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An efficient algorithm for color image segmentation

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Abstract
In field of image processing, image segmentation plays an important role that focus on splitting the whole image into segments. Representation of an image so that it can be more easily analysed and involves more information is an important segmentation goal. The process of partitioning an image can be usually realized by Region based, Boundary based or edge based method. In this work a hybrid approach is followed that combines improved bee colony optimization and Tabu search for color image segmentation. The results produced from this hybrid approach are compared with non-sorted particle swarm optimization, non-sorted genetic algorithm and improved bee colony optimization. Results show that the Hybrid algorithm has better or somewhat similar performance as compared to other algorithms that are based on population. The algorithm is successfully implemented on MATLAB.

Keywords image segmentation; improved bee colony optimization; Tabu search; non-dominated sorted particle swarm optimization; non-dominated sorted genetic algorithm.

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1 Introduction

Image segmentation is a recent research topic from the last two decades that results in various techniques related to image segmentation. There exist several applications and problems domain are there that are required to be processes so that image data can be interpreted in a particular domain or application specific manner. However, problem domain depends on various image types that can be analysed and further processed like color, grayscale, range, infrared, sonar, X-ray and many more (Kumar et al., 2014). Image segmentation is partitioning of an image into segments on the basis of homogeneous features, similarity between pixels in a specified region depends on different criteria like color, intensity or texture, so that objects in an image can be identified based on variations of intensity in an image. Existing research has shown that human vision can identify the same texture that has gradient variations of intensity and many image segmentation methods are proposed based on the variation in intensity. Image segmentation has been used for several applications such as in machine vision applications, it is viewed as a bridge between low level and high level vision subsystems, in medical imaging it is used as a tool to delineate anatomical structure and some other regions of interest whose a priori knowledge is commonly available and in statistical analysis, it is posed as a stochastic estimation problem, in which image structure has estimated prior distributions. In remote sensing, landscape change can be detected through segmentation and land use/cover can be classified with it (Dey et al., 2010).

2 Literature Review

Various segmentation methods are surveyed from the literature. Raja et.al (2005) analyse the performance of Efficient graph (EG) and Normalized cut (NC) like image segmentation methods. Image segmentation is treated as a problem of graph partitioning and a novel global criterion was proposed, NC that will segment the graph. Grady (2006) proposed random walk for image segmentation. He proposed that a label is assigned to each pixel and for every pixel highest probability is calculated, a segmentation with improved quality will be obtained. Theoretical properties that are associated with this algorithm are created along with the corresponding connections that are related to electrical circuits and discrete potential theory. A modified algorithm named FCM was proposed by Wang et.al (2008) that will do segmentation of MRI brain images. Problem with FCM algorithm is that it is noise sensitive due to which the spatial information is not considered. This problem is resolved by using algorithm named FCM algorithm that will incorporate the spatial neighbourhood details into previously used FCM algorithm and membership weight is modified for every function. Another method that is simpler and necessary which is used in image segmentation of grayscale is threshold segmentation. A common segmentation method of thresholding is Maximum entropy method that utilizes information about gray only. To accurately utilize spatial information related to greyscale images, a segmentation method is introduced named as 2D entropy segmentation by Zheng et al (2009).

The final solution of convergence rate of iteration and equation depends on the initial value which is selected this is a notable drawback for large scale images to be segmented when initial values are selected randomly. For that purpose, based on random walk model a novel image segmentation method was proposed by Lan et el (2009). The problem of categorizing set of pixel in image exists in image segmentation. For this purpose, a fast clustering algorithm is developed that is based on technology of identifying model and image segmentation and take into account the features of clustering technique used in image segmentation. This algorithm was proposed by Wang and Yang (2010). Extension of the segmentation technique of gray images can be used to color image segmentation, but most of the segmentation methods of original gray scale are not directly used to color image. Tang proposed a color image segmentation algorithm based on region growing that is developed by combining watershed algorithm along with seed region growing algorithm (Tang, 2010). Technique depending on region was used to determine the regions directly. Each pixel present in an image must be clustered in a region while performing region based segmentation. While performing that segmentation initially few of seed pixels are identified depending on some specific criteria. After that a homogeneous region of an image is obtained by growth process that will try to find an accurate segmentation of images into regions with the property that each connected component of a region meets exactly one of the seed (Synthuja et al., 2012).

Binh et al (2012) proposed genetic algorithm for improving image segmentation. They proposed a latest approach that deal with the problem related to digital images that is semantic segmentation. Their main focus is to enhance performance of few approaches related to state-of-the art for image segmentation. An enhanced and improved version of text on feature (Shotton, 2007) was exploited which can encode object layout and also image texture so that a robust classifier can be learned. Ju (2013) proposed a unique algorithm for image segmentation that works on edge detection along with K-means algorithm and an optimization algorithm named improved ant colony optimization. The presented algorithm can address the problem of slow convergence of the previously existing ant colony algorithm and decreases its related complexity. Later Sun (2015) proposed an image segmentation algorithm based on Swarm Intelligence Technology. As we know that image segmentation is a very popular technology in image processing. Image segmentation quality relates to succeeding processing directly such as image measurement and image recognition. In this paper a new intelligent optimization algorithm was proposed in which a new method of image segmentation namely wavelet transform for segmented images is combined with gray-scale morphology and rough sets theory to solve the problem of image noise. Mao et al (2006) proposed two improved algorithms for segmentation of cell. First, they demonstrated that pixel can be classified on the basis of color space for the purpose of color image segmentation is similar for performing segmentation of images that are grayscale with the help of thresholding. Depending on that result they proposed a two-step procedure for segmentation of color cells based on supervised learning, where initially color image is depicting to grayscale via a transform learned through supervised learning and then segments of objects can be achieved out of background for grayscale images. Tao et al (2007) proposed color image segmentation based on Normalized Cuts Mean Shift. This approach tries to perform robust and effective segmentation of color images by including the advantages of the normalized cut partitioning methods and mean shift segmentation. The proposed method is much more feasible for processing real time images because they require low computational complexity. An image is processed by implementing MS algorithm that will generate segments of the regions and hence maintains the characteristics of desirable discontinuity of the given image and then segmented regions can be shown with Ncuts and graph structures, method is helpful for the optimization of global clustering.

The proposed work is arranged in seven sections. Section 1 provides an introduction to image segmentation. Section 2 is about literature survey. Section 3 will discuss mathematical terms and algorithm that is used in proposed work. Section 4 describes the flow of proposed work. Section 5 describes tool that is used to implement proposed work and the working of system. Section 6 displays experimental results and finally, Section 7 describes the conclusion.

3 Proposed Work

Multiple objectives exist for image segmentation problem such as minimizing overall deviation, maximizing connectivity, reducing the error rate or feature of the classifier. Hence, image segmentation can be viewed as a multiobjective optimization problem. Approaches used for multi-objective are classified in two classes. The two approaches are Pareto-Optimal approaches and weighted sum method. One of the approaches that is weighted sum approach, in which the most appropriate solution of the problem which is related to the minimum or maximum value of the problem can be found by aggregating all objectives within a single function with the help of weighted formula. Two classes are used for multiobjective optimization from which one class is used for the conversion between MOO problem to a problem with single objective. Solution in this context is known as non-dominated solution or Pareto Optimal that are better as compared to the rest of the solutions but lesser to other solutions that are present in search space when all objectives are considered (Coello, 1998). In this study a new approach is proposed that combines two algorithms namely (IBMO) is combined with Tabu search. A best fitted multiobjective version of common ABC is IBMO. Brief description of ABC (Nayak, 2012), IBMO (Sag et al., 2015) and Tabu search (Kharma, 2012; Zhang, 2016) is given in past research.

3.1 Mathematical description

The parameters on which proposed algorithm is applied and results are evaluated are discussed below. The process of evaluating image segmentation is conventionally a tough deal because it is subjective in nature. This section describes the estimation metrics used in this study (Sag, 2015).

Local refinement error (LRE): LRE metric is used to represent an overlapping degree between partitioning of human perceptual and its segmentation. It depicts that the error must be minimum or equivalent to zero. LRE can be defined as:

$$LRE(S_1, S_2, Pi) = \frac{|R(S1,Pi) \setminus R(S2,Pi)|}{|R(S1,Pi)|}$$

where S_1 and S_2 are two segmentation of the same image. R (S, P_i) is the set of pixels corresponding to the region in segmentation S that contains pixel $P_{i.}$.

Due to non-symmetric nature of LRE, LRE matrix summation is not enough. In order to resolve this problem in every direction for each and every pixel both local consistency error (LCE) and Global consistency error (GCE) are calculated.

LCE is given by

$$LCE(S_1, S_2) = \frac{1}{N} \sum_{i=0}^{n} \min\{LRE(S1,S2,Pi), LRE(S2,S1,Pi)\}$$

GCE is given by

$$GCE(S_1, S) = \frac{1}{N} \min\{\sum_{i=1}^{n} LRE(S1,S2,Pi),\ \sum_{i=1}^{n} LRE(S2,S1,Pi)\}$$

Both the metrics lie in the range of [0,1] and results are shown better for values of lower metric. LRE is adapted as a measure to conquer the problem due to degeneration of segmentation. LRE is used to penalizes the dissimilarities present between segmentations that are proportional to overlapping region degree. This is termed as bidirectional consistency error (BCE) which is given by

$$BCE(S_{test}, \{S_k\}) = \frac{1}{N} \sum_{i=1}^{n} \min\{\max\{LRE(Stest,Sk,Pi), LRE(Sk,Stest,Pi)\}\}$$

where S_{test} denotes the achieved segmentation and $\{S_k\}$ is a set of possible ground truth segmentations of an image.

S_Dbw denotes the validity index which is given by

S_Dbw = scat(NC) + Dens_bw(NC)

It includes the summation of terms such as density and scattering. The scattering is used to measure the compactness of the clusters and which is defined as

$$Objective1 = scat(NC) = \frac{1}{NC} \sum_{k=1}^{NC} \frac{\|\sigma(Ck)\|}{\|\sigma(S)\|}$$

where $\boldsymbol{\sigma}(C_k)$ denotes variance of cluster C_k and $\boldsymbol{\sigma}(S)$ denotes variance of the dataset S. The term density is used to measure the separation of clusters and it is defined by

$$Objective2 = Dens_{bw(K)} = \frac{1}{NC(NC-1)} \sum_{k=1}^{NC} \sum_{l=1 \setminus t \neq k}^{NC} \frac{density(Ck,C1)}{\max\{density(Ck), density(C1)\}}$$

3.2 Proposed hybrid algorithm

IBMO is an optimization technique in which modifications are made in ABC algorithm for multiobjective optimization with the use of non-dominated strategy of sorting and prime concepts of Pareto-Optimal such as Pareto-dominancy, crowding distance (CD), external archive (EXA) etc (Zhang, 2012).

Tabu search was introduced by Fred W. Glover in 1986. It is a method of local search used to optimize mathematically (Zhang, 2013, 2016). Local searches identify a probable solution to a problem and checks its immediate neighbour in desire to find another better solution. Tabu search make use of memory structures to enhance the performance of these techniques that describe the visited solutions or user-provided sets of rules. Tabu search uses a local or neighbourhood search procedure to iteratively move from one potential solution x to an improved solution x' in the neighbourhood of x, until some stopping criterion has been satisfied. These memory structures consist of tabu list, which specify a set of rules and solutions that are banned and used to filter which solutions will be admitted to the neighbourhood N* (x) to be explored by the search. Moreover, a tabu list is a set of short-term solutions that have been visited in the recent past. This section provides proposed pseudo code of hybrid algorithm using Tabu and IBMO features:

Step 1: Input color image
Step 2: Extract feature for Gabor filter in local homogeneity and CIE color lab
Step 3: find edge detect using Canny and Sobel method
Step 4: now calculate feature vector for member of non-polynomial terms
Step 5: optimal seed positions are assigned
Step 6: find optimal position of seeded point threshold in homogeneity saturated pixel value when comparison is made between distance present between seeds and pixel that are its neighbour.
Step 7: put the neighbour pixel which would be follow for No of bees.
Step 8: check fitness of randomly till end of the process execution and put best pixel value and contain in (m x n) size matrix
Step 9: The evaluation ability of segmentation quality in considering with multiple criteria as a multi-objective optimization tool
Step 10: Acceleration Coefficient Upper Bound regions
Step 11: if (Empty Bee Structure)
Step 12: do
Step 13: put initial solution i in Image. Set i* = i and k=0.
Step 14: Set pixel Traverse=pixelTraverse+1 and generate a subset TL (tabu length) * of solution in Iteration (i, k) such that either one of the Tabu conditions hold
Step 15: if (Max Iter since the last improvement of i* is larger than a specified number of seeded region from upper bounded image)
Step 16: merge small and similar region

4 Process Flow Diagram

The process of proposed segmentation method is shown in Fig. 1. The proposed method is divided into three parts:

i) Features are extracted from the input color image
ii) Identification of ideal position of seed points and highest value of similarity by running hybrid algorithm of IBMO with Tabu Search.
iii) Seeded region growing procedure

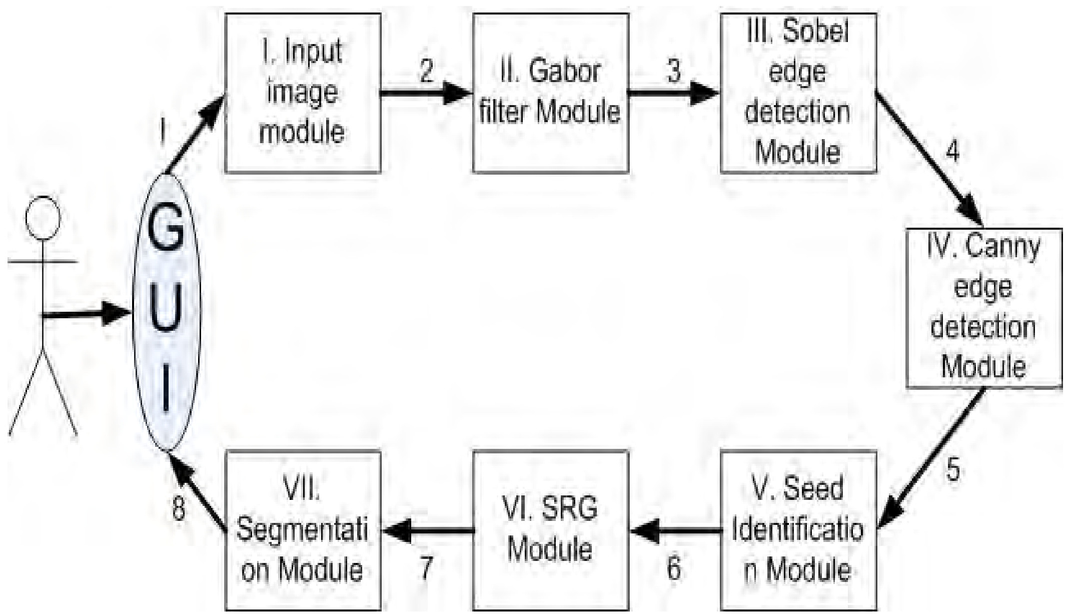

Fig. 1 Block diagram of proposed method.

Step I: Input Image Module

The segmentation process starts by providing a color image as input. Variety of colours can be generated by mixing the three primary colours that are Red, Green and Blue in appropriate proportion. A 24-bit colour image supports 16,777,216 varieties of colour combination. The proposed algorithm is applied on various color images taken from Berkeley segmentation dataset. Difference between colors can be defined with color spaces.

Step II: Gabor Filter Module

Gabor Filter is a linear filter used for edge detection. Gabor Filter's frequency and orientation representation is similar to those of human visual system and they are particularly appropriate for texture representation and discrimination. In the spatial domain, a 2D Gabor filter is a Gaussian kernel function modulated by a sinusoidal plane wave (Bhattacharya et al., 2013)

Step III: Sobel Edge Detection Module

Edge Detection is a technique used to identify the boundary of objects in an image. It identifies boundary by detecting the discontinuities in brightness. Edge detection is used for various purposes such as image segmentation, data extraction in field of image processing, computer vision and machine vision. Two masks are used by Sobel edge detection one is vertical and another one is horizontal. These masks are basically used for a 3 × 3 matrix (Mohammad et al., 2014)

Step IV: Canny Edge Detection Module

This algorithm was developed by John F. Canny. The algorithm runs in 5 separate steps:

a. Smoothing: To remove noise it blurs the image.

b. Finding gradients: when large magnitudes are present in the gradients of the image then the edges should be marked

c. Non-maximum suppression: Only local maxima should be marked as edges.

d. Double thresholding: Thresholding is used to determine potential edges.

e. Edge tracking by hysteresis: all those edges that are not connected to a certain edge are suppressed together and final edges are determined (Pkalra, 2009)

Step V: Seed identification Module

In this step optimal position of seeds are identified and the similarity between those seeds are also identified by applying a hybrid approach of IBMO and Tabu search.

Step VI: Seeded Region Growing Module

Modified seeded region growing (SRG) is also applied in this procedure. SRG starts from the basic center points that are known as seeds. After identifying the seeds similarity between adjacent pixel is checked and a region is generated by incorporating similar pixels.

Step VII: Segmentation Module

In this final step the segmented image is generated by using IBMO and it is compared with the segmented image generated from hybrid algorithm.

5 Implementation of System

In the proposed algorithm images are taken from the Berkeley segmentation Dataset (BSDS) and segmentation on these images are performed. BSDS is popularly used as benchmarking tool in past research (Sag et al., 2015). Images present in this dataset are used for image segmentation and boundary detection which is used by interested researchers. The segmentation database consists of 300 color and grayscale images that are natural. MATLAB is used to implement the proposed work. MATLAB stands for matrix programming language which was developed by MathWorks. It is a programming language that makes algebra programming simple. MATLAB is a fourth-generation high level programming language that provides an interactive environment for computation, visualization and programming. Functions of MATLAB that are used in proposed work are:

i) zeros: it will create an array of all zeros.
ii) randsrc: It will generate a random matrix using prescribed alphabets.
iii) round: It will round off the result value to nearest decimal or integer.
iv) eye: Eye function is used to generate identity matrix.
v) repmat: This function is used to repeat copies of array.
vi) Cost function: This function is used to optimize the results.
vii) imread: This function is used to read image from graphic file.
viii) imshow: This function is used to display image.

5.1 Working of proposed system

The proposed system will work in the following steps which are shown in the figures given below. The proposed system is developed for image that is 3096 which is obtained from the Berkeley segmentation dataset.

The following steps are performed while working on the image 3096

Step I: Input Image

In this step a color image is provided as input to the system as shown in Fig. 2 for the process of segmentation to be performed. The image is taken from the Berkeley segmentation database.

Fig. 2 Original image.

Step II: Gabor Filter

Next step which is performed after getting color image as input Gabor filter is applied on this image as shown in Fig. 3. Gabor filter is a linear filter which is used for edge detection.

Fig. 3 Gabor filter.

Step III: Sobel Edge Detection

It is used to detect edges. Derivative approximation is used by Sobel method to find edges. Sobel method returns edges at those points where the gradient of the considered image is maximum. Sobel edge detection is applied on the image that is obtained after applying Gabor filter. This is shown in Fig. 4.

Fig. 4 Sobel Edge Detection.

Step IV: Canny Edge Detection

Canny edge detection is also used to identify the edges. It is a multi-stage algorithm. Image which is generated after applying Gabor filter on that image Canny edge detection is applied and edges are identified as shown in Fig. 5.

Fig. 5 Canny Edge Detection.

Step V: Apply Proposed Algorithm

Proposed algorithm that is IBMO + Tabu search is applied on the image after detecting the edges. The proposed algorithm will run for the specified number of iteration and detect the boundary of the image where intensity value is changing. This is shown in Fig. 6.

Fig. 6 The proposed.

Step VI: Seeded region growing

In this process each pixel is compared with its neighbourhood pixel. If they belong to similar region, then they are merged together. Image that is generated after applying SRG is shown in Fig. 7.

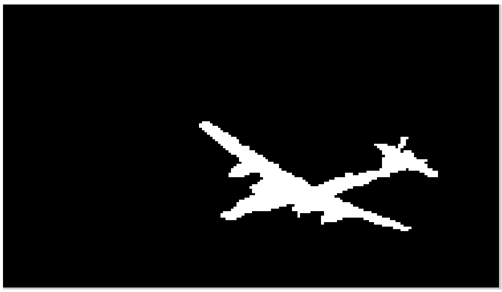

Fig. 7 Seeded Region Growing.

Step VII: Segmented image

Finally, the segmented image is generated after applying IBMO as shown in Fig. 8 and it is compared with the segmented image generated after applying proposed algorithm as shown in Fig. 9.

Fig. 8 Segmented image using IBMO.

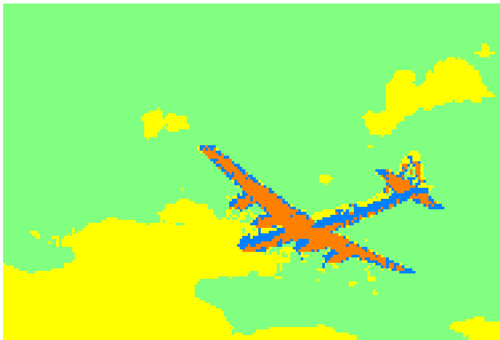

Fig. 9 Segmented image using proposed algorithm.

6 Experimental Results and Analysis

In the presented research paper, segmentation results are assessed. Moreover, segmentation results are contrasted and three benchmarking algorithms on the same dataset as past analyst had utilized. These algorithms are applied to same test image for examination of segmentation results (Table 1).

The results obtained after applying proposed algorithm to the Berkley segmentation data set images can be compared with previous benchmarking algorithm that are IBMO, NSPSO and NSGA2 through graph. Fig. 10 compares all of the four algorithms in terms of cost and number of iterations. Lower cost indicates that the algorithm is more efficient. The results are given for image 3096 as given in dataset.

Proposed algorithm is compared with other three benchmarking algorithms with the help of Fig. 10. This graph compares the algorithms based on the cost generated for given number of iterations. For iteration of cycle 0-50 the cost generated by proposed algorithm lies below 20, for IBMO the cost lies below 60 but above 20, for NSPSO the cost lies above 100 and for NGSA2 the cost lies 120. For each iteration every algorithm follows this order. Hence, it clearly shows that proposed algorithm generates minimum cost as compared to all the algorithms.

Table 1 Results of evaluation metrics for proposed method and other benchmarking algorithms.

BSDS test image number	Algorithm	LCE	GCE	BCE	Scattering	Density	S_Dbw	Elapsed time	Mean time
3096	IBMO + TABU	5.871^{-06}	0.0059	0.0029	0.0116	0.0070	0.2907	0.0307	0.0313
	IBMO	0.0269	0.0223	0.0265	0.1896	0.4526	0.6423	21.9992	21.2444
	NSPSO	0.0296	0.0255	0.0321	0.2505	0.0000	0.2505	31.7133	24.7723
	NSGA2	0.0322	0.0313	0.0440	0.0173	0.2522	0.2695	7.9517	224.7878
42049	IBMO + TABU	1.6371^{-05}	0.0164	0.0029	0.0231	0.0075	0.2878	0.0300	0.0156
	IBMO	0.1276	0.1268	0.3158	0.2049	0.7487	0.9536	33.2771	29.9665
	NSPSO	0.1290	0.1237	0.4163	0.1933	0.6398	0.8331	30.0563	30.9247
	NSGA2	0.1808	0.1638	0.2914	0.0001	0.0000	0.0001	76.0983	59.2360
86016	IBMO + TABU	9.3048^{-5}	0.0930	0.0029	0.1277	0.0077	0.2459	0.0335	0.0156
	IBMO	0.0203	0.0203	0.2735	0.1824	0.5024	0.6848	9.2608	8.2579
	NSPSO	0.0232	0.0232	0.2725	0.2096	0.0028	0.2125	9.8528	9.0692
	NSGA2	0.0291	0.0291	0.2735	0.1230	0.000	0.1230	33.4686	236.7810

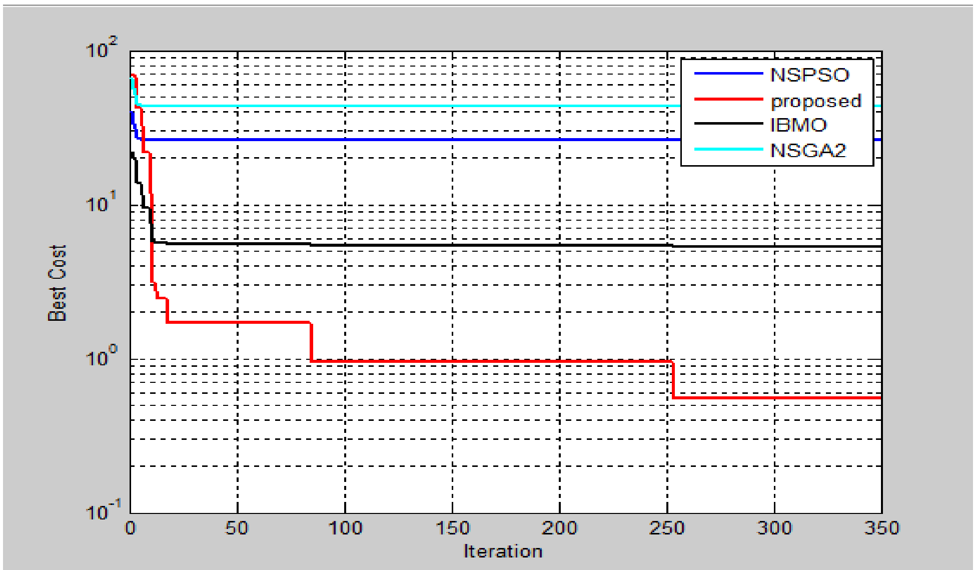

Fig. 10 Comparison of algorithms.

7 Conclusion

In this paper, a new hybrid algorithm has been proposed for segmentation of color images. Segmentation can be considered as a multiobjective clustering issue realized through grouping image features which have a decisive rule to obtain the regions of interest. Some of the major features for natural images are extracted by Gabor filter and Edge detection. The proposed algorithm is based on IBMO and Tabu search with seeded region growing technique. In this method instead of aggregation nature of S_Dbw, it is used as two distinct objectives that are scattering and density. The algorithm is implemented in MATLAB. The algorithm is applied on BSDS test images. Consequently, it can be concluded that this hybrid algorithm is a well-designed and promising method for image segmentation.

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