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

The recent advances in various applications, such as surveillance, security systems, computer animation, face tagging, human–computer interface, biometric identification, behavioral analysis, content-based image and video indexing applications, make face recognition very important. Face recognition can be defined as a process of identifying a person from a digital image or a video sequence. The goal of face recognition is to determine the identity of a person, which is based on the local binary patterns (LBP) concept for color face recognition. The rest of the paper is organized as follows. Section 2 presents brief surveys on LBP based face analysis with several recent variations. Section 3 presents a novel image representation scheme. Section 4 describes the algorithm of facial image processing. Section 5 presents conclusions and directions for future research.
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:

\[
A_1 = \begin{bmatrix}
-1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 0
\end{bmatrix},
A_2 = \begin{bmatrix}
0 & -1 & 0 \\
0 & 1 & 0 \\
0 & 0 & 0
\end{bmatrix},
A_3 = \begin{bmatrix}
0 & 0 & -1 \\
0 & 0 & 0 \\
0 & 1 & 0
\end{bmatrix},
A_4 = \begin{bmatrix}
0 & 0 & 0 \\
0 & 1 & -1 \\
0 & 0 & 0
\end{bmatrix},
A_5 = \begin{bmatrix}
0 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & -1
\end{bmatrix},
A_6 = \begin{bmatrix}
0 & 0 & 0 \\
0 & 0 & 0 \\
0 & 1 & 0
\end{bmatrix},
A_7 = \begin{bmatrix}
0 & 1 & 1 \\
0 & 0 & 0 \\
-1 & 0 & 1
\end{bmatrix},
A_8 = \begin{bmatrix}
0 & 0 & 1 \\
0 & 1 & 0 \\
0 & 0 & 0
\end{bmatrix}
\]

Figure 2. The coordinates and the order of 8 neighbor sampling points.

\[SP = \{(-1,-1),(0,-1),(1,-1),(1,0),(1,1),(0,1),(-1,1),(-1,0)\}\]

\[SP = \{(-1,-1),(-1,0),(-1,1),(0,-1),(0,0),(0,1),(1,-1),(1,1)\}\]

\[
B_k(f)_{n,m} = u[A_k(f)_{n,m}], \quad k = 1:8.
\]

\[
b_{n,m} = B_1(f)_{n,m} + 2^2B_2(f)_{n,m} + 2^3B_3(f)_{n,m} + \cdots + 2^7B_7(f)_{n,m}.
\]

\[
b_{n,m} = \sum_{k=1}^{8} 2^{k-1}[f_{n,m} - f_{n+s(k),m+p(k)}].
\]

Figure 3. (a) The image and (b) the EME visibility image. (c) The EME visibility image filtered by the 2-D Gaussian function.

Figure 4. (a) The LBP image and (b) the histogram of the image.

\[H(s)\]
The mapping by the Uniform color component is described by the operator $W_{k_{1},k_{2}}$. For $k_{1}=2$ and $k_{2}=8$, we have:

\[(g_{1})_{n,m} = T\left[(g_{1})_{n,m}\right],\]
\[(g_{k})_{n,m} = T\left[(g_{k-1})_{n,m} + B_{k}(f)_{n,m}\right].\]

(5)

The enhancement of the image is defined by:

$$E_{EM}(g) = \frac{1}{k_{1}k_{2}} \sum_{i=1}^{k_{1}} \sum_{j=1}^{k_{2}} 20 \ln \left[\frac{\max_{W_{k_{1},k_{2}}}(g_{n,m})}{\min_{W_{k_{1},k_{2}}}(g_{n,m})}\right].$$

(6)

where $g_{n,m}$ is the color components of the image, calculated with $\ell$-complex numbers can be effectively performed in the spatial domain.

Color Visibility Images

$F_{n,m} \mapsto \tilde{g}_{n,m}$

$E_{EM}(g) = \frac{1}{k_{1}k_{2}} \sum_{i=1}^{k_{1}} \sum_{j=1}^{k_{2}} 20 \ln \left[\frac{\max_{W_{k_{1},k_{2}}}(g_{n,m})}{\min_{W_{k_{1},k_{2}}}(g_{n,m})}\right].$

(6)

Here, $k_{1},k_{2}$ are $k_{1} \times k_{2}$ neighborhoods.

$\max_{W_{k_{1},k_{2}}}(g_{n,m}) = \max_{(m,n)} E_{EM}(g)$

$\min_{W_{k_{1},k_{2}}}(g_{n,m}) = \min_{(m,n)} E_{EM}(f)$

$E(g)_{n,m} = \ln \left[\frac{\max_{W_{k_{1},k_{2}}}(g_{n,m})}{\min_{W_{k_{1},k_{2}}}(g_{n,m})}\right]^{\beta}.$

(7)

$\beta = 0$ \quad $\min_{W_{k_{1},k_{2}}}(g_{n,m}) = 0$

$E(f)_{n,m} = \ln \left[\frac{\max_{W_{k_{1},k_{2}}}(f_{n,m})}{\min_{W_{k_{1},k_{2}}}(f_{n,m})}\right]^{\beta}.$

(8)

$F_{n,m} \mapsto \tilde{g}_{n,m}$

$E(g)_{n,m} = \ln \left[\frac{\max_{W_{k_{1},k_{2}}}(g_{n,m})}{\min_{W_{k_{1},k_{2}}}(g_{n,m})}\right]^{\beta}.\quad \text{(9)}$

Quaternion Image Gradients

\[ f_{n,m} = (r_{n,m}, g_{n,m}, b_{n,m}) \]

\[ f_{n,m} \mapsto E(f_{n,m}) = E(r_{n,m}), E(g_{n,m}), E(b_{n,m}). \quad \text{(8)} \]

\[ E(f)_{n,m} = \text{the EME visibility image of } f_{n,m}. \]

\[ E(c_{n,m}) = \ln \left[\frac{\max_{W_{k_{1},k_{2}}}(c_{n,m})}{\min_{W_{k_{1},k_{2}}}(c_{n,m})}\right]^{\beta}. \quad \text{(9)} \]

\[ q_{n,m} = a_{n,m} + (r_{n,m} + f g_{n,m} + k b_{n,m}). \]

\[ a_{n,m} = (r_{n,m} + g_{n,m} + b_{n,m}). \]

\[ a_{n,m} = (r_{n,m} + g_{n,m} + b_{n,m}). \]

\[ q_{n,m} = a_{n,m} + (r_{n,m} + f g_{n,m} + k b_{n,m}). \]

\[ a_{n,m} = (r_{n,m} + g_{n,m} + b_{n,m}). \]
$H_{n,m} = (H_{j})_{n,m} + (j(H_{j})_{n,m} + k(H_{j})_{n,m})$

$H_{n,m} = \sum_{n_{1}=1}^{L_{x}} \sum_{n_{2}=1}^{L_{y}} f_{n_{1},n_{2}}^{n_{0}} H_{n_{1},n_{2}}$

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

$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}, \quad G_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$

$H_x = (1 + (i + j + k))G_x$

$H_y = (1 + (i + j + k))G_y$

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.

$[(H(q))_x] = |H_x(q)| + |H_y(q)|$

$H_1 \neq H_2 \neq H_3$

Representation of Color Facial Images

Figure 9. The block-diagram of color facial image processing.
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.ferec.org/databases.

References


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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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