An Analytic Review on Image Enhancement Techniques Based on Soft Computing Approach

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Abstract This paper discusses various image enhancement techniques using soft computing approaches. The approaches used are genetic algorithm, fuzzy-based enhancement, neural networks, and optimization techniques (ant colony, bee colony, particle swarm optimization, etc.). The main objective of this paper is to identify the status of currently used soft computing approaches in image enhancement. Our study may help future researchers to overcome the current issues with existing approaches to improve the overall image quality.

Keywords Image enhancement · Image quality · Soft computing approaches · Digital image processing

1 Introduction

Image enhancement is the way of refining the quality of a digital image; thus, making processing of the image easier. After enhancement, the resulting image is better in quality, contrast and can be analyzed correctly by any of the image processing methods. Various techniques can be used for the same, but our study is limited to the techniques based on soft computing approaches. Image enhancement based on soft computing approaches discussed in this paper is genetic algorithm, fuzzy-based enhancement, neural networks, and optimization techniques (ant colony, bee colony, particle swarm optimization, etc.). It has been identified that these techniques provide better enhancement as compared to other traditional image

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enhancement techniques. In addition to this, they are easy to understand and implement.

This paper is divided into four sections. Section 1 is introduction about the image enhancement followed by review procedure in Sect. 2. Section 3 covers the detailed analysis of the selected papers. Finally, conclusions as well as answers to the research questions are discussed in Sect. 4.

2 Review Procedure

To study various image enhancement techniques based on soft computing approaches, we downloaded around 200 papers from IEEE, science direct, ACM, and several other popular digital libraries. We have adopted a similar approach taken by Singh et al. [1, 2] and then identified the most suitable papers using the following steps: (i) we downloaded around 200 papers using standard keywords, (ii) after reading the abstract, title, and conclusion of the downloaded papers, we filtered out 90 relevant papers, (iii) out of the 90 papers selected, we chose 45 most suitable papers related to the suitability of our study, (iv) after that, these papers were thoroughly studied, and the final outcome of each paper was recorded, (v) finally, we have summarized the findings in a tabular format and answered the research questions prepared for conducting systematic review. Following are the research goals to study the image enhancement techniques (Table 1 and 2):

3 Related Work

In this section, various papers related to image enhancement based on soft computing approaches have been taken into account for review and analysis.

In [3], Archana et al. discussed an image enhancement technique using genetic algorithm (GA) which modifies an image with natural contrast. The aim of local contrast enhancement is done by using a, b, c, k parameters with new addition in the range. On the basis of light and dark edges, the gray level of an image is increased. By checking the intensity of spatial edges, the GA measures the individual's fitness. In [4], Deborah et al. proposed a GA technique for magnifying and restoring the old

Table 1 Research questions identified

Research Questions
RQ1: To identify the various techniques used in the image enhancement based on soft computing approach?
RQ2: To compare the traditional image enhancement techniques with the soft computing-based image enhancement techniques?
RQ3: To identify strength and weaknesses of existing image enhancement techniques

Table 2 Search result details

S No.	Soft computing approach used	No. of papers downloaded	No of relevant papers found	Final no of papers chosen for review
1.	Genetic algorithm	42	20	8
2.	Fuzzy enhancement	71	25	18
3.	Neural networks	44	20	11
4.	Optimization technique (PSO, ABC, ACO)	30	10	5
5.	Hybrid	13	10	3
TOTAL		200	85	45

documented image. In this method, the material presents in old documents is retained into digital form. The number of edges having one pixel is the most excellent fitness function. Individuals that have fitness value identical to the fitness value of original image are the optimal solution. In [5], Ueda et al. analyzed an image enhancement system based on GA by acknowledging the liking of the user. GA finds the optimal parameters contained in the selective un-sharp masking of the sharpening system. Based on the liking of the user, the final sharpened image is built. In [6], Radlak et al. considered a method for attaining the optimization visuals by increasing the distance between various colors. The proposed method gives the best visualization result. Using the GA, the final output gives the benefits of pseudo-colorization. In [7], Wu et al. mentioned a method which merges the rough set technique and adaptive genetic algorithm for enhancing an image. Firstly, the image is considered as the knowledge system, and to categorize an image, classification method of rough set theory is used to merge noise attributes and image color attributes. Then, various image enhancement algorithms are applied to modify the image. In [8], Dongzhou et al. analyzed a hybrid genetic algorithm for enhancing an image. It merges the differential evolution with genetic algorithm. For searches and mutation, the fast searching ability of the hybrid genetic algorithm is used. At last, in their work, they have applied transformation function for image enhancement. In [9], Munteanu et al. analyzed an image enhancement method with user behavioral model. In this method, various genetic algorithms are used. This method tries to slightly automate the process of human interpretation which results in rich quality solutions, and hence less human effort is needed. In [10], Daniel et al. proposed a contrast enhancement technique purposely for retinal images. The proposed technique uses masking technique using the green plane and then applying an enhanced GA for the enhancement. The proposed technique is first applied on normal images and then successfully on retinal images. Finally, performance of the proposed technique is evaluated and is found to be better than other traditional techniques.

In [11], Hasikin et al. analyzed a fuzzy set theory method for enhancing the lower contrast image. This method maximizes the fuzzy measurements. The modification of the membership function is done by using the power law transforms and the saturation operator. In [12], Chaira et al. discussed a type II fuzzy

enhancement algorithm for image enhancement. Here, Hamacher T Norm is used for defining the new membership functions. It is then compared with other fuzzy image enhancement methods and is observed that the proposed technique gives better contrast images. In [13], Cepeda-Negrete et al. analyzed a fuzzy rule-based system which automatically chooses color constancy algorithms from white patch, gray world, and gray edge for enhancing the color of dark images. Twelve features, including seven colors, three textures, and two lightning features of each image are extracted for processing. In the end, best of the three algorithms is selected for any test image. In [14], Binaee et al. mentioned a noise reducing fuzzy filter which is applied on ultrasound images. It is used for enhancing the quality of ultrasound images, so that they can be efficiently analyzed without any error. The proposed technique contains two steps: detection and filtering. In detection, details of the image are extracted using two fuzzy rule-based system as well as local gradients. In filtering, de-noising of each region is done by a non-local means scheme in which fuzzy similarity is used for finding similarity in weights. In [15], Bing et al. proposed a new algorithm for image enhancement using information fusion for preserving edge information. It is actually a hybrid filter consisting of fuzzy-based region entropy and triangle module fusion operator for edge detection. In [16], Xiao-guang et al. discussed a generalized fuzzy enhancement method. This method overcomes, efficiently, the problem of information of middle- and low-gray levels lost in the method put forward by a previous study. The edge of processed image becomes distinguishable, and by using this method, better object information of low gray levels is kept. It gives highly enhanced image and improves contrast ratio. In [17], Balti et al. implemented fuzzy C-means algorithm for fingerprint image segmentation. Firstly, statistical features of the fingerprint image are extracted and then are used in the fuzzy C-means algorithm. K means algorithm is also used for comparison with the fuzzy C-means algorithm. Also, enhancement of the fingerprint is done by first calculating mean and variance of an image and then finding difference between the original and mean, as well as original and variance images. Resulting images are enhanced than the original image. In [18], Chaira et al. proposed a new technique for medical image enhancement. The technique consists of a Sugeno fuzzy system which uses an intuition-based method for finding membership values. This method is applied on the medical image to convert it into fuzzy image, and then the parameters are optimized using intuitionistic fuzzy entropy. In [19], Zhang et al. mentioned an improved edge detection and image enhancement algorithm which overcomes the shortcomings of algorithms proposed by a previous study for the same. Instead of choosing random threshold parameter value for enhancement, the proposed new method uses OTSU threshold which appropriately chooses the enhancement parameter and can be adjusted according to the requirement. The proposed method simplifies the complex transformation calculation of fuzzy space values and hence improves the performance of the edge detection and image enhancement process. In [20], Wang et al. proposed a new image enhancement algorithm which is an improvement of the Pal–King algorithm. It implements a new membership function which is used to map the image from space domain to fuzzy domain. Nonlinear transformation is then repeatedly applied

on the image for enhancement. Finally, inverse operation is applied to get enhanced gray scale values in spatial domain. In [21], Xian-Jiu et al. analyzed a new image enhancement technique for algae microscopic images. It is based on subdividing the image into low-pass part and high-pass part using filtering, enhancing each segment and combining the segments using fuzzification technique to get enhanced image. In [22], Wu et al. mentioned an algorithm for contrast enhancement and detection of edges of a blurred image. It is presented to extract as much information as possible from a blurred image. Algorithm used for the same is a multilevel fuzzy edge detection algorithm which is computationally fast from other algorithms and uses fuzzy operators for enhancement and edge detection. In [23], Jia et al. proposed a computationally fast and efficient fuzzy-based image enhancement algorithm. It uses a new linear membership function for converting the image from space domain to fuzzy domain. Then, for enhancement, the generalized fuzzy operator is applied. The new method shows improvement over the traditional image enhancement algorithms. In [24], Jinping et al. discussed a new improved fuzzy enhancement and edge detection algorithm which uses a Gaussian function. Gaussian function provides a notable improvement in the image's quality and edge extraction. In [25], Jaya et al. discussed a fuzzy rule for magnifying the image having lower contrast in the transformation domain. On both medical and general images, the test is carried out. The final output is compared with fuzzy INT operator. To assess the visualization quality and contrast of an image SDME, IEM, and EME metrics are properly used. In [26], Saeed et al. proposed an image's contrast magnification using the fuzzy set theory. In this method, the image is magnified by using the fuzzy set. The proposed algorithm is analyzed with all other algorithms. This algorithm is more preferable in terms of speed with respect to other algorithms. In [27], Raju et al. proposed an algorithm by using the fuzzy logic and histogram for magnifying an image. There are two parameters which are used in this method. The first parameter is K which is contrast identifying parameter, and the other one is M which is average intensity parameter. The RGB image is transformed to hue, saturation, and value (HSV) image. The strain is put on V component under the control of M parameter, so that the image can be magnified. In [28], Hanmandlu et al. implemented an image enhancement method by using the fuzzy intensification. In this method, the hue, saturation, and value (HSV) model's saturation and histogram are converted into the domain of fuzzy. The NINT operator is used in this method. The image's intensity specifications and the fuzzifier are assessed by effectively using the entropy and contrast in the domain of the fuzzy. This method is applicable for the images having the lower contrast and lower intensification.

In [29], Alilou et al. discussed a general regression based neural network technique which is used for image restoration and inpainting. In this technique, the missing regions of the image are defined by applying the GRNN to perform regression over the neighbor pixels. The proposed technique was found to be computationally efficient and easy to implement. It was tested on various gray scale and color images. In [30], Chitwong et al. discussed different image enhancement techniques by applying the competitive Hopfield neural network. The precision of clustering is better in simulated image and is shown by competitive Hopfield neural

network. The enhancement's performance is also finer than he fuzzy C-mean in different clusters for an image. In [31], Nieuwenhuis et al. proposed an adaptive filtering concept. It provides a framework to compose aforementioned high-level knowledge and using it to fix the filtering parameters locally. The performance is improved by using binary rotation of data and multiple class principal component analysis (PCA). In [32], Yin et al. discussed an ultrasound image modifying technique by applying the neural network. Mapping is formed by the artificially neural network. To the artificially neural network, a parameter is computed. The fusion of data is done by the fuzzy logic. To filter the sample data, an algorithm of local histogram is used. The algorithm that is proposed in this paper effectively maps with high-resolution image and low-resolution image. In [33], Zhang et al. considered a technique for high resolution by applying Hopfield neural network. In this method, the Hopfield neural network solves the ill-positioning super resolution problem. This method considers both the blurring and noise in an image and creates a great resolution image with no noise. The image produced by this method has best quality in respect of peak signal-to-noise ratio (PSNR). In [34], Pan et al. proposed a method for diagnosing different types of plants by digital images of leaves. In this method, the clear objects are made in the source image by the image enhancement process. After this, the image blocks are apportioned from the source because of different kinds of size and shape of the block of the image. By applying the image analysis tools, the properties like radius, sizes, solidity, eccentricity, and perimeters are calculated using neural network approach. In [35], Singh et al. analyzed an image enhancement technique for screening the luggage. In the neural network, the input is viewability measures and the output is the image enhancement algorithm. The best choice of the image enhancement algorithm is done by the prediction systems. Then, the prediction system and baseline system approach are compared. In [36], Ma et al. mentioned an algorithm for enhancing the image by using the pulse-coupled neural network and rough set. Firstly, the noise of the image is detected using pulse-coupled neural network time matrix and divides the image in three parts of image based on the noise features and intensity features. After this, denoise the image by applying filter method. At last, enhance the different parts of image by applying the various methods. This proposed algorithm shows better results for the image in the darker regions, and noise is also decreased. In [37], Rao et al. discussed the different types of image enhancement techniques. The good results are shown by the classical spatial filters, and there is very little complexity for computation. A multilayer self-organizing neural network with error back propagation depends on descent gradient is compared. A grand requirement of computations is required because of the adjustment of weights in every layer. In each iteration, the error is negligible. The computation speed of cellular neural network is very high when it's related to neural network. In [38], Weixin et al. implemented a X-ray image enhancement technique by using the Hopfield neural network. In this method, by using a suitable energy function, the image enhancement problem is converted to the optimizing problem. The procedure of normalization is not used in this method because the function for evaluating the quality is used for optimizing the image. In [39], Varghahan et al. discussed a technique for

enhancing the handwritten data by applying the neural network and threshold technic*al*. In this paper, various filtering techniques are discussed. For cleansing the image and reducing the noise, artificial neural network (ANN) showed the best result. Cleansing image result along with threshold technical is used for the training of the multilayer perceptron network.

In [40], Shanmugavadivu et al. discussed a contrast enhancement technique using the basic concept of histogram equalization. In this proposed technique, the image histogram is first divided into two parts using Otsu's threshold. After that, a set of optimized weighing constraints, which are formulated using particle swarm optimization (PSO), are applied over the two parts. The two parts are then equalized independently and then are combined to produce a contrast enhanced and brightness preserved image. In [41], Draa et al. implemented a meta-heuristic search technique named artificial bee colony (ABC) algorithm for image enhancement. In this, old gray levels of the input image are replaced by new enhanced gray levels. These new gray levels are searched for using the ABC algorithm. It is then compared with traditional image enhancement approaches as well as GA and is found to be better almost all of them. In [42], Gorai et al. discussed a particle swarm optimization (PSO)-based image enhancement technique. PSO depends on objective function optimized the parameters. The local information and global information of an input image are used by the intensity transformation function. To measure the quality of an image, the edge information and entropy are acknowledged by the objective function. With the help of scaling, the enhanced image is achieved. In [43], Benala et al. proposed an ABC optimizing algorithm for magnifying the image. This algorithm provides excellent magnitudes for an image. It is better than GA. The chance of dropping into local optimum is less in ABC algorithm. The main goal of this algorithm is to advance the local search ability of GA by maintaining the global search ability. In [44], Hanumantharaju et al. discussed a technique for magnifying an image by applying the particle swarm optimization. The algorithm uses criteria based on the information of edge and entropy of the image. By using this method, the specifications of the multiscale retinex like number of scales, Gaussian surround space constants, etc., are optimized. Their proposed algorithm resulted better image enhancement as compared to existing algorithms like histogram equalization, filtering, etc.

In [45], Zhou et al. explored a fuzzy-based image enhancement algorithm whose parameters are optimized using GA. In the proposed technique, firstly image is transformed from spatial domain to fuzzy domain. Then, membership function is optimized using GA and applied on the fuzzy image. Finally, image is converted back to space domain using de-fuzzification and enhanced image is obtained. Further, enhancement can be done by applying the same process again. In [46], Zhang et al. discussed a satellite cloud enhancing technique. In this method, the nonlinear transform parameters are adjusted to modify satellite cloud images. This method gives a reference for location of center and the prediction of the typhoon's intensity. In [47], Hoseini et al. considered a new hybrid technique for image enhancement. It combines the evolutionary techniques of GA, ant colony optimization (ACO), and simulated annealing (SA). Improvement is done on the fitness

Table 3 Various techniques Identified

Technique identified	Study ID
Genetic algorithm	[3–10]
Fuzzy-based enhancement	[11–28]
Neural network-based enhancement	[29–39]
Optimization algorithms	[40–44]
Hybrid approach	[45–47]

function of GA, whereas the ACO and SA techniques remain same. The combined algorithm is then compared with other traditional image enhancement techniques like linear contrast stretching, histogram equalization, fuzzy, etc. and is found to be better.

After reviewing all these 45 research papers, we have identified mainly five soft computing techniques as mentioned in Table 3 along with paper ID.

4 Conclusions

Research questions RQ1, RQ2, and RQ3 taken in Sect. 1 for systematic review are put forward in Table 1 and resolved after doing the analysis of papers in Sect. 3.

Answer to RQ1: various soft computing approaches used in this paper for image enhancement are GA, fuzzy-based enhancement, neural networks, and various optimization techniques like ABC, ACO, PSO, and hybrid approaches.

Answer to RQ2: the traditional algorithms used for image enhancement like histogram equalization, wavelet transform-based enhancement, contrast adjustment, etc., are compared with the enhancement techniques based on soft computing approaches. It is found after analyzing various papers that the soft computing approach is better than the traditional approaches since performance is better, which is shown in various papers. Better image enhancement results may be achieved using hybrid soft computing approaches, meta-heuristic approaches.

Answer to RQ3: strengths of existing image enhancement techniques

1. They can be used for linear stretching and visual perception when image has close contrast data.
2. They remove noise from the images and provide sharp image by applying local enhancement.
3. Histogram equalization is the most popular enhancement technique which calculates intensity of pixels and uses them for enhancement.

Weaknesses of existing image enhancement techniques

1. Existing image enhancement algorithms are very computation intensive and require a large amount of memory to store the intermediate data.

2. Algorithms are quite complex to understand and implement.
3. Very few techniques are practically used for image enhancement which leaves a large scope for new enhancement techniques.

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