ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 1, January 2014

Comparative Study on Braille Image Enhancement Using Spatial Domain Enhancement Techniques

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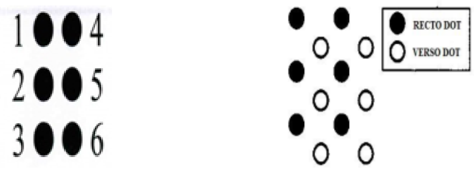
Abstract* - The aim of image enhancement is to improve the interpretability or perception of information in images for human viewers, or to provide better input for other automated image processing techniques. Optical Braille Recognition (OBR) system is computer software that automates the process of acquiring and processing images of Braille documents. The data is provided to the OBR system in the form of images of Braille embossed pages. The braille images are acquired digitally through scanners or digital cameras. The acquired Braille images are rarely of perfect quality. They may be degraded and corrupted due to irregular lightness, relatively low resolution. These noises can be eliminated by employing various image enhancement techniques prior to Braille recognition. Thus it provides high quality and clear embossing Braille image to locate the braille dots. This paper provides a comparative study of performance of various spatial domain filters as applied to the Braille image. Different filters have been evaluated experimentally and their performance is noted quantitatively using quality metric called Peak signal-to-noise ratio (PSNR). The experimental results confirm that the performance of Highboost filtering is comparatively better than the other techniques in terms of PSNR values. Further with respect to subjective measure unsharp masking can be used for braille dots extraction from the braille image, but with the loss in the PSNR value.

Index Terms - **Braille, Braille-cell, Inter point Braille, MSE, OBR, PSNR.**

I. INTRODUCTION

Braille is a series of raised dots that can be read with the fingers. The Braille system, devised in 1829 by Frenchman Louis Braille, is an essential tool with which people who are blind or whose eyesight is not sufficient for reading printed material. Braille is not a language, rather, it is a code by which many languages can be represented. Braille symbols are formed within units of space known as Braille cells. A full Braille cell consists of six raised dots arranged in three parallel rows each having two dots as shown in Fig 1(a). The dot positions being universally numbered 1 through 3 from top to bottom on the left, and 4 through 6 from top to bottom on the right [6].Sixty-four combinations (including the combination in which no dots are raised) are possible using one or more of these six dots [1].



(a) (b)

Fig: 1 (a) A basic Braille cell (b) Inter-point Braille.

Many documents are printed in inter-point form, meaning they are double-sided [7] as shown in Fig 1(b). As such, the depressions of the Braille of one side appear interlaid with the protruding Braille of the other side and Braille is generally printed on paper, with no ink to produce contrast between the raised characters and the background paper. However, imperfections in the page can appear in a scanned Braille image .Braille image enhancement is an important constituent in Braille Recognition System. Thus it is important to employ image enhancement techniques prior to Braille recognition to obtain a high quality and clear embossing Braille image to locate the Braille dots [4].

Image enhancement techniques can be classified into two categories: Spatial domain methods and Frequency domain methods. The spatial domain refers to the image plane itself and approaches in this category are based on direct manipulation of pixels in an image. Frequency domain processing techniques are based on modifying the Fourier transform of an image [2]. In the proposed work we reviewed and implemented various spatial domain enhancement techniques on braille image, which includes histogram equalization, enhancement using smoothing filter such as box filter, Weighted average filter, Gaussian filter, Median filter and enhancement

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
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using Sharpening filters such as Unsharp masking, Highboost filtering, Laplacian filter, Roberts filter, Sobel filter and prewitt filter.

The work is divided into five sections. In section II we discuss related works that are carried out by different authors, in section III we describe the proposed work which includes enhancement of the braille image using various spatial domain image enhancement techniques, in section IV performance of proposed work is evaluated using quality metric called PSNR value and in section V the conclusion for the proposed work and directions for future works are discussed.

II. RELATED WORK

Braille image preprocessing is one of the most important step in braille recognition system. The errors that are occurred while the images are acquired can be eliminated. Errors include noise, deformation, bad illumination or blurring. Image preprocessing can be used for image enhancement by reducing noise, sharpening images, or rotating a skewed page. The algorithms used differ from one system to another depending on the classification approach followed by researchers and developers.

In [11], during image acquisition, impulse noise was introduced in the image. These noises cause random fluctuation in gray-level values and it usually has a high spatial frequency. Therefore, a low-pass spatial Gaussian filter is applied to the image to attenuate the high spatial frequency noise from the image while at the same time preserving the detailed edge information of the Braille dots.

In [8], the image-processing module encompassed a variety of routines, each serving a different and crucial purpose as using random-noise reduction filter that was necessary to avoid undesired emphasis of noise.

The digitized Braille page images are noisy, and there is considerable spread in gray level values, the selection of threshold value was problematic in the histogram of Braille images are explained in [12].

In [9], preprocessing consists of two sub operations: noise filtering and edge enhancement. Noise filtering is achieved via a low-pass special Gaussian filter. Edge detection is achieved using convolution Sobel kernels.

Rawan Ismail et al. in [10] used the median filter to de-noise the image. Later on, the enhancement of dot shape is necessary. Therefore, the use of morphological operations – i.e. series of erosion and dilation operations using the disk shape- was suggested.

III. PROPOSED WORK

The main work of this paper is to enhance the braille image using various spatial domain image enhancement techniques. Braille image enhancement is an essential step in braille recognition in order to remove random noise typically consisting of sharp transitions in gray levels, irregular light and to obtain clear dot position, clear embossing of the braille dots and to highlight fine details in an image. Spatial domain filtering operations are performed directly on the pixels of an image. The process consists simply of moving the filter mask from point to point in an image. At each point (x, y), the response of the filter at that point is calculated using a predefined relationship. In this paper, the comparative studies on various image enhancement techniques using spatial domain techniques along with contrast enhancement and brightness preservation are experimentally evaluated. The filters used in this paper for smoothing are box filter, average filter, and for sharpening are median filter, Laplacian filter, unsharp masking, high boost filtering, Robert mask and sobel mask.

A. Histogram Equalization

Histogram Equalization is a technique which maps each luminance level to a new value such that the output image has approximately uniform distribution of gray levels. Histogram equalization is contrast enhancement technique in a spatial domain using histogram of an image [5].

Let the variable *r* represent the gray levels of the image to be enhanced. In the initial part of our discussion we assume that *r* has been normalized to the interval [0, 1], with r=0 representing black and r=1 representing white. Consider a discrete formulation and allow pixel values to be in the interval [0, L-1] and s is the enhanced output with a transformation of the form

$$s=T(r) \quad ; \quad 0 \leq r \leq L-1 \tag{1}$$

We assume that the transformation function T(r) satisfies the following conditions:

(a) T(r) is single-valued and monotonically increasing in the interval $0 \leq r \leq 1$; and

(b) $0 \leq T(r) \leq 1$ for $0 \leq r \leq L-1$.

The requirement in (a) that T(r) be single valued is needed to guarantee that the inverse transformation will exist, and the monotonicity condition preserves the increasing order from black to white in the output image. In Condition (b) the output gray levels will be in the same range as the input levels. Fig 2 gives an example of a

ISSN: 2319-5967
ISO 9001:2008 Certified
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transformation function that satisfies these two conditions [3]. The inverse transformation from *s* back to *r* is denoted by (2)

$$r = T^{-1}(s) \qquad ; \qquad 0 \le s \le L\text{-}1 \qquad (2)$$

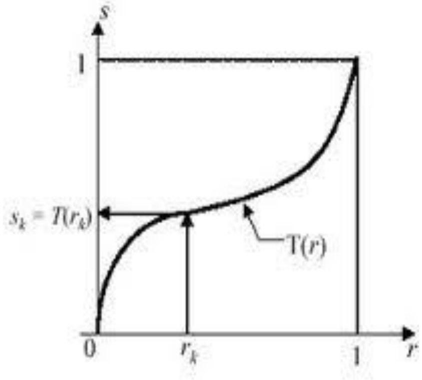

Fig: 2 A gray-level transformation function that is both single valued and monotonically increasing.

The gray levels in an image may be viewed as random variables in the interval [0, 1]. Random variables are described by its probability density function (PDF). Let pr(r) and $p_s(s)$ denote the probability density functions of random variables *r* and *s*, respectively. If pr(r) and T(r) are known and satisfies condition (a), then the probability density function ps(s) of the transformed variable *s* can be obtained using a rather simple formula

$$p_s(s) = p_r(r)\,\frac{dr}{ds} \qquad (3)$$

If $s=T(r) = (L-1)\int_0^r p_r(w)\,dw$, for $0 \le r \le 1$ represents the cumulative distribution function of random variable r. Then we have $\frac{ds}{dr} = (L\text{-}1)\, p_r(r)$, thus $p_s(s) = \frac{1}{L-1}$, $0 \le S \le L\text{-}1$

Using a transformation function equal to cumulative distribution of r produces an image whose gray levels have a uniform density, which implies an increase in the dynamic range of the pixels. For discrete values, instead of probability density function and integration we use probabilities (histogram values) and summations [3].

B. Smoothing Spatial Filter

Smoothing filters are used for blurring and for noise reduction. Blurring is used in preprocessing steps, such as removal of small details from an image prior to object extraction, and bridging of small gaps in lines or curves. Noise reduction can be accomplished by blurring with a linear filter and also by nonlinear filtering [3]. Linear filtering using box filter, weighted average filter and Gaussian filters will be discussed first and it is then followed by the non-linear filtering using median filter.

i. Box filter:

A spatial averaging filter in which all coefficients are equal is called a box filter. These types of filters are used for blurring and for noise reduction. The output of such a linear smoothing filter is simply the average of the pixels in the neighborhood of the pixel mask. The idea behind smoothing filters is straight forward. By replacing the value of every pixel in an image by the average of the gray levels in the neighborhood of the filter mask [3]. The Fig 3 shows the 3×3 box filter.

$$\frac{1}{9} * \begin{array}{|c|c|c|} \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline \end{array}$$

Fig: 3 Box filter of size 3*3

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The process results in an image with reduced 'sharp transitions' in gray levels. Hence the most obvious application of smoothing is noise reduction. Main disadvantage with such kind of filters is that they blur edges.

ii. Weighted Average filter

The weighted average filter indicates that pixels are multiplied by different coefficients by giving more weight to some pixels at the expense of others. The pixel at the center of the mask is multiplied by a higher value than any other. The other pixels are inversely weighted as a function of their distance from the center of the mask. The diagonal terms are further away from the center than the orthogonal neighbors [3].

1	2	1
2	4	2
1	2	1

$\frac{1}{16}$ *

Fig: 4 weighted average filter of size 3* 3

The Fig 4 shows the 3×3 weighted average filter. The basic strategy behind weighing the center point the highest and then reducing the value of the coefficients as a function of increasing distance from the origin is an attempt to reduce blurring in the smoothing process.

iii. Gaussian filter

Gaussian filters are a class of linear smoothing filters with the weights chosen according to the shape of a Gaussian function. The Gaussian smoothing filter is a very good filter for removing noise drawn from a normal distribution. The zero-mean Gaussian function in one dimension is

$$g(x)= e^{-\frac{x^2}{2\sigma^2}} \tag{4}$$

In (4), σ denotes the standard deviation of the distribution. For image processing, the two dimensional zero-mean discrete Gaussian function is used as a smoothing filter. It is given by

$$g[i, j] = e^{-\frac{(i^2+j^2)}{2\sigma^2}} \tag{5}$$

In (5), the Gaussian spread parameter *J* determines the width of the Gaussian. In two dimensions, Gaussian functions are rotationally symmetric therefore Gaussian smoothing filter will not bias subsequent edge detection in any particular direction. The Gaussian function has a single lobe. This means that a Gaussian filter smoothens by replacing each image pixel with a weighted average of the neighboring pixels such that the weight given to a neighbor decreases monotonically with distance from the central pixel. This property is important since an edge is a local feature in an image, and a smoothing operation that gives more significance to pixels farther away will distort the features [15].

iv. Median filter

Median Filter is a simple and non-linear filter which is based on order statistics. Median filtering is very widely used in digital image processing because it preserves edges while removing noise that are caused by the amount of intensity variation between one pixel and the other pixel. In the Fig 5 an example of median filter is shown. Here the pixel value of image is replaced with the median value [3].

		10	5	20			
		14	66	13			
		8	3	22			

3, 5, 8,10,13,14,20,22,66

Median (central value 66 is replaced by 13)

Fig: 5 median filter of size 3* 3

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The median is calculated by first sorting all the pixel values into ascending order and then replace the pixel being calculated with the middle pixel value as shown in Fig 5. If the size of the filter is chosen is even then average of two middle pixels are computed and it is used in place of the pixel to be evaluated in the original image. Median filters give better result in the presence of impulse noise since it appears as white and black dots superimposed on an image.

C. Sharpening Spatial Filters

The sharpening filters are used to highlight fine detail in an image or to enhance detail that has been blurred, either in error or as a natural effect of a particular method of image acquisition. Since averaging is analogous to integration, sharpening can be accomplished by spatial differentiation. Fundamentally, the strength of the response of a derivative operator is proportional to the degree of discontinuity of the image at the point at which the operator is applied. Thus, image differentiation enhances edges and other discontinuities and deemphasizes areas with slowly varying gray-level values [3].

i. Unsharp Masking and Highboost Filtering

Unsharp masking is a sharpening spatial filter used to sharpen images. It consists of subtracting a blurred version of an image from the original image itself [3]. The process of unsharp masking includes, blurring the original image, subtracting the blurred image from the original image resulting in mask and the mask is added to the original image. Thus unsharp masking can be expressed as

$$g_{mask}(x, y) = f(x, y) - \bar{f}(x, y) \quad (6)$$

Where, $g_{mask}(x, y)$ denotes the sharpened image and $\bar{f}(x, y)$ is a blurred version of f(x, y).
Then by adding a weighted portion of the mask to the original image we get

$$g(x,y) = f(x, y) + k * g_{mask}(x, y) \quad (7)$$

In equation (7), k is the weight. If the value of k=1, we get unsharp masking. When k > 1 high boost filtered image is obtained [7].

ii. Laplacian filter

A Laplacian filter is a second order derivative edge enhancement filter that generally highlights point, lines, and edges in the image and suppresses uniform and smoothly varying regions. The Laplacian is one of the simplest sharpening filters and it is a isotropic filter or rotation invariant [3]. A Laplacian filter forms another basis for edge detection methods. Laplacian mask which are frequently used are shown in Fig 6.

0	-1	0
-1	4	-1
0	-1	0

-1	-1	-1
-1	8	-1
-1	-1	-1

Fig: 6 Laplacian filter of size 3* 3

A Laplacian filter can be used to compute the second derivatives of an image, which measure the rate at which the first derivatives change. This helps to determine if a change in adjacent pixel values is an edge or a continuous progression. The second derivative (Laplacian) is more sensitive to changes. The Laplacian exhibits a "double edge" effect. The disadvantage is sensitivity to the noise. In detecting the edges and their orientations are increased in the noise to the image this will eventually degrade the magnitude of the edges [14].

iii. Roberts filter

The Roberts cross operator is used in image processing for edge detection. It is a non-linear edge detector filter. It was one of the first edge detectors and was initially proposed by Lawrence Roberts in 1965. Considering the intensity as a differential operator, the idea behind the Roberts cross operator is to approximate the gradient of an image through discrete differentiation which is achieved by computing the sum of the squares of the differences between diagonally adjacent pixels for edge-sharpening and isolation [3]. The Robert mask is shown in Fig 7.

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-1	0
0	-1

0	-1
-1	0

Fig: 7 Robert gross gradient operators

iv. Sobel Filter

The Sobel filter is a non-linear edge enhancement algorithm used in image processing. Technically, it is a discrete differentiation operator, computing an approximation of the gradient of the image intensity function. At each point in the image, the result of the Sobel operator is either the corresponding gradient vector or the norm of this vector. The masks in Fig 8 are called the Sobel operators.

-1	-2	-1
0	0	0
1	2	1

-1	0	1
-2	0	2
-1	0	1

Fig: 8 Laplacian filter of size 3* 3

The Sobel operator is based on convolving the image with a small, separable, and integer valued filter in horizontal and vertical direction and is therefore relatively inexpensive in terms of computations. The coefficients in the masks sum to 0, indicates that they would give a response of 0 in an area of constant intensity, since it is a derivative operator [3].

V. *Prewitt's Filter*

The Prewitt filter [3] is very similar to Sobel filter. The 3x3 total convolution mask is used to detect gradient in the X, Y directions as shown in Fig 9. Prewitt filter is a fast method for edge detection. The difference with respect to Sobel filter is the spectral response. It is only suitable for well-contrasted noiseless images [13].

-1	0	1
-1	0	1
-1	0	1

1	1	1
0	0	0
-1	-1	-1

Fig: 9 Prewitt gradient edge detector

IV. PERFORMANCE EVALUATION

Different spatial filtering techniques are applied to the scanned braille image. The performance of the filtering technique is experimentally evaluated using the quality metric Peak signal-to-noise ratio. The term peak signal-to-noise ratio (PSNR) is the ratio between the maximum possible power and the power of distorting noise that affects the quality of its representation of the image [16]. PSNR is usually expressed in terms of the logarithmic decibel scale. High value of PSNR indicates the high quality of image. To calculate the peak signal to noise ratio(PSNR) assume an input image is X(i, j) which contains $M \times N$ pixels and processed image Y(i, j). The expression used to determine the PSNR is given by

$$\text{PSNR} = 10.\log_{10}\left(\frac{\text{Max}^2}{MSE}\right) \quad (3)$$

Where, Max is the maximum gray level value of an image and MSE is the Mean Square Error. MSE is given by

$$\text{MSE} = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[X(i,j) - Y(i,j)]^2 \quad (4)$$

The mean squared error (MSE) for our practical purposes allows us to compare the true pixel values of original braille image to the degraded image. The MSE represents the average of the squares of the error between the actual image and noisy image. The error is the amount by which the values of the original image differ from the degraded image.

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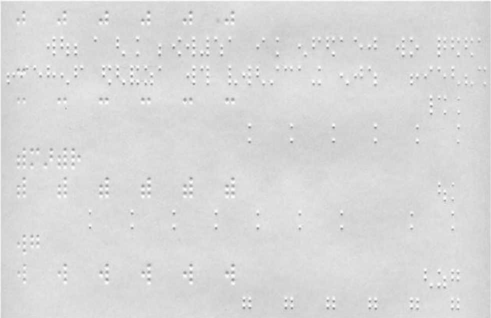
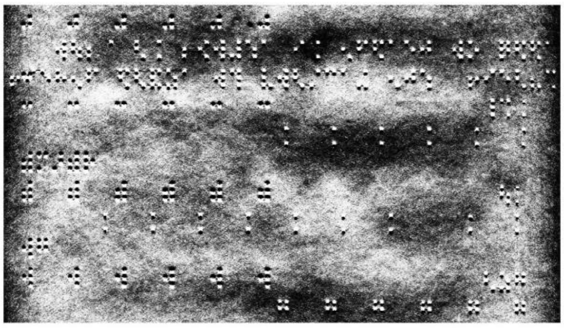
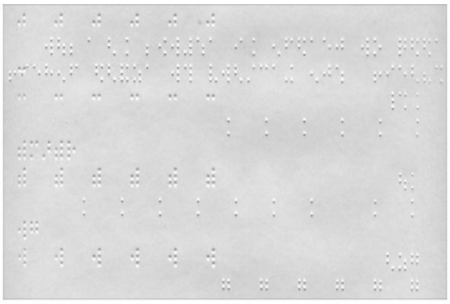


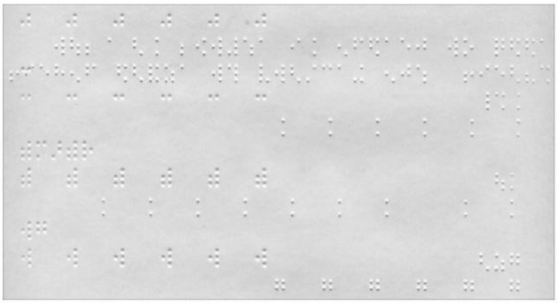
(a) Original braille image



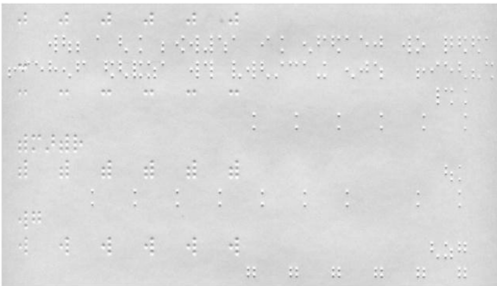
(b) Histogram equalized image



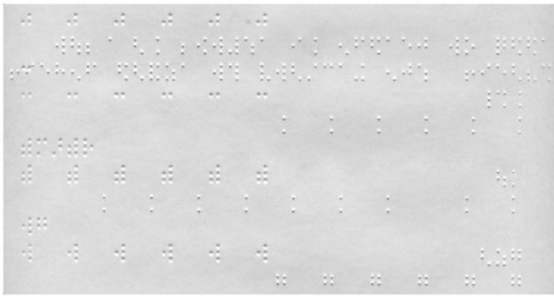
(c) Box Filtered image



(d) Weighted Average Filtered image

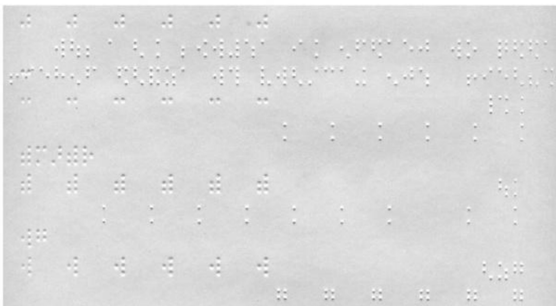


(e) Gaussian Filtered Output



(f) Median Filtered Output

(g) Unsharp masking Output



(h) Highboost Filtered Output

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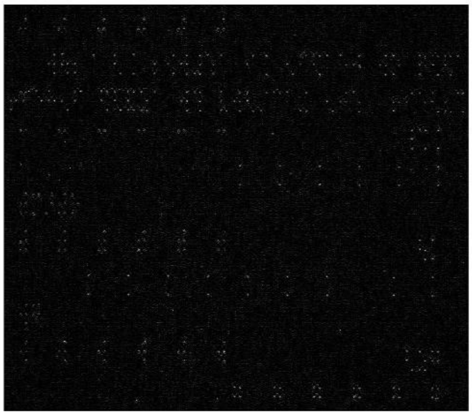
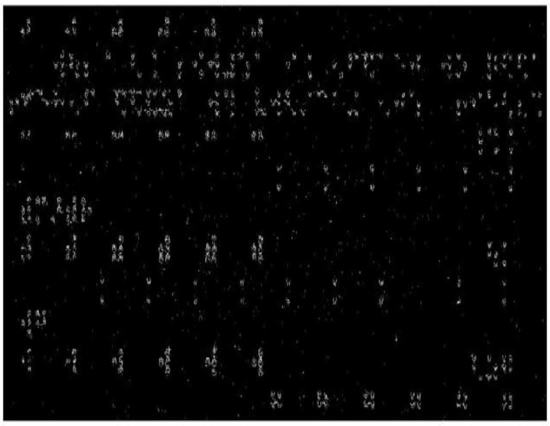
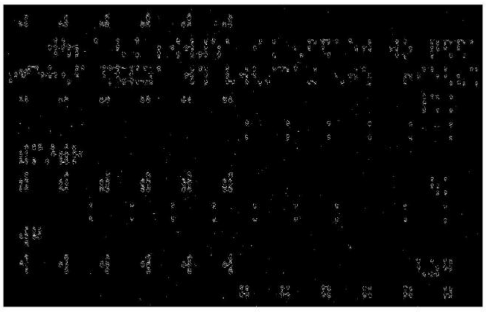


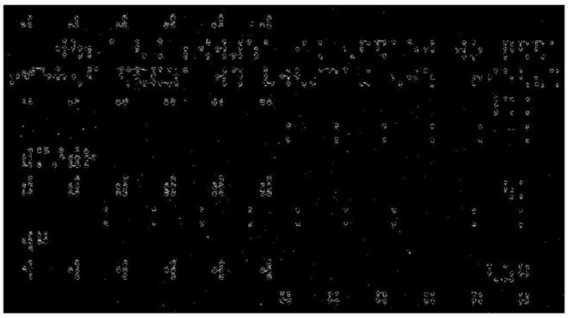
(i) Laplacian Filtered Output



(j) Edge detection using Robert



(k) Edge detection using Sobel



(l) Edge detection using Prewitt

Fig: 10 (a)The Original braille image, (b) (c) (d) (e) (f) (g) (h) (i) (j) (k) (l) the enhanced images using histogram equalization, box filter, Weighted average filter, Gaussian filter, Median filter, Unsharp masking, Highboost filtering, Laplacian filter, Roberts filter, Sobel filter and prewitt filters are shown respectively.

After histogram equalization image gets corrupted due to surrounding noise. Box filtered image Blurs both the background and foreground there by blurring the dot components also. Weighted average filter enhances the background as well as foreground and also enhances the dot information. Gaussian filtered image removes the noise due to false shadows. Median filtered image removes the impulse noise acquired during the image acquisition phase. Laplacian filter tends to extract the dot components but adds the impulse noise. Unsharp masking extracts only the dot components from the background which is not the case with high boost filtering. Edge detection techniques like Robert, sobel and prewitt operators fail to detect the correct edge information of the Braille dots as they are sensitive to the noise. The PSNR value of the various enhancement techniques is shown in Fig 11. The table.1 gives the performance comparison of the spatial domain enhancement techniques. The results obtained from MATLAB simulation shows that the performance of the Gaussian filtering is reliable for Braille image enhancement and also the subjective performance of unsharp masking is suitable for Braille dot recognition as compared to other spatial domain enhancement techniques.

ISSN: 2319-5967
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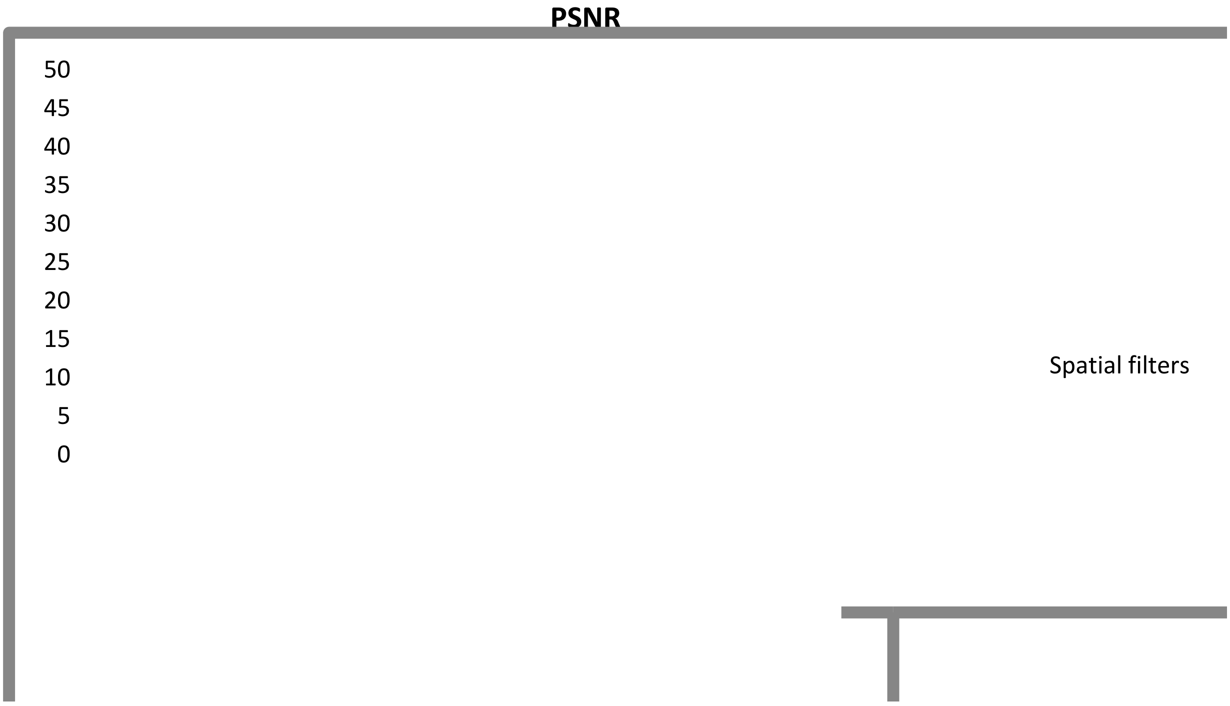

Fig: 11 PSNR values for different enhancement techniques used.

Table1. Performance Evaluation of different spatial domain image enhancement algorithms

Sl.No	Filtering technique	PSNR Measure in dB	
		3*3 mask	5*5 mask
1	Histogram equalization	7.09	7.09
2	Box filtering	34.71	31.85
3	Weighted average filtering	34.71	31.85
4	Gaussian filter	44.33	44.30
5	Median filtering	42.28	38.09
6	Unsharp masking	44.89	44.87
7	Highboost filtering	40.08	40.07

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ISO 9001:2008 Certified
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8	Laplacian filtering	1.47
	Edge detection	
9	Robert mask	1.39
10	Sobel mask	1.39
11	Prewitt operator	1.39

V. CONCLUSION

In this paper the spatial domain enhancement techniques for the braille image is studied. This comparative study reveals that the performance of Highboost filtering is relatively better than other techniques in terms of PSNR value. However it has the limitation that, it can only enhance the image but can't extract the braille image character from image. Further, unsharp masking can be used for braille dot extraction from the image but with the loss in PSNR value. As a future work we have planned to enhance the braille image using frequency domain enhancement technique as edges of the braille dots are high frequency information. Hence frequency domain enhancement technique for braille image can provide still better as compare to spatial domain.

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