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An Efficient Fingerprint Enhancement Technique using Wave Atom Transform and MCS Algorithm

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Abstract

Fingerprints are widely and successfully used for personal identification. This is mainly due to their individuality, stability through life, uniqueness among people, public acceptance and their minimum risk of intrusion. Fingerprint technology is a biometric technique utilized to identify persons based on their physical traits. The physical patterns of this technique consist of ridges and valleys that exist on the surface of fingertips. Fingerprint images are direction-oriented patterns formed by ridges and valleys. The eminence of the fingerprint image is determined by the sturdiness of a fingerprint authentication system. In order to improve the limitations of existing fingerprint image enhancement methods an efficient technique is proposed to deal with low quality fingerprint images. The proposed methodology can be divided into three modules. In the first module, the fingerprint image is subjected to denoising process where Wave atom transform is utilized. After the completion of this process the image enhancement is performed with the help of optimization algorithm. In our enhancement approach, a Modified Cuckoo Search (MCS) algorithm is used as an optimizer. This helps to look for the best gray level distribution that maximizes the objective function.

Keywords: Finger Print; Fitness Evolution Phase; Modified Cuckoo Search; Reject Worst Next Phase; Wave Atom Transform.

1. Introduction

In recent years, digital images have become increasingly popular all over the world. Several bodies like governmental, legal, scientific, and news media organizations rely on digital imagery[5]. Pre dominant areas such as vision, remote sensing, dynamic outlook investigation, independent routing, and biomedical image analysis require digital images with good contrast and details[1]. The fundamental goal of image compression is obtaining the best possible image quality at an allocated storage facility. The fingerprint image compression has a foremost task in a range of fields like Law enforcement, border security and forensic applications[2]. To prevent digital image forgeries from being taken as unaffected real image, investigators have build up a diversity of digital image forensic techniques. This happens while capturing, by utilizing camera or while storing the image, or for the purposes of digital transmission over the Internet[4].

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In the mid 19th century, the use of a person's fingerprints as a means of identification was first considered in the by Britisher's in order to exploit a simple procedure to combat, with the entitlement and land ownership. Recovering the residual traces of fingerprints from crime scenes was first applied toward the end of that century by John Faulds[6]. The matching performance of a fingerprint recognition system depends heavily on the image quality[8]. Image quality has a big impact on the performance of a fingerprint recognition system. The goal of image enhancement is to improve the overall performance by optimally preparing input images for later processing stages[7]. Fingerprint as a copyright protection datum can be viewed as a unique ID for each copy of multimedia that will be distributed through networks, such as peer-to-peer (P2P). Therefore, fingerprinting can help the source owner to trace the traitor who leaks out the multimedia file. Today, many multimedia producers have noticed that the copyrighted multimedia are freely shared in P2P networks[3]. The discrete wavelet transform is presently used to determine the fingerprint image compression standard. A series of works, however, argued that wavelets and related traditional multi-resolution norms are considered with a restricted dictionary made up of roughly isotropic elements occurring at all scales and locations[9]. The Wave Atom transform proves that warped oscillatory functions, a toy model for texture, have a significantly sparser expansion than in other fixed standard representations.

Among all the biometric indicators, fingerprints have a high level of reliability and are extensively employed by forensic specialists in scandalous investigations[4]. Fingerprint recognition is mainly as a trustworthy way of biometric validation. Wavelets and Curvelets have played a prominent role in several image processing tasks such as compression and denoising. The major drawbacks of these techniques are

- Wavelet transform fails to give effective representation of the images, which have edges.
- Curvelets fail to have significantly sparser expansion for warped oscillatory functions, a toy model for texture.

The rest of the paper is organized as follows: Section 2 gives a brief description about the recent research work that is carried out in the field of face recognition. Section 3 explains the proposed scheme of fingerprint image enhancement using proposed wave atom transform and MCS algorithm. Section 4 gives the results and discussion of our proposed method and Section 5 finally concludes our proposed method.

2. Related Work

Numerous research work has been done in the field of fingerprint image enhancement in recent years. Some of the recent researches done in the field of fingerprint image enhancement are mentioned below.

Bartunek *et al.*[11] proposed several improvements to an adaptive fingerprint enhancement method. This was based on contextual filtering where the term adaptive implies that parameters of the method are automatically adjusted based on the input fingerprint image. The processing blocks yields an improved and an adaptive fingerprint image processing method and the performance of the updated processing blocks was presented in the evaluation part. The algorithm was evaluated toward the NIST developed NBIS software. This was useful for fingerprint recognition on FVC databases.

Yang *et al.*[12] proposed an effective two-stage enhancement scheme in both the spatial domain and the frequency domain. This was done by learning from the underlying images. To remedy the ridge areas and to enhance the contrast of the local ridges, they first enhanced the fingerprint image in the spatial domain with a spatial ridge-compensation filter. It was to be noted that the parameters of the bandpass filters are gathered from both the original image and the first-stage enhanced image instead of acquiring from the original image alone. It enhances the fingerprint image significantly.

Minoru Kuribayashi[13] simplified the optimal detector by making statistical approximations and by using the characteristics of the parameters for generating codewords. After that, they proposed an orthogonal frequency division multiplexing-based SS watermarking scheme. This was used to embed the fingerprinting codeword into multimedia content. In a realistic situation, according to the principle, the signal embedded as a fingerprint was attenuated by lossy compression. Since the signal amplitude in a pirated codeword was attenuated, it was necessary to adaptively estimate the parameters before calculating the scores.

A fingerprint compression algorithm based on sparse representation was introduced by Shao *et al.*[14] which helped to obtain an over complete dictionary from a set of fingerprint patches. This allows us to represent them as a sparse linear combination of dictionary atoms. In the algorithm, they first constructed a dictionary for predefined fingerprint image patches. For a given fingerprint images, its patches were represented according to the dictionary by computing l0-minimization and then quantizing and encoding the representation. The effect of various factors on compression results was considered.

3. Proposed Methodology

Fingerprints are a regularly personal identification biometrics due to the individuality, stability through life, uniqueness among people, public acceptance and their minimum risk of intrusion. The proposed methodology is divided into the following modules. In the initial stage, the fingerprint image is subjected to denoising process with the utilization of Wave atom transform. After the denoising of the image, image enhancement is performed with the help of optimization algorithm. In our enhancement approach, a Modified cuckoo search (MCS) algorithm is used as an optimizer. This looks for the best gray level distribution that maximizes the objective function.

The flow diagram for the proposed method is shown in Fig. 1.

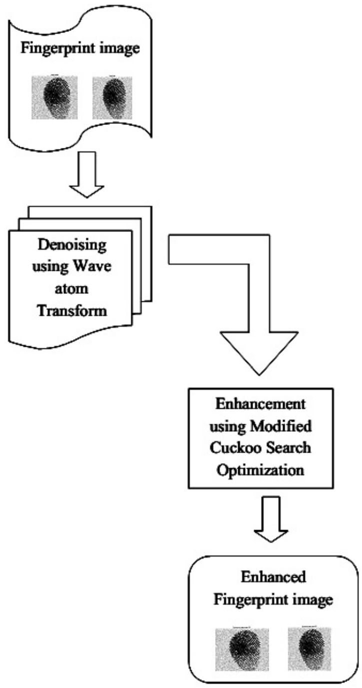

Fig. 1. Schematic Representation of Proposed Fingerprint Enhancement Technique.

3.1 Wave atom transform

The wave atom transform is utilized for denoising the images where the images that are to be processed in system have to be made noise free. To denoise the image using the wave atom transform we apply the following steps:

Step 1: To the input image, we apply the right circular shift process.
Step 2: Once the right circular shift is done, we apply the forward 2D Wave atom transform.
Step 3: After the application of 2D Wave atom transform we get waveatom coefficients to which hard thresholding is applied.
Step 4: Here we apply Inverse 2D wave atom transform to get of step 3 results.
Step 5: Finally to of step 4 result, we apply left circular shift which marks the completion of the denoising process Wave atom transforms are used with the directional frame to remove noise in finger print images. The image was reorganized from the remaining coefficients.

3.2 Enhancement using MCS

The Cuckoo search algorithm represents a biologically inspired algorithm which owes its origin to the breeding conduct of the cuckoos. Each egg signifies a solution where an egg of cuckoo corresponds to a novel solution. The various steps that are involved in the modified cuckoo search algorithm is explained in brief here:

Step 1: Initialization Phase

The population (P_i, where $i = 1, 2, N$) of host nest is initialized at random.

Step 2: Generating New Cuckoo Phase

With the help of the levy flights a cuckoo is selected randomly. This generates novel solutions, where the engendered cuckoo is evaluated by employing the objective function for ascertaining the excellence of the solutions.

Step 3: Fitness Evaluation Phase

The fitness function is evaluated in accordance with Equations 1 and 2 shown hereunder, followed by the selection of the best one.

$$F_m = \frac{P_C}{p_N} \tag{1}$$

$$fitness = \max imum\ popularity = F_m \tag{2}$$

where,

P_C - signifies the selected population
P_N - represents the total population

Step 4: Updation Phase

In the beginning, the solution is optimized by the levy flights by employing the cosine transform. Unless the superiority of new solution in the elected nest is advanced to the previous solution, it is restored by the new solution (Cuckoo). Otherwise, the preceding solution is considered to be the finest solution. The levy flights employed for the general cuckoo search algorithm is expressed by the eqn. (3) shown below

$$Lf_i^* = Lf_i^{(n+1)} = Lf_i^{(n)} + \alpha \oplus Lvy(N) \tag{3}$$

In modified cuckoo search, the above levy flight equation is modified by incorporating the Gaussian function for updation which is given in eqn. (4) below,

$$Lf_i^* = Lf_i^{(n+1)} = Lf_i^{(n)} + \alpha \oplus \eta_g \tag{4}$$

where,

$$\eta_g = \eta_0 \exp(-\mu C) \tag{5}$$

η_0, μ - Constants
C - Current generation

Step 5: Reject Worst Nest Phase

In this section, the worst nests are unobserved, there by considering their possibility values. Thus fresh ones are created. Thus to follow, the best solutions are distinguished and marked as optimal solutions.

Step 6: Stopping Criterion Phase

By employing the above-mentioned classification technique in an adept manner, we can achieve superlative classification accuracy.

4. Results and Discussion

The proposed technique has been implemented in MATLAB 7.14 and to process the finger print image enhancement, we have used Image Processing Toolbox. For the evaluation of the proposed methodology, we have considered many collected fingerprint images as input to our system.

The Fig. 2 given below shows the processed output for the normal input fingerprint images. For three different inputs the denoised and the enhance images using MCS are extracted and is depicted in the Fig. 2.

The parameters measures like PSNR, RMSE and MSE values for the processed output are tabulated and are depicted in the Table 1. For different images, say five, the measures are evaluated and for the same measures the graphical representation is drawn.

The Fig. 3 to Fig. 10 given below shows the graphical representation for PSNR, RMSE and MSE value.

The effectiveness of the proposed method is then evaluated by adding different types of noises to the input image and then the same image is enhanced using our proposed MCS algorithm. The various noises utilized for testing are Gaussian and Speckle noises. For each of the noise the corresponding parameter values are noted down and the graphical representation are done to show the effectiveness of our proposed method.

S. No.	Inputs	Image after denoising	Output Enhanced image (MCS)
1			
2			
3			

Fig. 2. Enhancement of Fingerprint Images.

Table 1. Parameter Values for Normal Images.

Images	Peak Signal-to-Noise Ratio (PSNR)	Root Mean Square Error (RMSE)	Mean Square Error (MSE)
1	65.6003	0.13435	0.01805
2	65.9798	0.1286	0.01654
3	64.8503	0.14646	0.02145
4	66.6276	0.11936	0.01425
5	66.6275	0.11936	0.01425

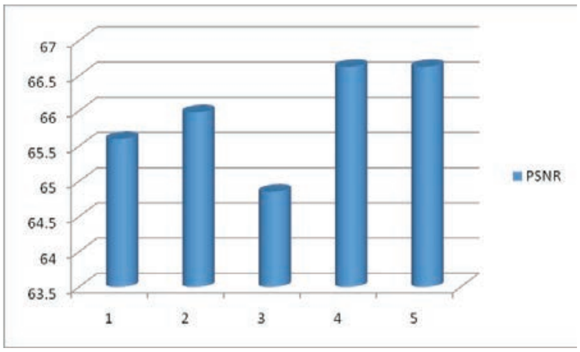

Fig. 3. Graphical Representation for PSNR Value using Proposed MCS Method.

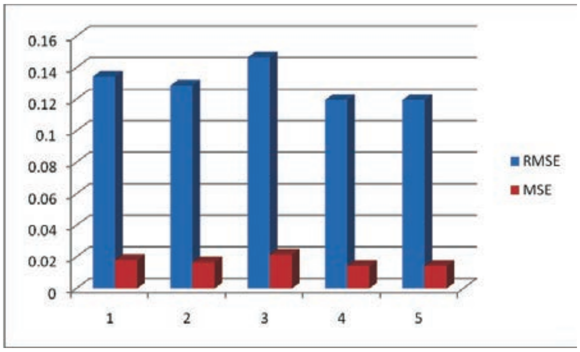

Fig. 4. Graphical Representation for RMSE and MSE Value using Proposed MCS Method.

i) Gaussian noise

S. No.	Input image	Noisy image	Denoised image	Enhanced output
1				
2				
3				

Fig. 5. Processed Output of Enhancement of Fingerprint Images with Gaussian Noise.

Table 2. Parameter Values for Noise Added Input Images.

Images	Peak Signal-to-Noise Ratio (PSNR)	Root Mean Square Error (RMSE)	Mean Square Error (MSE)
1	69.4697	0.08605	0.0074
2	74.6982	0.04713	0.00222
3	65.4292	0.13702	0.01877
4	77.0707	0.03587	0.00129
5	63.6225	0.1687	0.02846

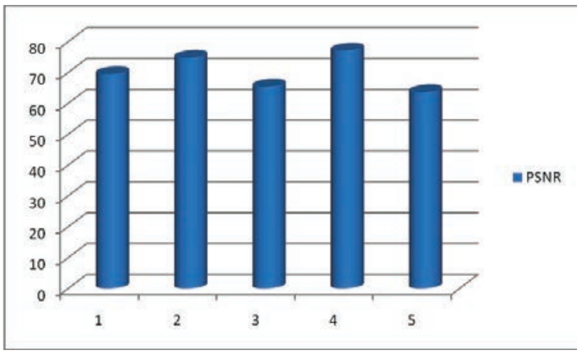

Fig. 6. Graphical Representation for PSNR Value for Input Images with Gaussian Noise.

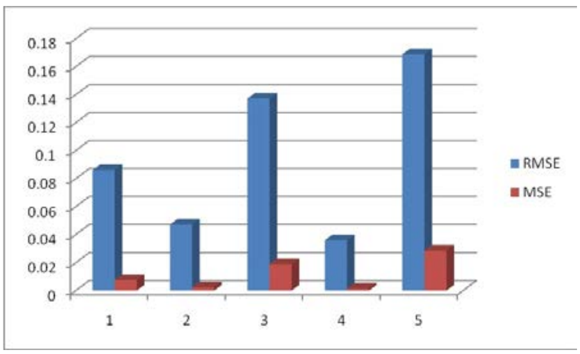

Fig. 7. Graphical Representation for RMSE and MSE Value for Input Images with Gaussian Noise.

ii) Speckle noise

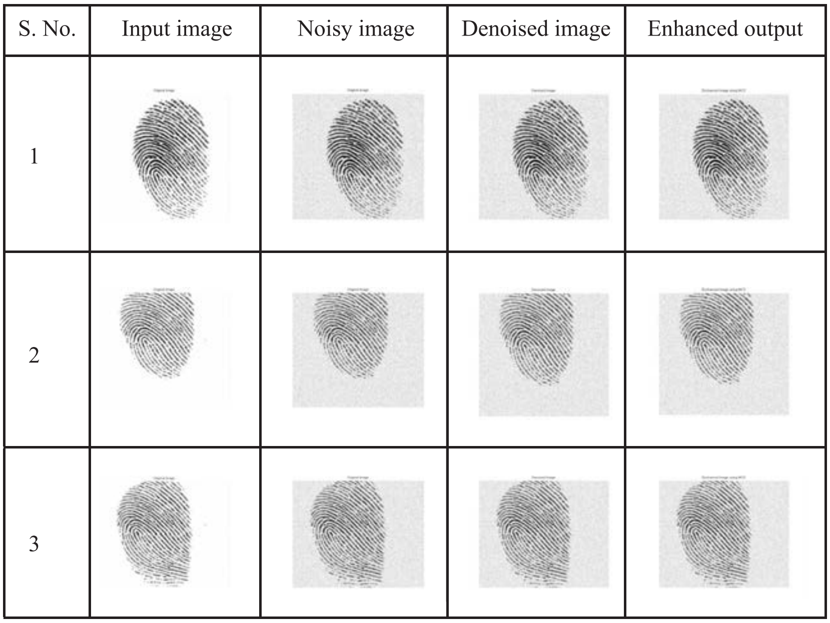

Fig. 8. Processed Output of Enhancement of Fingerprint Images with Speckle Noise.

Table 3. Parameter Values for Noise Added Input Images.

Images	Peak Signal-to-Noise Ratio (PSNR)	Root Mean Square Error (RMSE)	Mean Square Error (MSE)
1	74.4157	0.04869	0.00237
2	77.7654	0.03311	0.0011
3	77.7548	0.03315	0.0011
4	76.9896	0.0362	0.00131
5	71.9427	0.06473	0.00419

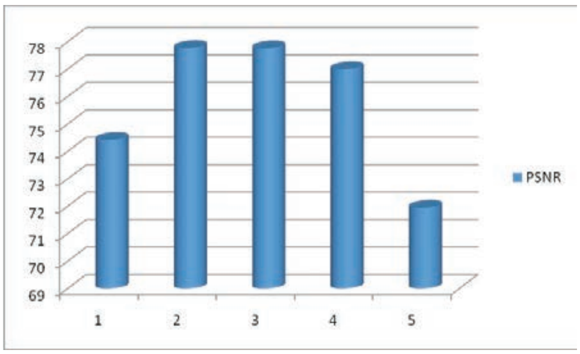

Fig. 9. Graphical Representation for PSNR Value for Input Image with Speckle Noise.

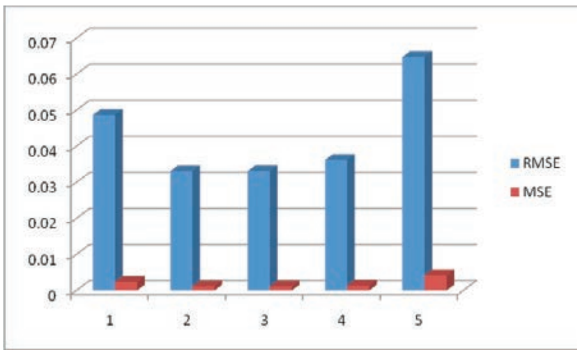

Fig. 10. Graphical Representation for RMSE and MSE Value for Input Image with Speckle Noise.

Table 4. Comparative of Our Proposed MCS based Enhancement with Existing Enhanced and Ordinary Cuckoo Search Methods.

	Peak Signal-to-Noise Ratio (PSNR)		
Images	Enhanced	Cuckoo Search (CS)	Modified Cuckoo Search (MCS)
1	47.9424	58.3672	65.6003
2	50.4453	56.4741	65.9798
3	48.8052	53.4896	64.8503
4	54.8575	51.3374	66.6276
5	55.8977	57.9701	66.6275

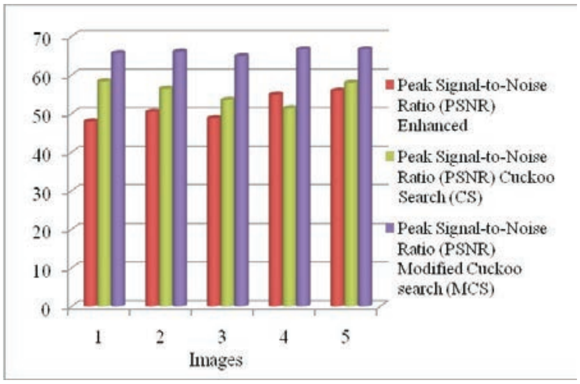

Fig. 11. Graphical Representation of PSNR Value for Various Images using Proposed and Existing Methods.

iii) Salt and pepper

The Table 4 given above shows the comparison of our proposed MCS based enhancement with existing enhanced and ordinary cuckoo search methods. The PSNR values for different input images for proposed and existing methods are evaluated and noted down in the table.

The Fig. 11 given above shows the graphical representation of the PSNR values for proposed MCS and other existing methods. From the graph it is clear that our proposed MCS has better performance when compared with the existing methods.

5. Conclusions

In this work, sequentially to deal with low superiority fingerprint images which have been the drawback of various existing method, an efficient technique for fingerprint image enhancement technique has been designed. The proposed methodology utilizes Wave atom transform for denoising and modified cuckoo search (MCS) algorithm is used as an optimizer to look for the best gray level distribution that maximizes the objective function. The proposed method of optimization aided in selecting better optimized gray level distribution which in turn aid in delivering improved enhancement to any sort of images. The results we obtained shows the effectiveness of proposed MCS algorithm based fingerprint enhancement technique as it delivers better PSNR value when compared with other existing techniques.

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