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Abstract—Image segmentation is a puzzled problem even after four decades of research. Research on image segmentation is currently conducted in three levels. Development of image segmentation methods, evaluation of segmentation algorithms and performance and study of these evaluation methods. Hundreds of techniques have been proposed for segmentation of natural images, noisy images, medical images etc. Currently most of the researchers are evaluating the segmentation algorithms using ground truth evaluation of (Berkeley segmentation database) BSD images. In this paper an overview of various segmentation algorithms is discussed. The discussion is mainly based on the soft computing approaches used for segmentation of images without noise and noisy images and the parameters used for evaluating these algorithms. Some of these techniques used are Markov Random Field (MRF) model, Neural Network, Clustering, Particle Swarm optimization, Fuzzy Logic approach and different combinations of these soft techniques.

Keywords*-Image Segmentation,BSD images,Soft Computing Techniques.*

I. INTRODUCTION

Image Segmentation is an important and difficult task in low level image processing, image analysis, computer vision, object recognition, feature extraction etc. Previously the segmentation algorithms were divided into two groups. 1) Discontinuity based approach (Edge detection) and 2) Similarity based approach (Thresholding, Region Growing). Each of these methods has their own advantages and disadvantages. At earlier stages edge detection approach was gaining more attention for segmentation. Canny [1] proposed an optimal edge detector for segmentation under noisy conditions. With the growth of various soft computing techniques, numbers of soft computing techniques were applied to improve the performance of image segmentation algorithms. Paik and *et al.* [2] used the multistate adalines to improve performance of edge detection. Fuzzy logic rules was used by Ching and *et al.*[3] on neighborhood of pixels for detection of discontinuities, similarly Bhandarkar and *et al.* [4] proposed a genetic algorithm based approach for image segmentation. It is interesting to note that none of the algorithm was having a performance evaluation parameter for comparison or objective evaluation of these algorithms. The human visual judgment was considered to be the best for comparing these methods. For segmentation on noisy images SNR (signal to noise ratio) was considered as one of the parameter. In 1996 Adam and *et al.* [5] proposed a methodology (Ground truth evaluation) for universal evaluation of segmentation algorithms. For objective evaluation of edge detectors, Doughtery and *et al.* [6] proposed a ROC (receiver operating characteristics), ratio of pixels identified as true edge pixels / false edge pixels. Malik and *et al.* in [7] proposed a database of manually segmented natural images by humans for ground truth evaluation and comparison, which is later used as a benchmark for objective evaluation of segmentation algorithms known as (Berkeley segmentation dataset) BSD.

II. CLASSIFICATION OF ALGORITHMS

With so many algorithms being developed for segmentation, classification of various techniques becomes an essential task. The classifications of these algorithms are as follows.

1. Histogram shape-based methods (where the peaks, valleys, curvatures, etc., of the smoothed histogram are analyzed)
2. Clustering-based methods (where the grey level samples are clustered in two parts as background and foreground or, alternately, are modeled as two Gaussian distributions)
3. Object attribute-based methods (where a measure of similarity between the grey level and segmented images, edges, number of objects, etc., are investigated)
4. Morphological operations.
5. Spatial relation-based methods (where probability mass function models take into account correlation between pixels on a global scale are used).
6. Color image segmentation (where all of the listed techniques of gray images are applied for color images as well). Researchers have applied Soft computing approaches like (Neural Network, Fuzzy set theory, Clustering etc.) on each of these algorithms or in combination.

III. LITERATURE STUDY

Malik and *et al.* proposed an algorithm for partitioning grayscale images into disjoint regions of coherent brightness and texture in [8]. The cues of contour and texture differences are exploited simultaneously. Contours are treated in the intervening contour framework, while texture is analyzed using textons. The spectral graph theoretic framework of normalized cuts is used to find partitions of the image into regions of coherent texture and brightness. The ground truth evaluation was considered for comparison.

Konishi and *et al.* in [21] used edge detection for segmentation; they formulate edge detection as

statistical inference .This statistical edge detection is data driven. Here pre-segmented images to learn the probability distributions of filter responses conditioned on whether they are evaluated on or off an edge. Ground truths of images are considered and performance is measured on Receiver Operator Characteristic (ROC) curves basis. The main disadvantage of this method is, it uses pre-segmented images for learning on one dataset of images and then it is applied on other dataset.

Liang and *et al* [22] proposed and approach for detection of edges in noisy images. Here pixels are classified as fuzzy sets based on their gray values. The performance of the algorithm is somewhat similar to that of the Canny algorithm but proposed one is significantly faster. Here the ground truth evaluation and evaluation parameter for comparison is not considered.

An image segmentation method is proposed by Dong and *et al.* in [24] for the segmentation of color image based on neural networks. In order to measure the color difference properly, image colors are represented in a modified color space L**u**v*. It uses color reduction and color clustering technique with Neural Network. The ground truth evaluation and performance parameter is not considered.

Evans and Liu proposed a Morphological gradient approach to color edge detection based on vector differences. The technique is computationally efficient and can also be readily applied to other vector-valued images [25]. The performance is compared with (vector order statics) VOS method and MVD (minimum vector dispersion) method. The method is robust to noise and computationally efficient. Performance evaluation parameter used here is SNR for noisy images.

Dollar and *et al.* proposed a supervised learning algorithm for edge and object boundary detection called Boosted Edge Learning (BEL). A decision of an edge point is made independently at each location in the image. It uses Probabilistic Boosting Tree classification algorithm for learning [26]. The algorithm is compared with Konishi and *et al*, It is highly scalable, adaptive and comparison is done on BSD images.

Nikou and *et al.* proposed a new approach for image segmentation based on a hierarchical and spatially variant mixture model. According to this model, the pixel labels are random variables and smoothness prior is imposed on them [27] .Comparison is done with Finite mixture model (FMM) and spatially invariant finite mixture model (SVFMM) on BSD images. Parameter used for evaluation is Probabilistic Rand Index (PRI).

In 2007, Unnikrishnan and *et al.* proposed (NPR) Normalized probabilistic Rand Index and Probabilistic Rand Index (PRI) parameter for objective evaluation and quantitative comparison of image segmentation algorithms [28].It has following characteristics .It does not degenerate with respect to special segmentation cases. It does not make any assumptions about the data. It is normalized to give scores which are comparable between algorithm and images.

Max Mignotte in [29] proposed an approach for segmentation by using Fusion of histogram and k-means cluster in different color space. The proposed method is fast to implement. The performance is compared with N-cuts, mean shift and compression based texture merging (CTM) methods. It gives better segmentation and PRI when evaluated on BSD images.

Yuan and *et al* [30] proposed a method for segmentation by determining automatic thresholds using picture contents A gradient of histogram and quad tree decomposition technique is used for determining automatic threshold. It considers the ground truth evaluation and algorithm is compared with E-GVF (extended –gradient vector flow) and watershed region growing. Performance evaluation parameter used is SNR on BSD images.

Ugarriza and *et al.* proposed automatic images segmentation by dynamic region growth in [31], which uses color gradient detection and clustering technique. The algorithm produces better segmentation and higher NPR, comparison is done on BSD images.

Bhoyar and Kakde[32] proposed an image segmentation algorithm based on JND (Just noticeable difference) histogram. The method is compared with (conventional color histogram) CCH. It gives better results than CCH technique. The algorithm is faster and gives better PRI and PSNR values. Here ground truth is not considered. Comparison is done on BSD images.

Nikou and *et al.* proposed a new Bayesian model for image segmentation based upon Gaussian mixture models (GMM) with spatial smoothness constraints [33].It uses ground truth evaluation, the algorithm is compared with N-cuts and Gaussian blurring mean shift algorithm (GBMS). The performance evaluation parameters used are PSNR and PRI on BSD images. The method is robust to noise and does not need any parameter before training.

Bhoyar and Kakde [34] proposed modified FCM (Fuzzy C-Means) approach to color image segmentation using JND (Just Noticeable Difference) histogram. The approach is compared with the (fuzzy c-means) FCM for segmentation, which is faster than FCM. The method gives greater PRI and PSNR ratio when compared to FCM on BSD images.

Max Mignotte proposed a novel segmentation approach based on a Markov random field (MRF) fusion model which aims at combining several segmentation results associated with simpler clustering models in order to achieve a more reliable and accurate segmentation result [45]. It considers the ground truth, The algorithm is compared with CTM, mean shift and N-cuts, It gives better PRI compared to N-cuts, mean shift and CTM, comparison is one on BSD images.

Arbelaez and *et al.* proposed a unified approach to contour detection and image segmentation. Contour detector combines multiple local cues into a globalization framework based on spectral clustering and segmentation algorithm consists of generic machinery for transforming the output of any contour

detector into a hierarchical region tree [46]. The method outperforms the recent methods on image segmentation, having better segmentation compared to other algorithms on BSD images, algorithms compared are (mean shift, Canny, N-cuts, quad tree) greater PRI compared to other algorithms.

A particle swarm optimization (PSO) based approach was proposed by Setayesh and *et al.* in [47] for noisy images. It uses a rectangular size of four and eight movement directions; it uses Pratt's Figure of Merit (PFOM) and PSNR for comparison on noisy images. Performance is better compared to Canny algorithm but computationally expensive than Canny.

An approach for edge detection using independent component analysis is proposed by Mendhurwar and *et al.*in [48]. The proposed approach works well under noisy conditions when compared with Canny method. The performance is compared on PSNR and no ground truth evaluations of images are considered. The method is robust to noise and detect better edges under noisy conditions.

Max Mignotte proposed a multidimensional scaling based multiresolution model for image segmentation ,it uses k-means clustering approach[50], the method outperforms the recent methods for segmentation, ground truth evaluation of BSD images are considered, Gives better PRI than algorithms (CTM, SVGMM, Mean shift, N-cuts, JND, PCA, GBMS) compared. The performance is not considered under noise.

IV. COMPARISON OF ALGORITHMS

Based on performance parameter and images used, comparisons of these algorithms are given in the table below

TABLE I. COMPARISON OF METHODS

SR No.	Source	Nature of Algorithm	Ground Truth Evaluation	Algorithms Compared	Performance Evaluation Parameter	Findings
1	[51]Frei and Chen .IEEE trans on Computers. (1977)	Orthogonal Basis	No	Kirsch, Sobel	None	Subtle Edges, Costly Computation, Sensitive to Noise.
2	[1]J .Canny IEEE Trans on Pattern Analysis and Machine Intelligence,(PAMI) (1986).	Gradient of Gaussian Smoothed Image.	No	None	None	Robust to Noise, Complex computations.
3	[2]Palk and *et al* PR Society. Pergamon (1992).	Edge detection using multistate ADALINES	No	Canny ,LOG	SNR	Preserve Edges, Robust to noise.
4	[3]Ching and *et al* (1993) IEEE.	Fuzzy Logic Approach	No	Lapalcain ,Sobel	SNR	Robust to noise.
5	[4] Bhandarkar and *et al* PR Society. Pergamon.(1994)	Genetic Algorithm based cost minimum optimization	No	None	None	Robust to noise.
6	In 1996, A methodology (Ground truth evaluation) was proposed by Adam Hoover and *et al.* to evaluate image segmentation algorithms This is used later for evaluation of image segmentation algorithms. [5]					
7	In 1998, Doughtery and Bowyer proposed a method for objective evaluation of edge detection algorithm (ROC analysis, ratio of true positive pixels / false positive pixels).[6]					
8	In 2001, A database for evaluating image segmentation algorithms was proposed by Martin and *et al.* known as (Berkeley Segmentation database) BSD.[7] which later used as a benchmark for evaluating image segmentation algorithms					

SR No.	Source	Nature of Algorithm	Ground Truth Evaluation	Algorithms Compared	Performance Evaluation Parameter	Findings
9	[8]Mailk and *et al* IJCV 2001.	Normalized cuts for portioning images into disjoint regions	Yes	Canny with different thresholds.	None	Better segmentation,
10	[52]Chan and *et al* IEEE trans on Image Processing.2001	Curve evolution, Mumford-shah functional for segmentation	No	None	None	No need for filtering or smoothing for noisy images, robust to noise, preserve edges.
11	[21]Konishi and *et al*, IEEE trans on Image Processing.2003	Use pre -segmented images for learning and evaluating using Probabilistic Bayesian inference.	Yes	Canny	Roc	Learning on one dataset and adapt them to other dataset for image segmentation.
12	[22]Liang and *et al*, PR society.2003	Fuzzy classes of pixels.	No	Canny	None	Fast implementation, robust to noise**.**
13	[24]Dong and Xie, IEEE trans on Neural Network.2005	Neural network, Color clustering.	No	None	None	Neural network and color clustering seems promising tool for color image segmentation.
14	[25]Evans and Liu, IEEE trans on Image Processing. 2006	Morphological gradient approach to color edge detection	No	VOS (vector order statistics), MVD (minimum vector dispersion) Compass operator.	SNR	Robust to noise, less complex, faster computation.
15	[26]Dollar and *et al*, IEEE (CVPR) 2006.	Learning using Probabilistic boosting tree classification.	Yes	Konishi and *et al.*	None	Highly adaptive and scalable, training is used on BSD.
16	[27]Nikou and *et al*, IEEE trans on Image Processing. 2007	Hierarchical and variant mixture model, clustering based.	Yes	FMM, Spatially variant finite mixture model(SVFMM)	PRI, Berkeley segmentation dataset. (BSD)	
17	In 2007, Unninkrishnan and *et al* proposed Probabilistic Rand Index (PRI) and Normalized Probabilistic Rand Index (NPR for objective evaluation and quantitative comparison of image segmentation algorithms. [28]					
18	[29]M. Mignotte, IEEE trans on Image Processing.2008	Fusion of histogram based , k-means cluster	Yes	N-cuts, mean shift, compression based texture merging.(CTM)	PRI, BSD	Simple, fast
19	[30]Yuan and *et al* , Eurasip journal on image and video processing.2009	Gradient of histogram Quad tree decomposition.	Yes	Extended – gradient vector flow (E-GVF), watershed region growing.	SNR, BSD	Fewer computations, robust to noise.
20	[31]Ugarriza and *et al* ,IEEE trans on Image Processing.2009	Color gradient (vector) detection technique, dynamic region growth, clustering.	Yes	Fusion of color and edge information(GRF)	NPRI,BSD	Better segmentation, greater NPRI.
21	[32]Bhoyar and Kakade. IJIP 2010.	Just noticeable difference (JND) histogram based.	Yes	Conventional color histogram (CCH)	PRI, PSNR,BSD	
22	[33]Nikou and *et al*, IEEE trans on Image Processing.2010	A Bayesian model based upon Gaussian mixture model(GMM)	Yes	N-cuts, Gaussian blurring mean shift algorithm (GBMS).	PSNR, PRI BSD.	Robust to noise, does not need any parameter before learning.
23	[34]Bhoyar and Kakde, Electronic letters on (CVIA) 2010.	Fuzzy C-means approach to JND histogram.	Yes	Fuzzy C- means. (FCM)	PRI, PSNR, BSD	Better PRI, computationally faster than FCM.
24	[45]Max Mignotte, IEEE tans on Image Processing.2010.	Bayesian model on Markov random field(MRF)	Yes	CTM, mean shift, N-cuts.	PRI,BSD	Better PRI compared to other algorithms.
25	[46]P. Arbelaez and *et al* , IEEE trans on (PAMI)2011	Spectral clustering, hierarchical region tree.	Yes	Mean shift, N-cuts, Canny.	PRI,BSD	Outperforms all recent algorithms gives Better PRI.

SR No.	Source	Nature of Algorithm	Ground Truth Evaluation	Algorithms Compared	Performance Evaluation Parameter	Findings
26	[47]Setayesh and *et al* , ACM 2011.	Particle swarm optimization.	Yes	Canny	PSNR, PFOM (Pratt's figure of merit)	Better detection of edges, computationally expensive.
27	[48]Mendhurwar and *et al*, Eurasip journal, ISRN Signal processing.2011	Edge detection in noisy images using independent component analysis.	No	Canny	PSNR	Robust to noise, better segmentation under Gaussian noise.
28	[50]Max. Mignotte, IEEE trans on Neural networks.2011.	Multiresolution clustering based, multidimensional scaling k-means based	Yes	CTM, SVGMMM, mean shift, N-cuts, GBMS,JND, and PCA, using BSD.	PRI,BSD	Greater PRI, better segmentation, not considered under noisy conditions.

V. CONCLUSION

The paper describes an overview of various image segmentation algorithms used for noisy and non noisy images with different parameters used for evaluation of these algorithms. It is found that the methods for image segmentation for noisy images generally uses PSNR as a parameter for comparison without ground truth evaluation while for non-noisy images, researchers used ground truth images mainly with PRI(Probabilistic Rand Index) parameter for comparison of segmentation techniques. Thresholding or histogram approach for segmentation is fast to implement, but generally gives poor result. Whereas color clustering and mixture models with soft computing approaches, provide greater PRI on BSD images with better results for segmentation.

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