Super-resolution Guided Pore Detection for Fingerprint Recognition

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Abstract

Performance of fingerprint recognition algorithms substantially rely on fine features extracted from fingerprints. Apart from minutiae and ridge patterns, pore features have proven to be usable for fingerprint recognition. images, but Although features from minutiae and ridge patterns are quite attainable from low-resolution using pore features is practical only if the fingerprint image is of high quality which necessitates a model that enhances the image quality of the conventional 500ppi legacy fingerprints preserving the fine details. To find a solution for this, we adopt a joint learning-based approach that combines both super-resolution and pore detection networks. Our modified single image Super-Resolution Generative Adversarial Network (SRGAN) framework helps to reliably reconstruct high-resolution fingerprint samples from low-resolution ones assisting the pore detection network to identify pores with ahigh accuracy. The network jointly learns a distinctive feature representation from a real low-resolution fingerprint sample and successfully synthesizes a high-resolution sample from it. To add discriminative information and uniqueness for all the subjects, we have integrated features extracted from a deep fingerprint verifier with the SRGAN quality discriminator. We also add ridge reconstruction loss, utilizing ridge patterns to make the best use of extracted features. Our proposed method solves the recognition problem by improving the quality of fingerprint images. High recognition accuracy of the synthesized samples close to the original high-resolution ones validate the effectiveness of our proposed model.

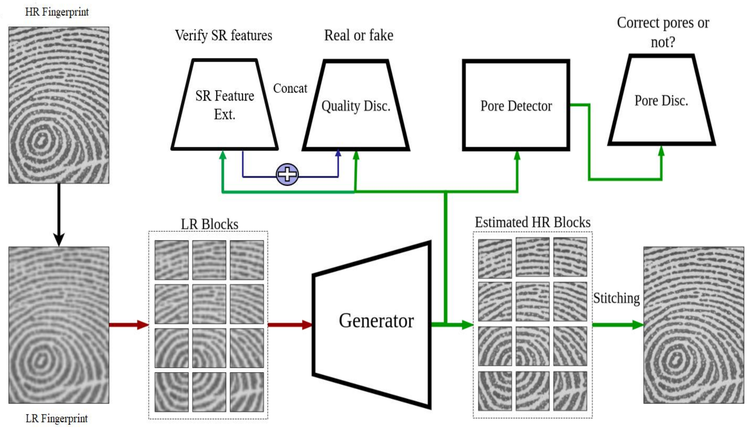
Motivation

Pore detection is a crucial step in designing a fingerprint recognition system which greatly impacts the overall system performance. A remarkable pore detection accuracy is achievable with an increase in resolution. Therefore, we propose a modified single-image SR algorithm using the Super-Resolution Generative Adversarial Network (SRGAN) [1] tailored for fingerprint pore detection. We have used all three level features namely minutia, ridge patter and pore features extracted from fingerprints for better recognition performance.

Contributions

- We develop a deep fingerprint SR model which employs SRGAN to reliably reconstruct high resolution fingerprint samples from their corresponding low-resolution samples.
- We adopt a pore detection scheme that helps the SRGAN model to focus on level-3 features while synthesizing HR fingerprint samples. A jointly trained deep SR and pore detection framework is proposed.
- To better utilize the ridge information of fingerprint samples in combination with pores, we have incorporated a ridge reconstruction loss making use of level-2 and level-3 features in our overall objective function, which helps to improve the fingerprint recognition accuracy of our model
- In addition, to make sure that the framework retains class identity, we have used an auxiliary deep verifier module combined with a quality discriminator to conduct fusion at the feature level.

Proposed Architecture



Training Losses

- MSE Loss

$$l_{MSE} = \frac{1}{N}\sum_{n=1}^{N}\frac{1}{WH}\sum_{w=1}^{W}\sum_{h=1}^{H}\left\|(I_n^{HR})_{w,h} - G(I_n^{LR})_{w,h}\right\|^2$$

- Adversarial Loss

$$\ell_{adv} = \min_G \max_D [E_{I^{HR}\sim P_{train}(I^{HR})}[logD(I^{LR}, I^{HR})] + E_{I^{LR}\sim P_G(I^{LR})}[log(1 - D(I^{LR}, G(I^{LR})))],$$

- Perceptual Loss

$$\ell_{per}^{SR} = \frac{1}{N}\sum_{n=1}^{N}\frac{1}{C_j W_j H_j}\sum_{c=1}^{C_j}\sum_{w=1}^{W_j}\sum_{h=1}^{H_j}||\phi_j^c(I_n^{HR})_{w,h} - \phi_j^c(G(I_n^{LR})_{w,h}||^2,$$

- Ridge Loss

$$G_j^{\phi}(y)_{c,c'} = \frac{1}{N}\sum_{n=1}^{N}\frac{1}{C_j W_j H_j}\sum_{w=1}^{W_j}\sum_{h=1}^{H_j}\phi_j(y_n)_{c,w,h}\,\phi_j(y_n)_{c',w,h},$$

$$G_j^{\phi}(\tilde{y})_{c,c'} = \frac{1}{N}\sum_{n=1}^{N}\frac{1}{C_j W_j H_j}\sum_{w=1}^{W_j}\sum_{h=1}^{H_j}\phi_j(\tilde{y_n})_{c,w,h}\,\phi_j(\tilde{y_n})_{c',w,h}.$$

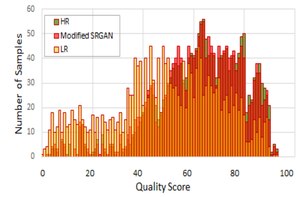
$$\ell_{ridge}^{J} = \sum_{j=1}^{J}||G_j^{\phi}(\tilde{y}) - G_j^{\phi}(y)||_F^2.$$

- Total Loss

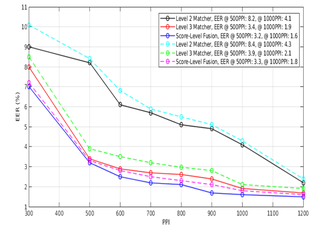
$$\ell_{Total}^{G} = \lambda_1\ell_{MSE} + \lambda_2\ell_{adv} + \lambda_3\ell_{per} + \lambda_4\ell_{ridge} + \lambda_5\ell_{pore},$$

Experimental Results

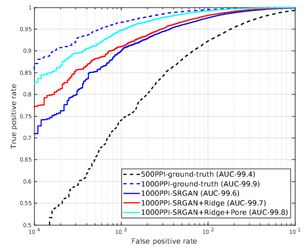
- Image quality comparison of LR, real HR and generated samples rom our modified SRGAN for an upscale factor 2*x*



- Fingerprint recognition performance evaluated at multiple resolutions using different level features for an upscale factor 2×. Solid lines represent he EER values for the PolyU DBI dataset [2] and dashed lines are for the EER values in the FVC2000 DB1 dataset [3]



- ROC curves for real HR, generated samples from SRGAN and our modified SRGAN for an upscale factor 2



Conclusion

This paper proposes a jointly optimized fingerprint recognition framework using the concept of super-resolution and pore detection. The model is able to generate HR fingerprint samples, learn pore locations, ridge structure and other details from LR samples. The increase in resolution helps to achieve a high pore detection accuracy, which in turn forces the generator to produce high quality synthesized fingerprint samples. Also, integrating features extracted from a deep verifier with a quality discriminator preserves the individuality in our reconstructed samples. Reliable reconstruction of 1000 ppi fingerprint from its 500 ppi equivalent proves the validity of our approach.

References

[1] C. Ledig, L. Theis, F. Huszar, J. Caballero, A. Cunningham, A. Acosta, ´ A. Aitken, A. Tejani, J. Totz, Z. Wang et al., "Photo-realistic singleimage super-resolution using a generative adversarial network," in Proceedings of the IEEE conference on computer vision and pattern recognition, 2017, pp. 4681–4690.

[2] "Polyu hrf database," http://www4.comp.polyu.edu.hk/~biometrics/HRF/HRF old.htm, accessed: 3.21.2020

[3] D. Maio, D. Maltoni, R. Cappelli, J. L. Wayman, and A. K. Jain,"FVC2000: Fingerprint verification competition," IEEE transactions on pattern analysis and machine intelligence, vol. 24, no. 3, pp. 402–412, 2002.