FINGERPRINT VERIFICATION USING OPTICAL SHIFTED PHASE-ENCODED JOINT TRANSFORM CORRELATION

M. Nazrul Islam
Email: islamn@farmingdale.edu
Security Systems, Farmingdale State University of New York
2350 Broad Hollow Road, Farmingdale, New York

Abstract: Automatic fingerprint verification is an important tool of any security and monitoring systems. An optical joint transform correlation technique is proposed for efficient real-time recognition of fingerprints. The proposed technique employs optical lenses and spatial light modulators to process the given images and hence it can yield the verification decision almost instantaneously. The optical correlator is modified by incorporating phase shifting and phase encoding of the reference fingerprint to avoid unnecessary correlation signals and hence make the best utilization of the space and bandwidth resources. The given input image of fingerprint is correlated directly with the reference fingerprint and a highly distinctive correlation signal is produced if the given fingerprint is of an authorized person, while a negligible correlation signal is produced for all unauthorized fingerprints. The proposed technique is capable of recognizing multiple authorized fingerprints simultaneously in a given input scene containing more than one fingerprint. Performance of the proposed techniques is investigated through computer simulation involving real-life fingerprint images.

Key Words: fingerprint verification, joint transform correlation, fringe-adjusted filter, pattern recognition.

I. INTRODUCTION

Fingerprint has widely been utilized as an efficient biometric feature to identify a human being. Real-time automatic fingerprint verification is a necessary and very important tool for any kind of security and monitoring applications [1]. Optical joint transform correlation (JTC) technique has been observed to be very efficient for real-time pattern recognition systems, because it allows real-time updating of the reference image, permits parallel Fourier transformation of the reference image and input scene, operates at video frame rates and eliminates any precise positioning requirement of complex matched filters in the Fourier plane [2]. However, classical JTC technique suffers from poor correlation discrimination, wide sidelobes, pair of correlation for each object, and strong zero-order correlation. Different algorithms have been proposed to overcome the limitations of the classical JTC technique, namely binary JTC [3], phase-only JTC [4], and fringe-adjusted JTC [5]. Though these techniques are able to solve some of the problems mentioned above, but they are not as efficient as required for practical real-time applications. A new efficient and successful optical JTC algorithm has been proposed named shifted phase-encoded fringe-adjusted JTC (SPFJTC) technique [6-7]. It yields a single and very distinctive correlation signal with high discrimination between the target image and the non-target images and the background, and also operates well in noisy input scenes.

The objective of this paper is to develop a fingerprint verification technique employing the SPFJTC algorithm for automatic and real-time applications. The reference fingerprint image is correlated with the given fingerprint images and a correlation signal is generated in the output plane which distinguishes a fingerprint in the database from that not included in the database.

Computer simulation is carried to investigate the performance of the proposed technique involving real-life fingerprint images.

II. ANALYSIS

Figure 1 shows the block diagram of the proposed optical shifted phase-encoded fringe-adjusted joint transform correlation (SPFJTC) technique for distortion-invariant fingerprint verification system. The reference fingerprint image, $r(x, y)$, from the database is first Fourier transformed and multiplied by a random phase mask, $\phi(x, y)$, as given by

$$R(u,v)=|R(u,v)|\exp[j\Phi_r(u,v)]\times\Phi(u,v) \tag{1}$$

where u and v are mutually independent frequency domain variables, $R(u, v)$ and $\Phi_r(u, v)$ are the amplitude and phase, respectively, of the Fourier transform of $r(x, y)$, and $\Phi(u, v)$ is the Fourier transform of $\phi(x, y)$. Inverse Fourier transformation of Eq. (1) yields the phase-encoded reference image which is then fed into two parallel channels, where one channel introduces a 180 degree phase shift. Next, the input scene containing one or more unknown fingerprint images, $t_i(x, y)$, is now introduced to both the channels to form two joint images as given by

$$f_1(x,y)=r(x,y)\otimes\phi(x,y)+\sum_{i=1}^{K}t_i(x,y) \tag{2}$$

$$f_2(x,y)=-r(x,y)\otimes\phi(x,y)+\sum_{i=1}^{K}t_i(x,y) \tag{3}$$

where K is the number of fingerprint images in the input scene. From the Fourier transformation of the above equations we can obtain two joint power spectra (JPS) as given by

$$\begin{aligned}|F_1(u,v)|^2 &= |R(u,v)\Phi(u,v)|^2+\sum_{i=1}^{K}|T_i(u,v)|^2\\ &+\sum_{i=1}^{K}R(u,v)T_i^*(u,v)\Phi(u,v)+\sum_{i=1}^{K}R^*(u,v)T_i(u,v)\Phi^*(u,v)\\ &+\sum_{i=1}^{K}\sum_{j=1,j\neq i}^{K}T_i(u,v)T_j^*(u,v)+\sum_{i=1}^{K}\sum_{j=1,j\neq i}^{K}T_i^*(u,v)T_j(u,v)\end{aligned} \tag{4}$$

$$\begin{aligned}|F_2(u,v)|^2 &= |R(u,v)\Phi(u,v)|^2+\sum_{i=1}^{K}|T_i(u,v)|^2\\ &-\sum_{i=1}^{K}R(u,v)T_i^*(u,v)\Phi(u,v)-\sum_{i=1}^{K}R^*(u,v)T_i(u,v)\Phi^*(u,v)\\ &+\sum_{i=1}^{K}\sum_{j=1,j\neq i}^{K}T_i(u,v)T_j^*(u,v)+\sum_{i=1}^{K}\sum_{j=1,j\neq i}^{K}T_i^*(u,v)T_j(u,v)\end{aligned} \tag{5}$$

It can be observed from the above equations that both the JPS signals contain a number of terms to produce auto-correlation and cross-correlation terms in the output plane. However, the following operation will eliminate the unnecessary correlation signals automatically, where the JPS in Eq. (5) is subtracted from that in Eq. (4) and the resultant signal is multiplied again by the same phase mask used earlier. Thus we get the modified JPS as

$$P(u,v)=\left[|F_1(u,v)|^2-|F_2(u,v)|^2\right]\Phi(u,v) \tag{6}$$
$$=2\left[\sum_{i=1}^{K}R(u,v)T_i^*(u,v)\Phi^2(u,v)+\sum_{i=1}^{K}R^*(u,v)T_i(u,v)\right]$$

The final correlation signal can be obtained by taking inverse Fourier transformation of Eq. (6). It may be noted that the first term in the above equation will produce a correlation which will be scattered in various directions in space because of the random nature of the phase mask. Therefore, ultimately only the second term will produce a single correlation signal per each potential target fingerprint in the output plane.

Next a modified fringe-adjusted filter (FAF) is also developed to enhance the correlation performance of the technique. The filter transfer function can be expressed as

$$H(u,v)=\frac{C(u,v)}{D(u,v)+|R(u,v)|^2} \tag{7}$$

where $C(u,v)$ and $D(u,v)$ are either constants or functions of u and v. The parameter $C(u,v)$ is used to avoid having an optical gain greater than unity, while $D(u,v)$ is used to overcome the pole problem. Since the power spectra of the reference fingerprint can be pre-calculated and stored, incorporation of FAF in the proposed technique will not adversely impact the processing speed.

Thereafter, the JPS as given in Eq. (6) is multiplied by the FAF transfer function as given by Eq. (7) to yield an enhanced JPS whose inverse Fourier transformation will finally result in a single and very sharp correlation peak for each potential target fingerprint present in the given input scene.

III. Simulation Results

Performance of the proposed fingerprint verification technique is evaluated using a computer simulation program developed in MATLAB software and employing a set of real-life fingerprint images. Figure 2 shows the correlation performance using a sample fingerprint as the reference image for the SPFJTC technique. The same fingerprint is employed in the input scene and the resultant correlation output shown in Fig. 2(c) clearly verifies the efficiency of the technique, because it generates a very sharp and highly distinctive correlation peak.

Then a different version of the same target fingerprint recorded at a different time is introduced into the input scene as shown in Fig. 3(b). Though the input image varies significantly from the reference image in the database, but the proposed technique is observed to be very successful in recognizing the fingerprint by producing a distinct correlation peak as shown in Fig. 3(c). Now a non-target fingerprint is employed in the input scene as shown in Fig. 4(b). The correlation signals in Fig. 4(c) rejects the fingerprint by generating noisy signal where there is no distinctive peak.

Next, the proposed technique is investigated employing an input scene shown in Fig. 5(b), which contains multiple fingerprint images among which two are potential target fingerprints. The correlation output in Fig. 5(c) shows two sharp peaks corresponding to the target fingerprints while rejecting all non-target fingerprints. Finally, an input scene is considered in the simulation which is corrupted by noise as shown in Fig. 6(b). The correlation output in Fig. 6(c) confirms that the proposed technique is very efficient and successful in verifying the target fingerprints even in noisy environment. Similar other investigations are carried out with other fingerprint images and in different practical scenarios where in every case the proposed technique is observed to perform excellent.

IV. Conclusion

An efficient and high-speed fingerprint verification technique is proposed in this paper. The proposed technique is observed to be very successful in recognizing a target fingerprint which is included in the database and reject any other fingerprints. It produces an efficient correlation output which clearly identifies the target fingerprints. The technique is also capable of identifying multiple fingerprints in the same input scene simultaneously. Computer simulation results verify the effectiveness of the technique in different practical real-life scenario, like noisy scenes. Optical implementation of the technique will yield a real-time fingerprint verification system for security applications.

References

[1] S. Prabhakar and A. K. Jain, “Decision-level fusion in fingerprint verification,” *Pattern Recognition*, vol. 35, pp. 861 – 874, 2002.

[2] C. S. Weaver and J. W. Goodman, “Technique for optically convolving two functions,” *Applied Optics*, vol. 5, pp. 1248 – 1249, 1966.

[3] B. Javidi and C. Kuo, “Joint transform image correlation using a binary spatial light modulator at the Fourier plane,” *Applied Optics*, vol. 27, pp. 663 – 665, 1988.

[4] A. K. Cherri and M. S. Alam, “Reference phase-encoded fringe-adjusted joint transform correlation,” *Applied Optics*, vol. 40, pp. 1216 – 1225, 2001.

[5] M. S. Alam and M. A. Karim, “Fringe-adjusted joint transform correlation,” *Applied Optics*, vol. 32, pp. 4344 – 4350, 1993.

[6] M. R. Haider, M. N. Islam, M. S. Alam and J. F. Khan, “Shifted phase-encoded fringe-adjusted joint transform correlation for multiple target detection,” *Optics Communications*, vol. 248, pp. 69 – 88, 2005.

[7] M. R. Haider, M. N. Islam and M. S. Alam, “Enhanced class associative generalized fringe-adjusted joint transform correlation for multiple target detection,” *Optical Engineering*, vol. 45, no. 4, pp. 048201-1 – 048201-10, 2006.

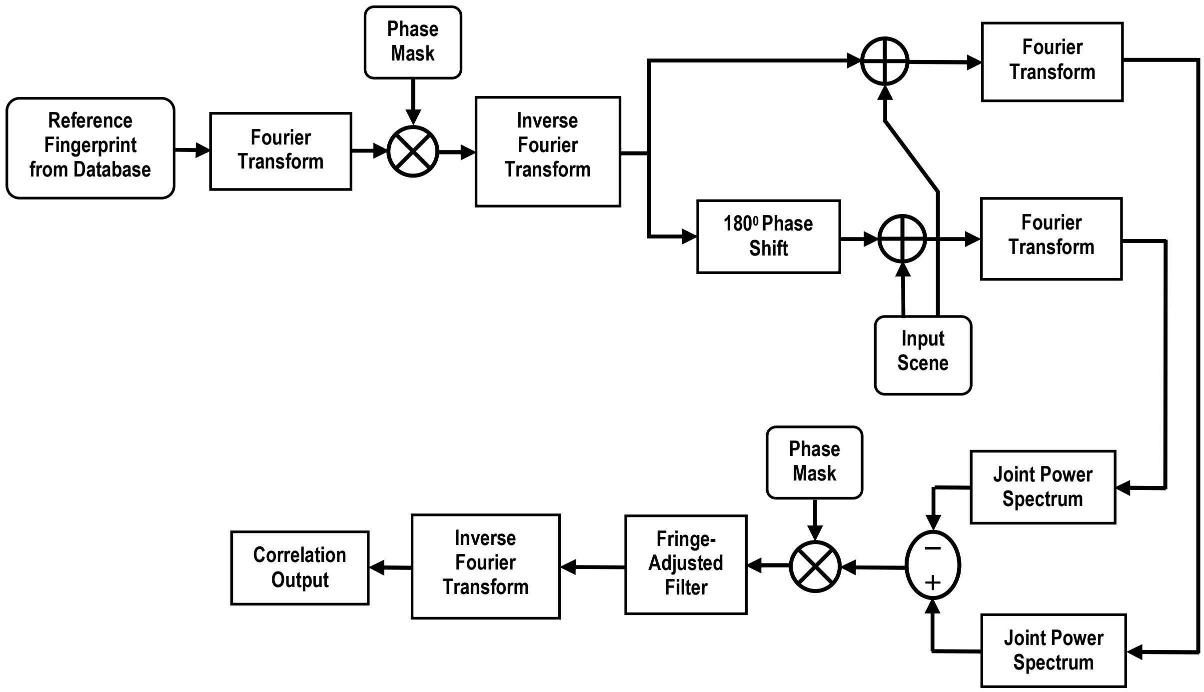


Figure 1: Block diagram of shifted phase-encoded fringe-adjusted joint transform correlation technique

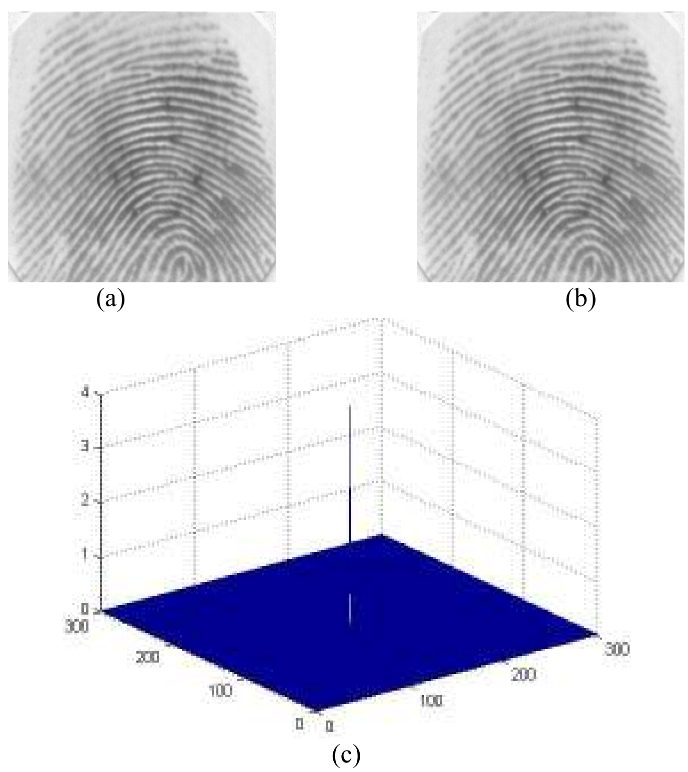


Figure 2: Correlation performance using a target fingerprint: (a) reference fingerprint from database, (b) input fingerprint, (c) correlation output

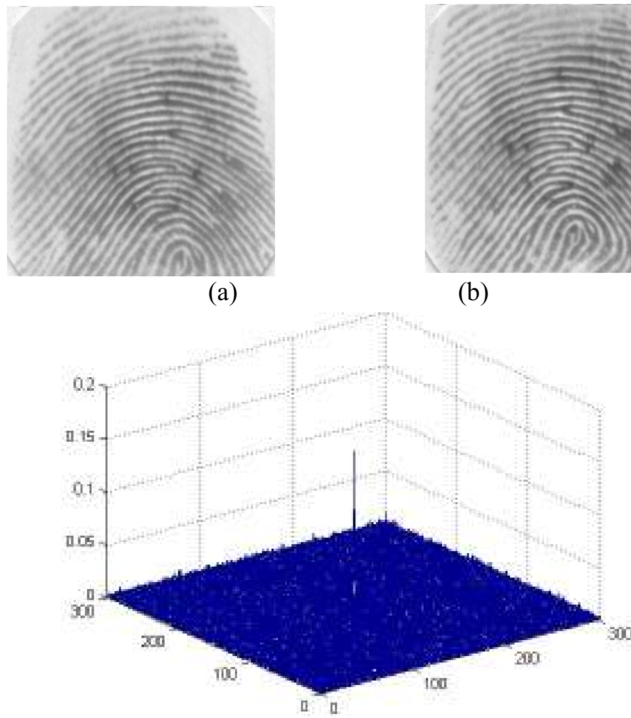


Figure 3: Correlation performance using a target fingerprint which is recorded at different time: (a) reference fingerprint, (b) input fingerprint, (c) correlation output

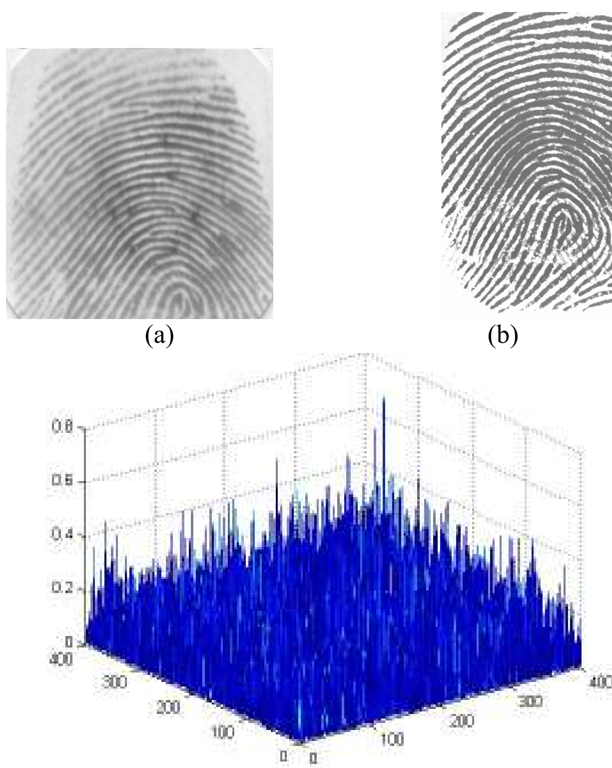
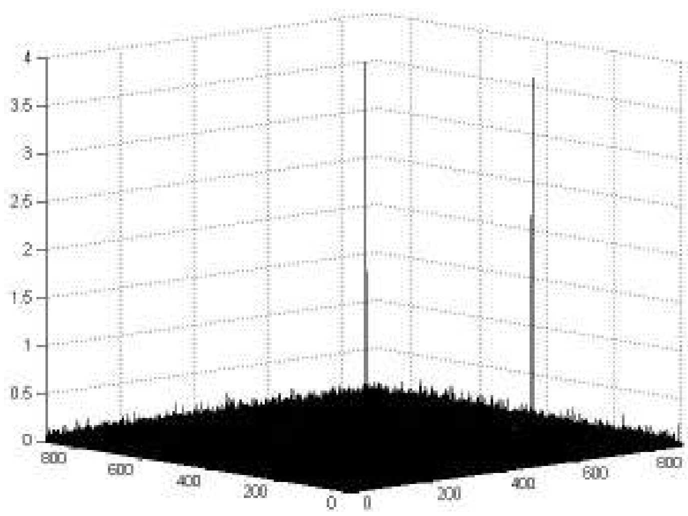


Figure 4: Correlation performance using a non-target fingerprint: (a) reference fingerprint, (b) input fingerprint, (c) correlation output

(a)

(b)



(c)

Figure 5: Correlation performance with an input scene having multiple fingerprints: (a) reference fingerprint, (b) input scene, (c) correlation output

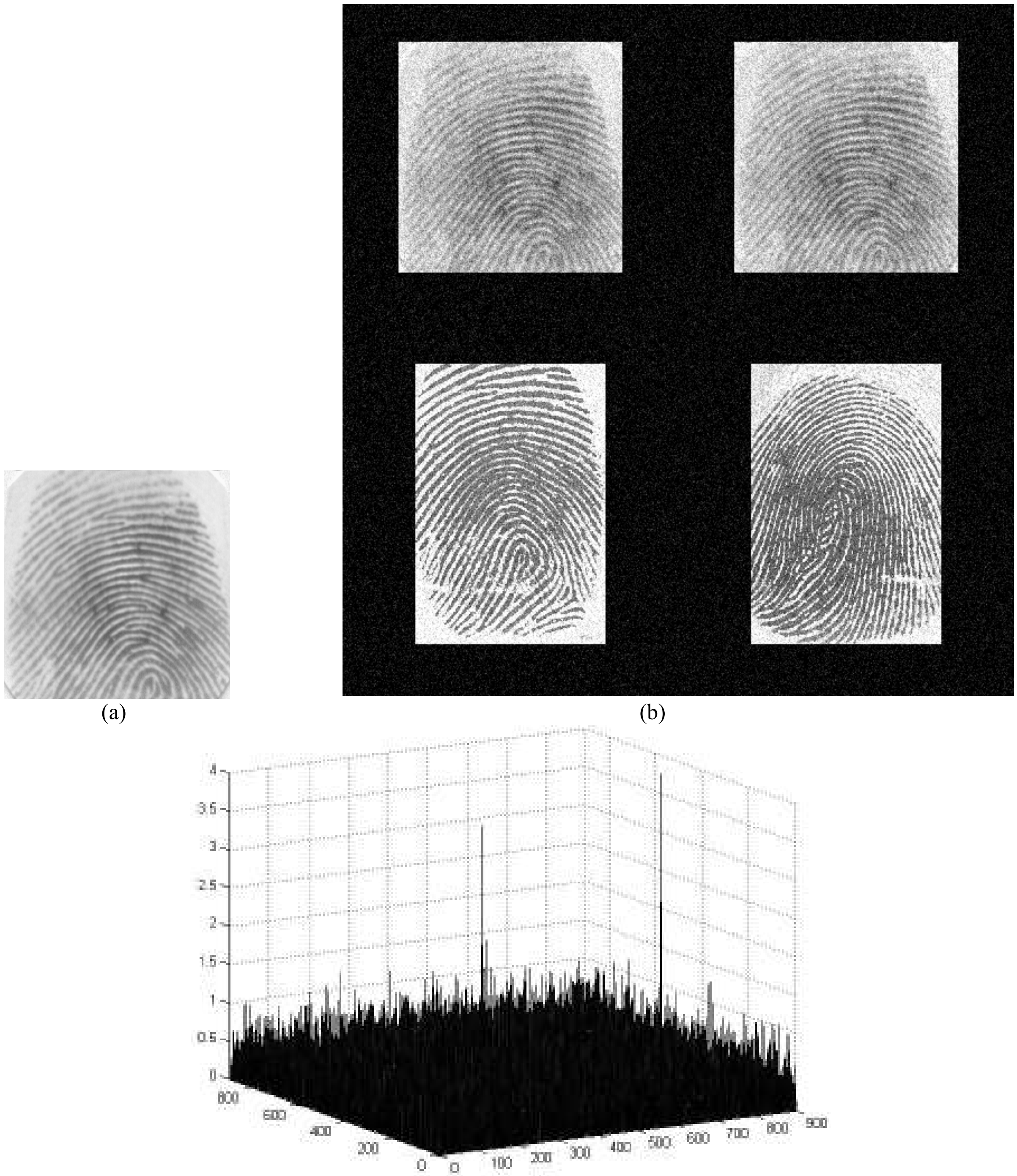


Figure 6: Correlation performance with an input scene having multiple fingerprints and corrupted by noise: (a) reference fingerprint, (b) input scene, (c) correlation output