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안전 검증을 위한 광-디지탈 지문인식 시스템

Opto-Digital fingerprint identification system for security verification

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ABSTRACT

We propose an Opto-Digital hybrid fingerprint identification system based on the binary phase extraction joint transform correlator(BPEJTC) for validation and security verification. It is shown that since the BPEJTC provides higher peak-to-sidelobe ratio than that of the conventional JTC and does not cause correlation peaks due to intra-class association, this system is well-adaptive to the multiple object environments. Experimental results show that this system has a good performance in the presence of multiple images and the variations of the same person.

국 문 요 약

본 논문에서는 BPEJTC에 근거한 광-디지탈 지문인식 시스템을 구성하여 안전검증에 응용 가능함을 보였다. BPEJTC 시스템은 기존의 JTC 에 비해 높은 상관 값을 가지므로 유사 지문 간의 상관이 발생하지 않으며, 입력에 여러개의 지문이 존재하는 경우에도 잘 적응할 수 있는 장점을 지닌다. 컴퓨터 시뮬레이션 및 실험을 통해 본 시스템이 변형된 동일인의 지문 혹은 여러종류의 다른지문으로부터 동일 지문을 인식할 수 있음을 보였다.

1. INTRODUCTION

It is well known that fingerprints have been used as a unique identifier of individuals. In the area of optical security, the optical fingerprint identification systems based on the joint transform correlator (JTC) have been shown to perform well[1,2].

The conventional JTC has shown many problems such as intra-class crosscorrelation, strong dc, and low peak-to-sidelobe ratio etc. To make

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the peak-to-sidelobe ratio higher and a correlation peak width narrower, several modified versions of the JTC, for example, binary joint transform correlator(BJTC) and amplitude compensated JTC were proposed and evaluated compared with the conventional JTC. In a BJTC, a joint transform power spectrum (JTPS) was binarized by properly thresholding it with an particular value like mean or median value. Despite of the dramatic improvements in the peak-to-sidelobe ratio, the BJTC could produce spurious correlation peaks, i.e. false alarms, as well as misses at an output correlation plane. Also, the performance of the modified JTC has been investigated in the presence of multiple objects[4~6].

We introduced the binary phase extraction JTC (BPEJTC) that has many advantages over the conventional JTC and the BJTC[7,8]. The BPEJTC produces significantly higher peak-to-sidelobe ratio than that of the JTC and a smaller number of false alarms than that of the BJTC. Moreover, it is not required to calculate the threshold value for the binarization, which saves computation time and has a good discrimination performance for multiple targets.

In this paper, an Opto-Digital hybrid fingerprint identification system based on the BPEJTC is proposed. This suggested system, which utilizes the inherent spatial frequencies of fingerprint images, conducted the fingerprint recognition through the phase matching in the spatial frequency plane between the phase signals extracted from the references and an input image. The multiple reference fingerprint images were stored in a data base. The input image is sent to the BPEJTC for comparison with a data base of reference fingerprints to determine the individual's identity. The recognition system is implemented in the hybrid form in which the 2-D spatial frequencies of the fingerprint images are generated by the optical unit and its phase signals are extracted by the digital unit. The optical unit composed of a couple of lenses, LCDs and CCD detectors was mainly used to take the Fourier transform operations. And the digital unit controlling the entire system played a part in modifying and binarizing the JTPS, which makes this system perform better than the conventional JTC or BJTC-based system. In the BPEJTC system, the fingerprint identification is performed by the phase matching between the reference images and an input image. For the performance evaluation of the proposed fingerprint identification system, some experiments are optically conducted by testing the multiple reference fingerprint images and the results are proved to be highly acceptable.

2. BPEJTC

Fig. 1 shows the input plane of JTC that contains the reference image and the input images. Let the reference image and the input images are positioned in the lower and upper half of the input plane, respectively.

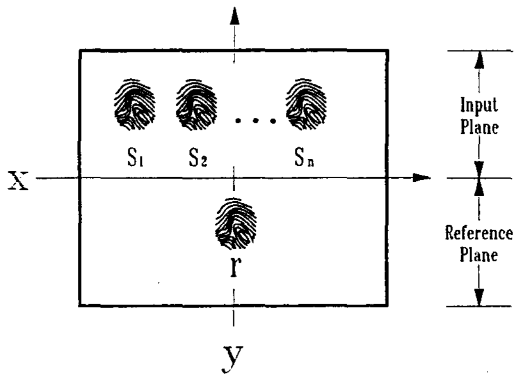


Fig. 1 The input plane of JTC

$$r(x, y)=r(x-x_0, y-y_0),$$

$$s(x, y)=\sum_{i=1}^{n} s_i(x-x_i, y-y_i) \quad \cdots\cdots (1)$$

where $r(x, y)$ is the reference image and $s_i(x, y)$ is the input images which may contain multiple target. By coherent illumination, jointly Fourier transformed, its joint transform power spectrum (JTPS) is written as

$$E(u, v)=|R(u, v)|^2+\sum_{i=1}^{n}|S_i(u, v)|^2$$

$$+\sum_{i=1}^{n} R(u, v)S_i^*(u, v)\exp\{-j[(x_0-x_i)u+(y_0-y_i)v]\}+\sum_{i=1}^{n} R^*(u, v)S_i(u, v)\exp\{j[(x_0-x_i)u+(y_0-y_i)v]\}+\sum_{i=1}^{n-1}\sum_{k=i+1}^{n} S_i(u, v)S_k^*(u, v)\exp\{-j[(x_i-x_k)u+(y_i-y_k)v]\}+\sum_{i=1}^{n-1}\sum_{k=i+1}^{n} S_i^*(u, v)S_k(u, v)\exp\{j[(x_i-x_k)u+(y_i-y_k)v]\} \quad (2)$$

After an inverse Fourier transformation, the complex light field at the correlation output plane becomes

$$C(x, y)=r(x, y)\otimes r(x, y)+\sum_{i=1}^{n}[s_i(x, y)\otimes s_i(x, y)]+\sum_{i=1}^{n}[r(x, y)\otimes s_i(x, y)]*\delta(x+x_0-x_i, y+y_0-y_i)+\sum_{i=1}^{n}[r(x, y)\otimes s_i(x, y)]*\delta(x-x_0+x_i, y-y_0+y_i)+\sum_{i=1}^{n-1}\sum_{k=i+1}^{n}[s_i(x, y)\otimes s_k(x, y)]*\delta(x+x_i-x_k, y+y_i-y_k)+\sum_{i=1}^{n-1}\sum_{k=i+1}^{n}[s_i(x, y)\otimes s_k(x, y)]*\delta(x-x_i+x_k, y-y_i+y_k) \quad (3)$$

where the mathematical functions * and ⊗ denote the correlation and convolution operations, respectively. Note that the first two terms of Eq. (3) are the autocorrelation signals diffracted around the origin of output correlation plane, while the second two terms represent the crosscorrelation signals between the reference and the input images and the last two terms represent intra-class crosscorrelation signals. In the presence of multiple targets, the autocorrelation and intra-class crosscorrelation signals can make the false alarms and missing.

To alleviate this problem, in the BPEJTC system, the conventional JTPS is modified. The pow spectrums of the reference and input image are as follows.

$$E_r(u, v)=|R(u, v)|^2 \quad (4)$$

$$E_s(u, v)=\sum_{i=1}^{n}|S_i(u, v)|^2+\sum_{i=1}^{n-1}\sum_{k=i+1}^{n} S_i(u, v)S_k^*(u, v)\exp\{-j[(x_i-x_k)u+(y_i-y_k)v]\}+\sum_{i=1}^{n-1}\sum_{k=i+1}^{n} S_i^*(u, v)S_k(u, v)\exp\{j[(x_i-x_k)u+(y_i-y_k)v]\} \quad (5)$$

In order to remove the autocorrelation and intra-class crosscorrelation signals, the JTPS of Eq. (2) is subtracted by Eq. (4) and Eq. (5) and the resultant JTPS is given by

$$E_{NEW}(u, v)=\sum_{i=1}^{n} R(u, v)S_i^*(u, v)\exp\{-j[(x_0-x_i)u+(y_0-y_i)v]\}+\sum_{i=1}^{n} R^*(u, v)S_i(u, v)\exp\{j[(x_0-x_i)u+(y_0-y_i)v]\}=2\sum_{i=1}^{n}|R(u, v)||S_i(u, v)|\cos\{\phi_r(u, v)-\phi_{s_i}(u, v)-(x_0-x_i)u-(y_0-y_i)v\} \quad (6)$$

The new JTPS is found to be very similar to the VanderLught matched filters. In case the reference and the input images are the same targets, $|R(u, v)||S_i(u, v)|$ has the positive values. Therefore, the sign of $E_{NEW}(u, v)$ is entirely dependent on the values of cosine and, we can get the bipolar JTPS as Eq. (7).

$$E_{bny}(u, v)=\begin{cases} 1 & \cos(\Phi)\geq 0 \\ -1 & \cos(\Phi)<0 \end{cases} \quad (7)$$

Because the phase variable Φ of the cosine function in Eq. (7) represents the distance between the input and reference images, the resultant correlation signals become very similar to those of the phase only correlator(POC) as Eq. (8).

$$C(x, y)=\sum_{i=1}^{n}\{edge[s_i(x, y)]\otimes edge[r(x, y)]\}*\delta(x+x_0-x_i, y+y_0-y_i)+\sum_{i=1}^{n}\{edge[r(x, y)]\otimes edge[s_i(x, y)]\}*\delta(x-x_0+x_i, y-y_0+y_i) \quad (8)$$

where the edge[○] is the ideal edge signal of the image.

Accordingly, the BPEJTC system is analyzed to have the same correlation discrimination performances with the POC and it can get rid of the correlation errors due to the autocorrelation and intra-class crosscorrelation signals which are occurred in multiple targets situation[9].

3. FINGERPRINT IDENTIFICATION SYSTEM

Fig. 2 shows the system diagram for the fingerprint identification using the BPEJTC. Here, the optical paths are designated by dashed line and digital paths are single arrows. In the optical unit, the input fingerprint image captured by a CCD is sent to the BPEJTC. In the input plane of the BPEJTC, the reference images and the input image from the CCD are placed on the upper and lower halves of the input spatial light modulator (SLM), respectively. In a data base, the references of fingerprint images were stored for multiple fingerprints identification. By coherent illumination, jointly Fourier transformed, its joint transform power spectrum(JTPS) is captured by a CCD. The digital unit controlling the entire system played a part in modifying and binarizing the JTPS. The modified JTPS is transferred to the SLM. Finally, after Fourier transformed, the correlation output is detected again by the CCD to determine the individual's identity.

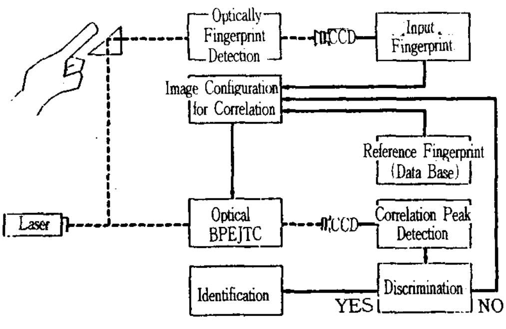


Fig. 2 The block diagram of the fingerprint identification system

4. EXPERIMENTS

Fig. 3 shows the Opto-Digital setup for the BPEJTC-based fingerprint identification system. The system consists of the phase extraction part based on BPEJTC and the identification part of fingerprints. As the input devices and optical detectors, CCD cameras were used. The high resolution LCDs were used for SLM.

In the BPEJTC system, the reference and the input fingerprint images were displayed onto the upper and lower halves of the LCD1, respectively. By coherent illumination, jointly Fourier transformed, its JTPS is captured by a CCD. To get the modified JTPS of BPEJTC, we used B/S, two stoppers, and three CCD cameras. In the digital unit, the JTPS is modified following the procedure that the value of power spectrum PS1 and PS2 were inversed and added to the JTPS. The modified JTPS based on the BPEJTC is transferred to LCD2. Finally, after inverse Fourier transformed, the correlation outputs were displayed at the output plane.

To evaluate this fingerprint identification system, we used the printed fingerprint images for CCD inputs and the correlator part was optically composed. The digital unit consists of DT2851 image grabber and IBM PC Pentium to store the reference data base, modify the JTPS, and control the LCDs. The optical unit of the system consists of a CCD camera controlled by NTSC timing signal, a Fourier lens, He-Ne laser source, and EPSON LCD of 320×220 pixels with 2.54×1.90cm.

Four fingerprint images were used for multiple references, which are stored in a data base. Fig. 4 and Fig. 5 show the experimental results. The i--

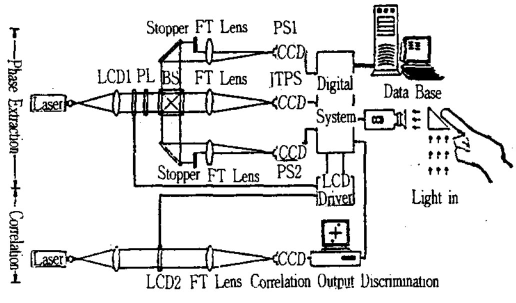
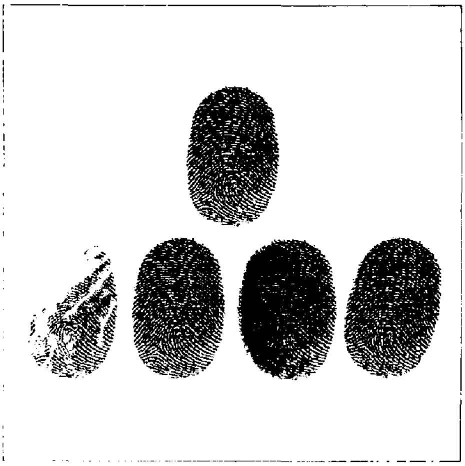
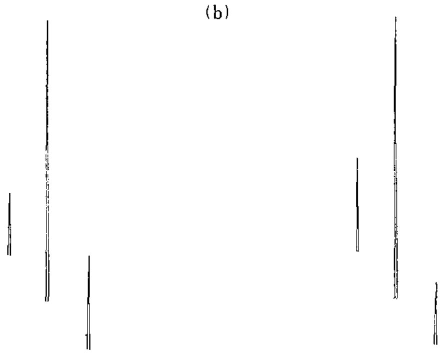


Fig. 3 Opto-Digital setup for the BPEJTC-based fingerprint identification system



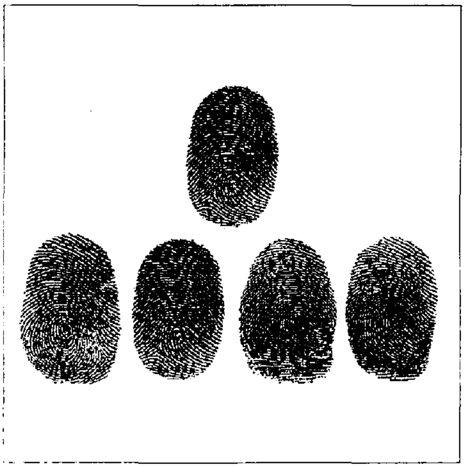
(a)

(b)

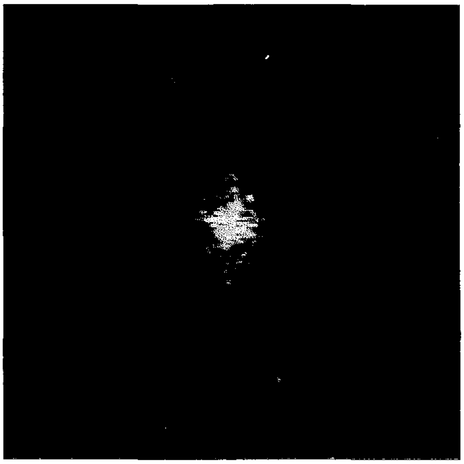


(c)

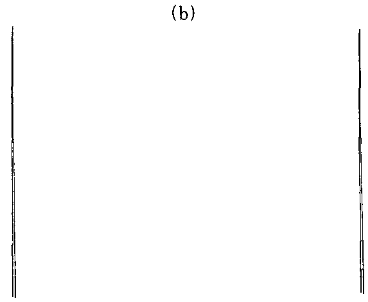
Fig. 4 (a) The input plane that has the references of the same person, (b) The correlation output, (c) The computer simulation



(a)



(b)



(c)

Fig. 5 (a) The input plane that has the references of other persons, (b) The correlation output, (c) The computer simulation put fingerprint and the reference fingerprints were displayed onto the lower and upper halves of the LCD, respectively. In Fig. 4(a), as the reference fingerprints, we use the variations of the same person such as partial, original, blurred and rotated versions of the same person. Fig. 4(b) is the correlation outputs of these input and the corresponding computer simulation results are shown in Fig. 4(c). From the Fig. 4, the correlation performance of the proposed system is analyzed to be somewhat insensitive to the partial and blurred versions. These characteristics are resulted from the fact that the operation of the BPEJTC-based fingerprint identification system is based on the phase matching correlation between input and reference fingerprints.

There was no correlation output when the rotated fingerprint was used as the reference, which means this system lacks in rotation invariance. To solve this kind of problems, we are considering a modified system that consists of the proposed system and distortion-invariant pattern recognition system. This system has a good recognition performance within ±3° rotated and 60% partial image. But, this recognition rate dependent upon the thresholding level of JTPS. Fig. 5(a) shows the input plane that has the references of one same and three other's fingerprints. Fig. 5(b) and 5(c) show the correlation output and computer simulation. There were no correlation output when other people's fingerprints were used as the reference, which is caused by the strong phase matching property of the proposed system. The system can output correlation peaks in 5 clock period, beginning with the reception of an input image. Since one clock period corresponds to a two field period in NTSC standard, i.e. 1/30 sec, the proposed system can handle 6 frames per second[10].

5. CONCLUSION

We introduced a hybrid fingerprint identification system based on the BPEJTC. The proposed system operated well in the presence of multiple references. The BPEJTC conducted the fingerprint identification through the phase matching between the phase signals extracted from the reference and input images. It has been shown experimentally that this system has a good performance in the presence of multiple images for the fingerprint identification. We expect that this system will be useful when the input fingerprints can be recognized with distortion-invariant property.

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