Color Facial Image Representation with New Quaternion Gradients

Artyom Grigoryan and Sos Agaian*, Department of Electrical and Computer Engineering, The University of Texas at San Antonio, USA, Computer Science Department, College of Staten Island and the Graduate Center, Staten Island, NY, USA

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 algorithm of facial image processing can be described by the following flows.

Stage 1. The visibility image is obtained by applying one of the gray new methods, or from the color image. Stage 2. The 2D Gaussian mask is employed for smoothing the visibility image.

The block-diagram of the facial image representation is shown in Fig. 1. The visibility image is processed by 2D Gaussian filter to obtain the grayscale facial image. The grayscale facial image is processed to obtain the LBP image. The histogram of LBP is constructed by binning the LBP image. The histogram is used as the feature for color face recognition.

Fig. 1. The block-diagram of the facial image representation.
\[ h_{n,m} = \frac{1}{K} \exp \left( -\frac{n^2 + m^2}{2\sigma^2} \right) \]

\[ K = \sum_{n=-L_1}^{L_1} \sum_{m=-L_2}^{L_2} \exp \left( -\frac{n^2 + m^2}{2\sigma^2} \right) \]

Stage 3. A complex gradient image composition is calculated. In the \( (2L_1 + 1) \times (2L_2 + 1) \) \( 3 \times 3 \) window \( W \), we consider the following simple set of eight gradient operators:

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

\[
A_4 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & -1 \\ 0 & 0 & 0 \end{bmatrix}, & A_5 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, & A_6 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & -1 & 0 \end{bmatrix}.
\]

\[ A_7 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ -1 & 0 & 0 \end{bmatrix}, & A_8 = \begin{bmatrix} 0 & -1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \]

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

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

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\[ b_{n,m} = B_1(f)_{n,m} + 2^2B_2(f)_{n,m} + 2^3B_3(f)_{n,m} + \cdots + 2^7B_8(f)_{n,m}. \]

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

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.
\[
(g_3)_{n,m} = T \left[(g_1)_{n,m}\right], \\
(g_2)_{n,m} = T \left[(g_{k-1})_{n,m} + B_k(f)_{n,m}\right], \quad k = 2, 8. \quad (5')
\]

\[
\text{EME}(g) = \frac{1}{k_1 k_2} \sum_{k=1}^{k_1} \sum_{l=1}^{k_2} \ln \left[\frac{\max_{W_{k,l}}(f_{n,m})}{\min_{W_{k,l}}(f_{n,m})}\right]. 
\] (6)

\[
E(g)_{n,m} = \ln \left[\frac{\max_{W_{k,l}}(f_{n,m})}{\min_{W_{k,l}}(f_{n,m})}\right]^{\beta}. \quad (7)
\]

\[
E(c)_{n,m} = \ln \left[\frac{\max_{W_{k,l}}(c_{n,m})}{\min_{W_{k,l}}(c_{n,m})}\right]^{\beta}. \quad (9)
\]

\[
E(c)_{n,m} = k \left[\frac{\max_{W_{k,l}}(c_{n,m}) - \min_{W_{k,l}}(c_{n,m})}{\max_{W_{k,l}}(c_{n,m}) + \min_{W_{k,l}}(c_{n,m})}\right]. \quad (11)
\]

\[
\text{EME}(g) = \ln \left[\frac{c_{n,m} - \text{mean}_W(c_{n,m})}{c_{n,m} + c_0}\right]. \quad (10)
\]

\[
E(c)_{n,m} = k \left[\frac{\max_{W_{k,l}}(c_{n,m}) - \min_{W_{k,l}}(c_{n,m})}{\max_{W_{k,l}}(c_{n,m}) + \min_{W_{k,l}}(c_{n,m})}\right].
\]

\[
E(c)_{n,m} = \ln \left[\frac{c_{n,m} - \text{mean}_W(c_{n,m})}{c_{n,m} + c_0}\right].
\]

**Figure 5.** (a) The color “flowers” image, (b) the MEVCI, and (c) grayscale image of the MEVCI.

\[
E(c)_{n,m} = k \left[\frac{\max_{W_{k,l}}(c_{n,m}) - \min_{W_{k,l}}(c_{n,m})}{\max_{W_{k,l}}(c_{n,m}) + \min_{W_{k,l}}(c_{n,m})}\right].
\]

**Figure 6.** (a) The color “pepper” image, (b) the MVCI, and (c) grayscale image of the MVCI.

\[
f_{n,m} \rightarrow E(f_{n,m}) = E(f_{n,m}), E(g_{n,m}), E(b_{n,m}).
\]

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

\[
E(c_{n,m}) = \ln \left[\frac{\max_{W_{k,l}}(c_{n,m})}{\min_{W_{k,l}}(c_{n,m})}\right]^{\beta}.
\]

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

\[
E(c_{n,m}) = \ln \left[\frac{\max_{W_{k,l}}(c_{n,m})}{\min_{W_{k,l}}(c_{n,m})}\right]^{\beta}.
\]

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

**Quaternion Image Gradients**

\[
q_{n,m} = a_{n,m} + (r_{n,m} + g_{n,m} + kb_{n,m}). \quad (12)
\]

\[
a_{n,m} = (r_{n,m} + g_{n,m} + b_{n,m}).
\]
The quaternion operators defined with such components are shown in the block diagram of Fig. 9. The quaternion gradient operators defined with different components can also be considered similar to the RGB model case. The algorithm of facial color image recognition can be accomplished by analyzing the obtained quaternion image for color facial image presentation.

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The main parts of processing the color facial image, when the color image is transformed into the quaternion space. The color image can be processed by the quaternion gradient operators defined with different components. The representation of color facial images can be described by the following steps.

1. To obtain binary images from the eight gradient operators, the color facial image is transformed into the quaternion space. The color image can be processed by the quaternion gradient operators defined with different components.

2. The quaternion gradient operators defined with different components can also be considered similar to the RGB model case. The algorithm of facial color image recognition can be accomplished by analyzing the obtained quaternion image for color facial image presentation.

3. The quaternion gradient operators defined with different components can also be considered similar to the RGB model case. The algorithm of facial color image recognition can be accomplished by analyzing the obtained quaternion image for color facial image presentation.

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Figure 11. (a) The LBP image and (b) the histogram of this image.

Figure 12. (a) The last binary image \((g_{k})_{m,n}\) before the mapping, (b) the uniform LBP image, and (c) the histogram of the image.

Figure 13. (a) The image and the quaternion Sobel gradient image (b) before and (c) after filtering by the 2-D Gaussian function.

Figure 14. (a) The last binary image \((g_{k})_{m,n}\) before the mapping, (b) the uniform LBP image, and (c) the histogram of the image.

Figure 15. (a) The image and the quaternion Prewitt gradient image (b) before and (c) after filtering by the 2-D Gaussian function.

Figure 16. (a) The last binary image \((g_{k})_{m,n}\) before the mapping, (b) the uniform LBP image, and (c) the histogram of the image.

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.face-rec.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.

Sos Agaian received the M.S. degree in mathematics and mechanics from Yerevan University, Armenia, the Ph.D. degrees in math and physics from Steklov Institute of Mathematics, Russian Academy of Sciences, and in engineering from Institute of Control System, Russian Academy of Sciences. He is professor of the Science Department, College of Staten Island. He is Fellow of the SPIE, IEEE, AAAS, and IS&T. He has authored of 500 scientific papers, 7 books, holds 14 patents.