Performance Evaluation of Two-Way Fused Gaussian Spatial and Intensity Kernels for Seismic Image Enhancement with Adaptive Tuning

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Abstract: **Present work is implementation of image enhancement by way of fused Gaussian spatial and intensity Kernels. Weight coefficients of kernels made to update accordingly with noise variations. This technique was applied in the field of seismic exploration applications with an object to improve quality of seismic image and first time applied onto the seismic image generated in Indian subcontinent. The fused enhancement was compared with conventional enhancement, such as median filtering, histogram equalization, and with non fused separate Gaussian spatial and intensity kernel. By observing enhancement evaluation metrics, Mean Absolute Error (MAE) and Contrast to Noise Ratio (CNR), it is evident that fused Gaussian spatial and intensity based enhancement technique is superior than conventional median, histogram equalization, and non fused separate spatial and Intensity Kernel in improving the seismic image quality.**

Key words**:** Image Enhancement, Seismic Image, Fused Spatial and Intensity Kernels, Mean Absolute Error and Contrast to Noise Ratio.

I. INTRODUCTION

Images comprises of numerous features and play pivotal role in science and engineering. Visualization of images has significant role in analysis and interpretations. Seismic image is earth's subsurface image constructed using reflected seismic waves through measuring ground motion. Seismic waves are produced on or near the earth subsurface by an explosion or by a mechanical impact that arrive at the surface being reflected by different subsurface layers, and are captured by sensors, geophones and seismometers. Images are formed by integrating recorded seismic data over source and receiver coordinates [1].

Recorded seismic data is of natural noise, includes cultural and wind nose, and instrumental noise, includes Brownian and electronic noise [2]. Seismic image constructed from these data of poor quality and low contrast. Quality of images distorted and degraded during acquisition and construction. Poor quality images not only limit the horizons of interpretation but also hamper successive image processing stages. To represent seismic image in more visibly palatable way image enhancement comes into picture with an objective to improve and bring out visual content which are otherwise not visible for perception and interpretation [3].

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To date most of the seismic image enhancement techniques are high frequency enhancement methods, unsharp masking methods, and wavelet threshold algorithms [4] and so on. This paper describes the use of two way fused Gaussian spatial and intensity kernel for seismic image enhancement and first time applied to seismic image generated in Indian subcontinent. Conventional nonlinear enhancement methods, such as, median filter and histogram equalization is also implemented and compared with two way fused Gaussian method. Quality of enhancement is evaluated using evaluation metrics, i.e., Mean Absolute Error (MEA) [5] and Contrast to Noise Ratio (CNR) [6].

II. IMAGE ENHANCEMENT

Enhancement mainly deals with representing the image in more pleasing form for perception. It is inflating image quality through manipulation leading to improved visibility. In general seismic image enhancement is majorly through the median filters and histogram equalization. Median filter is template based with ability to suppress the noise. Though it improves the image quality contributes more to blurring thus limiting interpretation capabilities [7]. Histogram equalization is to improve dynamic range of image by means of pixel manipulations. It is converting image histogram into uniform distribution. Though the contrast improves few details disappears [8]. Fused Gaussian spatial and intensity kernel was implemented with an aim to improve the image quality with adaptively changing Gaussian weight coefficients with noise variations. This technique was applied onto the seismic images of Indian subcontinent. Results obtained encouraging in comparison with conventional enhancement methods, namely median filtering and histogram equalization, and along non fused separate Gaussian spatial and intensity kernel.

III. ENHANCEMENT BY TWO WAY FUSED GAUSSIAN SPATIAL AND INTENSITY KERNELS

Mixed Gaussian kernels mostly used for photographic images and seldom used on seismic images. With fused spatial and intensity kernel an attempt has been made for seismic image improvement. The basic idea is convolution by kernels. In simple terms it is shift invariant image filtering. Spatial kernel depicts the output by averaging intensities at pixel positions and its effectiveness of spatial kernel is limited by blurring due its dependency on pixel distances than its values. Spatial kernel is given by

$$Gs[I]_j = \sum [\frac{1}{2\pi {\sigma_s}^2} e^{-\frac{|i-j|^2}{2{\sigma_s}^2}}] \times I_j \quad (1)$$

Where I – input Seismic Image, i – center position and j – pixel position whose weight to be replaced, σ's – standard deviation and defines neighbourhood size.

Intensity Kernel estimates the output by averaging pixel values in the neighbourhood and is given as

$$Gi[I]_j = \sum [\frac{1}{2\pi {\sigma_r}^2} e^{-\frac{|I_i-I_j|^2}{2{\sigma_r}^2}}] \times I_j \quad (2)$$

I_i and I_j, Pixel value at position i and j respectively

Two way fused Gaussian spatial and Intensity Kernel estimates the value at a pixel position as weighted average of neighbouring pixel. It exploits a pixel to contribute to the output it must occupy nearby position along with approximately similar value.

$$Tw[I]_i = \frac{1}{\left[\frac{1}{2\pi\sigma_s^2} e^{-\frac{|i-j|^2}{2\sigma_s^2}}\right] \times \left[\frac{1}{2\pi\sigma_r^2} e^{-\frac{|I_i-I_j|^2}{2\sigma_r^2}}\right]} \sum \left[\frac{1}{2\pi\sigma_s^2} e^{-\frac{|i-j|^2}{2\sigma_s^2}}\right] \times \left[\frac{1}{2\pi\sigma_r^2} e^{-\frac{|I_i-I_j|^2}{2\sigma_r^2}}\right] \times I_j \quad (3)$$

IV. OUTPUTS

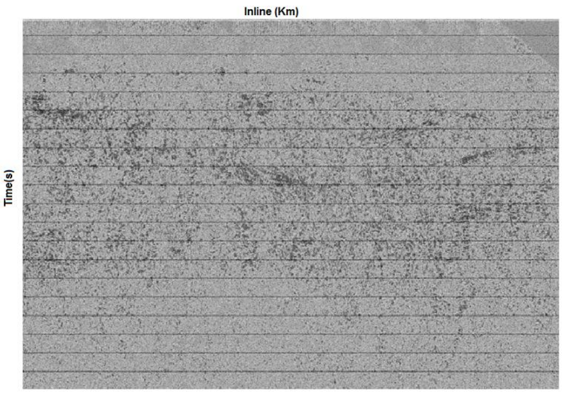

Fig.1. Input Seismic Image

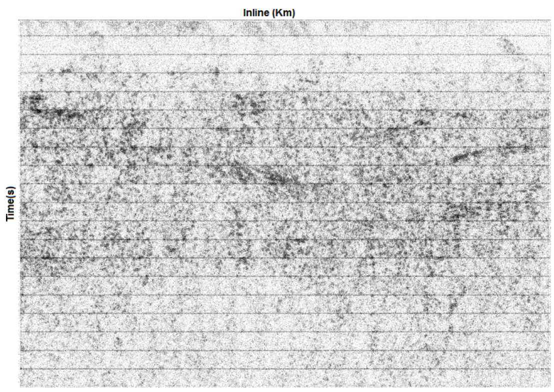

Fig. 2. Enhanced Seismic Image by Two way Fused Spatial and Intensity Kernel

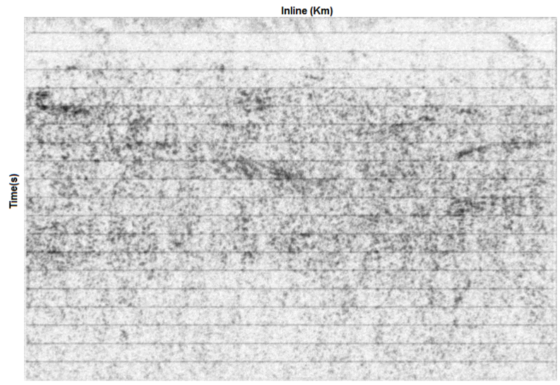

Fig. 3. Enhanced Seismic Image by Gaussian Spatial Kernel

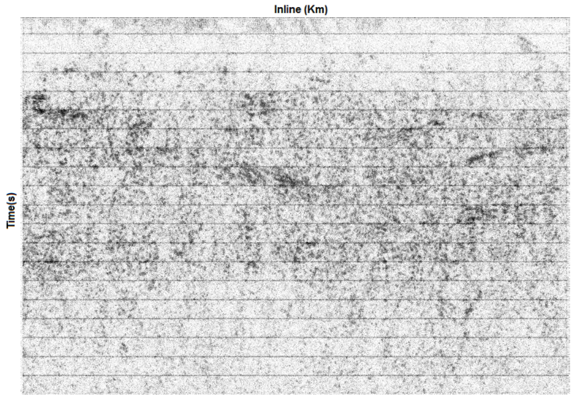

Fig. 4. Enhanced Seismic Image by Gaussian Intensity Kernel

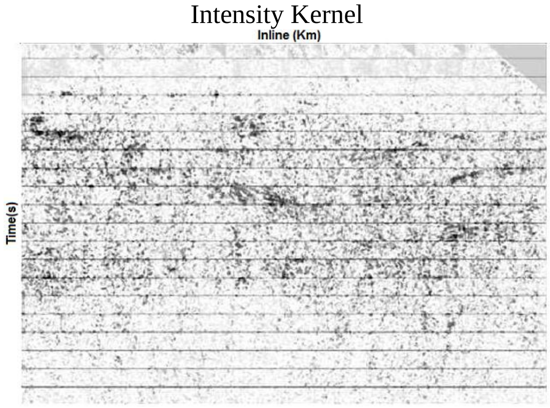

Fig. 5. Enhanced Seismic Image by Median Filter

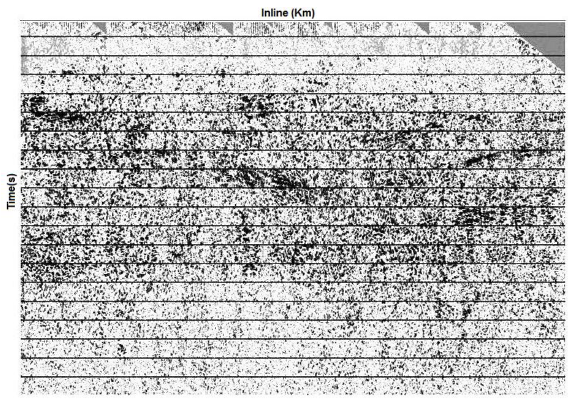

Fig. 6. Enhanced Seismic Image by Histogram Equalization

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V. IMAGE ENHANCEMENT METRICS

Enhancement of images assessed both subjectively and objectively. Subjective evaluation is looking for visual quality improvement of the input seismic image, fig.1 against fig. 2-6. Objective evaluation is estimation of metrics, though there exist numerous metrics, Mean Absolute error (MEA) [5] and Contrast to Noise ratio (CNR) [6] has been used for evaluation of enhancement methods by following mathematical formulations. The estimations were tabulated in Table 1.

$$MAE = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}|n(i,j)| \quad (4)$$

$$CNR = \frac{\mu_r - \mu_n}{\sigma_n} \quad (5)$$

where

$$n(i,j) = r(i,j) - e(i,j)$$

$$\mu_r = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1} r(i,j)$$

$$\mu_n = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(n(i,j))$$

$$\sigma_n^2 = \frac{1}{MN-1}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(n(i,j)-\mu_n)^2$$

VI. CONCLUSION

Two-way fused Gaussian Spatial and Intensity kernel was implemented for seismic image enhancement. Its subjective and objective evaluation was done against conventional median and histogram equalization method for seismic image enhancement along against with no fused separate spatial and intensity kernels. Both subjective evaluation of visual image quality, figure 2 against figure 3-6 and estimated objective image enhancement evaluation metrics, low MEA and high CNR (table 1), clearly indicates that two way fused kernels has superior performance over conventional median and histogram equalization methods as well as over no fused separate spatial and intensity kernels.

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Table.1

Enhancement evaluation metrics

S.No	Enhancement Method	Mean Absolute Error (MAE)	Contrast to Noise Ratio (CNR)
1	Two way Fused Kernel	1.2838	89.9216
2	Spatial Kernel	9.3045	20.4392
3	Intensity Kernel	1.7396	75.7343
4	Median Filter	3.8296	32.3383
5	Histogram Equalization	41.1789	10.9671

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