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METHODS

Image Enhancement and Features Extraction of Electron Microscopic Images Using Sigmoid Function and 2D-DCT

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ABSTRACT An innovative image enhancement and feature extraction technique that is based on the modified sigmoid function and two-dimensional DCT has been developed. The proposed technique uses a modified sigmoid function that accommodates the original microscopic input image characteristics. A novel block-based input value coupled with the modified sigmoid function is used in this proposed technique to provide good contrast enhancement of an image, resulting in localised contrast enhancement. Singular value decomposition played an important role after DCT because the singular value matrix determines the intensity values of the provided microscopic image. Changes in the singular values have an immediate impact on the intensity of the microscopic input image. The proposed methodology essentially converts the input picture into the SVD-DCT domain, normalises the singular value matrix, and finally reconstructs the enhanced image using inverse DCT. Simulation findings demonstrate that the proposed technique produces significantly superior improved results compared to other current approaches. Various essential characteristics of actinomycetes become evident once electron microscopic images are enhanced, such as long filaments, coils or spirals, rod shapes, and spore patterns. The presented method works successfully and efficiently for various bright and dark microscopic images.

INDEX TERMS Enhancement, modified sigmoid function, SVD, adaptive histogram equalization, DCT.

I. INTRODUCTION

In the era of the internet and technology, the processing of images is done by using digital computers [1] for various applications such as image enhancement, compression, face recognition and feature extraction. For improving the visual features of an image nowadays, image enhancement has become a very popular technique [2]. This research proposes microscopic image enhancement for feature extraction using modified sigmoid function and two-dimensional discrete cosine transform (2D-DCT). Various image enhancement techniques [3] work adaptively in many applications, while for colonies of micro-organisms, the subjective quality of an image becomes a paradigm. In the present era, adaptive image enhancement has become an emerging technique in microbiology, satellite imaging, real-time photography and medical science to extract the original and important features [3]. Recently MARN technique was proposed which work on end-to-end model for improving low-contrast images and uses the low contrast picture along with the IA map as input to develop an image-to-illumination mapping that directs the model to anticipate very precise inverse

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illumination map for image enhancement [4]. But in the microbiology field, due to the size of micro-organisms, the actinomycetes images need more enhancement to extract valuable features. Due to the very small size of actinomycetes, the important features of micro-organisms are not visible; therefore, microscopic images need enhancement. While capturing the image in a bad environment, whether it is a very dark or bright environment, the authentic and important featured contents are lost in those regions that are much bright or dark [5]. The key crucial issue is the improvement of the contrast of the microscopic image that composed of all necessary information which is not visible. Recently, various experts and researchers discussed different technique for image enhancement, such as Frequency Domain Enhancement Techniques, Contrast Limited Adaptive Histogram Equalization (CLAHE), Gamma Correction, General Histogram Equalization (GHE), Enhancement Filtering Methods, Local Histogram Equalisation (LHE) and other existing techniques [5]–[7]. These existing methods are very easy and effectively used to enhance contrast [8]. Various existing techniques [9]–[16] are used for image enhancement. But these available existing image enhancement techniques lack their performance because information depends on the histogram. During the enhancement process of an image, complete information is lost from an image. In the last few years, Discrete Wavelet Transform (DWT) has become an authentic tool used to analyse the audio signal's features because of its time-dependent nature. Nowadays, DWT is widely used in image processing domains such as compression, remote sensing, enhancement and removing noise [8]. In this research paper, four important techniques such as CLAHE, Modified Sigmoid Function, 2D-DCT and SVD are combined for enhancement and feature extraction. The singular value decomposition (SVD) is a complex or real matrix factorisation. SVD is a method of decomposing a matrix into three other matrices: First, there's an orthogonal matrix, a diagonal matrix is the second type of matrix, and the transpose of an orthogonal matrix is [8] that is the third matrix. Several researchers proposed other image equalisation techniques that depend on the equalisation of the singular value matrix computed with the help of the SVD method [2], [8], [17]. The SVD of a microscopic input image is expressed in matrix form as given below:

$$A = U_A \Sigma_A V_A^T \tag{1}$$

where U_A and V_A are hanger and aligner square matrices (orthogonal), respectively, the singular values are grouped on the diagonal of matrix, and initial enhancement is a result of scaling of singular values of coefficients of the DCT [8], [17]. This singular value matrix indicates the image's intensity value, and the variation on singular values correspondingly modifies the input image intensity values. As Σ_A consists of information related to the intensity of an image; here, for the analysis, different kind of images has been taken for the proposed work. In SVD, the ratio of the resulting normalised matrix's highest singular value to its mean and variance is both zero and one, respectively. It's calculated like this:

$$\xi = \frac{\max(\Sigma_{N(\mu=0,var=1)})}{\max(\Sigma_A)} \tag{2}$$

where, $\Sigma_{N(\mu=0,var=1)}$ is the synthetic intensity matrix's singular value matrix. Now with the help of this coefficient, regeneration of equalized image is possible by using

$$E_{Equalized\,A} = U_A(\xi \Sigma A)V_A^T \tag{3}$$

$E_{Equalized\,A}$ denote an equalized image. The primary task of equalization is to eliminate the illumination from an image that occurred due to a blurring effect and low contrast image [2], [18]. Discrete cosine transformation (DCT) provide significant role in image processing applications. [19]–[23] like filtering, compression, enhancement and segmentation. DCT is an authentic transform for extracting texture features from the image [24]. The spatial domain waveform can be converted into a frequency domain waveform by applying DCT, represented by coefficients [19], [21], [22]. The DCT divides the coefficients into lower frequency elements and higher frequency elements. The inverse DCT is the reverse procedure of DCT used to recreate spatial domain samples (IDCT) [19]. The following equation is the general mathematical formulation for a one-dimensional DCT (total data points are N) [19]–[22]:

$$F(u) = \left(\frac{2}{N}\right)^{\frac{1}{2}} \sum_{i=0}^{N-1} \Lambda(i) \cos\left[\frac{\pi u}{2N}(2i+1)\right] f(i) \tag{4}$$

The inverse 1D-DCT transform, on the other hand is denoted by $F^{-1}(u)$, where

$$\Lambda(i) = \begin{cases} \frac{1}{\sqrt{2}}, & if\ \varepsilon = 0 \\ 1, & otherwise \end{cases}$$

Mathematical expression for the two dimensional (image size is $N \times M$) DCT is given as follows [19], [22]:

$$F(u,v) = \left(\frac{2}{N}\right)^{\frac{1}{2}} \left(\frac{2}{M}\right)^{\frac{1}{2}} \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} \Lambda(i)\Lambda(j) \times \cos\left[\frac{\pi u}{2N}(2i+1)\right] \cos\left[\frac{\pi v}{2M}(2j+1)\right] f(i,j) \tag{5}$$

The inverse 2D-DCT transform, on the other hand, is denoted by $F^{-1}(u,v)$, where

$$\Lambda(\varepsilon) = \begin{cases} \frac{1}{\sqrt{2}}, if\ \varepsilon = 0 \\ 1 \quad , otherwise \end{cases}$$

II. OVERVIEW OF SIGMOID FUNCTION AND SVD

A. SIGMOID FUNCTION

Han *et al.* were the first who proposed the sigmoid function in 1995, and it's a limited differentiable mathematical function that's defined for all real numbers [25], giving it continuous and nonlinear properties. The sigmoid term comes from the shape of the sigmoid function waveform, formed like the

letter "S" in the English alphabet [26]. This function is a version of the logistic function that is given

$$f(x) = \frac{1}{1 + e^{-\frac{-(x-\alpha)}{\beta}}} \tag{6}$$

It effectively transforms entire range of x into [0 1] domain, then uses α and β to get the sigmoid function's centre and width, respectively.

A window-based modified sigmoid function is used of different sizes ($3 \times 3, 5 \times 5, 7 \times 7, 9 \times 9$) for the proposed work. This modified sigmoid function applied on the entire image, starting at the top left corner. The user determines the size of the window or block, and blocks of smaller sizes result in more image enhancement. The modified sigmoid function works pixel by pixel adaptively on the complete image. Hence, it efficiently smoothens the local histogram and enhances the image quality. Each pixel of the image created after applying the modified sigmoid function ($O_s(k, l)$] has same intensity value like input image ($f(k, l)$) and added to the mask. If ($f(k, l)$) is the input microscopic image then modified sigmoid function is defined as given below [27]

$$f_m(k, l) = k_1 * \frac{f(k, l)}{1 - \exp(k_1 * (f(k, l)) + k_1 * k_2)} \tag{7}$$

$$f_m(k, l) = k_1 * \frac{f(k, l)}{1 - \exp(k_1 * (f(k, l)) + k_1 * k_2)} \tag{8}$$

where, ($f_m(k, l)$) represents the modified sigmoid function, ($P_s(k, l)$) is obtained processed image, k_1 and k_2 are the two essential control parameters. These control parameters control the actual contrast and normalize the greyscale values. The starting value of k_2 is set to 0.5, that is the grey scale's middle value. On the other hand, various microscopic images require different greyscale values to be enhanced. As a result, in our experiments, an acceptable range of values for k_2 must be chosen. The values of k_1 and k_2 should be in the range of 1 to 25 and 0 to 1 respectively for effective contrast enhancement of a microscopic input image. But when $k_1 = 6$ is used, the contrast is changed on a small scale, when $k_1 = 1$ is used, the contrast is reduced by roughly 20% of the original value, and when $k_1 = 12$ is used, the contrast is increased to 2.5 times with respect to original value. In Matlab software, simulation is carried out 200 times to optimise the values of k_1 and k_2 concerning the brightness and contrast parameters. After this, determine the best values for k_1 and k_2, which are 12 and 0.5, respectively. This performs well and effectively for all types of images and actinomycetes electron microscopic images.

B. SVD

The SVD is computed with the help of three viewpoints that are mutually compatible [28]. SVD converts similar data into a group of dissimilar variables that discloses the original data's relationships [29]. Apart from that, SVD recognizes and sorts the dimensions for which data items show higher variance, resulting in which original data points can only be approximated by fewer dimensions. Therefore, singular value decomposition (SVD) is used for data reduction and feature extraction and image enhancement [30].

III. PROPOSED METHODOLOGY

The proposed image enhancement technique is applied to microscopic pictures of actinomycetes that had poor visual quality and required improvement for feature extraction in this proposed work. The proposed image enhancement algorithm comprises four stages: In the first stage, the low contrast greyscale input microscopic picture is initially processed using contrast limited adaptive histogram equalization (CLAHE), which increases the contrast level of an input image. Then in the second stage, the microscopic image is processed by block ($3 \times 3, 5 \times 5, 7 \times 7, 9 \times 9$) based modified sigmoid function that changed the dynamic range of the micro-scopic input image. This modified sigmoid function works like a mask. It is applied to the whole image, as a result of which intensity values are increased adaptively and smoothens the local histogram. Further, it involves two parts to enhance the microscopic image, as shown in Figure 1. The first part is SVD, as discussed earlier, and the singular value matrix [29]. As SVD is composed of illumination contents of an image, illumination of an image depends on the conversion of singular values; hence, other information about the image will remain the same as earlier [30]. The beauty of this proposed method is the application of modified sigmoid function, due to which optimization is achieved, as discussed in the previous section. Every significant equation in the DCT domain represents the frequency features of the microscopic image and DCT frequency. In this research work, the low frequency (called DC components) DCT coefficients contain the structural information for microscopic images. As a result, it will gather and store all information connected to the edge from all conceivable degradation of microscopic pictures by isolating the AC components (coefficients of high-frequency) and then using illumination enhancement in the DC components (coefficients of low-frequency) [31]–[33]. The DCT technique is followed by IDCT, which allows for reconstructing the original image. The resulting image will be increased by illumination, and it will be finer and have strong contrast qualities [30].

After applying modified sigmoid function $O_s(k, l)$ is obtained and then it is processed with the help of GHE to produce $\hat{A}$. Then, DCT is applied to both images, transforming the image into higher frequency components and lower frequency components [19], [21], [22]. Further, the coefficient of correction for the singular value matrix is computed with the help of Eq.(9) as given below:

$$\xi = \frac{\max(\Sigma_{\hat{D}})}{\max(\Sigma_D)} \tag{9}$$

where, $\Sigma_{\hat{D}}$ represents the DC coefficients singular matrix of original microscopic image and Σ_D represents the DC coefficients of singular matrix of an output microscopic image obtained by GHE. After this process, the new microscopic

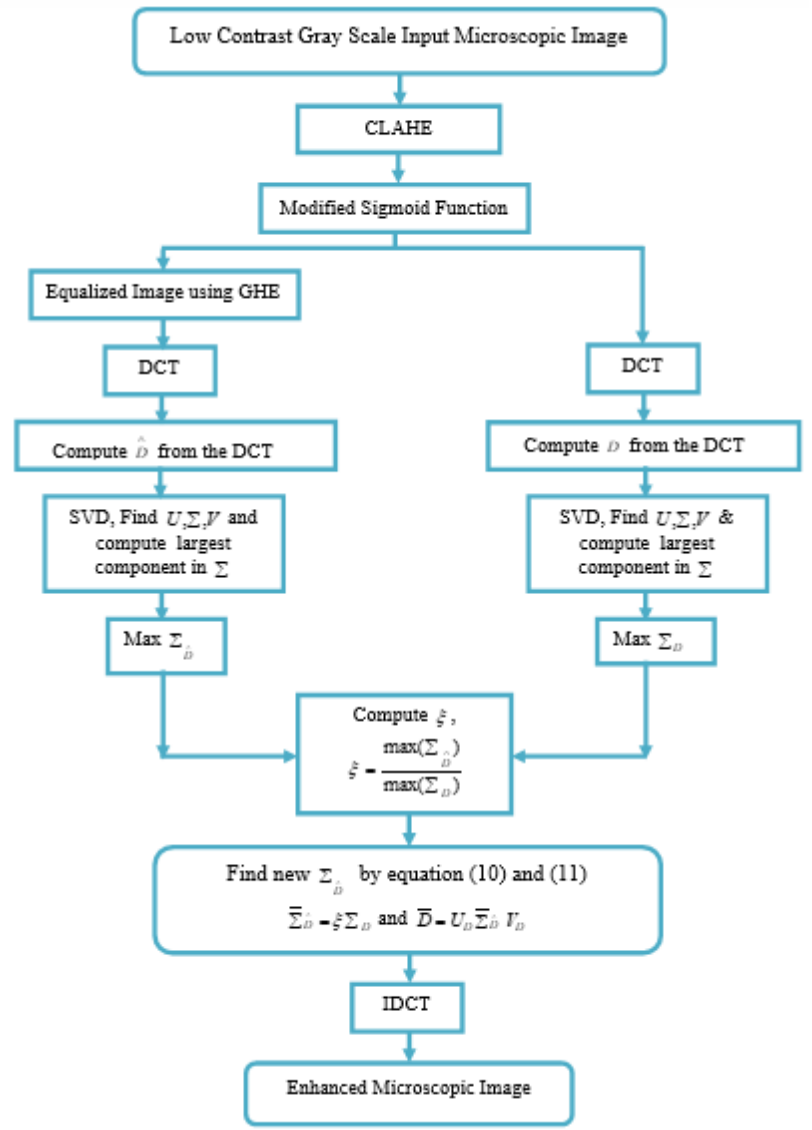

FIGURE 1. Proposed image enhancement and feature extraction algorithm.

image is investigated with the help of following equations:

$$\bar{\Sigma}_{\hat{D}} = \xi \Sigma_D \tag{10}$$

$$\bar{D} = U_D \bar{\Sigma}_{\hat{D}} V_D \tag{11}$$

where, $\bar{D}$ represents the frequency coefficients (lower) of original microscopic image which is reconstructed with the help of IDCT to obtain the corresponding equalized image $\bar{A}$ as follows:

$$\bar{A} = IDCT(\bar{D}) \tag{12}$$

IV. RESULTS AND DISCUSSIONS

The presented technique's effectiveness and efficiency are evaluated on various images with varying contrast and resolution. The proposed technique used Matlab software for simulation and all experimental operations. Four distinct contrast actinomycetes, the microscopic images of size 512×512, are employed in our experimental study for feature extraction and image enhancement. Quality analysis criteria such as EME (Measure of Enhancement), EMF (Measure of Enhancement Factor), MSE (Mean Square Error), and PSNR (Peak Signal to Noise Ratio) [36] are used to assess the reliability and performance of the proposed image enhancement technique. As a result of these quality factors, the overall quality of the resultant enhanced microscopic image is significantly better than the original microscopic image, as seen by improved PSNR, EMF, and EME values. For a given input microscopic image $f(k, l)$ of size $M \times N$, Panetta *et al.* [37] and Tang *et al.* [9] defined the EME as given below:

$$EME = \left(\frac{1}{s_1 * s_2}\right) \sum_{t=1}^{s_1} \sum_{s=1}^{s_2} \left[20 \ln \left(\frac{f_{\max,s,t}}{f_{\min,s,t}}\right)\right] \tag{13}$$

FIGURE 2. (a) Girl's input image of size 512 × 512 (b)Resultant enhanced image using [3] technique, EMF=1.87 (c) Resultant enhanced image obtained by proposed technique (3 × 3 block size), EMF=2.48 and (d) Resultant enhanced image obtained by proposed technique (7 × 7 block size), EMF=2.33.

Algorithm 1 Proposed Algorithm

1: BEGIN Algorithm
2: Read the low contrast microscopic image into Matlab.
3: Now, equalize the electron microscopic image using CLAHE.
4: Apply modified sigmoid function to the microscopic image.
5: Now, perform global histogram equalization using GHE technique
6: Determine the DCT for improved contrast of the microscopic image.
7: Now, find out the value of variables $\hat{D}$ and D in the DCT processed microscopic image.
8: Then SVD is utilized to acquire U, Σ, V and locate the greater component in Σ.
9: Find the $\max(\Sigma_D)$ and $\max(\Sigma_{\hat{D}})$ by using singular value decomposition method.
10: Find ξ with the help of Eq.(9)
11: Now, find the new value of $\max(\Sigma_{\hat{D}})$ using Eq.(10 and 11)
12: Now compute IDCT.
13: Resultant enhanced microscopic image.
14: END Algorithm

where, an input image $f(k, l)$ is partitioned into $s_1 \times s_2$ blocks, The pixel's lowest and largest values for each block are $f_{\min,s,t}$ and $f_{\max,s,t}$ respectively. The following is the EMF (measure of enhancement factor) between the output enhanced image obtained and the input microscopic image:

$$EMF = \frac{EME\ of\ \ the\ output\ Enhanced\ Image}{EME\ of\ the\ input\ microscopic\ image} \tag{14}$$

Peak Signal to Noise Ratio (PSNR) is a quality parameter that measures the difference between an input microscopic image and an enhanced output microscopic image and it is defined as:

$$PSNR = 10 \times \log\left(\frac{255^2}{MSE}\right) \tag{15}$$

where,

$$MSE = \frac{1}{n^2}\sum_{k,l=0}^{n-1}[f(k,l) - g(k,l)]^2$$

and n represent the size of microscopic image. Arya *et al.* [3] the technique was employed on Girl's image, having a size of 512 × 512, as shown in Figure 2(a), and the obtained resultant microscopic image, as shown in Figure 2(b). The enhanced image has an EMF value of 1.87. The proposed technique with varied block sizes (3 × 3 and 7 × 7) was applied to improve the visual quality of the image that is shown in Figure 2(a). Figures 2(c) and 2(d) have EMF values of 2.48 and 2.33, respectively, for these enhanced images. The proposed method produces 32.62% higher EMF (for 3×3 block size) and 24.59% more EMF (for 7×7 block size) than the Arya *et al.* [3] algorithm. Arya *et al.* [3] the technique was applied to the Peppers image having a size equal to 512 × 512, as shown in Figure 3(a), to check the precision, reliability, accuracy, and efficiency of the proposed algorithm and obtained enhanced image is given in Figure 3(b) that have EMF 2.5812. Furthermore, the proposed technique was applied to the Peppers image as given in Figure 3(a), utilising block sizes 3×3 and 7×7. The enhanced images obtained for block sizes 3×3 and 7×7 are shown in Figures 3(c) and 3(d), for which EMF values are 2.98 and 2.84, respectively. In comparison to the Arya *et al.* [3] technique, the proposed image enhancement technique yields 15.45% (for 3 × 3 block size) and 10.02% (for 7 × 7 block size) more EMF values. As a result, the proposed technique's accuracy and performance have improved significantly.

The proposed technique's performance and accuracy are compared that is based on EME and EMF quality parameters with other existing image enhancement techniques like EHS (Exact Histogram Specification) of Coltuc *et al.* [10],

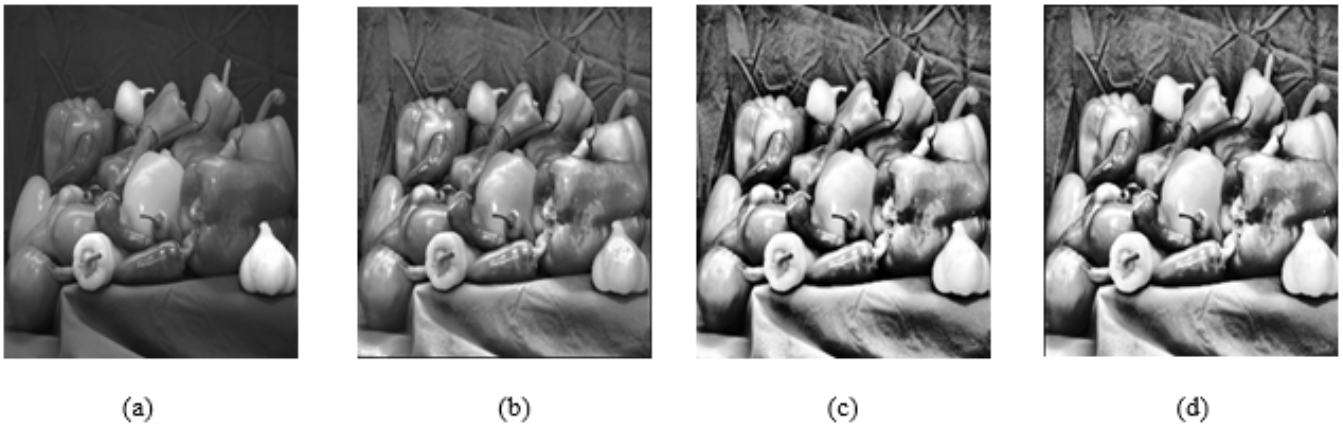

FIGURE 3. (a) Peppers input image of size 512 × 512 (b)Resultant Enhanced image using [3] technique, EMF=2.5812 (c) Resultant enhanced image obtained by proposed technique (3 × 3 block size), EMF=2.98 and (d) Resultant enhanced image obtained by proposed technique (7 × 7 block size), EMF=2.84.

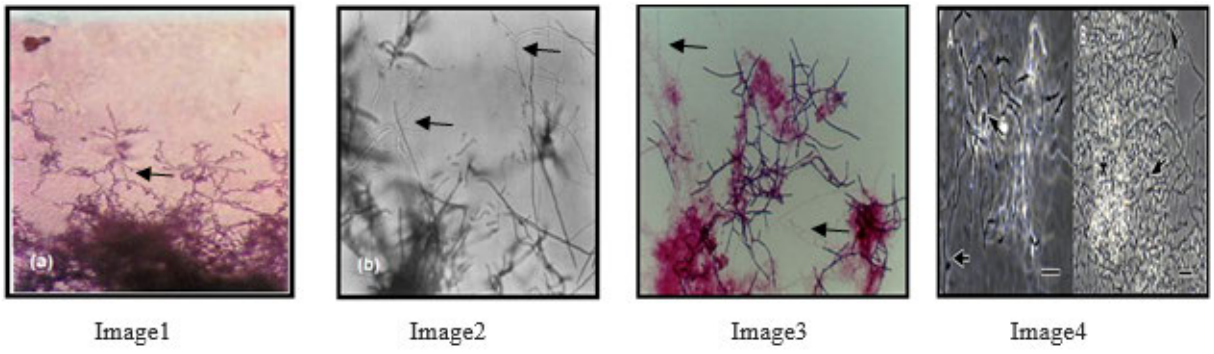

FIGURE 4. Electron microscopic images of actinomycetes were used as the original input images.

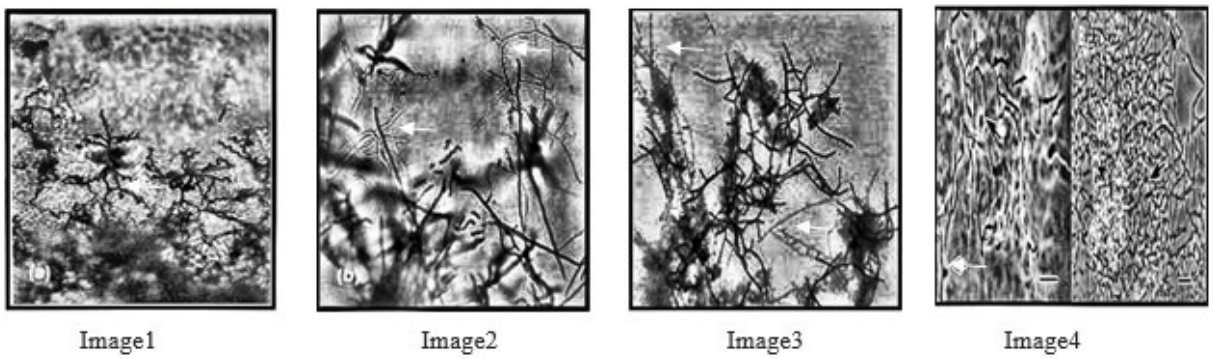

FIGURE 5. Obtained enhanced microscopic images of actinomycetes using proposed technique.

AR (Alpha Rooting) of Aghagolzadeh *et al.* [11], BPDFHE (Brightness Preserving Dynamic Fuzzy Histogram Equalization) of Sheet *et al.* [12], AHE (Adaptive histogram Equalization) of Pizer *et al.* [13] and Zuiderveld [14], MCEDRC (Multi Contrast Enhancement with Dynamic Range Compression) of Lee *et al.* [15], MCE (Multi Contrast Enhancement) of Tang *et al.* [9], UWCNN technique [34], CLAHE-LD technique [35], ACEBSF (Adaptive Contrast Enhancement Based on modified Sigmoid Function) of Shyam Lal *et al.* [16] and Arya *et al.* [3] algorithm. The proposed algorithm is evaluated on four different microscopic images of actinomycetes with variable contrast and resolution, namely Image1, Image2, Image3, and Image4. As shown in Figure 7 and Table 1, this proposed technique improves performance regarding EME and EMF values due to its effective performance. Further, for validation of the proposed technique, the obtained enhancement results are compared with the help of quality metrics with eight

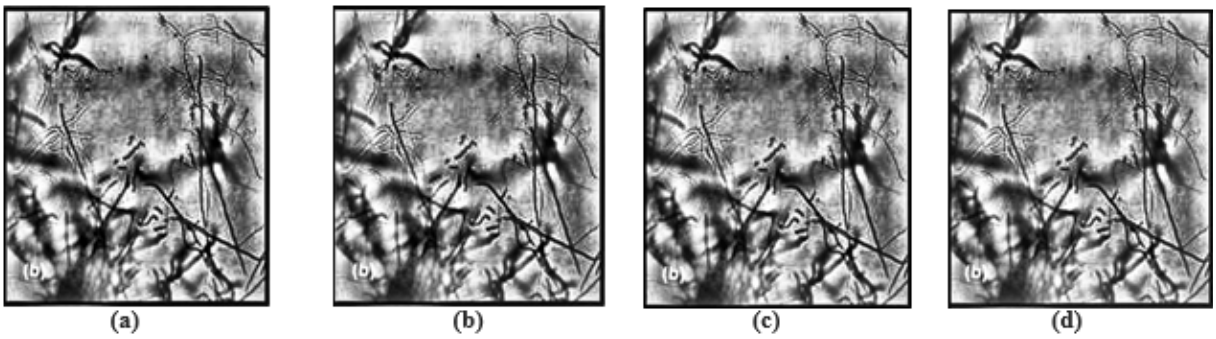

FIGURE 6. Resultant enhanced Images of Image2 by using proposed algorithm,(a) For 3 × 3 block size, EMF=3.86 (b) For 5 × 5 block size, EMF=3.58(c) For 7 × 7 block size, EMF=3.47 (d) For 9 × 9 block size, EMF=2.98.

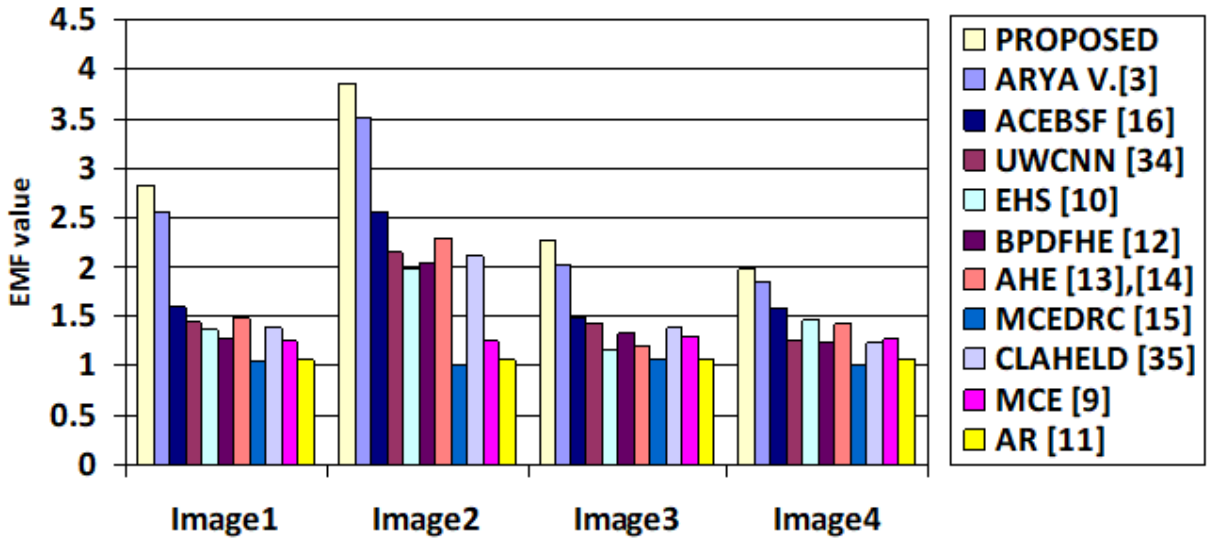

FIGURE 7. EMF values for resultant enhanced images by using different existing techniques.

TABLE 1. Performance comparison of existing methods with the proposed algorithm.

Image	Technique	[12]	[13], [14]	[10]	[11]	[34]	[15]	[9]	[35]	[16]	[3]	Proposed
Image 1	EME (Original)	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65
	EME (Output)	9.82	11.36	10.45	8.10	11.06	7.80	9.48	10.62	12.16	19.71	21.58
	EMF	1.28	1.48	1.36	1.06	1.44	1.04	1.26	1.38	1.59	2.57	2.82
Image 2	EME (Original)	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62
	EME (Output)	9.38	10.62	9.14	4.89	9.93	7.54	9.41	9.74	11.82	16.25	17.83
	EMF	2.03	2.30	1.98	1.06	2.14	1.01	1.26	2.10	2.56	3.51	3.86
Image 3	EME (Original)	8.87	8.87	8.87	8.87	8.87	8.87	8.87	8.87	8.87	8.87	8.87
	EME (Output)	11.71	10.55	10.28	9.40	12.73	7.91	9.71	12.26	13.21	17.84	20.31
	EMF	1.32	1.19	1.16	1.06	1.43	1.06	1.30	1.38	1.49	2.01	2.28
Image 4	EME (Original)	13.90	13.90	13.90	13.90	13.90	13.90	13.90	13.90	13.90	13.90	13.90
	EME (Output)	17.16	19.85	20.29	14.73	17.58	7.54	9.48	17.19	21.96	25.67	27.52
	EMF	1.23	1.42	1.46	1.06	1.26	1.01	1.27	1.23	1.58	1.84	1.97

other existing contrast enhancement algorithms, as shown in Table 1, which shows that the proposed enhancement algorithm is more powerful from the perspective EMF and EME values. Figure 5 clearly shows that the presented technique produces improved visual results, precision, and accuracy, resulting in which essential aspects of actinomycetes may be seen in the enhanced images as a result.

As a result of the novel enhancement process, actinomycetes have several distinguishing characteristics: Figure 5 (a) shows a spiral or coil pattern in the chain, Figure 5 (b) shows a long filament, Figure 5 (c) shows a rod shape geometry grouped in a chain pattern or rod filamentous pattern, and Figure 5 (d) shows a single spore at a branch (d). Compared to the original input actinomycetes

TABLE 2. Comparison of the proposed algorithm's performance for various block sizes.

Image	Parameters	3×3 Block Size	5×5 Block Size	7×7 Block Size	9×9 Block Size
Image1	EME (Original)	7.65	7.65	7.65	7.65
	EME (Output)	21.58	19.50	18.51	16.14
	EMF	2.82	2.55	2.41	2.10
	MSE	5.64	6.23	7.93	8.11
	PSNR (dB)	40.65	40.22	39.17	39.07
Image2	EME (Original)	4.62	4.62	4.62	4.62
	EME (Output)	17.83	16.54	16.07	13.81
	EMF	3.86	3.58	3.47	2.98
	MSE	4.33	4.71	6.06	6.21
	PSNR (dB)	41.80	41.43	40.34	40.24
Image3	EME (Original)	8.87	8.87	8.87	8.87
	EME (Output)	20.31	19.33	18.36	15.25
	EMF	2.28	2.17	2.06	1.71
	MSE	4.07	4.62	5.47	5.59
	PSNR (dB)	42.07	41.52	40.79	40.69
Image4	EME (Original)	13.90	13.90	13.90	13.90
	EME (Output)	27.52	26.96	26.27	24.18
	EMF	1.97	1.93	1.89	1.73
	MSE	4.61	5.71	7.09	7.19
	PSNR (dB)	41.53	40.60	39.66	39.60

images, these microscopic features (indicated with arrows) are more clearly visible in enhanced images. The arrows sign marked in the original input images of actinomycetes (shown in Figure 4) shows that the images are of poor visual quality. As a result, crucial properties of the actinomycetes strain are not visible due to which unable to isolate a new strain. The presented enhancement technique used in this study is based on block-based adaptive contrast enhancement in conjunction with a modified sigmoid function and DCT.

Consequently, as shown in Figure 4, it solves the problem of poor visual quality from microscopic images and significantly improves the visual quality for the feature extraction. Since this proposed technique is effective, it can isolate the new strains and secondary metabolites, amino acids, enzymes, and other compounds. Table 2 shows the MSE, PSNR, EME, and EMF values for various block sizes, and it could be shown that the proposed technique produces higher EMF for the 3×3 block size than the other (5×5, 7×7, 9×9) block sizes. The resultant enhanced images of Image2 using the proposed algorithm for various window sizes are shown in Figure 6. The proposed technique increases the image's visual quality while simultaneously preserving significant features and maintaining the brightness level in microscopic images, as shown by the enhancement results.

V. CONCLUSION

This paper proposed a block-based adaptive contrast enhancement technique with modified sigmoid function and DCT for microscopic image enhancement and feature extraction. This method has been tried on various microscopic and other images with varying contrast and resolution. The proposed work's subjective and qualitative enhancing efficiency has been assessed. Based on MSE, PSNR, EME, and EMF, the proposed technique's enhancement results are compared to those of other existing enhancement techniques for electron microscopic images. We can see from the data that the proposed algorithm works well for smaller picture block sizes (3×3) instead of larger image block sizes ($5 \times 5, 7 \times 7, 9 \times 9$). As a result, we can infer that the proposed algorithm outperforms other current image-enhancing approaches for smaller block sizes in terms of superiority and resilience. The findings depicts that the proposed strategy for contrast enhancement and feature extraction of electron microscopic images works efficiently and effectively. After enhancing electron microscopic pictures of actinomycetes, numerous highly significant and authentic properties such as long filament, coil or spiral, spore and rod form structures are extracted for feature extraction. This proposed technique can be applied to various images, including satellite images, radar photos, cardiac ECHO images, X-ray images, MRI images, electron microscope images, micro-organism images, and real-life photographic images with poor contrast issues during acquisition.

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CODE AVAILABILITY

The code for this work will be made accessible to the respective authors upon reasonable request to the corresponding author.

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