Edge Detection Algorithm Based on BEMD for Liver CT Images

Gajendra Kumar Mourya, Manashjit Gogoi, Akash Handique

Abstract: ***Liver edge identification requires for its volume estimation from CT image and this process is a prerequisite for liver diagnosis and treatment planning. In this article, an edge detection algorithm proposed based on Bi-dimensional Empirical Mode Decomposition (BEMD) and Fourier Transform. Intrinsic mode function (IMF) extracted from BEMD and mixed with the Fourier phase of the original image to get edge profile. The proposed method extensively evaluated on Berkeley Segmentation Data Set (BSDS-500) and compared with Sobel and Canny operators. Results achieved Mean Square error 0.04±0.01 and PSNR 62.27±1.1. In conclusion, The BEMD approach capable of identifying image edges with high accuracy compared with state of the art.***

Keywords: BEMD, CT Image, Edge Detection, Fourier transform, IMF

I. INTRODUCTION

The liver is one of the largest organs in the human anatomy that situated on the right side of the abdominal region. Liver diseases are one of the major medical problems. Mortality reached 216,865 or 2.44% of the total deaths in India[1]. Liver abnormality diagnosed by Histopathology before that, it can be prognoses using advanced medical imaging techniques like Computed Tomography (CT) and Magnetic Resonance Imaging (MRI). CT images widely used for abdominal organ diagnosis and radiation therapy planning cause faster acquisition and high resolution [2], [3]. Image edges are typically a boundary between various regions of the image. Edges are a high-frequency component of the image and characterized as a sudden change in pixel intensity. Liver edge detection and segmentation is prerequisite for computer-aided diagnosis and treatment planning.

Canny edge detection manuscript is one of the most cited among various edge detection research works. This algorithm is capable of segmenting out thick and thin edges along with prominent connections. Some time generates false positive edges too [4].

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Sobel is also one of the famous edge detection algorithm work on gradient operations use for detecting lines within an image [5]. The first empirical mode decomposition introduces by Huang et al. in the year of 1989 for a time series analysis of nonlinear and non-stationary signals and demonstrates natural phenomena. Nunes et al. develop an algorithm based on the Bi-dimensional Empirical Mode of Decomposition (BEMD), to extract different image features at various spatial frequencies for synthetic and natural images [6]. Liang et al. discuss an edge detection algorithm based on EMD and tested on general-purpose images [7]. Liu et al. investigate the BEMD and receiver operating curve (ROC) application for detecting underwater image edge [8]. Dong et al. proposed an edge enhancement algorithm based on BEMD and wavelet theory to enhancing medical images. They address the limitation of tradition medical image edge detection methods and verify the effect on edge enhancement [9]. Liu et al. proposed an approach of using BEMD for medical image decomposition and feature extraction for retrieving medical images. Explained these unique features improved retrieval performance [10]. Cheng introduces a modified BEMD with approaches to high-resolution images by splitting the image into several blocks and processing them individually, reducing computational resources and nicely explained fundamentals of decomposition method [11]. Zhao et al. proposed an edge enhancement technique for the radiographic weld image by using Bi-dimensional Empirical Mode Decomposition (REIM), BEMD followed by edge enhancement operation [12].

Shen et al. proposed a method that utilizes the Periodic Compactly Supported Radial Basis Function (PCSRBF) to improve the Bi-dimensional Empirical Mode Decomposition [13]. Liu et al. proposed an image de-noising method that uses Partial Differential Equations (PDE) and the Bi-dimensional Empirical Mode Decomposition. PDE of IMS's summed with residue followed by reconstruction [14]. However, BEMD is used for image feature extraction, edge enhancement and edge detection without considering the real phase of the image that leads to false edges. The proposed algorithm consists of mixed BEMD amplitude and Fourier phase of the input image to detect real edges. The developed algorithm considers spatial and frequency domain features while detecting edges. This algorithm deployed for liver edge detection from CT images.

The remaining paper is structured as follows. Section 2 explained the detailed methodology. The proposed method results are discussed in Section 3. Section 4 concludes the paper with future scope.

II. METHODOLOGY

In the proposed approach, BEMD and 2D Fourier Transform used to detect image edges. The projected methodology is depicted in Fig. 1, which comprises of various steps. First, Edge magnitude extraction trough BEMD, second is phase extraction from the original image and last is mixing amplitude and Fourier phase followed by a morphological operation. BEMD decomposes an image into its distinct frequency components in the descending order known as Intrinsic Mode Functions (IMF'S). BEMD decomposes an input image into its constituents' descending frequency components and a residue; the 2D Fourier Transform algorithm used to find the magnitude and phase components of an image. Decomposed frequency component combined with the phase of the original image to detect edges. The BEMD of the image $f(x,y)$ expresses, as shown in equation (1).

$$f(x,y) = \sum_{i=1}^{n} imf_i(x,y) + R_n(x,y) \qquad (1)$$

Where $imf_i(x,y)$ = i^{th} *IMF* and $R_n(x,y)$ = residue of function at n^{th} iteration.

IMF_1 and IMF_2 utilized to extract edges of the image because they contain high-frequency components. The image expressed as a two-dimensional signal $f(x,y)$, the mean value of surface as $mf(x,y)$. The difference between the original signal $f(x,y)$ and $mf(x,y)$, is known as the Intrinsic Mode Function (IMF) (equation (2)).

$$imf_1 = f(x,y) - mf(x,y) \qquad (2)$$

Obtained IMF's are shown in equation (3).

$$imf_n = m^{n-1}f(x,y) - m^n f(x,y) \qquad (3)$$

Adding equations (2) and (3),

$$f(x,y) = \sum_{i=1}^{n} imf_n(x,y) + m^n f(x,y) \qquad (4)$$

Expression of each IMF and residue components of the image represented by Equation (4). Decomposing an image by BEMD Algorithm can extract various image details and edge information. The first IMF ($\mathrm{imf_1}$) and second IMF ($\mathrm{imf_2}$) extracted and it's average ($\mathrm{imf_{avg}}$) calculated, as shown in equation (5). The magnitude component of $\mathrm{imf_{avg}}$ is considered for further processing.

$$imf_{avg} = (imf_1 + imf_2)/2 \qquad (5)$$

The input image decomposed into its Fourier Phase ($\mathrm{FT_\theta}$) and Fourier Magnitude ($\mathrm{FT_r}$) using the Two-Dimensional Fourier Transform. Fourier phase component ($\mathrm{FT_\theta}$) mixed with a magnitude of the average IMF's to obtain a Fourier space image, as shown in equation (6).

$$F(c,d) = (imf_{avg}) * \exp(i * angle((FT_\theta))) \qquad (6)$$

Where $\mathrm{F(c,d)}$ = Fourier domain image.

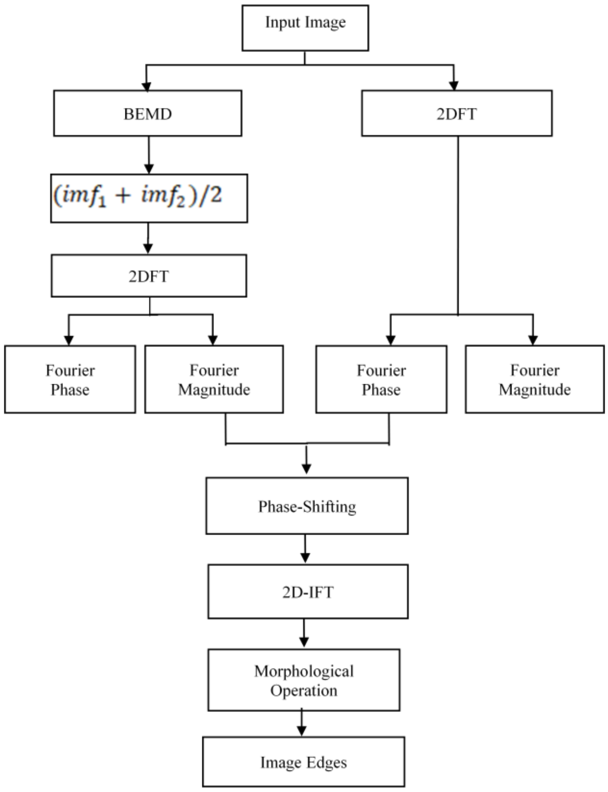

Fig.1. Flowchart of Algorithm

Fourier domain Image $\mathrm{F(c,d)}$ that re-transformed into the spatial domain image using Two-Dimensional Inverse Fourier Transform discussed in equation (7).

$$f(a,b) = \frac{1}{MN}\sum_{c=0}^{M-1}\sum_{d=0}^{N-1} F(c,d)e^{-i2\pi\left(\frac{ca}{M}-\frac{db}{N}\right)} \qquad (7)$$

Where $\mathrm{f(a,b)}$= resultant edge enhanced image. Resultant Image $\mathrm{f(a,b)}$ Converted into a binary image by Otsu's threshold method [15]. The morphological operation applied to remove isolated pixels and to replace thick edges by thin edges.

Evaluation Measures

The description of evaluation measures is as follows [15], [16].

Mean Square Error (MSE)

The MSE shows a common distortion measure between the ground truth and predicted image. MSE for an image of dimensions (m*n) as shown in equation (8)

$$MSE = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}(Aij - Bij)^2 \qquad (8)$$

Where A = Ground truth image and B = Predicted image. Smaller MSE represents a better result.

Peak Signal to Noise Ratio (PSNR)

PSNR is the measurement of reconstruction quality. It described as the ratio of the maximum possible power of a signal to the power of the corrupting noise. PSNR represented in equation (9).

$$PSNR(db) = 10 \log \frac{255^2}{MSE} \qquad (9)$$

A higher PSNR value indicates a good quality of edge image.

Normalized Absolute Error (NAE)

NAE expressed in equation (11)

$$NAE = \frac{\sum_{i=1}^{m} \sum_{j=1}^{n} (|Aij - Bij|)}{\sum_{i=1}^{m} \sum_{j=1}^{n} (Aij)} \qquad (11)$$

Where A = Ground truth image and B = Predicted image. Smaller MSE represents a better result.

Structural Similarity Index (SSIM)

SSIM is measured image quality. SSIM expressed in equation (12)

$$SSIM(A, B) = \frac{(2\mu_A\mu_B + C_1)(2\sigma_{AB} + C_2)}{(\mu_A^2 + \mu_B^2 + C_1)(\sigma_A^2 + \sigma_B^2 + C_2)} \qquad (12)$$

A higher SSIM value indicates better quality edges.

III. RESULT AND DISCUSSION

The proposed edge detection algorithm evaluated on Berkeley Segmentation Data Set BSDS500 consists of 500 natural images and ground-truth [17]. This data provided edge profile image corresponding to each natural image. The method quantitatively evaluated corresponds to their ground truths. Results compared with well-known Canny and Sobel methods (Fig. 2). The canny operator produces false edges, as shown in column number three of Fig. 2. It depicts that the proposed method produces good edges characteristics compare to Canny and Sobel.

CT scan dataset from Decathlon-10 Grand-Challenge[18] deploys for testing the proposed algorithm. This challenge floated ten different tasks; we utilize the task 3 data set. Task 3 is automatic segmentation of liver from volumetric CT data, 131 training and 70 volumetric data provided. Ground truth contain binary image for liver and non liver image. The visual results of selected subjects are shown in Fig. 3. The first column shows the Input Image, the second column shows the edge enhanced image, and the third column shows the desired output. Test results are cropped across the presence of the liver instead of showing 512*512 dimension images. It shows that the liver edges highlighted nicely.

A comparison of the planned method with two edge detection algorithms in terms of evaluation measures and their descriptive statistics tabulated for BSD-500 data (Table I). The proposed method yields average MSE of 0.04 with the 0.01 standard deviation.

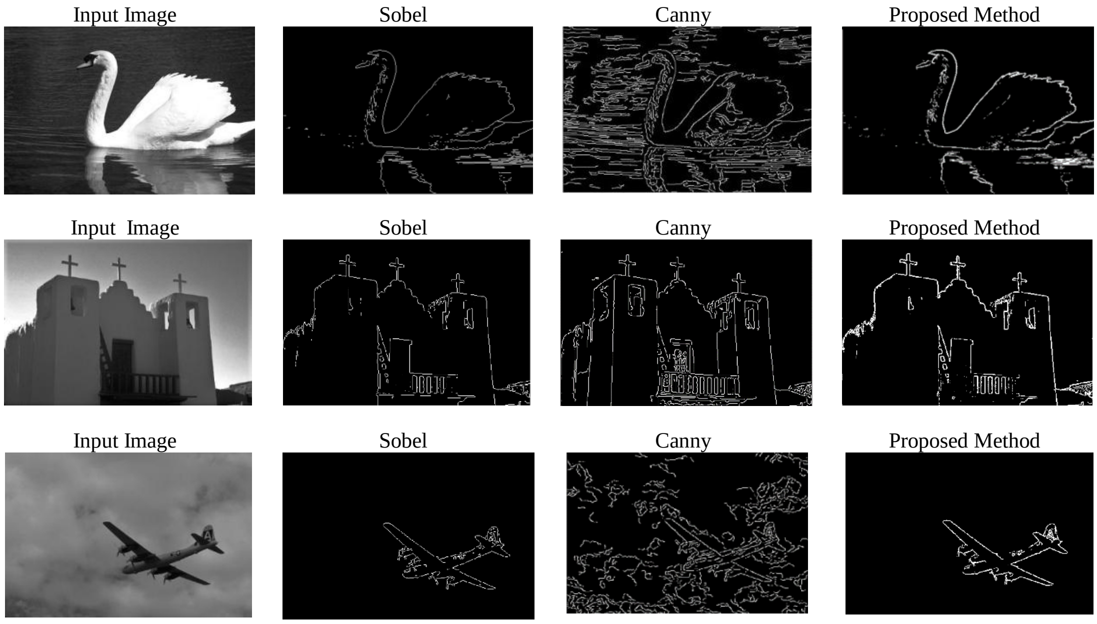

Fig. 2. The test result of the proposed method on BSDS500 sample images

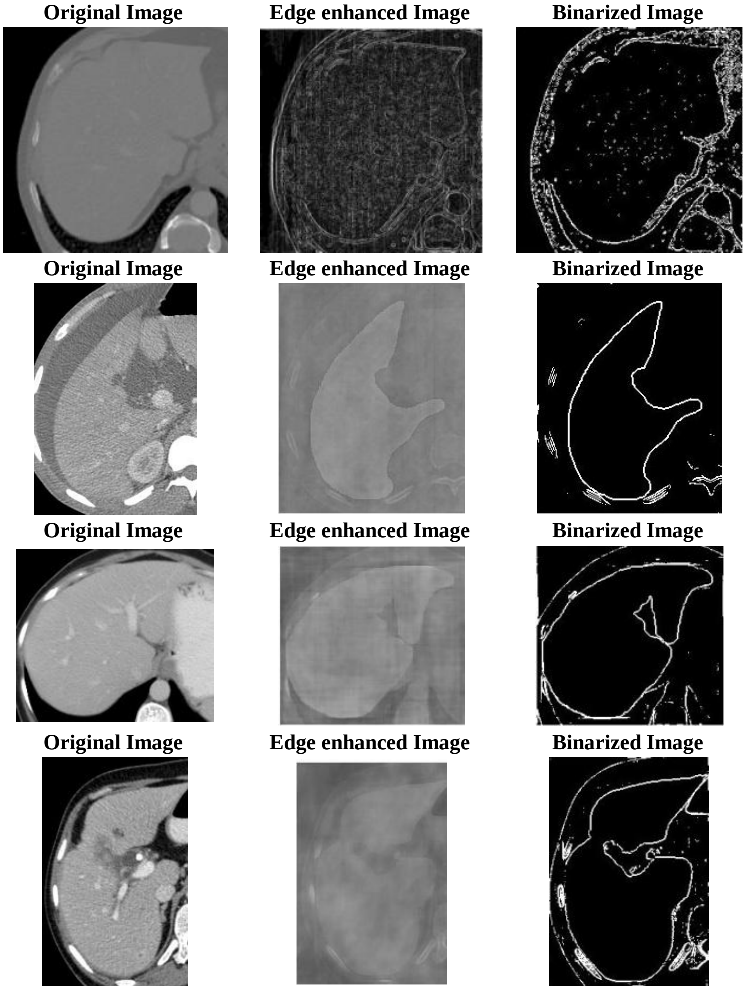

Fig.3. Results for Liver boundary extraction from CT Image

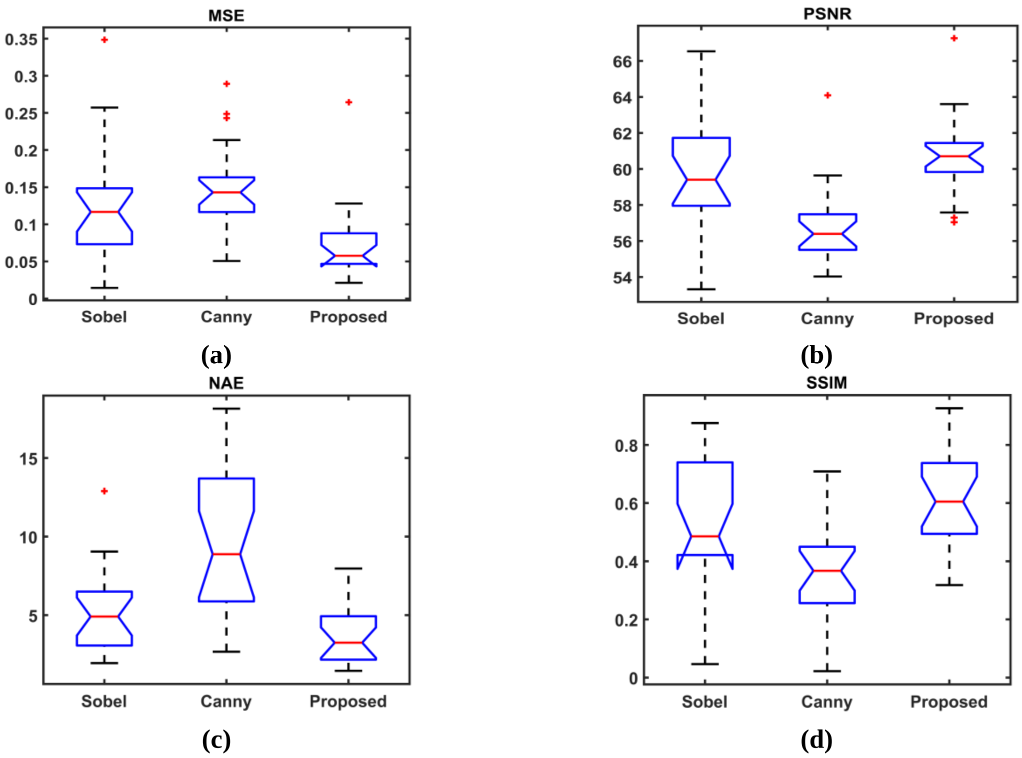

Fig. 4. Box plot for evaluation parameters (a) MSE (b): PSNR, (c) NAE (d): SSMI

Table- I: Proposed Method comparison with Canny and Sobel on BSDS500 Data Set

Sl. No.	Method	MSE ±SD	PSNR±SD	NAE±SD	SSIM±SD
1	Proposed Method	0.0395±0.01	62.2730±1.1081	4.8586±.8889	0.6500±0.1174
2	Canny	0.0993±0.0278	58.9508±2.8850	12.0041±6.4979	0.4467±0.1485
3	Sobel	0.0768±0.0715	61.0247±4.4212	8.1971±9.6718	0.7754±0.1407

Evaluation measure scores of the proposed method are higher than Sobel and Canny operators. Fig. 4 shows the box plot corresponds to evaluation parameters concerning Sobel, Canny and proposed method, respectively. The performance of the proposed method is consistent for all evaluation parameters and gets a very less number of outliers marked as '+' signs within the box plot. Proposed method whiskers width is promising and consistent.

IV. CONCLUSION

An edge detection algorithm proposed for liver edge detection from CT-images. This technique explains the 2D application of the Empirical Mode of Decomposition by blending with the Fourier phase for edge detection. The proposed method has the potential to segment edges and showing significant differences. We believe that this was first work when BEMD mixed with a phase of image. Recently Artificial Intelligence (AI) is a fast developing era due to high computation capability. BEMD based technique may use as one of the data augmentation methods in the Deep learning technique. Near future BEMD technique can be a supporting tool for the explainable AI. The proposed algorithm can be enhanced while extending the proposed method to 3D BEMD, preferably in 3D segmentation of the Liver and its blood vessels from CT image. In conclusion, the obtained results demonstrate substantially significant performance with consistency and robustness.

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