Fingerprint Salt & Pepper Noisy Image Enhancement with Threshold Method

Mahmut Ince¹, Songfeng Lu², Saad Ali Alfadhlí³, Ismail Maulood⁴, Shayem Saleh Alresheedi⁵

¹,³School of Computer Science and Technology, Huazhong University of Science and Technology, Wuhan 430074, China
²School of Cyber Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, China
⁴Department of Research and Development, Directorate of Scientific Affairs, Ministry of Higher Education and Scientific Research, Erbil, Kurdistan Regional Government, Iraq
⁵War College, National Defense University, Riyadh, KSA

E-mail: ²lusongfeng@hust.edu.cn, ¹mahmutince@hust.edu.cn

Abstract. We present an adaptive threshold method for salt and pepper noisy fingerprint images. At first, we applied a threshold algorithm to detect noisy and corrupt pixels. Fingerprint image optimized with window filter produced pixels values. We measured the quality of the fingerprint images with peak signal to noise ratio and other efficient noise removing techniques were compared with it. The result shows improving performance of our method with remove salt and pepper noise from a fingerprint image. Our present work is useful to reduce or minimize medium level noise in fingerprint image. In future, we will work to reduce more than 80 percent noise level in fingerprint image.

Keywords: Salt-pepper noise, Image denoising, Adaptive threshold

1. Introduction

A fingerprint has become a more popular biometric recognition system due to permanency, easy implementation, small size sensor and affordable cost. Despite of these advantages, fingerprint identification and verification system have a challenge with low-quality fingerprint image and noise. The fingerprint images may have noise cause of low-quality images due to sensors, dust particles, oil, dryness, non-cooperated user [1-5].

Consequently, noise detection and noise filtering is still challenging in fingerprint image processing. Noise filtering techniques are important in the enhancement process effect fingerprint image quality, image quality effect fingerprint features and features affect biometric system accuracy. Previous literature proposed several nonlinear filters to remove unwanted effect as salt -pepper noise from fingerprint images [6-8]. As the median filter shows simple and efficient computational performance [9-10] but disadvantage of this filter is that they are efficient only in low noise density if fingerprint image includes high-density noise than some patches are visible and edge details will disappear [11]. Centre
weighted median filter, Dual window selective median switching filter, adaptive median filter are proposed to protect edge pixel [12-13].

Filters are applied on the previous pixel and if current pixels are damaged or include noise it can degrade image quality [14]. A low-quality image can lost useful image details. To solve this shortcoming, two-stage methods have proposed. The main idea of this method helps to detect noisy or corrupted pixel which has separated from other pixels [15].

Most of the previously proposed methods use two stages to improve image quality such as an improved Progressive Switching Median Filter [16], Recursive Weighted Median Filter [17], Dual Windows Selective Median Switching Filter [18], Adaptive Image Denoising Method [19], etc. We used 3 x 3 windows for noise detection, to detect noisy, clear and corrupted pixels. We describe test window, a central pixel of window. In this study we determine the threshold for detecting noise. This noise will change with the algorithm result value. The outline of the work is organized as follows, after Section 1; Section 2 shows the proposed algorithm method. Section 3 shows the proposed method, experiments, comparison of results from different efficient filters and discussion. Section IV consist of conclusions.

2. Proposed Algorithm

2.1. Modified Impulse Noise Model
In this model image inspected in pixel level, pixels are effected with [0, 255] peak values. Unchanged pixels stay the same as before (genuine) [20-22].

The method is shown at the below:

\[
S(X) = \begin{cases}
\frac{q}{2} X_{ij} = 0 \\
1 - \frac{q}{2} X_{ij} = W_{ij} \\
\frac{q}{2} X_{ij} = 255
\end{cases}
\] (1)

Where q is noisy pixel density, S(X) is possibility function, \(W(i,j)\) is the original image pixel intensity, and \(X(i,j)\) is the intensity of the noisy pixel.

2.2. Modified Decision-Based Algorithm
In [23] presented algorithm accepts all pixel intensity in 0 and 255 noisy pixel detection window is 3 x 3. If the calculated value of a pixel in the range [0, 255] then it is, a clear pixel and the algorithm will not change pixel. If value is not in range then the pixel is affected by noise and it changes with the median value of the window method.

3. Proposed Method
In this study, our proposed method convolutes decision-based method and adaptive threshold methods. We used a threshold to determine a noisy pixel. In this process, the central pixel value of (3 x 3) window plays a vital role. For threshold, central pixel values used to decide that pixel are corrupted or not, if pixel values are higher or less than the central pixel values of the range then those pixels accept the noise.

The decision-based algorithm used for change corrupted or noisy pixels after the detection phase. In another word, let the grey level Image S of size \([M \times M]\), where \(M \in R \& 0 \leq M \leq 255\). \(X(i, j)\) pixel of S filtered by [3 x 3] filtering window “W”, formed by dividing the image. Also, we propose the minimum level threshold \((Thr_{\text{min}})\) and maximum level threshold \((Thr_{\text{max}})\) that computed in Eq. (3) and (4) as a threshold which we used to detect corrupted pixels.

Pixels are filtering by window filter can be shown as below:

\[
M_w = \frac{1}{W_x W_y} \sum_{i=0}^{255} \sum_{j=0}^{255} X_w(i, j)
\] (2)

Thus, the Eq.2 can efficiently give the mean of window value \(M_w\) for every filtering window in the image.

\[
Thr_{\text{min}} = M_w \times (1 - \theta)
\] (3)
\[Thr_{\text{max}} = M_w + \{255 - M_w\} \times \theta \] (4)

Where \( \theta \in R \) & 0 \leq \theta \leq 1 is a constant value calculated by the image [24] as shown in Eq. 5

\[\theta = \sqrt{\frac{2\sigma^2\text{log}(m)}{m}}\] (5)

We compare the \(Thr_{\text{min}}\) and \(Thr_{\text{max}}\) with central pixel values to detect noisy pixels. So, if the values are within the range of \(M\), the system accepts them as a noise-free as shown in the below formula (CIPw: Noise free pixel):

\[\text{CIP}_w \begin{cases} Thr_{\text{min}} \leq \text{CIP}_w \leq Thr_{\text{max}} \text{ (clean pixel)} \\ Else \text{ Corrupted} \end{cases}\] (6)

Corrupted pixel detected then the DbA used to replace a corrupted pixel with calculated window values. Proposed modified Denoising algorithm follows the below steps:

**Input:** The grayscale fingerprint image \(F(i, j)\)

**Output:** Denoised, repaired fingerprint image

**Step 1:** 3 x 3 windows select

**Step 2:** Mean, \(M_w\) of \(F(i, j)\) in filtering window estimates

**Step 3:** \(\theta\) calculated by Eq.5

**Step 4:** Thresholds \(Thr_{\text{min}}\) and \(Thr_{\text{max}}\) calculated from Eq.3 and Eq.4

**Step 5:** If \(Thr_{\text{min}} \leq \text{CIP}_w \leq Thr_{\text{max}}\) then \(\text{CIP}_w\) is clear pixel; else \(\text{CIP}_w\) will be replaced by DbA value.

**Step 6:** Optimal values obtained

**Step 7:** Exit

The result obtains in the following platform as follows: The hardware platform: CPU Intel i5 3.00 GHz, Software platform: Matlab 2019a. The new algorithm verified with the following methods. Standard median filter (SmF), Window median filter (WmF), Progressive switching median filter (PsMF) and Recursive enhanced median filter (ReMF) [15-18].

Fingerprint verification competition (FVC 2002) DB1 and DB2 used for validating the proposed algorithm. Fingerprint images set to 256 x 256 pixels. The quality and performance measurement is the peak-signal-to-noise ratio (PsNR) used for renovation. Renovated image \((F_R)\) of size \(M \times M\) concerning the original image \((F_0)\) as:

\[\text{PsNR} (F_0, F_R) = 10\log_{10} \frac{255^2}{Mse}\] (7)

\[\text{MsE} ((F_0, F_R) = \frac{1}{MN} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} (F_R(i,j) - F_0(i,j))^2\] (8)

**Figure 1:** The resized original grey images: from FVC2002 (i) DB1, (ii) DB2
Table 1. Fingerprint image in FVC 2002 DB1 with PsNR results for salt and pepper noise

| Method | Noise Ratio (PsNR) |
|--------|-------------------|
|        | 50%  | 60%  | 70%  | 80%  |
| SmF    | 9.6  | 7.3  | 6.46 | 4.43 |
| CwMF   | 14.52| 11.43| 7.86 | 4.96 |
| PsMF   | 15.51| 13.92| 12.36| 8.75 |
| ReMF   | 19.83| 14.72| 11.92| 7.84 |
| Proposed | 19.95| 19.8 | 16.98| 15.62|

Table 2. Fingerprint image in FVC 2002 DB 2 with PsNR results for salt and pepper noise

| Method | Noise Ratio (PsNR) |
|--------|-------------------|
|        | 50%  | 60%  | 70%  | 80%  |
| SmF    | 10.6 | 8.3  | 6.46 | 5.43 |
| CwMF   | 16.52| 11.48| 7.86 | 4.96 |
| PsMF   | 18.53| 15.40| 13.92| 6.14 |
| ReMF   | 21.83| 20.78| 14.72| 10.61|
| Proposed | 23.68| 22.53| 19.80| 17.76|

Figure 2. PsNR result for different de-noising methods for DB1 (CwMF is Curved weighted median filter)

Figure 3. PsNR result for different denoising method graph for FVC 2002 DB2
4. Results and Discussion
Fingerprint image noise density is chosen from 50% to 80% and result value of different denoising method and our proposed method are given in Table 1 and Table 2. Quality performance measured by PsNR. The graphical result is given for DB1 and DB2 in Figure 2 and Figure 3. Our proposed algorithm shows high performance in more noise fingerprint images. PsMF also has showed good performance.

![Figure 4](image)

**Figure 4.** Original fingerprint image, noisy fingerprint image and filtered fingerprint image shown (i) Original image; (ii) Noise image; (iii) SmF; (iv) CwMF; (v) PsMF; (vi) ReMF; (vii) Proposed Algorithm.

Our present work is useful to reduce or minimize medium level noise in fingerprint image. In future, we will work to reduce more than 80 percent noise level in fingerprint image

5. Conclusion
We introduced an adaptive threshold-based algorithm, used salt pepper noise for increase performance of the biometric system. Our method uses a PsNR measurement scale to compare with other methods. Noise level is chosen in between 50% to 80%. In each selected scale noise level fingerprint image, our proposed method had a better result than other methods.

References

[1] Batool A and Tariq A 2011 Computerized system for fingerprint identification for biometric security *IEEE 14th Int. Multitopic Conf.* 102 DOI: 10.1109/INMIC.2011.6151452

[2] Singh S P, Ayub S and Saini J P 2016 Literature survey on different type of fingerprint recognition *3rd Int. Conf. on Computing for Sustainable Global Development (INDIACom) New Delhi* pp 3748–55
[3] Wang Q and You S 2008 Feature selection for real-time image matching systems Proc. of the 17th Int. Conf. on Pattern Recognition p 1–4 DOI: 10.1109/ICPR.2008.4761164

[4] Kolsch T, Keyser D, Ney H and Paredes R 2004 Enhancements for local feature based image classification Proc. of the 17th Int. Conf. on Pattern Recognition Cambridge p 248–51 DOI: 10.1109/ICPR.2004.1334070

[5] Gottschlich C 2012 Curved-region-based ridge frequency estimation and curved gabor filters for fingerprint image enhancement IEEE Transactions on Image Processing pp 2220–7 DOI: 10.1109/TIP.2011.2170696

[6] Zhang P and Li F A 2014 New adaptive weighted mean filter for removing salt-and-pepper noise IEEE Signal Processing Letters vol. 21 pp 1280–3 DOI: 10.1109/LSP.2014.2333012

[7] Soni A and Shrivastava R 2017 Removal of high density salt and pepper noise removal by modified median filter Inventive Communication and Computational Technologies (ICICCT) pp 282–5 DOI: 10.1109/ICICCT.2017.7975204

[8] Fareed S B S and Khader S S 2018 Fast adaptive and selective mean filter for the removal of high-density salt and pepper noise IET Image Processing vol. 12 pp 1378–87 DOI: 10.1049/iet-ipr.2017.0199

[9] Han K, Wang Z and Chen Z 2018 Fingerprint image enhancement method based on adaptive median filter 24th Asia-Pacific Conf. on Communications (APCC) pp 40–4 DOI: 10.1109/APCC.2018.8633498

[10] Makhlja S, Khatwani A and Roja M M 2017 Performance analysis of latent fingerprint enhancement techniques Int. Conf. on Innovative Mechanisms for Industry Applications (ICIMIA) pp 96–100 DOI: 10.1109/ICIMIA.2017.7975580

[11] Zhang M M, Kouri D J and Zhang D S 2017 Dual window selective median switching filter 11th Int. Conf. on Signal Processing and Communication Systems (ICSPCS) pp 1–3 DOI: 10.1109/ICSPCS.2017.8270512

[12] George G, Oommen R M, Shelly S, S Philipose S and Varghese A M 2018 A survey on various median filtering techniques for removal of impulse noise from digital image Conf. on Emerging Devices and Smart Systems (ICEDSS) Tiruchengode pp 235–8 DOI: 10.1109/ICEDSS.2018.8544273

[13] Hou L, Kuo C, Lin Z and Yu C 2015 Efficient image denoising scheme for removal of impulse noise 2015 IEEE 4th Global Conf. on Consumer Electronics (GCCE) pp 298–9 DOI: 10.1109/GCCE.2015.7398612

[14] Raza M T and Sawant S 2012 High density salt and pepper noise removal through decision based partial trimmed global mean filter 2012 Nirma University Int. Conf. on Eng. (NUiCONE) pp 1–5 DOI: 10.1109/NUiCONE.2012.6493236

[15] Qian Y 2019 Removing of Salt-and-pepper Noise in images based on adaptive median filtering and improved threshold function 2019 Chinese Control And Decision Conf. (CCDC) pp 1431–6 DOI: 10.1109/CCDC.2019.8832612

[16] Wang Z and Zhang D 1999 Progressive switching median filter for the removal of impulse noise from highly corrupted images IEEE Transactions on Circuits and Systems II: Analog and Digital Signal Processing vol. 46 pp 78–80 DOI: 10.1109/82.749102

[17] Arce G R and Paredes J L 2000 Recursive weighted median filters admitting negative weights and their optimization IEEE Transactions on Signal Processing vol. 48 pp 768–79 DOI: 10.1109/78.824671

[18] Zhang M M, Kouri D J and Zhang D S 2017 Dual window selective median switching filter 2017 11th Int. Conf. on Signal Processing and Communication Systems (ICSPCS) Gold Coast, QLD pp 1–3 DOI: 10.1109/ICSPCS.2017.8270512

[19] Zhang X, Xiong R, Ma S and Gao W 2014 Artifact reduction of compressed video via three-dimensional adaptive estimation of transform coefficients IEEE Int. Conf. on Image Processing (ICIP) pp 4567–71 DOI: 10.1109/ICIP.2014.7025926

[20] Soni A and Shrivastava R 2017 Removal of high density salt and pepper noise removal by
modified median filter \textit{Int. Conf. on Inventive Communication and Computational Technologies (ICICCT) Coimbatore} pp 282–5 DOI: 10.1109/ICICCT.2017.7975204

[21] Cumpim C and Punchalard R 2017 Sliding block shepard interpolation method for removing high-density impulse noise \textit{Int. Electrical Eng. Congress (iEECON) Pattaya} pp 1–4 DOI: 10.1109/IEECON.2017.8075884

[22] Cherrat E M, Alaoui R, Bouzahir H and Jenkal W 2017 High density salt-and-pepper noise suppression using adaptive dual threshold decision based algorithm in fingerprint images \textit{Intelligent Systems and Computer Vision (ISCV)} pp 1–4 DOI: 10.1109/ISACV.2017.8054913