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A working prototype of "contrast enhancement of brightness-distorted images by improved adaptive gamma correction" method using "Embedded System"

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Abstract*: A real time working prototype of adaptive gamma correction method using embedded system for image and video enhancement proposed here. Contrast enhancement (CE) plays an important role in the improvement of visual quality for computer vision, pattern recognition and digital image processing. We used CE techniques for optimum results and focus on the CE of brightness distorted images which own a relatively high or low global intensity. The existing adaptive gamma correction (AGC) techniques are revisited and improved formally. We find that such methods are incapable to be directly used to enhance globally bright images and the image structure in local bright regions may be lost in enhancing dimmed images. In order to attenuate such deficiency we proposed real time working prototype. This technique useful for reduce darkness and fog. Real time execution is a challenging task, so we focus for the development of an embedded system using raspberry-pi.*

Keywords: Contrast enhancement (CE), Adaptive Gamma Correction (AGC), Embedded System (ES).

1. INTRODUCTION

Image enhancement is the way toward changing digital images with the goal that the outcomes are progressively reasonable for show or further image analysis. For instance, we can remove noise, sharpen, or brightness of an image, making it simpler to distinguish key highlights. The aim of image enhancement is to improve the interpretability or perception of information in images for human viewers or to give 'better' contribution for other automated image processing techniques. In past few decades different types of image enhancement methods have been developed by various groups of researchers [1]-[10]. One such class of image enhancement methods is 'adaptive gamma correction' (AGC) based methods. In these types of methods each intensity value of given digital images is enhanced by modifying it using a power of gamma. The value of variable gamma is calculated by considering various properties of given digital image.

Gamma correction function is a function that maps luminance levels to compensate the non-linear luminance effect of display devices (or sync it to human perceptive bias on brightness). Gamma can be any value between 0 and infinity. If gamma is 1 (the default), the mapping is linear. If gamma is less than 1, the mapping is weighted toward higher (brighter) output values. If gamma is greater than 1, the mapping is weighted toward lower (darker) output values.

The transformation function of the AGC is based on the traditional gamma correction given by:

$$Y = c.X^{\gamma}, \quad (1)$$

Where X in and Y out are the input and output image intensities, respectively, c and γ are two parameters that control the shape of the transformation curve. In contrast to traditional gamma correction, AGC sets the values of γ and c automatically using image information, making it an adaptive method.

Contrast enhancement (CE) plays an important role in digital image enhancement so we used CE techniques for optimum results. For bright images CE negative images used and truncated cumulative distribution function (CDF) used for dimmed images CE. This technique useful for reduce darkness and fog. Real time execution is a challenging task, so we focus for the development of an embedded system using raspberry-pi.

Contrast enhancement (CE) plays an important role in the improvement of visual quality for computer vision, pattern recognition and digital image processing. We focus on the CE of brightness distorted images which own a relatively high or low global intensity. The existing adaptive gamma correction (AGC) techniques are revisited and improved formally .Such methods are incapable to be directly used to enhance globally bright images and the image structure in local bright regions may be lost in enhancing dimmed images. In order to attenuate such deficiencies an improved AGC method [3] by integrating the strategies of negative images and CDF truncation proposed by others. Although much work has been done in the field of AGC based digital image processing methods[1]-[10] yet there is still a need of real time AGC based image enhancement method that can enhance visibility of all types of gray scale and color images without distorting color or other meaningful details of the image.

We are proposing a real time working prototype of AGC method using embedded system (ES) for image and video enhancement.
The experimental results show that the proposed method is able to enhance contrast of given image without much affecting its mean brightness.

2. Preliminaries

In our contrast enhancement (CE) scheme we focus on the CE of two types of brightness-distorted images, i.e. – the dimmed and the bright ones. As for an input image[1],

$$I(p,q), here \quad p = 1,2,3.....X; and \quad q = 1,2,3.....Y \quad (2)$$

Its type is first identified by thresholding the statistical quantity

$$k = \frac{I_l - S_k}{S_k}, \quad (3)$$

$$where \quad I_l = \frac{\sum_p \sum_q I(p,q)}{XY} \quad (4)$$

The constant S_k is defined as the expected global average brightness for normal natural images. The experimental statistics from several standard images database show that S_k is appropriate to be set as about the half of maximum pixel intensity, i.e., 128 for 8-bit images. The input image is judged as dimmed if $k \prec -\alpha_k$ and bright if $k \succ \alpha_k$ where α_k is the threshold used for distinguishing brightness- distorted images from normal ones. The image with normal luminance $(|k| \le \alpha_k)$ are found to be unfit for AGC – based enhancement, thus they would not be addressed by our techniques.

In terms of the identified image types of bright and dimmed, the AGC based on negative image and CDF truncation are applied respectively for achieving contrast improvement and brightness restoration.

2.1 AGC via negative image

CE of bright images is novelly proposed by applying AGCWD to their negative version. Specifically, the negative image denoted by I' is formally defined as

$$I'(p,q) = 255 - I(p,q), \quad (5)$$

$$where, p = 1,2,3,...,X; and; q = 1,2,3,...,Y \quad (6)$$

I' own massive low intensity pixels and can be considered as a dimmed image. As a result, the AGCWD can be subsequently applied to I', which yields an immediate enhanced image I_e'. Lastly I_e' is reverted back to positive image space for yielding the final enhanced image I_e.

2.2 AGC via truncated CDF

The bright regions degraded by AGCWD should attribute to the inappropriate setting of gamma parameter. To attenuate should deficiency Gang Cao [3] and his team member propose to truncate the cumulative distribution function (CDF) curve for limiting it below a reasonable threshold? As such, the corresponding CDF-based gamma can avoid being decreased overly towards zero. They improve the AGCWD method by truncating the adaptive gamma parameter as follows-

$$\gamma_w'(\ell) = \max(\alpha, 1 - C_w(\ell)), \quad (7)$$

Where max (. , .) is the maximizing operator, α is the threshold used for CDF truncation. When $C_w(\ell)$ is larger than $1-\alpha$, $\gamma'(\ell)$ would be boosted to α. As such the bright image regions would not be corrected with a rather low gamma value and the details loss could be avoid. Through such truncation, $\gamma_w(\ell)$ keeps longer than α so that the contrast adjustment for bright pixels are restricted reasonable. Meanwhile, the gamma value α is also small enough for extending the dynamic range of dimmed pixels.

3. Flow chart of the work

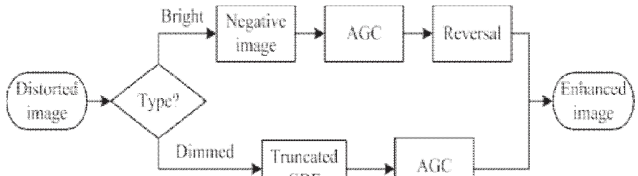


Fig.1 Flowchart of the gamma correction based method[1]

As shown in the above flowchart, initially type of the image is determined by using some mathematical processing. Also for different types of images namely bright and dimmed, different pipeline of processing is followed in the method proposed by G. Cao et. al. [3].

3.1 For Bright Image

Negative image- based AGC method relies on the successfulness of AGCWD in enhancing the dimmed negative image. An early and rapid decrease occurs in the adaptive gamma mapping curve generated from negative image. Consequently both the brightness and contrast can be enhanced reasonably .However, if AGCWD is directly applied to the bright image, a worse result would be gained due to the used improper mapping function.

3.2For Dimmed Image

There exists a serious problem in AGCWD the edges in bright regions. Such detail loss phenomenon is typically incurred by AGCWD in enhancing the images with bright regions, which are universal in real applications. This deficiency should attribute to the used overly low gamma values in transforming the median and high intensity pixels indicate that $\gamma_w(\ell)$ continues to monotonously decrease from 0.25 towards 0 in processing the remaining pixels with gray levels within [50, 255]. Especially for the bright regions which typically own high intensity pixels. To attenuate such deficiency, G.Cao proposed to truncate the CDF curve for limiting it below a reasonable threshold.

4. Hardware Used

4.1 Raspberry-pi 3 "Model B Original with Onboard Wi-Fi and Bluetooth"

Fig. 2 Raspberry- pi 3 [11]

The Raspberry Pi 3 – Model B **Original** quad-core 1.2GHz 64Bit SoC and onboard WiFi and Bluetooth is a third generation product which maintains the same popular board format as other raspberry pi modules, but it has faster **1.2GHz 64Bit SoC,** and onboard WiFi and Bluetooth. Raspberry **Pi 3 Model B ARMv8 w/ 1GB RAM** provides the same Pi features as before but with double the ram and a much faster processor. The Pi 3 has two major upgrades. The first is a next-generation Quad-Core Broadcom BCM2837 64-bit ARMv8 processor and the second is the addition of a built-in **BCM43143 WiFi chip**.

4.2 Camera- 5MP Raspberry Pi 3 Model B Camera

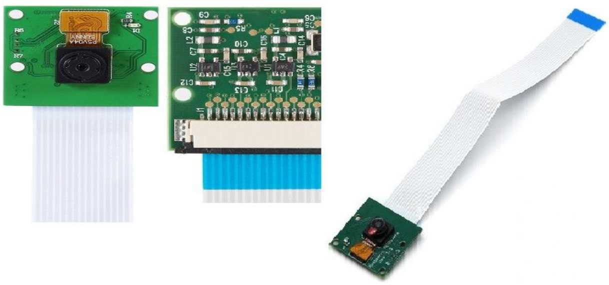


Fig.3 5MP Raspberry Pi 3 Model B Camera Module [12]

The 5MP Raspberry Pi 3 Model B Camera Module Rev 1.3 with Cable equips flexible cable for attaching with Raspberry Pi 3 Model B. The 5MP camera module is perfect for small Raspberry Pi projects which have very little space allowance just boot up the latest version. The sensor itself has a native resolution of 5 megapixels and has a fixed focus lens onboard. In terms of still images, the camera is capable of 2592 x 1944 pixel static images, and also supports 1080p30, 720p60 and 640x480p60/90 video.

4.3 Screen- 7″ Official Raspberry Pi Display with Capacitive Touch screen

Fig.4 7″Official Raspberry Pi Display with Capacitive Touch screen [13]

The 7" Touch screen Monitor for Raspberry Pi gives the ability to create all-in-one, integrated projects such as tablets, infotainment systems and embedded projects. The 800 x 480 display connects via an adapter board which handles power and signal conversion. Only two connections to the Pi are required; power from the Pi's GPIO port and a ribbon cable that connects to the DSI port present on all Raspberry Pi's.

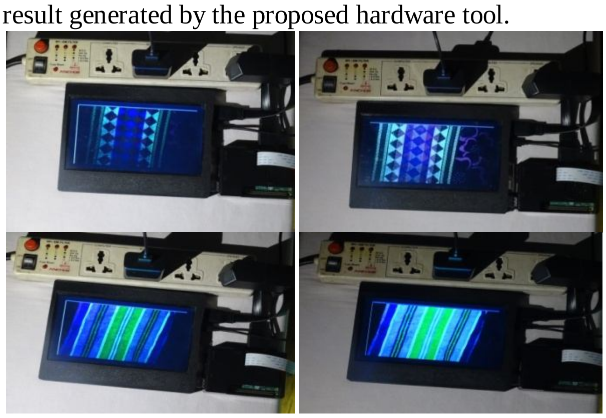
5. Assembling Different Parts of Our Hardwar Tools

Fig.5 Assembling steps of different parts of our hardware tool.

In first two rows (from left to right) shows various hardware used in a real-time working prototype, i.e.- raspberry pi, camera, HDMI TO HDMI cable, adaptors, display, wireless keyboard & mouse. The third to the fifth row shows various assembling steps, i.e. raspberry-pi to display connection, adaptor connection, keyboard & mouse connection, etc. The last two images of the fifth row along with the last row show the working of the tool along with some results images.

6. Few Results on Images

In this subjection we are going to show few enhancement result generated by the proposed hardware tool.



Input Image **Processed Image**

Fig.6 Few results generated by the developed hardware tool.

It is clear from the above figure that the I-AGCWD method improves overall visibility of the images. This method is able to enhance contrast of bright as well as dimmed images in efficient manner. Also, the proposed hardware implementation of the I-AGCWD method is able to process image in real time. This makes the I-AGCWD method a superior choice over all other methods for overall contrast enhancement of all types of image.

7. Conclusion

In this work we have developed a working prototype of the famous improved AGCWD method. Initially we have studied few basic image enhancement based methods and then tried to find a method that is most suitable for real time processing. We have found that the I-AGCWD method suits our requirements. Next was the selection of proper hardware for creating a working prototype of the method. For doing this we have chosen the "raspberry-pi" architecture. We have successfully assembled the hardware architecture. Also, we have implemented the method for the real time environment. Experimental results have shown that the proposed working prototype is capable in enhancing the bright as well as dimmed image in real time. So it is best suited for all type of real time applications.

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