A Fuzzy Set Approach for Edge Detection

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Abstract

Image segmentation is one of the most studied problems in image analysis, computer vision, pattern recognition etc. Edge detection is a discontinuity based approach used for image segmentation. An edge detection using fuzzy set is proposed here, where an image is considered as a fuzzy set and pixels are taken as elements of fuzzy set. The proposed approach converts the color image to a partially segmented image; finally an edge detector is convolved over the partially segmented image to obtain an edged image. The approach is implemented using MATLAB 7.11. (R2010b). In this paper, an attempt is made to evaluate edge detection using ground truth for quantitative and qualitative comparison. 30 BSD (Berkeley Segmentation Database) images and respective ground truths are used for experimentation. Performance parameters used are PSNR (dB) and Performance ratio (PR) of true to false edges. Experimental results shows that the proposed approach gives higher PSNR and PR values when compared with Canny's edge detection algorithm under almost all scenarios. The proposed approach reduces false edge detection and identification of double edges are minimum.

Keywords: Edge Detection, Fuzzy Set, BSD (Berkeley Segmentation Database), Ground Truth, PSNR.

1. INTRODUCTION

Image Segmentation is an important and difficult task in low level image processing, image analysis etc. Edge detection is one of the important techniques used for image segmentation. Earlier 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 of research on image segmentation, edge detection (Like Prewitt, Sobel) was gaining more attention compared to region growing. Image Segmentation process simplifies, further analysis of images by reducing the amount of data to be processed significantly, at the same time useful structural information of object boundaries are preserved. There are numerous applications of image segmentation like Remote Sensing, Analysis of Medical Images, Industrial Machine Vision for Product Assembly and Inspection, Automated Target Detection and Tracking, Fingerprint Recognition, Face Recognition, Astronomical Study etc. As a result it remains an active area of research.

1.1 Edge Detection

An edge is a sudden change in the pixel intensity of the image. It contains the critical characteristics and important features of an image. An edge is a boundary between the object and its background, also the process of detecting boundaries between object and background in image is known as edge detection. It facilitates, further processing of image like feature selection etc. These all put together edge detection as one of the most important task in computer vision and image processing. In recent years, researchers have applied various soft computing techniques for edge detection to improve segmentation results for various images and to enhance edge detection technique. Canny [1] proposed a method which is able to detect both strong and weak edges and look more promising to detect edges under noisy conditions. In [2] comparative analysis of various edge detection techniques is given. It is shown that Canny, LOG, Sobel, Prewitt, Roberts's exhibit better performance, respectively.

1.2. Characteristics of Edge Detector.
1. To identify less number of false edges and detection of real edges should be maximum.
2. The marked pixels should be closer to the true edge.
3. Error of detecting more than one response to single edge (double edges) should be less.
4. To design one edge detector that performs well in several contexts (Satellite images, face recognition, medical images, natural images etc.)

This paper is organized as follows: Section (2) emphasizes on work done on edge detection and image segmentation using soft computing approaches with images and parameters used for evaluation. Proposed approach is presented in Section (3). Experimental setup and results are shown in Section (4) and conclusion and future scope are discussed in Section (5).

2. RELATED WORK

Several approaches have been proposed for edge detection, a few of them are discussed here. Konishi and *et al.* [12] formulate edge detection as a statistical inference. They used 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. J Patel and *et al.* [7] proposed an algorithm based on fuzzy systems and fuzzy rules, where Sobel and Lapalacian values are computed and applied to fuzzy system. The proposed approach reduces false edge detection and detection of multiple responses to a single edge is less when compared to Sobel and Laplacian methods. Ground truth evaluation was not discussed here. An algorithm to detect continuous and smooth edges using particle swarm optimization was proposed by Mahdi Setayesh and *et al.* [14]. The results showed that the algorithm performs better and less sensitive to impulsive noise than Canny. The algorithm takes much longer time to execute when compared to Canny method. An approach for edge detection using independent component analysis is proposed by Mendhurwar and *et al.* [15], the proposed approach works well under noisy conditions when compared with Canny's 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. Abdallah A. Alshennawy and Ayman A. Aly [8] proposed a fuzzy logic technique for edge detection without determining the threshold value. The algorithm works well and gives line smoothness and straight for the straight lines, corners get sharper and less detection of double edges when compared to Sobel method, Ground truth evaluation was absent. Many of these approaches discussed here evaluate edge detection without using ground truth of images, results in perplexity for quantitative and qualitative performance evaluation of approaches.

3. PROPOSED APPROACH

In this paper, an approach for edge detection using fuzzy set theory is proposed. In Psychological terms, when humans view a color object, we tend to describe it by its hue, saturation and intensity (H, S, I). Keeping in mind these terms, first RGB color image is converted into HSI image. We, as humans perceive image primarily due to dominant wavelength of light reflected by an object i.e. Hue and amount of light reflected by that object i.e. Intensity. Using this fact, saturation component is removed from HSI image and hue and intensity components are added to form a new hue and intensity (HI) image. The pixel values in the range [0 to 1] are mapped to [0 to 255] to make computations easier to understand. The obtained (hue and intensity) HI image looks like a gray image with pixel values from 0 to 255.

3.1 Fuzzy Membership of Pixels

This HI image is considered as a fuzzy set and the pixels are taken as elements of a fuzzy set. Fuzzy membership of pixel elements is defined based on their constant gray (HI) value. Maximum number of pixels having a constant gray value has the highest degree of membership i.e. 1. Similarly, second maximum set of pixels having constant gray value (pixel value) has the next membership i.e. less than 1. Each pixel in an image holds their membership value depending upon number of pixels having same pixel (gray) value. Now a pixel in this Fuzzy image (Set) has three features:

1. Spatial co-ordinates i.e. (x, y) co-ordinates.
2. Pixel Value (gray value).
3. Fuzzy membership (membership value).

The fuzzy Set F of image is defined as follows:

F= $\{(x, \mu F(x), x \in X\}$, where $\mu F(x)$ denotes the membership value of (pixel) element x in (Image) Fuzzy Set F.

The next step is to employ fuzzy rule on all set of pixels, which results in a partially segmented image. Let A be the set of pixels in fuzzy set F with constant gray value g1 and membership value m1. Similarly, let B be the set of pixels in the same fuzzy set F with constant gray value g2 and membership value m2. Let C (g3, m3) be the union of the two sets A and B holds true if it satisfies following conditions:

1) If difference between membership values of A and B is less than or equal to 0.2 ($|m1-m2| <=0.2$).
2) Difference between gray values of A and B is less than or equal to 32 ($|g1-g2|<=32$).

If the pixel sets satisfies above two conditions then a new set C(m3,g3) is created using set A and B i.e. C=(AUB), where m3=max(m1,m2) and g3=respective gray value of max(m1,m2).The two pixel sets A and B are replaced by pixel set C in image. This procedure is repeated for all set of pixels, results in partially segmented image. Histograms of HI image and partially segmented image are shown in Figure (1) and Figure (2) respectively.

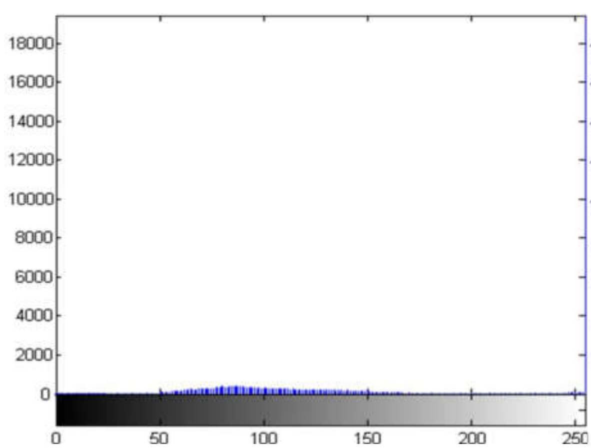


FIGURE 1: Histogram of HI image

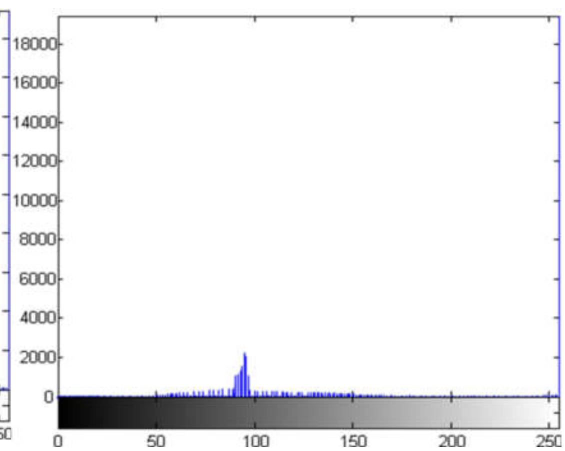


FIGURE 2: Histogram of Partially Segmented Image.

3.2 Edge Detection of Obtained Fuzzy Image

A 3×1 gradient operator in horizontal and vertical direction is shown in Figure (a). These masks are convolved over partially segmented image obtained in step 3.1. Gx, Gy are used to detect edges in horizontal and vertical directions respectively.

Gx

1
0
-1

Gy

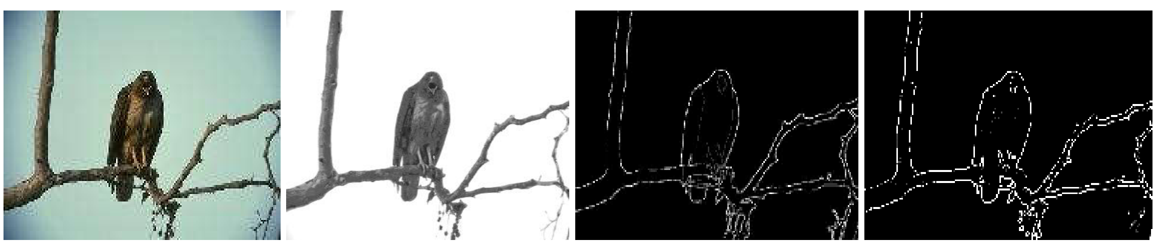
1	0	-1

FIGURE (a): 3×1 Edge operator

The resultant magnitude of edge pixels are calculated using equation (3.1)

$$G=\sqrt{(Gx)^2+(Gy)^2} \quad (3.1)$$

These 3×1 masks requires less computations to detect edges compared to other 3×3 masks used (Like Prewitt, Sobel). It also reduces blurring effect while detecting edges. Generally, real image comprises of both strong and weak edges. Here, two thresholds are set for edges, higher threshold and lower threshold. Edges above higher threshold are strong edges and edges above lower threshold are weak edges. Higher threshold value used is 0.3 for strong edges and for weak edges lower threshold is 0.4 × high threshold. Figure (3) shows the original, partially segmented, ground truth and obtained edged image in (a) (b) (c) and (d) respectively.



(a) (b) (c) (d)

FIGURE 3: (a) BSD image, (b) Partially Segmented, (c) Ground Truth, (d) Proposed Approach

4. EXPERIMENTAL SETUP AND RESULTS

The approach is simulated using MATLAB 7.11 (R2010b). BSD (Berkeley Segmentation Dataset) images [5] and respective ground truths are used for experimentation. Performance parameters used are PSNR and PR (Ratio of true to False Edges). Results shows that the proposed approach detect real edges as shown in ground truth and gives higher PR. Performance Ratio (PR) is the ratio of true to false edges. It is calculated as given in equation (4.1).

$$PR=\frac{\text{True Edges (Edge pixels identified as Edges)}}{\text{False Edges (Non edge pixels identified as edges)} + \text{(Edge pixels identified as Non-Edge pixels)}}\times 100 \quad (4.1)$$

The performance and comparative results are shown in Table 4.1. The proposed approach is compared with Canny's algorithm using Ground Truth of respective images. Results show that the proposed approach gives higher PSNR and PR than Canny's approach. After number of experiments it is found that the default sigma value available in Matlab 7.11 i.e. 1 and threshold=0.3 for Canny approach offer better result than other sigma and threshold values. Here threshold value =0.3 and default sigma=1 for Canny is used for comparison. In proposed approach higher threshold value used is 0.3 for strong edges and for weak edges lower threshold is 0.4 × high threshold. As thickness of edge determines whether an edge is strong or weak edge, to distinguish between strong and weak edges thinning operation is not performed on the resultant edged image. Resultant edged image and respective ground truth of images are shown in Figure (4) through Figure (6).

BSD Image	**Proposed (T=0.3)**		**Canny (T=0.3,σ=1)**	
No.	**PSNR(dB)**	**PR**	**PSNR(dB)**	**PR**
135069	23.9931	28.0419	23.9735	14.1513
176039	23.487	10.113	23.4721	6.9261
15088	23.3953	17.7663	23.3726	8.8939
12074	23.246	10.8485	23.2335	7.2393
210088	23.0247	13.2036	23.0153	8.7167
28075	22.981	8.1661	22.9767	8.2033
108073	21.5224	10.3232	21.5102	5.8069
3096	21.4337	9.5958	21.4189	5.5835
134052	21.2345	11.0943	21.2264	6.4736
189080	20.9949	12.4702	20.9795	8.993
189011	20.6976	10.5861	20.6882	6.3055
253036	20.4997	21.8664	20.4877	12.6724
8068	20.1987	4.951	20.1962	4.9881
310007	20.1268	15.2524	20.122	11.3261
3063	20.0554	4.3045	20.0496	4.0618
118035	19.9305	17.5689	19.9168	10.3822
41004	19.8741	15.4356	19.8647	9.2601
23025	19.7884	11.2603	19.7855	10.5085
176035	19.758	11.4857	19.7472	6.8046
113044	19.442	16.7319	19.4237	11.3814
197017	19.2163	14.7429	19.2133	11.1349
181018	19.121	10.4562	19.1163	7.4872
35070	18.9703	23.8817	18.9636	16.6493
163014	18.7961	16.2093	18.7877	10.9464
101087	18.423	11.1953	18.417	9.962
157055	18.174	11.6058	18.1672	9.8996
242078	18.1425	16.5446	18.1324	11.006
42049	17.9908	27.2644	17.9737	14.8333
245051	17.3586	26.2115	17.3408	13.9813
35010	17.2309	21.85	17.214	12.5393

TABLE 4.1: Comparison of Approaches.

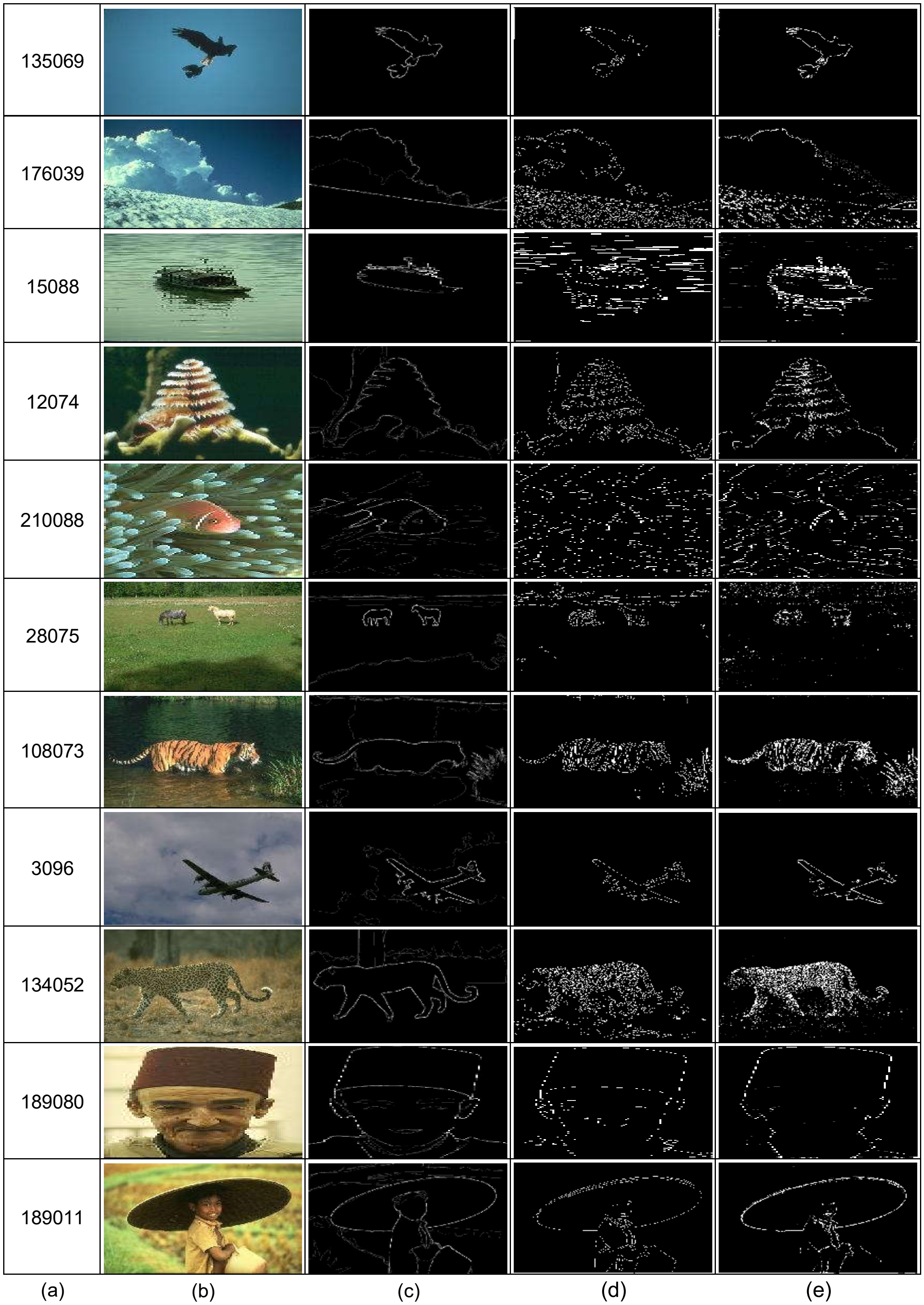


FIGURE 4: Column (a) Image No., Column (b) BSD image,
Column (c) Ground Truth, Column (d) Canny's approach, Column (e) Proposed approach

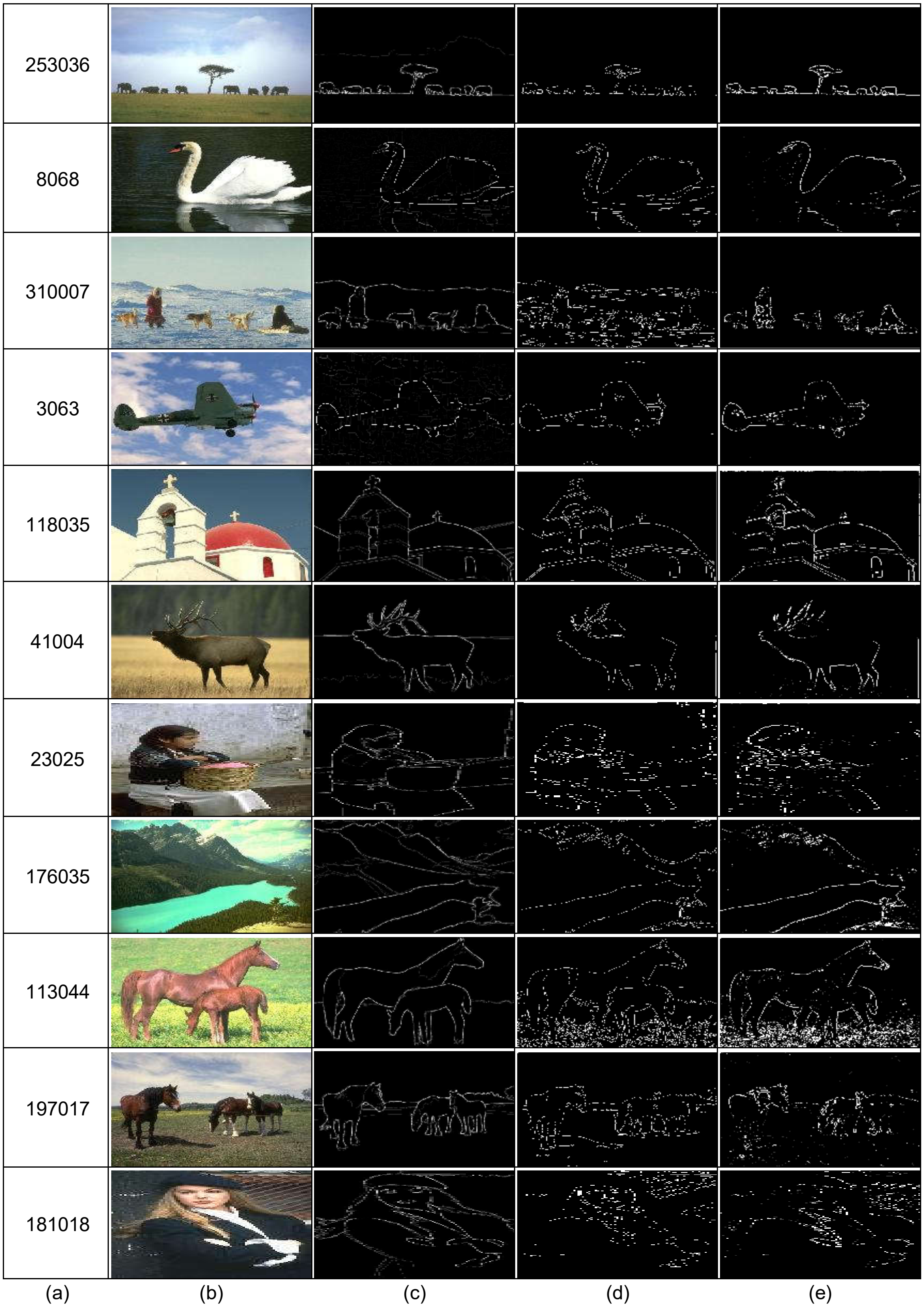


FIGURE 5: Column (a) Image No., Column (b) BSD image,Column (c) Ground Truth, Column (d) Canny's approach, Column (e) Proposed approach

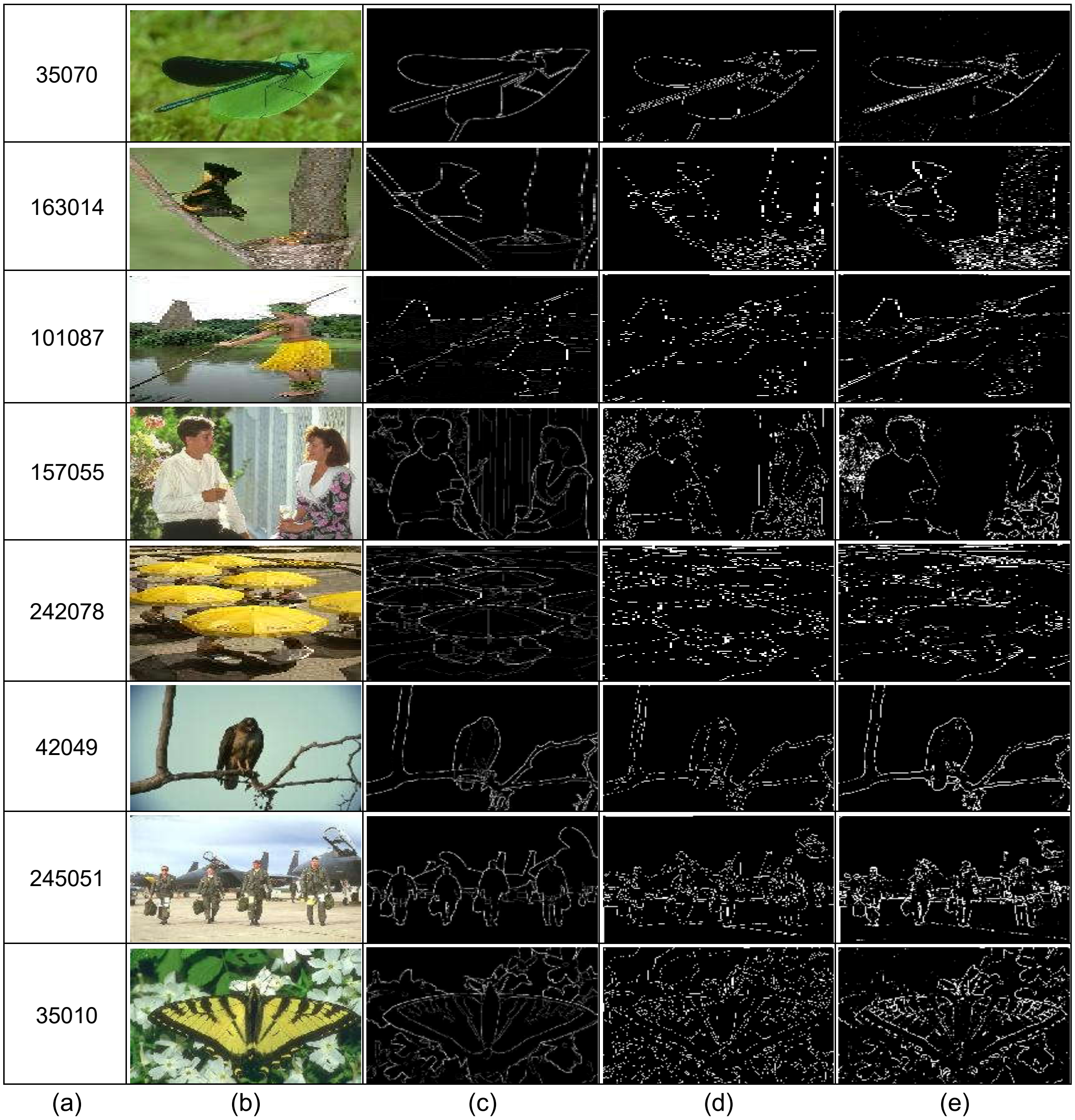


FIGURE 6: Column (a) Image No., Column (b) BSD image,Column (c) Ground Truth, Column (d) Canny's approach, Column (e) Proposed approach

5. CONCLUSION AND FUTURE SCOPE

Edge detection is one of the important techniques used for image segmentation. Image segmentation remains a puzzled problem even after four decades of research. In this paper, a soft computing approach based on Fuzzy Set is proposed for edge detection, where an image is considered as a Fuzzy Set and pixels are taken as elements of Fuzzy Set. The fuzzy approach converts the color image to a partially segmented image, finally an edge detector is convolved over the partially segmented image to obtain edged image. As, proposed edge operator does not perform blurring on image, double edges are less identified. Generally real images comprises of both strong and weak edges. The proposed approach gives both strong and weak edges having different edge strength using higher and lower thresholds.

As mentioned in [4] decades of research on edge detection has produced N edge detectors without a solid basis to evaluate the performance. Many researchers compare edge detection algorithms without using ground truth of images, results in perplexity to evaluate and compare these algorithms. In this paper, an attempt is made to evaluate edge detection using ground truth for quantitative and qualitative comparison. Experimentation is carried out using BSD (Berkeley Segmentation Database) images [5] and respective Ground Truths. The performance evaluation parameters used are PSNR and PR (Ratio of True to false Edges). Experimental Results shows that the proposed approach gives higher PSNR and PR values compared to Canny's approach. It reduces false edge detection and identification of double edges are minimum, Also the marked pixel is closer to the true edge. Here memberships of pixels are calculated based on their constant gray (HI) value. In future, using spatial co-ordinates, different combinations color components of different color models, fuzzy membership of pixels can be calculated.

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