Automatic Global Image Enhancement by Skin Dependent Exposure Correction

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***Abstract* - The proposed method describes an automatic exposure correction algorithm improved by a skin recognition technique. The approach analyzes the Bayer data, captured using a ccd/cmos sensor, or the corresponding color generated picture; after identifying the skin key features, the algorithm adjusts the exposure level using a '*camera response*'-like function. This method aims to solve some of the typical drawbacks featured by handset devices (e.g. mobile phones) where several factors contribute to acquire bad-exposed pictures: poor optics, absence of flashgun, etc.**

***Index Terms*—Skin recognition, Exposure Correction, Bayer Pattern.**

I. Introduction

Image capturing device market is focused on quality enhancement and reduction of processing time [6]. Quality improvement is obtained by increasing the resolution of the sensor and/or by using more sophisticated image-processing algorithms [2], [4], [7] and [9]. One of the main problems affecting image quality, leading to unpleasant pictures, comes from improper exposure to light. Beside the sophisticated features incorporated in today's cameras (i.e. automatic gain control algorithms), failures are not unlikely to occur. Some techniques are completely automatic, cases in point being represented by those based on "average/automatic exposure metering" or the more complex "matrix/intelligent exposure metering". Others, again, accord the photographer a certain control over the selection of the exposure, thus allowing space for personal taste or enabling him to satisfy particular needs.

Despite the great variety of methods for regulating the exposure and the complexity of some of them, it is not by any means rare for images to be acquired with a non-optimal or incorrect exposure. This is particularly true for handset devices (e.g. mobile phones) where several factors contribute to acquire bad-exposed pictures: poor optics, absence of flashgun, etc.

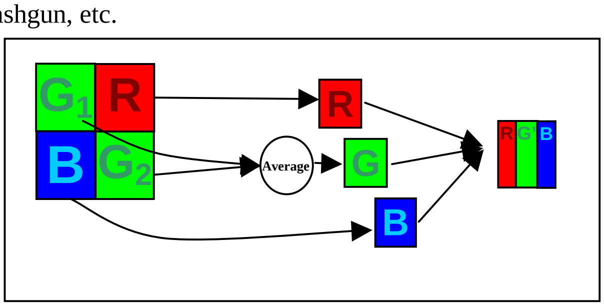

Figure 1. Bayer data sub-sampling generation.

Of course there is not an exact definition of what a correct exposure should be. It is possible to abstract a generalization and to define as best the particular exposure that enables one to reproduce the most important regions (deemed to be such in accordance with contextual or perceptive criteria) with a level of grey, or brightness, more or less in the middle of the possible range.

Our former work [1], presented an algorithm that identifies the visually relevant regions of the image by adjusting the exposure such that they occupy mid tone levels; this previous implementation differs from the algorithm described in [5] in that the whole processing is performed directly on Bayer pattern images [3], and simpler statistical measures were used to identify *information carrying* regions. The new exposure correction technique described in this paper is designed essentially for mobile sensors applications. This new element, present in newest mobile devices, is particularly harmed by "backlight" when the user utilizes a mobile device for video phoning. The detection of skin characteristics in captured images allows selection and properly enhancement and/or tracking of regions of interest (e.g. faces).

The rest of the paper is organized as follows. Next section describes both skin recognition and exposure correction techniques used for automatic enhancement. In section 3 experimental results show the effectiveness of the proposed technique. A conclusion Section closes the paper tracking directions for future works.

II. Approach Description

The proposed Skin-based Exposure Correction algorithm is defined as follows:

- Luminance extraction. If the algorithm is applied on Bayer data, in place of the three full color planes, a sub-sampled (quarter size) approximated input data (See figure 1) is used.
- Using a suitable skin recognition technique algorithm a "skin" value is associated to each pixel.
- Once the 'visually important' pixels were identified (e.g. the pixels belonging to skin features) a global tone correction technique is applied using as main parameter the mean gray levels of skin regions.

A. Skin Recognition

Most existing methods for skin colour detection usually threshold some sort of measure of the likelihood of skin colours for each pixel and treat them independently. Human skin colours form a special category of colours, distinctive from the colours of the most other natural objects. It has been

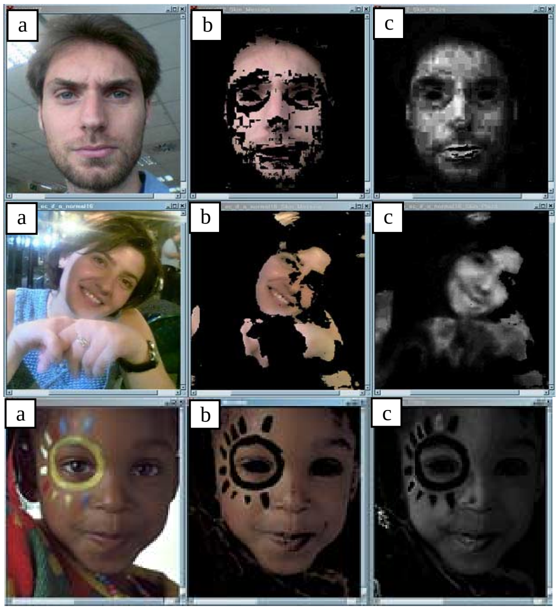

Figure 2. Skin recognition examples on RGB images. a) Original images acquired by Nokia 7650 phone (first and second row) with VGA sensor and compressed in Jpeg format; b) Simplest Threshold Method Output; c) Probabilistic Threshold Output. Third image (a) is a standard test image.

found that human skin colours are clustered in various colour spaces [10], [14]. The skin colour variations between people are mostly due to intensity differences. These variations can therefore be reduced by using chrominance components only.

Yang et al [13] have demonstrated that the distribution of human skin colours can be represented by a two-dimensional Gaussian function on the chrominance plane. The center of this distribution is determined by the mean vector $\vec{\mu}$ and its shape is determined by the covariance matrix Σ; both values can be estimated from an appropriate training data set. The conditional probability $p(\vec{x} \mid s)$ of a block belonging to the skin colour class, given its chrominance vector $\vec{x}$ is then represented by:

$$p(\vec{x} \mid s) = \frac{1}{2\pi} \left| \Sigma \right|^{-\frac{1}{2}} exp\left\{ \frac{-[d(\vec{x})]^2}{2} \right\} \quad (1)$$

where $d(\vec{x})$ is the so-called Mahalanobis distance from the vector $\vec{x}$ to the mean vector $\vec{\mu}$ and defined as:

$$[d(\vec{x})]^2 = (\vec{x} - \vec{\mu})' \Sigma^{-1} (\vec{x} - \vec{\mu}) \quad (2)$$

The value $d(\vec{x})$ determines the probability that a given block belongs to the skin colour class. The larger the distance $d(\vec{x})$, the lower the probability that the block belongs to the skin colour class.

Due to the large quantity of colour spaces, distance measures, and two-dimensional distributions, many skin recognition algorithms can be used. The skin colour algorithm is independent from exposure correction, thus we introduce two different alternative techniques aimed to recognize skin regions:

1. By using the input YCbCr image and the conditional probability (1), each pixel is classified as belonging to a skin region or not. Then a new image with normalized grayscale values is derived, where skin areas are properly highlighted (Figure 2.c). The higher the grey value the bigger the probability to compute a reliable identification.
2. By processing an input RGB image, a 2D chrominance distribution histogram (*r*, *g)* is computed, where *r=R/(R+G+B)* and *g=G/(R+G+B).* Chrominance values representing skin are clustered in a specific area of the (*r*,*g*) plane, called *"skin locus" (*figure 3.c), as defined in [12]. Pixels having a chrominance value belonging to the skin locus will be used to correct exposure.

For Bayer data, the skin recognition algorithm works on the RGB image constructed by sub-sampling the original picture, as described in figure 1. Then one of the aforementioned techniques can be applied.

B. Exposure Correction

Once the visually relevant regions (e.g. skin) are identified, the exposure correction is carried out using the mean gray value of those regions as reference point. A simulated camera response curve is used for this purpose, which gives an

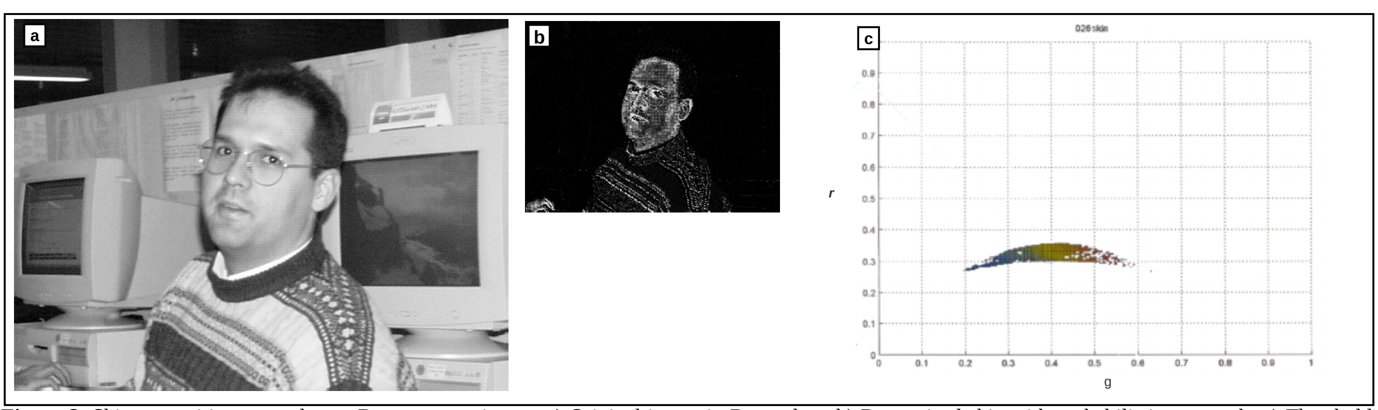

Figure 3. Skin recognition examples on Bayer pattern image. a) Original image in Bayer data; b) Recognized skin with probabilistic approach; c) Threshold skin values on *r-g* bi-directional histogram (*skin locus*).

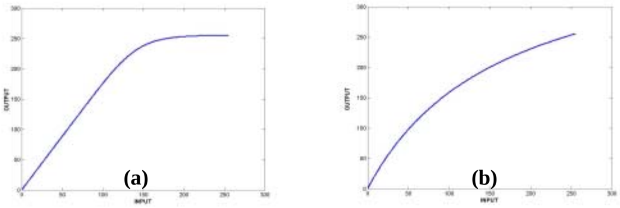

Figure 4. LUTs derived from curves with (a) A=7 and C=0.13; (b) A=0.85 and C=1.

estimate of how light values falling on the sensor become final pixel values. Thus it is a function

$$f(q) = I \qquad (3)$$

where q represents the 'light' quantity and I the final pixel value [2]. This function can be expressed ([5], [7]) by using a simple parametric closed form representation:

$$f(q) = \frac{255}{\left(1+e^{-(Aq)}\right)^{C}} \qquad (4)$$

where parameters A, and C can be used to control the shape of the curve and q is supposed to be expressed in 2-based logarithmic unit (usually referred as "stops"). These parameters could be estimated, depending on the specific image acquisition device, using the techniques described in [7] or chosen experimentally. The offset from the ideal exposure is computed using the f curve and the average gray level of visually relevant regions *avg*, as:

$$\Delta = f^{-1}(128) - f^{-1}(avg) \qquad (5)$$

The luminance value $Y(x,y)$ of a pixel (x,y) is modified as follows:

$$Y'(x,y) = f(f^{-1}(Y(x,y)) + \Delta) \qquad (6)$$

Note that all pixels are corrected. Basically the previous step is implemented as a LUT transform (Fig.4 shows 2 correction curves with different A, C parameters). These new Y' values are used to properly modify all RGB original values like in [11].

III. Experimental Results

The proposed technique has been tested using a large database of images acquired at different resolutions, with different acquisition devices, both in Bayer and RGB format. In the first case the algorithm was inserted in a real-time framework, using a CMOS-VGA sensor on "*STV6500 - E01*" Evaluation Kit equipped with "*502 VGA sensor*" [15]. In figure 5 screen-shots of the working environment are shown. Another screen-shots sequence is illustrated in figure 6. In the RGB case the algorithm was implemented as post-processing step. Examples are shown in figure 7.

IV. Conclusions

A method for automatic exposure correction, improved by a skin recognition technique, has been described. The approach is able to analyze the Bayer data captured by a ccd/cmos sensor, or the corresponding color generated picture; once the skin key features were identified, the algorithm adjusts the exposure level using a 'camera response'-like function. The method can solve some of the typical drawbacks featured by handset devices due to poor optics, absence of flashgun, etc. The overall computation time needed to apply the proposed algorithm, is negligible, thus it is well suited for real time applications. Experiments show the effectiveness of the techniques in both cases.

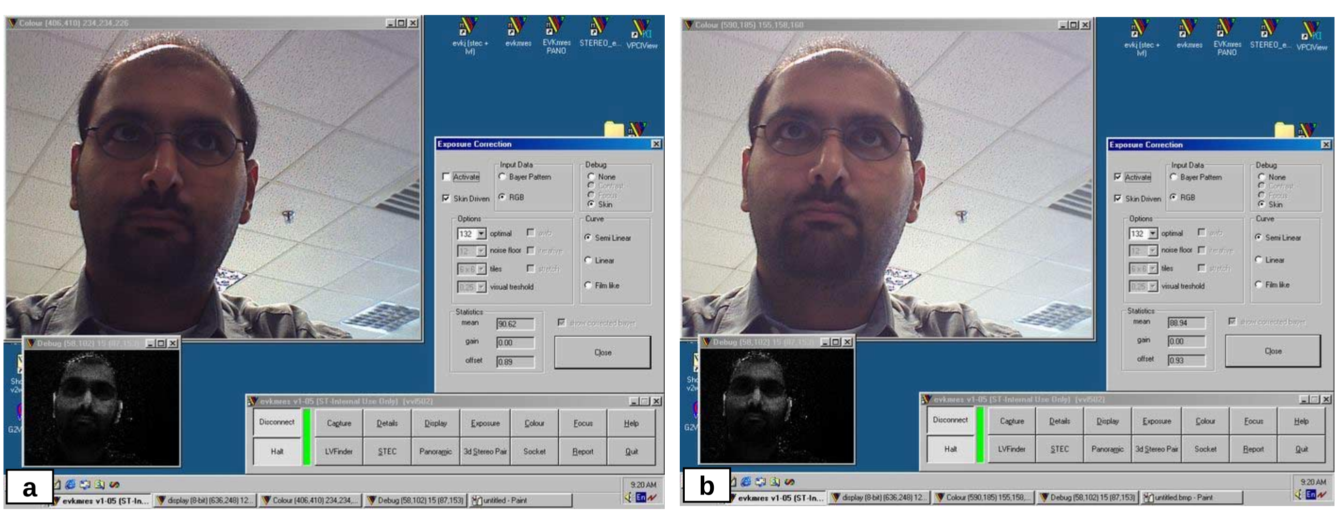

Figure 5. Framework interface for STV6500 - E01 EVK 502 VGA sensor: (a) before and (b) during real-time Skin Dependent Exposure Correction. The small window with black background represents the detected skin.

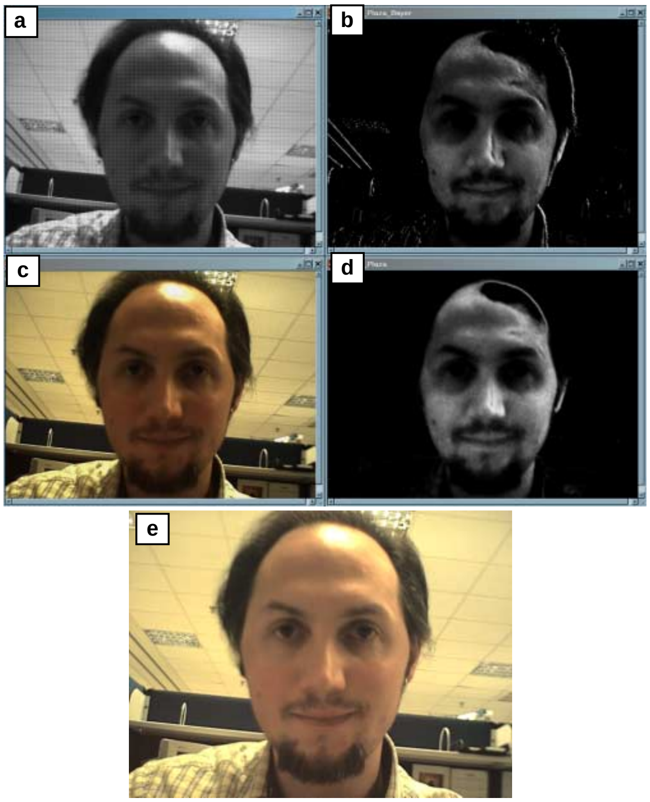

Figure 6. Experimental results by real-time and post processing: (a) Original Bayer input image; (b) Bayer Skin detected in real-time; (c) Color Interpolated Image from Bayer Input; (d) RGB Skin detected in post processing; (e) Exposure Corrected Image obtained from RGB image.

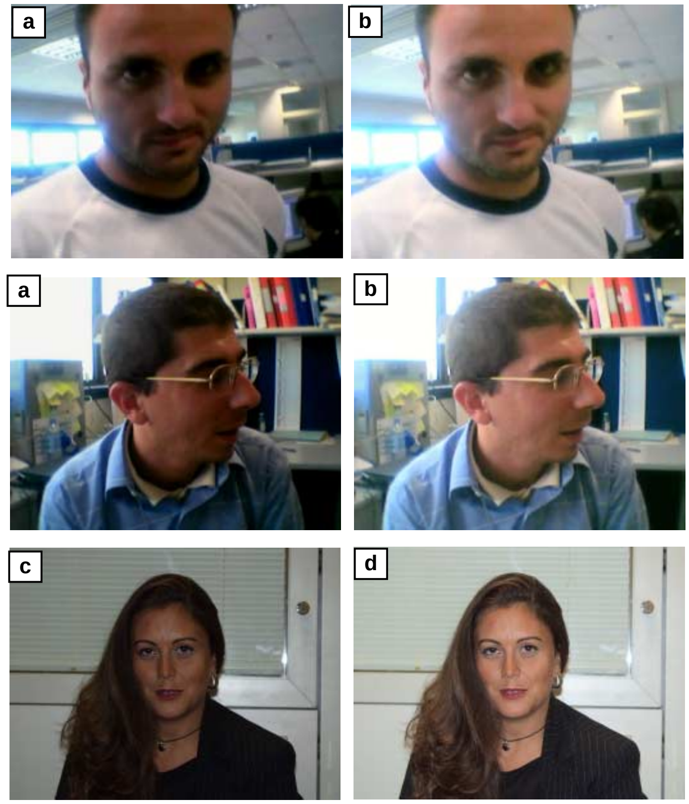

Figure 7. Experimental results: (a) original images acquired by Nokia 7650 VGA sensor compressed in Jpeg format; (b) Corrected output; (c) Image acquired with CCD Sensor (4,1 Mega Pixels) Olympus E-10® Camera; (d) Corrected output image.

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