FACE RECOGNITION BY USING REAL-TIME JOINT TRANSFORM CORRELATOR WITH COMPRESSED REFERENCE IMAGES

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ABSTRACT: A new optical method for implementing face recognition by using real-time joint transform correlator with compressed reference images is proposed to improve processing time and to solve storage problem. The compression is based on lossy Joint Photographic Experts Group (JPEG) scheme. The effect of compressing reference on the face recognition is quantitatively studied by using two different contrasts of human face image. The simulation results show that the face recognition by using joint transform correlator with compressed high-contrast human face as the reference is more robust to both noise and contrast difference than that of the low-contrast compressed reference.

KEYWORDS: optical face recognition, joint transform correlator, correlation performance, JPEG image compression

1. INTRODUCTION

Face recognition via correlation-based method can be implemented by using either digital or optical approach. In the field of optical pattern recognition, a real-time joint transform correlator (JTC) is one of the most promising architectures for performing image correlation (Yu, and Lu 1984). In real-time JTC, a face image to be recognized is captured by a CCD camera, while the reference face images are stored as database in a computer system. The face target and the face reference images are displayed onto an electrically addressed spatial light modulator (EASLM) placed in a front focal plane of a Fourier transforming lens. By illuminating the EASLM with a coherent plane wave, a joint power spectra (JPS) is generated at the back focal plane of the lens. The generated JPS is then captured by the CCD sensor. By Fourier transforming either optically or digitally the recorded JPS, the correlation output is produced. The degree of similarity between the target and the reference is measured by considering the quality of the correlation output. Although the JTC architecture is indeed useful for implementing real-time face recognition system, a serial nature of signal communication between the computer and the EASLM during transferring the joint target and the reference images onto the EASLM introduces a time delay. In real-world automatic face recognition, we may have to deal with a large number of references which covers all possible facial distortions of the target such as rotation, orientation, and scale changes. This requires considerable storage capability. One practical approach to solve these problems is to compress the reference face images. In this study, we investigate quantitatively the effects of JPEG reference image compression on the correlation performance of the JTC under situations where the target is suffered from noise and has contrast difference with respect to the reference.

2. REAL-TIME JTC WITH COMPRESSED REFERENCE IMAGES

Figure 1 shows an optical setup for implementing face recognition by using real-time JTC with compressed reference images. In this setup, the compressed reference $r_c(x,y)$ retrieved from the computer and the target $t(x,y)$ images are displayed side-by-side onto EASLM which can be mathematically written as

$$f(x,y) = r_C(x - x_0, y) + t(x + x_0, y), \tag{1}$$

with x_0 corresponds to the position of the images in the x direction. Under a presence of an additive white Gaussian noise $n(x,y)$ and a contrast difference between the target and the compressed reference images, Eq. (1) can be rewritten as

$$f(x,y) = r_C(x - x_0, y) + c_T t(x + x_0, y) + n(x + x_0, y), \tag{2}$$

where c_T is the amplitude ratio of the target image to the reference image. After a Fourier transformation by using a Fourier transform lens (L_1), its generated joint power spectra (JPS) is recorded onto CCD sensor. By displaying the captured JPS onto the EASLM, the second Fourier transformation produces the correlation output at the back focal plane of the lens L_1. The correlation function located at $x = \pm 2x_0$ is found to be

$$\begin{aligned} I(x,y) = c_T[&r_C(x,y) \otimes t^*(-x,-y) \otimes \delta(x - 2x_0)] \\ &+ r_C(x,y) \otimes n^*(-x,-y) \otimes \delta(x - 2x_0), \end{aligned} \tag{3}$$

where $\otimes$ denotes correlation. Equation (3) indicates that besides the contrast and noise, the correlation output depends also on image quality of the compressed face reference $r_C(x,y)$.

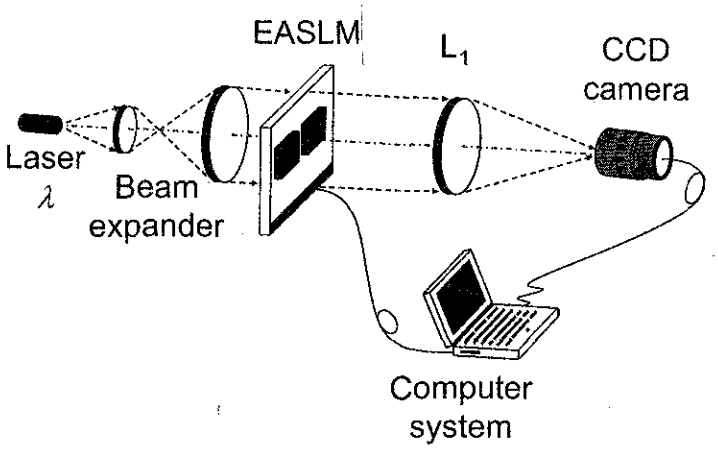

Figure 1. Optical setup of the real-time JTC

3. RESULTS AND DISCUSSIONS

In order to study the effects of compressing reference images on the recognition performance of the human face recognition by using the JTC, two human face images with different contrast were first prepared. These images consisted of 124×186 pixels with gray scale levels and were 23 Kbytes in size. The contrast of image is determined by computing the contrast function defined as

$$C(u,v) = \frac{2A(u,v)}{DC}, \tag{4}$$

where $A(u,v)$ is the amplitude of the Fourier spectrum of the image. Figure 2 show the 1-D plot of the contrast function of the low- and high-contrast human faces. It is clear that the high-contrast face

image has higher amplitude of the spatial-frequency content than that of the low contrast. This also implies that the high-contrast face image contain more high-spatial frequency components.

The reference images were compressed into the JPEG format by using the ACDsee software (The 2000 ACD systems, Ltd.) with different compression levels. In this software, the compression quality is determined by a parameter called the quality factor (QF) whose value can be varied from 0 to 100. The higher the QF the bigger the file size of the compressed image. The quality of compressed reference images is assessed with respect to the original version by using the compression ratio (CR) defined as the ratio of the uncompressed to the compressed file size (Pennebaker, and Mitchell 1997). Figure 3 shows the CR of the compressed high- and low-contrast references as a function of the QF. The results show that the CR of the low-contrast image is higher than that of the high-contrast image. As shown in Figure 2, this is due to the fact that the low contrast image contains more low spatial-frequency components than the high-contrast image does. The quantization process of the JPEG algorithm done on the low-contrast image gives high redundancy of zeros which can be efficiently encoded by a run length encoding and a Huffman coding.

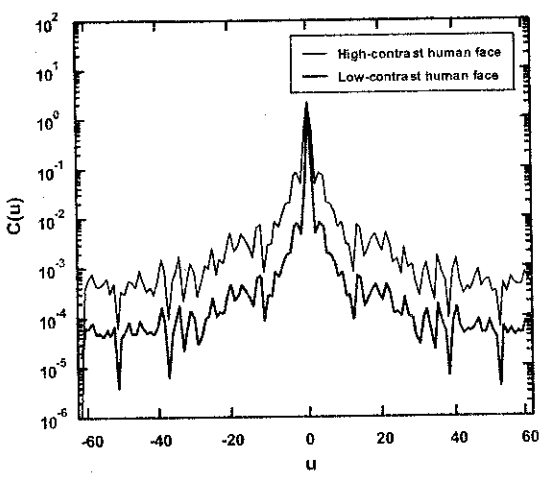

Figure 2. 1-D of the contrast function of face image

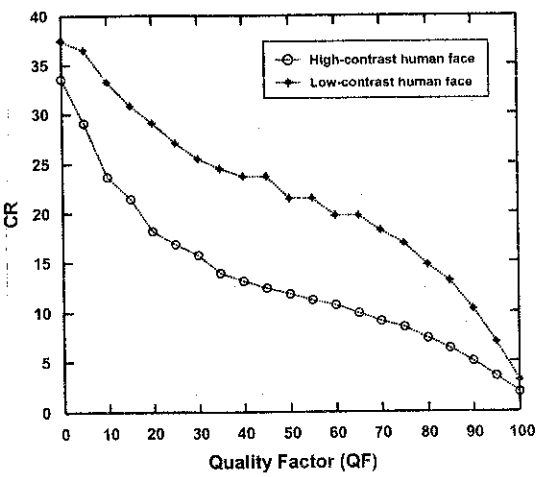

Figure 3. The CR as function of the QF

In the simulation, the target and the compressed reference face images were combined to form the joint input image pixels with a separation of $2x_0 = 248$ pixels. The FT of this joint input image was calculated by using the 2-D FFT command of the Matlab 6.1 (The math works, Inc.). The correlation quality of the JTC output was quantified by measuring a ratio of the correlation peak intensity to the standard deviation of the correlation intensity (PCD) given by

$$PCD = \frac{I(i,j)_{\max}}{\left\{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left[I(i,j) - E\{I(i,j)\}\right]^2\right\}^{1/2}}, \tag{5}$$

where $I(i,j)_{\max}$ is the maximum intensity of the correlation output, while $E\{I(i,j)\}$ is the mean of the correlation intensity. A large PCD means that the correlation function has a sharp peak and thus, the degree of similarity between target and reference is high. In order to compare the recognition performance at difference compression levels, each PCD is normalized by its autocorrelation value.

3.1 Compressed High-Contrast Human Face as the Reference Image

Figure 4 shows the normalized PCDs as a function of the QF of the compressed high-contrast human face for different target scenes. It is clear that for all given types of targets, the normalized PCDs almost do not vary with respect to compression levels. This indicates that the presence of the noise and the contrast difference between the target and the reference do not affect the correlation performance of the JTC by using the compressed high-contrast human face reference, because the term $r_C(x,y) \otimes t^*(-x,-y)$ gives broad correlation output with high peak intensity. The degradation caused by the noise term $n(x,y) \otimes t^*(-x,-y)$ and the contrast difference described by the factor c_T do not change significantly the standard deviation of the correlation output. As a result, the normalized PCDs are always maximum for nearly all target scenes.

3.2. Compressed Low-Contrast Human Face as the Reference Image

Figure 5 shows the variation of the normalized PCDs as a function of the QF of the compressed low-contrast human face for different target scenes. The normalized PCDs are greater than 0.9 and almost constant for all compression levels, except when the QF is less than 20. The results also show that the recognition performance of the JTC by using the compressed low-contrast human face as the reference is more affected by the noise in comparison with the high-contrast reference. As shown in Figure 3, the CR of the low-contrast human face is the higher than that of the high-contrast human face. Therefore, it is worth mentioning that although by using a small file size of the compressed reference, the JTC gives a good recognition performance.

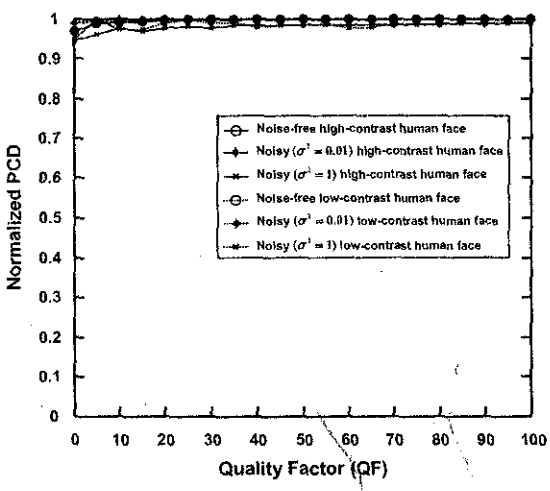

Figure 4. Face recognition performance of the JTC with the compressed high-contrast human face as reference image

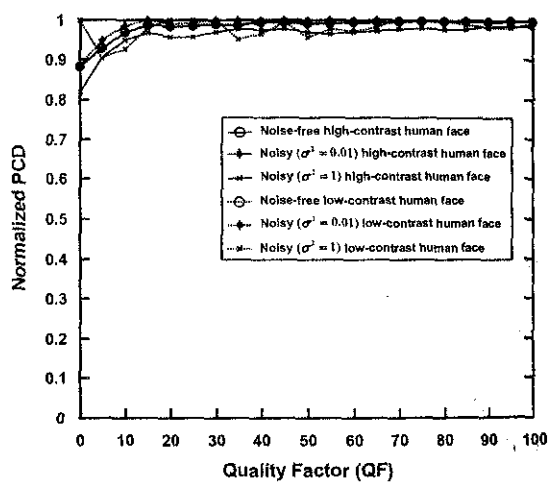

Figure 5. Face recognition performance of the JTC with the compressed low-contrast human face as reference image

4. CONCLUSIONS

We have proposed a real-time JTC by using the JPEG-compressed reference images as a practical way of solving the storage problem and improving the response time of the automatic face recognition systems. We have studied quantitatively the effects of the lossy-JPEG compression on the face recognition performance by using the normalized PCD. This study took into account the presence of noise in the input and the contrast difference between the target and the reference that may rise due to unbalance illuminations. Since the CR of the high-contrast human face is lower than that of the low-contrast human face for all QF, the effects of compression of the high-contrast human

face reference on the correlation performance of the JTC is not significant for all given target scenes. In addition, although the correlation performance of the JTC by using the compressed low-contrast human face decreases at the low QF, the degradation due to the noise presence and the contrast difference is small.

5. REFERENCES

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