A Novel Neural Network Based Edge Detector for Non-Synthetic and Medical Images

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ABSTRACT: Edges are the feature points of different objects in a digital image having dissimilar intensities. Edge detection is one of the active research area intended to highlight those pixels whose intensity changes very sharply in a digital image. This technique is employed as pre-processing stage in different application areas like Image Segmentation, Registration, feature extraction, Machine vision and many more. There are numerous approaches developed so far for edge detection but an optimal edge detector shall be designed that may perform excellently on all types of test images and shall satisfy different criteria of selection viz., robustness, efficient use of resources and adaptability. In this paper, a novel edge detection technique implementing Back-propagation Artificial Neural Network with multi-thresholding is proposed. It is observed that the proposed neural edge detector not only computes a better qualitative analysis for non-synthetic as well as medical images but also gives promising qualitative analysis in terms of MSE, MAE & PSNR.

KEYWORDS: Artificial Neural Network, Edge detection, Multi-thresholding, Optimal edge detector, Tsallis entropy

INTRODUCTION

Edge detection is a technique used to highlight those feature points in a digital image where intensity of pixels changes very abruptly. These points are usually boundaries/edges of distinct objects, so this technique is named as edge detection. Edge detection is being employed as pre-processing stage in different application areas like Image Segmentation, Registration, feature extraction, Machine vision etc. Some major challenges faced for the selection of a particular edge detector are: false detection of edges [1][2], presence of noise[3], low contrast [4] and poor thresholding [5]. Issue of noise and poor contrast can be solved by noise filtering and image enhancement technique respectively. Thresholding plays a vital role in edge detection, as use of single level thresholding of an image leads to the loss of prominent detail. Binarization of input gray scale image f(x, y) by using a single threshold level (T) is given by equation 1.

\[ g(x, y) = \begin{cases} 0, & \text{if } f(x,y) < T \\ 1, & \text{if } f(x,y) > T \end{cases} \] (1)

On the other hand, Multi-thresholding is a technique which is used to find more than one threshold levels. It helps to minimize the error occurred as compared to single level thresholding. The use of multiple threshold levels say T₁, T₂, Tₙ for Binarization is given by equation 2, where \( n₁, n₂, ..., nₙ = \{0, 1\} \)

\[ g(x, y) = \begin{cases} n₁, & \text{if } 0 < f(x,y) < T₁ \\ n₂, & \text{if } T₁ < f(x,y) < T₂ \\ nₙ, & \text{if } T₂ < f(x,y) < Tₙ \end{cases} \] (2)

This paper discusses related work in section II. Section III described the proposed edge detection algorithm followed by discussion on results, conclusion and future work in section IV, V and VI respectively.
II. RELATED WORK

The classical approach used for detection of edges include Gradient based operators (Sobel, Roberts, and Prewitt), and Laplacian-based (LOG) detectors. Gradient edge detectors are simple to use but very sensitive to noise [6] and thus not suitable for medical image analysis. On the other hand, Laplacian-based filters have better SNR due to Gaussian smoothening[7], [8] but it gives false zero crossing. The kernels used for these operators are shown in figure 1.

![Kernels for edge detection](image)

**Fig. 1 a) Sobel Operator   b) Prewitt Operator   c) Roberts Operator  d) LOG operator**

Apart from the classical detectors, some advanced edge detectors such as, Gaussian based (Canny) and Fuzzy/Neural based edge detectors are also deployed widely in many applications. Canny edge detector is proposed by J. F. Canny in 1986 [9]. It consists of multi-stage procedure for edge detection as shown in figure 2. Canny edge detection algorithm is developed for optimal detection of edges but gives false result at corners and curves.

![Flowchart of Canny edge detection](image)

**Fig.2. Flowchart of Canny edge detection algorithm**

Classical approaches are unable to model complex problems and become ineffective in noise and dynamically changing environment. Over the past years, nature-inspired computational methodologies enable the computer systems to perform reasoning and making intelligent decisions of their own [10]. Thus, some latest edge detectors are developed in recent years with the use of fuzzy logics and artificial neural networks. Fuzzy method deals with reasoning that aims on “approximation” rather than “exact” values.

YasarBecerikli et al.[11] proposed a new Fuzzy approach for edge detection. The Proposed rule-based fuzzy algorithm offered easy adaptability to thickness and structure of edges. Results demonstrated better edges in comparison to classical methods like Sobel, Roberts and Prewitt.

Jinbo Wu et al. [12] proposed a Fast Multilevel Fuzzy Edge Detection (FMFED) for Blurry Images. The FMFED algorithm first enhances the image contrast by double thresholding and then extracts edges by using gradient values. Results demonstrate better performance in terms of thin and true edges.

Kenji Suzuki et al. [13] proposed a Neural Edge Enhancer (NEE) for supervised edge enhancement from noisy images. The network used supervised learning & trained through a set of input noisy images. The comparison...
demonstrated the superior robustness of neural edge detector to noisy images in comparison to conventional edge enhancers.

Hamed Mehrara [14] proposed a novel edge detection using Back Propagation Neural Network (BPNN). In this technique, the neural network is trained by using 16 possible quad pixels binary images and then implemented on Input Gray scale images after single-level binarization.

S Abid et al. [15] proposed novel neural network approach for edge detection. This algorithm used Multilayer Perceptron (MLP) to detect edges in noisy & low contrast gray scale images. Simulated results on synthetic and real images showed promised results in terms of precision & localization.

Jesal Vasavada et al. [16] proposed an edge detection method for gray scale images based on BP Feed-forward Neural Network to detect edges in gray scale images. The network is trained by back-propagation learning algorithm for Standard deviation and gradient values. The proposed scheme reveals better results in comparison to Prewitt, Roberts, Sobel, LOG.

**III. PROPOSED NEURAL EDGE DETECTOR**

The design methodology of proposed edge detector is shown in figure 3. The first and foremost step is to convert the input grayscale image into Binary form by using three threshold levels $T_1$, $T_2$, & $T_3$ (as given in eq. 2) which are computed using Tsallis Entropy [17] based Multi-Thresholding.

![Proposed Algorithm](image1)

Then this Binary image is disintegrate into 3x3 windows and is applied as an input to a Neural Edge Detector which decides that whether the input centre pixel of window is an edge or not, as shown in figure 4. This network is using a supervised back-propagation neural network, which in turn uses delta rule for learning [18]. The network structure is 9x5x1 (9 inputs, 5 hidden and 1 outputs). Proposed BPNN is trained with 100 sample images of 3x3 size with learning rate of 0.9 and sigmoidal activation function. Samples are selected in such a way that trained BPNN will also perform accurately to unknown input patterns.

![Proposed Neural Edge Detector](image2)
Finally, the output images are analysed at various qualitative and quantitative parameters. The results are also compared with the results of traditional & existing neural edge detectors.

IV. RESULTS AND DISCUSSION

In this section, the proposed algorithm is compared with different edge detection techniques like Sobel, Roberts, Prewitt, Canny and General Neural Network (Quad Pixel Neural Network trained for possible 16 patterns [14]) viz Visual inspection, MSE, MAE, and PSNR. Comparison is performed on two different types of test images as shown in figure 5.

![Original test images](image_url)

Figure 6 shows the qualitative comparisons of results obtained for Non-synthetic RGB image through various operators. Qualitative Comparison is done by visually inspecting the edge quality of edge map.
Figure 7 shows the qualitative comparisons of results obtained for Medical image through various operators. It is observed that the edge details obtained through proposed technique (refer the edge details of clouds in fig. 6(f) & edge linking of boundaries in fig. 7(f)) is far much better than the other existing techniques.
Apart from the qualitative analysis, the quantitative analysis is also compared for both input images at various quality parameters. Figure 8 shows the quantitative comparisons viz MSE, MAE, PSNR obtained for Non-synthetic RGB image through various operators.

![Fig.8 Quantitative comparison of results for non-synthetic input image using various operators](image)

Figure 9 shows the quantitative comparisons viz MSE, MAE, PSNR obtained for Medical image through various operators.

![Fig.9 Quantitative comparison of results for Medical input image using various operators](image)

It is clearly observed that the MSE & MAE offered by proposed technique is least in comparison to all other existing traditional & advanced edge detection techniques for both types of input images. Similarly, the PSNR for proposed detection algorithm is highest in comparison to others.

V. CONCLUSION

In this paper, a novel edge detection technique based on Multi-Thresholding with ANN is presented. The results obtained through proposed method performs better than various well known conventional edge detection techniques in terms of Quality edges, MSE, MAE and PSNR. The proposed method produces true thin edges, manifesting more detail and the reduction in Mean Square Error (MSE) and Mean Absolute Error (MAE) as compared to competitors are highly commendable. High Peak Signal to Noise ratio (PSNR) of proposed edge detector in both non-synthetic & medical test images clearly demonstrate the superior quality of output edges.
VI. FUTURE WORK

It is planned to design an optimal neural edge detector that not only performs better on real and medical images but also yields good results in noisy or blur conditions.

REFERENCES