Color Facial Image Representation with New Quaternion Gradients

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Abstract

This paper proposes a new color image representation and multiple feature fusion based method for improving color face recognition performance under different lighting conditions. First, a new image color image representation has been derived. Second, a quaternion gradient has been given to enhance and extract the faces/object's edges, contours, and texture. Also, we propose a novel feature representation based on Quaternion Gradient-based LBP tool for color face recognition. Finally, we present a concept of combining the color facial recognition system, which is based on the local quaternion gradients based binary patterns LBP Image Representation, and a new color-to-gray new mapping. The presented concept can be used for surveillance, security systems, computer animation, face tagging, human–computer interface, biometric identification, behavioral analysis, content-based image and video indexing applications.

Introduction

Gradients

Recently, several face recognition methods based on Local Binary Patterns (LBP) over the whole facial image have been developed. As well, most of face recognition algorithms have been developed for grayscale images but relatively less explored for color cases. The same limitations are made to represent color face images in different color spaces, such as RGB, YCrCb, and HSI. In this section we briefly describe LBP for face recognition. A few attempts have been made to extend the LBP to color images in the RGB space, adding redundant information in the color channels. This is to avoid dealing with the complexity of color images. However, the RGB space is not ideal for color face recognition due to its poor appearance of redundant information in the color channels. In this paper, we make an attempt to use the LBP in the HSI space, which is a more natural color space for facial recognition. The presented concept for color face recognition is based on the local quaternion gradients based binary patterns LBP Image Representation, and a new color-to-gray new mapping. The presented concept can be used for surveillance, security systems, computer animation, face tagging, human–computer interface, biometric identification, behavioral analysis, content-based image and video indexing applications.

Figure 1. The block-diagram of the facial image representation.

\[ f_{n,m} \rightarrow V(f)_{n,m}, \quad n = 0:(N - 1), m = 0:(M - 1). \]

\[ V(f)_{a,b} \rightarrow V(f)_{a,b} \otimes h_{a,b}. \]
The kernel of the Gaussian function is of size \((2L_1 + 1) \times (2L_2 + 1)\).

Stage 3. A complex gradient image composition is calculated. In the square window \(W\), we consider the following simple set of eight gradient operators:

\[
\begin{align*}
A_1 &= \begin{bmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{bmatrix}, & A_2 &= \begin{bmatrix} 0 & -1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, & A_3 &= \begin{bmatrix} 0 & 0 & -1 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}, \\
A_4 &= \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & -1 \\ 0 & 0 & 0 \end{bmatrix}, & A_5 &= \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & -1 & 0 \end{bmatrix}, & A_6 &= \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & -1 & 0 \end{bmatrix}.
\end{align*}
\]

These eight neighbor points are called the sampling points (SP). The set of sampling points can also be considered in the following order:

\[
\begin{align*}
SP &= \{(-1,-1),(0,1),(1,0),(1,1),(0,0),(-1,0),(-1,1),(-1,-1)\}.
\end{align*}
\]

The LBP image can also be written in the standard form

\[
H(f) = \sum_{k=1}^{n} 2^{k-1} |f_{n,m} - f_{n+k(SSP),m+p(k)}|.
\]

\(T\) is the Heaviside function that is defined as

\[
H(s) = \begin{cases} 1 & \text{if } s \geq 0 \\ 0 & \text{otherwise} \end{cases}
\]

The histograms of the LBP images and part (b) of the EME visibility images are shown in Fig. 4.
\((g_{3})_{\text{h,n,m}} = T\left((g_{3})_{\text{h,n,m}}\right)\).
\((g_{k})_{\text{h,n,m}} = T\left((g_{k-1})_{\text{h,n,m}} + b_{k}(f)_{\text{h,n,m}}\right), \quad k = 2:8. \quad (5')\)

\(f_{\text{h,n,m}} \Rightarrow g_{\text{h,n,m}}\)

\(E(g) = \frac{1}{k_{1}k_{2}} \sum_{k_{1}} \sum_{k_{2}} 20 \ln \left[ \frac{\max_{W_{k_{1}}}(g_{\text{h,n,m}})}{\min_{W_{k_{1}}}(g_{\text{h,n,m}})} \right], \quad (6)\)

\(E(f) = \ln \left[ \frac{\max_{W_{k_{1}}}(f_{\text{h,n,m}})}{\min_{W_{k_{1}}}(f_{\text{h,n,m}})} \right]. \quad (7)\)

\(E(c) = \ln \left[ \frac{\max_{W_{k_{1}}}(c_{\text{h,n,m}}) - \min_{W_{k_{1}}}(c_{\text{h,n,m}})}{\max_{W_{k_{1}}}(c_{\text{h,n,m}}) + \min_{W_{k_{1}}}(c_{\text{h,n,m}})} \right]. \quad (8)\)

\(E(c) = 255 \beta \frac{g_{\text{h,n,m}} - \text{mean}(c_{\text{h,n,m}})}{g_{\text{h,n,m}} + c_{0}} \quad (9)\)

\(E(c) = \frac{\max_{W_{k_{1}}}(c_{\text{h,n,m}}) - \min_{W_{k_{1}}}(c_{\text{h,n,m}})}{\max_{W_{k_{1}}}(c_{\text{h,n,m}}) + \min_{W_{k_{1}}}(c_{\text{h,n,m}})} \quad (10)\)

\(E(c) = k \frac{\max_{W_{k_{1}}}(c_{\text{h,n,m}}) - \min_{W_{k_{1}}}(c_{\text{h,n,m}})}{\max_{W_{k_{1}}}(c_{\text{n,m}}) + \min_{W_{k_{1}}}(c_{\text{n,m}})} \quad (11)\)

Color Visibility Images

\(EME(g) = \frac{1}{k_{1}k_{2}} \sum_{k_{1}} \sum_{k_{2}} 20 \ln \left[ \frac{\max_{W_{k_{1}}}(g_{\text{h,n,m}})}{\min_{W_{k_{1}}}(g_{\text{h,n,m}})} \right], \quad (6)\)

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Quaternion Image Gradients

\(f_{\text{n,m}} = (r_{\text{n,m}} + g_{\text{n,m}} + b_{\text{n,m}})\)

\(f_{\text{n,m}} \Rightarrow E(f)_{\text{n,m}} = E(c_{\text{n,m}}), E(g_{\text{n,m}}), E(b_{\text{n,m}}). \quad (8)\)

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not all edges can be found by edge detection in color images. Thus, we consider two quaternion gradients of the form $H_{x}$ and $H_{y}$, which are size of the mask.

$H_{n,m} = (1 + (i + j + k))((H_{x})_{n,m} + (i(H_{x})_{n,m} + j(H_{y})_{n,m} + k(H_{y})_{n,m})\]

$y_{n,m} = \sum_{s=1}^{l_{x}} \sum_{t=1}^{l_{y}} q_{r=s,m-t} h_{n,m} x_{n,m}$

Thus, we consider two quaternion gradients

$H_{x} = (1 + (i + j + k))g_{x}$

$H_{y} = (1 + (i + j + k))g_{y}$

The quaternion operators defined with such masks are called the Sobel gradient. The quaternion gradient operators defined with different components can also be considered similar to the RGB model case. The algorithm of face image processing can be described by the following steps.

1. The facial color image recognition can be accomplished by analyzing the average of colors in the RGB model
2. Color facial image presentation.
3. Classification, when the color image is transformed into the quaternion space. The color image can be processed by the quaternion gradient operations or a visibility classification, when the kernel is a pure quaternion image, and then can be processed by the quaternion gradient operations.

$H(q)_{n,m} = |H_{x}(q)_{n,m}| + |H_{y}(q)_{n,m}|$

$H_{1} \neq H_{j} \neq H_{k} \neq H_{i}$

$H_{q} = \begin{bmatrix} 1 & 2 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$

$G_{x} = \frac{1}{4} \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad G_{y} = \frac{1}{4} \begin{bmatrix} 1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$

Figure 7. (a) The imaginary part and (b) the real part of the quaternion $H_{x}$-Sobel gradient image.

Figure 8. (a) The imaginary part and (b) the real part of the quaternion $H_{y}$-Sobel gradient image. (c) The magnitude of the quaternion Sobel gradient image.

Figure 9. The block-diagram of color facial image processing.

Figure 10. (a) The original image and the quaternion gradient image (b) before and (c) after filtering by the 2-D Gaussian function.

Representation of Color Facial Images

The main parts of processing the color facial image are size of the mask.

$H_{x} = (1 + (i + j + k))g_{x}$

$H_{y} = (1 + (i + j + k))g_{y}$

Thus, let the convolution mask is

$H_{n,m} = (1 + (i + j + k))((H_{x})_{n,m} + (i(H_{x})_{n,m} + j(H_{y})_{n,m} + k(H_{y})_{n,m})\]

$y_{n,m} = \sum_{s=1}^{l_{x}} \sum_{t=1}^{l_{y}} q_{r=s,m-t} h_{n,m} x_{n,m}$

Thus, we consider two quaternion gradients

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Figure 1. (a) The LBP image and (b) the histogram of this image.

Figure 2. (a) The last binary image (g_b)_{n,m} before the mapping, (b) the uniform LBP image, and (c) the histogram of the image.

Figure 3. (a) The image and the quaternion Sobel gradient image (b) before and (c) after filtering by the 2-D Gaussian function.

Figure 4. (a) The image and the quaternion Prewitt gradient image (b) before and (c) after filtering by the 2-D Gaussian function.

Summary

A novel face recognition approach is proposed, by using multiple feature fusion across color, spatial and frequency domains. The proposed approach is useful and applicable not only for face recognition, but also for object recognition.

We are planning to evaluate the presented face recognition concept, by using the color FERET database: http://www.facerec.org/databases.

References


Author Biography

Artyom Grigoryan received the MS degrees in mathematics from Yerevan State University (1978), in imaging science from Moscow Institute of Physics and Technology (1980), and in electrical engineering from Texas A&M University (1999), and PhD degree in mathematics and physics from Yerevan State University (1990). He is an associate professor of the ECE Department, College of Engineering, University of Texas at San Antonio. He is author of 4 books, 10 book-chapters, 3 patents, 120 papers.

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