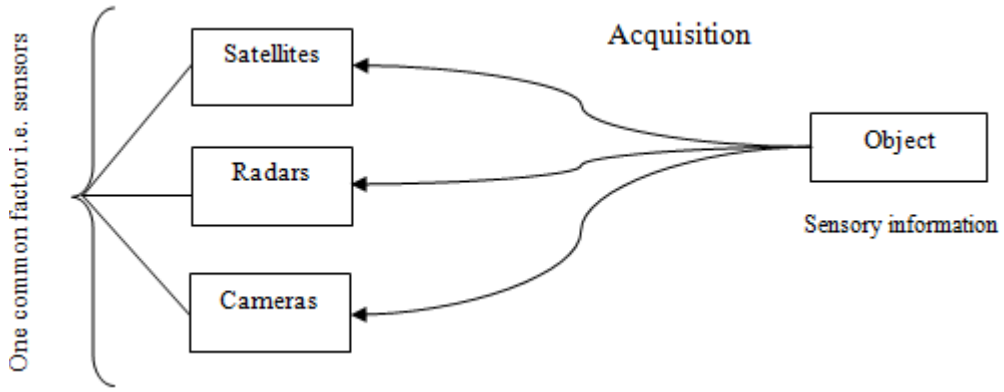

Figure 1: Acquisition of sensory information by digital sensors (Digital image)

In 1960's the processing of the digital image is consider to be expensive affair because of the expensive hardware included and digital image sensors has witnessed revolutionary changes from past few decades and the hardware cost has drastically reduced which makes digital image processing applicable to wide range of applications belongs to different research fields. Digital image processing has various advantages over the analog image processing which results in the high quality digital images with better quality.

A. Adaptive Image enhancement

Acquisition of the digital image is the initial step where the quality is decided and the key factor which decides the image quality is the environment in which it has acquired. If the image has acquired at abnormal lighting conditions then it results in the low quality image, if the hand shake has occur while acquiring the image then it results in the distorted and noisy image. Conversion of the acquired image content to better visualized content is technically called as adaptive image enhancement.

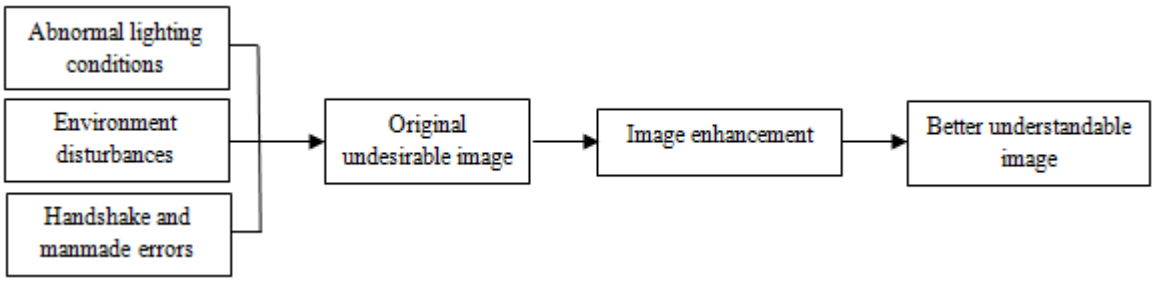

Figure 2: Adaptive image enhancement

Digital images acquired by the digital sensors are considered as the original images and the content in the acquired original images may be in degraded or better visualized. The process of transforming the degrade mode of content in acquired original image to better understandable image is called as image enhancement and image enhancement process uses different approaches as filtering approaches, frameworks, algorithms in order to get the clarity in the images which are often corrupted by the noise, blur and artifacts.

The digital image examination is done in accurate manner by histogram and enhancement process first uses the histogram before perform any task of image enhancement which helps in yielding the better quality image. The X-axis and Y-axis of the histogram represents the 0 to 255 (on X-axis) and number of pixels (Y-axis). The most popular enhancement schemes are contrast enhancement and filtering.

The satisfactory factors which predicts the quality of the image relies on adverse factors like abnormal lighting conditions as seen in the evening time, capturing device failure etc. These types of conditions results in the low quality image and in some conditions degraded image will be the outcome. So the undesirable image content either by environmental issues or manmade errors which is technically called as aesthetic and pragmatic needs enhancement process to make the undesirable form of content to understandable form of content. Image enhancement schemes are already in usage in various imaging devices for better tone mapping and in the end all this process is performing to provide better visualized content to the human visual system.

When the image is acquired by using digital sensors then the resultant raw image with big bit length makes it incompatible to be displayed in normal displays and this problem is analyzed in early ages of digital image processing. After research for decades the problem is resolved by using popular techniques namely gamma correction which makes raw format of image to display on the normal displays by using suitable dynamic range.

2. Problem Statement

Adaptive image enhancement is an important digital image processing aspect which helps to solve various issues occurs in the real time in many research fields. Although tremendous has been registered in the past two decades to get high quality images but still acquiring the original image is a area of concern and image enhancement needs more attention to get suitable image with substantial content which is visualized in better way by human visual system.

In this work generalized image enhancement model is proposed to tackle the drawbacks like color consistency, tone correction, abnormal lighting conditions, imaging system failure, etc.

Traditional image enhancement algorithms are relied on single framework based which fails to meet the practical requirements in terms of producing better quality with good tonal correction for human perception.

An integrated image enhancement model namely generalized image enhancement model is designed by integrate the non-linear white balance and contrast enhancement into unified framework based on the convex programming. The proposed uses different parameters of various enhancement techniques into consideration to create a meaningful joint strategy image enhancement model and finally extensive experimental results show the effectiveness of the proposed over traditional image enhancement techniques. Finally the computational complexity is also analyzed.

3. Aim and Objectives

A. Aim

The main aim of the project is to create adaptive enhanced image content by enhancing the undesirable image using the generalized equalization model

B. Objectives

- Initial step is to establish the generalized equalization model for adaptive image enhancement by properly analyzing the relationship between the image histogram and contrast

- Acquisition of the image by cost effective imaging devices results in undesirable form of images and usage of imaging model along with the linear transform mechanism maps the image into ideal from original (White balancing)
- Restoring the degraded mode information to better visualized information is done by using the contrast enhancement
- A unified model is proposed in this work by taking different parameters such as non linearity, tone distortion, etc belongs to various image enhancement techniques.
- Integration of non-linear contrast enhancement and white balancing approaches are done by using the convex programming

4. Literature Review

In this chapter, a brief description of adaptive image enhancement works by some prominent authors is presented. Finally tabular column is presented to give the information about the parameters and limitations about the works discussed here.

A. A new image enhancement algorithm which deals with dark regions and edges are proposed by ADIN RAMIREZ RIVERA, BYUNGYONG RYU, AND OKSAM CHAE in the year 2012 [1]. Generally when the images are captured in abnormal lighting conditions it results in the dark images which has tiny amount of brightness. The intention of the method is to preserve flat regions information by smoothness, gradient (edge) sharpening and enhancing dark regions. The outcome of this work is to maximum enhancement by adaptively creating mapping functions producing the ad hoc transformation to every individual image.

B. A non linear transform based color image enhancement approach is proposed by DEEPAK GHIMIRE AND JOONWHOAN LEE in the 2011 [2]. RGB color space is the basic color space for color images but RGB color space won't accept any changes in terms of brightness and angle. In this work for processing the image to create th meaningful enhanced image RGB to HSV color space is done. Here the enhancement process is carried on color image and processing of the color image is based on the HSV (hue saturation value) and in this work illuminance component V of the HSV color space is the key component for image enhancement and remaining two components of the H and S are kept unchanged.

C. Multiscale retinex image enhancement scheme based on fusion approach for color restoration is proposed by SUDHARSAN PARTHASARATHY, PRAVEEN SANKARAN in the year 2012 [3]. Generally cost effective imaging systems captured images are low in quality and the display won't display the image in reliable way. Multi scale retinex algorithm has two important steps to enhance the image based on contrast parameter, in the initial step gain values of each and every pixel is taken into consideration and in the latter step the background power consumption is minimized for better visualization of the image. Displays like organic light emitting diode (OLED) uses the multi scale retinex algorithm for good quality of vision and the entire process is automatically carried on by automatic computer vision system. Adaptive image enhancement is an important step in the situation where the image is captured by cost effective imaging systems results in abnormal images.

5. Proposed Methodology

5.1 Initialization

The image representation is done in two ways (i) Two dimensional image representation where content can be perceived by the human visual system (ii) Representing the digital image content in graphical way for better analysis of pixel statistics in the form of bars (technically called bins). In order to process the digital image which in degraded way both representations are taken into consideration for providing more enhanced image in accurate manner. In literature wide range of works have reported on adaptive image enhancement based on fuzzy, filters, algorithms, and transforms, but hardly these approaches are succeed to attain enhanced image in approximate manner.

An adaptive image enhancement approach is presented in this paper to attain good image enhancement for better perception of content in the digital image. Initially a relationship between the non-linear image contrast and histogram is analyzed to establishing the proposed model namely generalized image enhancement model. In proposed model a series of mathematical functions and definitions are proposed for analyzing non linearity, tone distortion and context free contrast. All parameters relationships are taken into considerations based on the different parameters in the joint model. The proposed non-linear generalized equalization model combines the all histogram based toned mapping algorithms and the generalized algorithm based on convex programming and joint strategy of white balancing and non-linear contrast. Both white balancing image enhancement method and adaptive contrast enhancement are unified for the creation of the generalized equalization model

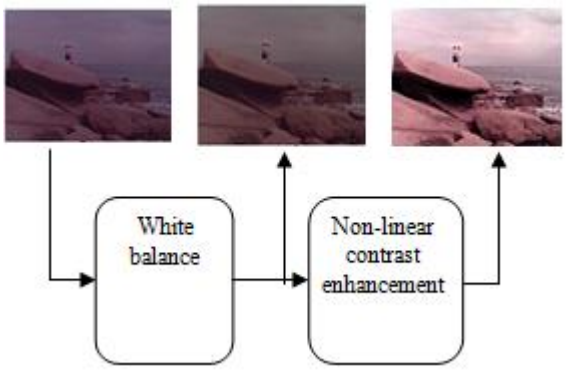

Figure 3: Representation of Traditional enhancement strategy

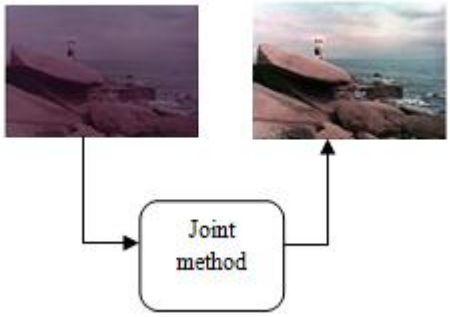

Figure 4: Representation of adaptive enhancement strategy

5.2 White balancing

RGB color space is considered as the primary source to notate the color image. The acquisition of the digital image by using cost effective digital sensors in abnormal lighting conditions results in color bias. Color bias is referred as the problem of leaning one of the primary colors into another and when it happens it results in the evolution of the new color i.e. secondary color. To create the good correlations between the primary colors is the primary task accomplished by estimating the light source and once th creation of the good correlation between the primary colors fails then linear transform is vividly applied on the image to map the first image.

5.3 Non-linear contrast enhancement

Digital image processing is combination of many fundamental steps and image restoration is the one of the important which is still considered as the area of concern in the field of digital image processing.

As reported in the literature image restoration process is carried on based on the contrast enhancement algorithms. Restoration process recovers original image information from degraded media. Among all reported contrast enhancement approaches global histogram equalization is the popular choice for image restoration. Other contrast enhancement approaches include as follows
(a) Local histogram equalization
(b) Spatial filtering image enhancement
(c) Texture synthesis approach
(d) Transform based methods

5.4 Histogram Based Analysis (White Balancing)

Image enhancement has prominent role in all image processing applications and white balancing is popular mechanism. The key factors in histogram based analysis in terms of white balancing are color constancy and relationship establishment. Color constancy approach in traditional focus on the leaning based systems while white balancing focus on low level approach.

The digital image expressed by suing Lambertian surface model is as follows

$$f_c = \int r(\lambda)\, l(\lambda) m_c(\lambda)\, d\lambda \quad (1)$$

The above expression consists of for imporatnt parameters which helps in image enhancement process namely visble light wavelength represented by λ, surface reflectance is represented by. $r(\lambda)$, light source representation is by $l(\lambda)$ and finally (λ) represents the camera sensitivity. The image in the Lambertian surface model is represented in the RGB color space which helps in estimating the light sources which is totally different from the paper work. The RGB color space consist of three channels and another widely acceptance approach for color constancy is gray world hypothesis which assumes average reflectance. Finally both these assumptions are unified as follows

$$\left(\frac{\int |f(x)|^{\alpha} dx}{\int dx}\right)^{\frac{1}{\alpha}} = Ce \quad (2)$$

The left side of the expression 2 can be rewritten based on the image histogram viewpoint as

$$\left(\frac{\int |f(x)|^{\alpha} dx}{\int dx}\right)^{\frac{1}{\alpha}} = \begin{pmatrix} (P_r^T)^{\frac{1}{\alpha}} \\ (P)^{\frac{T}{g}} \\ \left((P)^{\frac{T}{b}}\right) \end{pmatrix} \quad (3)$$

The connection between the histogram and white balancing sis notated by the expression 3 and the resultant image is as follows

$$e_C(\alpha) = \frac{(P_C^T h_C^{\alpha})^{\frac{1}{\alpha}}}{\sqrt{\sum_{c=r,g,b}(P_C^T h_C^{\alpha})^{\frac{2}{\alpha}}}} \quad (4)$$

Finally the resultant of the white balancing in terms of image histogram is denoted by $\hat{h}_C$ and $\hat{h}_C$ is computed as follows

$$\hat{h}_C = \frac{1}{e_C(\alpha)\sqrt{3}} \hat{h}_C \quad (5)$$

Th white balancing image enhancement process is linear in approach results in the good quality image but fails to give original content as output image. The usage of the linear transformation is the key factor in the white balancing process. In the latter section analytical differences between the contrast enhancement and white balancing are displayed based on the linear transformations

5.5 Histogram Based Analysis (Adaptive Contrast Enhancement)

Contrast and brightness are two key factors for practical visualization 2D signal to human visual system as image. After white balancing in terms of histogram, contrast enhancement is popular image enhancement mechanism which has wide range varieties.

The representation of the context free contrast is as follows

$$C = P_C^T S_C \quad (6)$$

The contrast enhancement definition allows to achieve maximum contrast levels by binary image, minimizes the contrast as zero when the image is taken as constant. The achieved contrast levels are represented as follows

$$\hat{S}_C = argmax\ P_C^T S_C s.t\ \sum_{i=1}^{K} S_{ci} = L_C\ ,S_{Ci} \geq d \quad (7)$$

Where the first constraint makes sure that the output image still has a suitable dynamic range and the second constraint denotes the minimum distance between adjacent gray levels as d.

$$h_{ci} - C \sum_{j=n}^{i} P_{Ci} \quad (8)$$

Here C ,is a constant. Eq. (8) also gives a relationship between histogram and the distance between adjacent intensity levels, as following shows

$$\hat{S}_{ci} = \hat{h}_{ci} - \hat{h}_{c,i-1} = \hat{C}_{pci} \quad (9)$$

According to (8), (9), histogram equalization is equivalent to solving following optimization problem

$$\hat{S_C} = argmax \frac{1}{\|P_C^{-1} S_C\|}, \quad (10)$$
$$S.t. \sum_{i=1}^{K} S_{Ci} = L_C, \quad S_{Ci} \geq d$$

The performance of histogram equalization is not optimal in most situations. The essential reason for its limited performance is the questionable assumption that the histogram of ideal image obeys uniform distribution. To get better equalization result, we need to find a better distribution which is a big challenge. Recently, some adaptive histogram equalization methods are pro-posed but gave neither a clear definition of contrast nor an explicit objective function of contrast enhancement like (7), (10) shows. A common feature of all the enhancement methods mentioned above is that the transform of histogram is non-linear, which is different from white balancing.

5.6 Proposed Method

The aims of establishing the non-linear generalized equalization model include: 1) giving a unified explanation to white balancing problem and contrast enhancement problem; 2) providing an explicit objective function for these two problems and proposing a joint algorithm for them; 3) controlling the performance of the algorithm by as few parameters as possible. The proposed model is inspired by (7), (10). Although (7),(10) seem to be very different, if we regard the order of and

$$\hat{S}_C = argmax \frac{1}{\|P_C^{-\beta} S_C\| n}$$
$$S.t. \sum_{i=1}^{K} S_{Ci} = L_C, \quad S_{Ci} \geq d \quad (11)$$

Both (10) and (7) have interesting relationships with (11)

According to the analysis above, (11) provides a reasonable and unified definition with the objective function of contrast enhancement. We will further take white balancing into the model. Based on (4), (11), we formulate the generalized equalization model mathematically as follows

$$\hat{S_C} = argmax \sum_{c=r,g,b} \|P_C^{-1} S_C\|_n,$$
$$S.t \sum_{i=1}^{K} S_{Ci} = \frac{1}{\#_C(\alpha)\sqrt{3}} \sum_{i=1}^{K} S_{Ci}, \quad S_{Ci} \geq d \quad (12)$$
$$G = \frac{P_C^T S_C}{P_C^T S_C}, NL = \|\nabla(\hat{S}_C - \hat{S}_C)\|2 \quad (13)$$

However, separate nonlinear transform of histograms of three channels may cause tone distortion. In the next section, we will theoretically prove that the proposed method, with a suitable configuration of parameters, can achieve a best trade-off between contrast enhancement and tone adjustment.

6. Results and Analysis

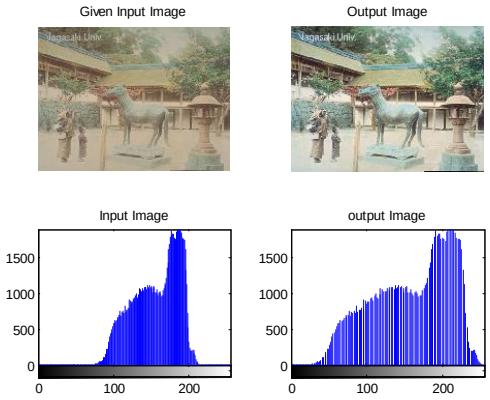

Figure 2: Adaptive image enhancement by non-linear generalized equalization model (Horse image)
Elapsed time is 0.366000 seconds

7. Conclusion

Adaptive image enhancement is the fundamental step in the image processing to get better understandable image from low quality degraded mode. In this paper a novel image enhancement method based on generalized model is proposed based on image histogram and contrast relationship. Finally the experimental results conclude that integration of the non-linear contrast enhancement and white balancing results in the better quality image which can perceived by the human visual system in pleasant way. In this model different adaptive image enhancement methods are unified to yield the better image with low complexity and high performance than the traditional enhancement algorithms.

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