Single-Sided Braille into Corresponding Text

A. Pandian, Bipasha Biswas, Abhishek Kumar

Abstract: ***The world is moving at a rate too fast for us to fathom. Our world is not functionally accessible for individual of any disability to be completely independent. For the mankind to move forward with time, a holistic approach in development can create an environment where no individual can feel overlooked. It is estimated that approximately 1.3 billion people live with some form of vision impairment out of which 36 million people are blind [1]. Without proper integration of such people in our society; every discovery, every news is creating a divide between the people whose mental abilities are impalpable otherwise. With this paper, our aim is to convert the Braille books written in regional language (in this case, Hindi) into its corresponding text format so that those people can be part of the world every Scientist, Engineer, a Visionary, every child dreamed of. In this project, a picture of braille text would be fed as an input and a series of techniques in preprocessing, Segmentation, Character Extraction, Character Recognition and Text Conversion will be applied to it resulting in an output image that will be the corresponding Hindi format of that braille text image. The main application of this could be seen in the lives of the families of the visually impaired to understand what is inscribed in the braille format, correction of the answer-script of any braille exams, cross-checking for errors in manufacturing of braille documents, and increase in opportunities for participation of visually impaired in the social section of life.***

Keywords: Character Extraction, preprocessing, Segmentation, Text Conversion.

I. INTRODUCTION

Braille is writing system invented by Louis Braille which uses the sense of touch. The reader caresses over the dots with its fingertips to recognize the pattern of dots. Every character, symbols, word of any other language are mapped to unique pattern dot. These dots are raised on a paper. A standard braille page is 11 x 11 inches with a maximum of 25 lines per page accommodating 40-42 braille cells per line. The dot height is 0.5 mm and horizontal and vertical spacing is about 2.5 mm between the dots. The whitespace between the dots of the adjacent cell horizontally is 3.5 mm and 5mm vertically. There are two formats for braille: single side of a sheet or both side of a braille sheet (inter-point braille). More information can be accommodated on the inter-point braille, where the dots are punched on both sides of the sheet with a slight diagonal offset. According to the encoding used the braille can be divided into three categories. The grade 1 braille, corresponds each cell to a character. Grade 2 braille aims to represent each cell to a group of characters. Grade 3 braille uses their own dialect of code. It is a non-standardized format. This project aims to convert regional Hindi language braille to its speech. This project comes under the domain of natural language processing. Optical braille recognition system involves Braille image acquisition, braille image pre-processing, braille dot segmentation, braille dot recognition and conversion into natural language characters.

II. RELATED WORK

There are many researchers who have worked on the optical braille recognition system for visually impaired. T. D. S. H. Perera, and W. K. I. L. Wanniarachchi [2] proposed a system on optical braille translator for Sinhala language braille. The research work was based on technique where various algorithm was implemented on MATLAB environment. Various image processing techniques like erosion, dilation, image subtraction was performed before converting gray-scale image into Binary image. For image enhancement hole-filling and noise reduction techniques were carried out. The braille characters were also correctly aligned. Row summation was used to identify the average vertical distance between two rows. For braille character segmentation a computer algorithm was developed to find the approximate vertical and horizontal position of characters automatically. It translates Sinhala braille to Sinhala language and grade1 braille to English with 99% of accuracy. It was also capable of recognizing numbers both in Sinhala and English.

Gabriel B. Holandaa, João Wellington M. Souzaa, Daniel A. Limaa, Leandro B. Marinhoa, Anaxágoras M. Girãob, João Batista Bezerra Frotab, Pedro P. Rebouças Filhoa [3] presented an OCR system on android platforms to aid reading with a refreshable braille display in real time. Low-pass filter were used to eliminate and reduce noise in the pre-processing step. To perform a balanced segmentation region growing and watershed segmentation similarity methods and connected object and connected contours for discontinuance were used. Five pattern recognition techniques were used. Among them was K-nearest neighbor algorithm, Support vector machine model for classification and regression analysis, the Bayesian decision theory for pattern classification, the optimum-path forest algorithm, multi-layer perceptron was used. The methods used resulted in more than 98% accuracy and remained stable with lower standard deviation. N.D.S.M.K.De Silva, S Vasanthapriyan [4] used gaussian blur for noise removal in their pre-processing stage. Adaptive thresholding was done using Otsu's method for image binarization. To perform smoothing operations, a filter can be applied to input image using Emgucv. Gamma correction was done on gray image to increase details of the braille dots. Sharp braille dots were obtained using erosion. Braille cell segmentation was performed using Diacritic mapping was used.

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The system created was cost-effective and did not require high processing power hardware or complicated equipment.
Shafaf Ibrahim, Nor Azrin Tarmizi, Nurbaity Sabri, Nur Farahin Mohd Johari,Ahmad Firdaus Ahmad Fadzil [5] proposed a system for braille image recognition with the accuracy of 97.44 % .For data pre-processing ,a technique of unsharp masking is implemented. Converting the RGB image into grayscale carries intensity information. For feature extraction bag of features were used and stored in the database. K-Means clustering and speeded up robust features were used for efficiency in the feature extraction. A blob detector which is based on Hessian matric was used to detect the interest points. Support vector machine classifier was used for image classification. Vishwanath Venkatesh Murthy, M Hanumanthappa [6] aimed to improve optical braille recognition in the pre-processing stage. Histogram equalization, linear and smoothing spatial filter, Box filter, weighted average filter, Gaussian filter, Median filter, Sharpening Spatial filters, Unsharp masking and high boost filtering, Laplacian filter, Roberts filter, Sobel Filter, Prewitt's filter have been applied to remove the impulse in the braille image pre-processing technique. All these techniques lead to high computation time.
AbdulMalik AlSalman, Ali El-Zaart, Saleh Al-Salman, Abdu Gumaei [7] used Between-Class Variance with a mixture of Gamma distributions as a new method for segmentation. It solves the issue of non-symmetric histogram of Braille images. To reduce the computational time and to find the optimal threshold value they have applied this method iteratively. Joko Subur, Tri Arief Sardjono, Ronny Mardiyanto [8] uses Find Contour technique for Braille Character recognition. The find contour technique aims to get the contour of the black dots on the image dot Braille. The accuracy level achieved is 100% on the image of 0 degrees to 0.5 degrees. The accuracy level decreases when the image is tilted more than 1 degree. Kirill Smelyakov, Anastasiya Chupryna, Dmytro Yeremenko, Anton Sakhon, Vitalii Polezhai [9] researched an Optical Braille character recognition system using artificial neural networks method. Multilayer perceptron was used by the system at its basics which was implemented using modified Backpropagation algorithm. This reduces the convergence time and has a good performance rate. Bindhu K Rajan and Anjitha [10] V proposed a method for converting Braille code to Malayalam voice message using MATLAB for implementation. In this image enhancement is done to remove the unwanted dots. For image filtering Gaussian Filter has been used as it removes the unwanted dots and smoothens the scanned image. Profiling is used for image segmentation. Profiling is used to store the number of foreground pixel. Erosion and dilation is done to detect the image features. Once the feature extraction is done, the recognition of each character is performed by comparing the segmented Braille characters with database. Shreekanth, T, Udayashankara, V. [11] proposed a two stage segmentation technique for segmenting the inter-point braille dots into recto and verso dots. Distance thresholding along with horizontal and vertical projection profile are integrated to perform character segmentation. For line segmentation horizontal projection profile method is used.

III. EXPERIMENTAL PROCEDURE

This section discusses about the suitable methods for implementation with previous researcher's knowledge. This section states the step by step methodology and sub-categorizes the methodological process and techniques used.

Initially an input image of a braille document is acquired through Image acquisition. The input image then undergoes pre-processing which includes conversion of RGB image to gray scale image, Noise removal and image binarization, edge detection and sharpening. After the input image has been processed it undergoes segmentation which includes line, word and character level segmentation.

A.Image Acquisition

It is the first step to acquire the image. It is the manual step in which a Braille document was scanned by a scanner or an image of the Braille document captured by a mobile camera was used. Images that are taken by camera lead to occur irregular lighting, relatively low resolution problems and scanners create impulse noise in the image and that noise leads to different grey-level values and produce a high spatial frequency so the ways that researchers supposed to pre-process the Braille image include converting Red ,Green ,Blue RGB image to grayscale image, Gaussian filtering, median filtering, erosion, and dilation. Thus, the time and accuracy taken to translate the braille document depends on the quality of the image scanned.

B. Image Pre-Processing

The image pre-processing step describes the several steps to enhance and correct the several attributes of the input image.

a) Grayscale Conversion

After this image is converted to gray scale image. Since color images have three mediums to represent image pixel values (red, green and blue) converting the RGB image to grayscale makes image processing easier. The following equation is used to do the grayscale conversion.

$$Y = 0.3 \times R + 0.59 \times G + 0.11 \times B \qquad (1)$$

Y is corresponding pixel gray value which contain 0-255 value range with single channel. R,G,B represent the color Red, Green, Blue respectively. According to the equation, the color Red has a contribution of 30% Green has the highest contribution in all the three colors that is 59% and blue has contributed 11%.

b) Noise Removal

In this system, Bit plane slicing techniques is used. It emphasizes on the contribution made by specific bits to the total appearance of the image. Bit planes of the 8-bit gray scale image can be used as representation extending from bit plane 0 for the least significant bit(LSB) to bit plane 7 for the significant bit (MSB).In terms of 8-bits byte, all lower order bits are contained in plane 0 and all higher order bits are contained in plane 7.As compared to methods used by other researchers

[2],[3], the advantage of this techniques is that helps in visualizing the vital information contained in every little bit of image.

In this procedure, the input Braille image is read. The image is converted to gray scale image if it is a color image. After the grayscale conversion each pixel of the image is converted to the binary form. Once the image is converted into binary form Bit-plane slicing of the image is performed. In this work only the top Bit-plane is considered since experimentally it was found that it envisioned more information regarding the braille dots and was valid for various resolution. The thresholding function for extracting bit-plane 7 is defined in Eq.2 for the 8 -bit image.

$$T(s7) = \begin{cases} 1, & 128 \le f(x,y) \le 255 \\ 0, & 0 \le f(x,y) \le 127 \end{cases} \quad (2)$$

Where, $f(x, y)$ is the input gray level image, T (s7) the thresholding function for the respective bit planes. The image is then reconstructed using only the bit plane 7 using Eq. (2).

A fragment of the original scanned Braille image and bit-plane sliced of the single braille document is showed below in fig.2 and fig.3.

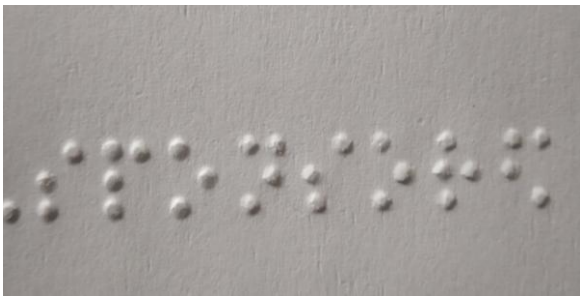


Fig.1 Fragment of an Original Scanned Braille document

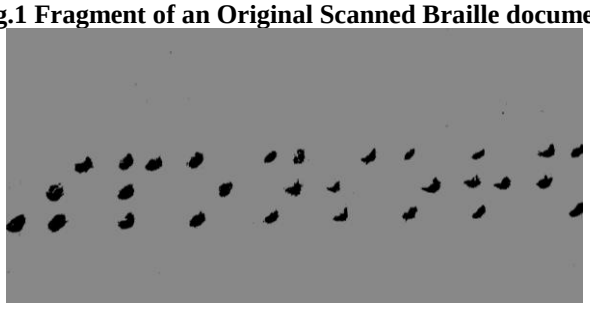


Fig.2. Reconstructed Image using only Bit Plane 7

c) Image Binarization

For image binarization, we use Otsu's thresholding method. Arbitrary chosen value is used as a threshold in global threshold but Otsu's method avoids choosing a value and determines the value automatically. The following equation shows Otsu's algorithm which tries to find a threshold value (t) which minimizes the weight within-class variance while working with Bimodal Images.

$$\sigma^2_{\omega}(t) = q_1(t)\sigma_1^2(t) + q_2(t)\sigma_1^2(t) \quad (3)$$

From the algorithm it takes the middle of those histogram peaks and calculate the within-class variance.

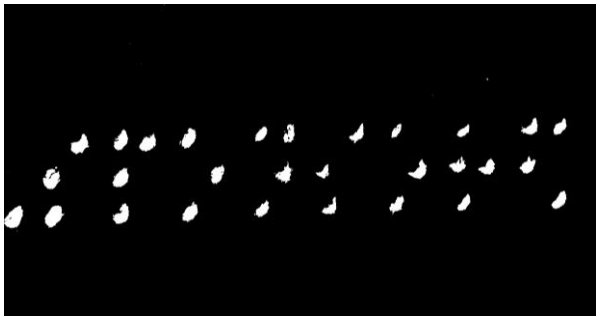


Fig. 3 Bit Plane 7 thresholded image using Adaptive Otsu's thresholding method.

d) Edge detection and sharpening

Once the Luminance of the image is corrected Erosion and dilation is done using Morphological function to make the edges of the braille dots sharp.

Erosion shrinks an image by stripping away a layer of pixels from both the inner and outer boundaries of the regions.

The holes and gaps between regions become larger and small details are eliminated.

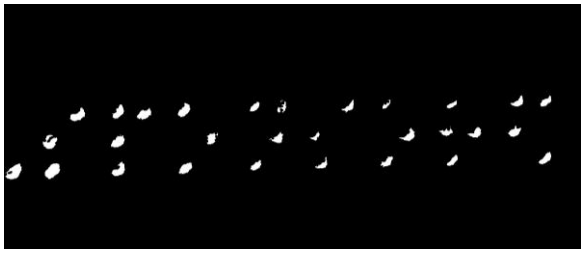


Fig 4 Eroded image

Dilation has the opposite effect to erosion -- it adds a layer of pixels to both the inner and outer boundaries of regions. The holes enclosed by a single region and gaps between different regions become smaller, and small intrusions into boundaries of a region are filled in.

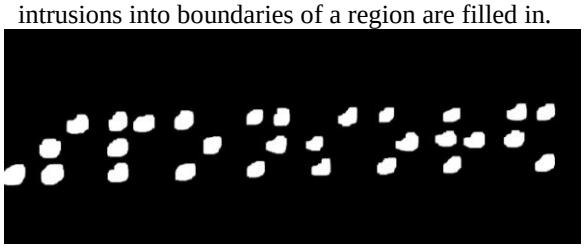


Fig 5 Dilated image

C.Braille cell segmentation

As given in fig.6 , the distance between the two centers of adjacent dots in a particular cell is 2.5 mm both vertically and horizontally.

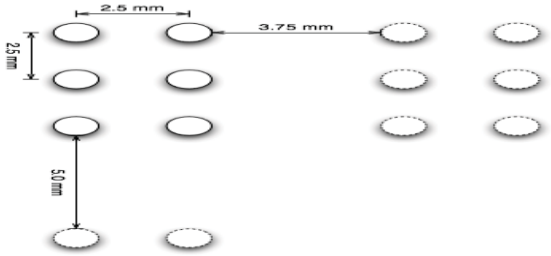


Fig.6. Braille cell with its Dimensions

The segmentation of the braille image is done in the following sequence: 1) Line level segmentation 2) Word level segmentation 3) Character level segmentation.

IV. RESULT AND DISCUSSION

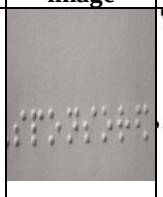
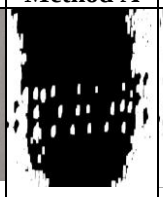
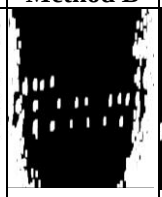
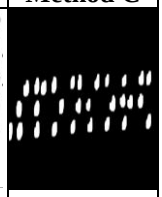
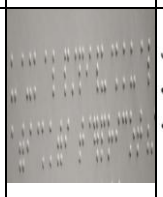
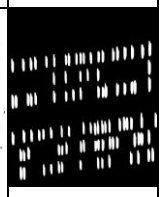
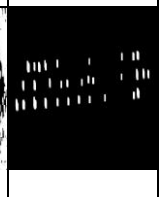
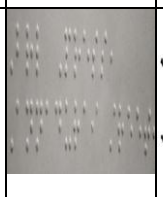
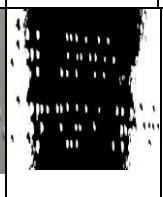
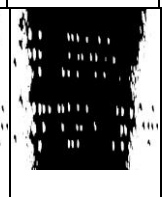
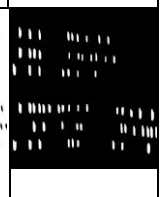
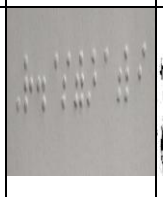
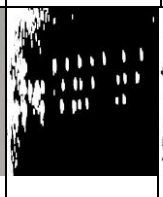
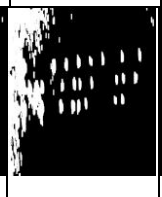
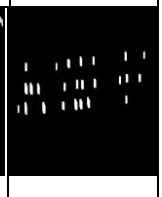
To evaluate the methods and techniques, Scanned Braille pages were used. Most of the techniques used were successfully executed. For implementation, OpenCv Python has been used.

Challenges faced while processing the model were finding the appropriate data for acquisition, finding the right set of pre-processing techniques to give the desired and accurate results.

The below table shows the output and analysis of the various methods tested and applied to get the required image.

The methods tested for noise removal from the converted gray scale image followed by thresholding, erosion and dilation are 1) Gaussian Blur filter 2) Median blur filter 3) Bit-plane slicing.

Table-I: Output analysis of dataset

S.no	Input image	Output Method A	Output Method B	Output Method C
1.				
2.				
3.				
4.				
5.				

***Input images** – Dataset images
***Output Method A**- Gaussian blur filtering
***Output Method B**- Median Blur filtering
***Output Method C**- Bit-plane slicing

Table-I demonstrates the output of 5 sample dataset images out of the 10 images chosen as dataset who have undergone the three methods as stated above. Similar results were obtained from the other 5 dataset images. Table – II shows the observed Average time take by the three method for processing each of the given input image.

Table -II: Processing time for each method

Input	TIME(s)		
	Method A	Method B	Method C
Image 1	0.04401062	0.12664604	7.04325204
Image 2	0.03914672	0.08849822	15.0506945
Image 3	0.03736146	0.07749782	2.94120696
Image 4	0.03736146	0.09823284	4.84477182
Image 5	0.0363745	0.06529452	2.38341184

***Input (as given in Table-I)** – Dataset images
***Output Method A**- Gaussian blur filtering
***Output Method B**- Median Blur filtering
***Output Method C**- Bit-plane slicing

From Table-II we can see that time taken by Method C that is the Bit-plane slicing method takes the highest processing time among the three methods compared. Method A (Gaussian filter) takes the lowest time for processing the image.

Table -III: Observations from Different methods

S.no	Gaussian Filter	Median Filter	Bit-Plane slicing
1.	Details of the Braille dots at the corner and edges or sides of the image are lost or distorted.	As compared to Gaussian Blur, more number of pixels of the Braille dots are lost or distorted at the edges and the corners of the image.	Most of the details of the Braille dots are retained, that is lesser number of Dot pixel lost.
2.	Noise pixels in the image is removed only to some extent. Most of the noise are still retained at the edges and the corners.	Presence of noise pixel is more as compared to Gaussian filter thus resulting into more loss of pixels and braille dot details.	Most of the noise are removed from the image giving a sharper and clearer output.
3	Lowest processing time as compared to other two methods.	Low processing time as compared to Bit-Plane slicing.	Highest processing time among the three methods tested.
4.	Comparative lesser sharper details of Braille dots.	Lesser sharp details of braille dots as compared to gaussian filter and Bit-plane slicing.	The Braille dots are much sharper and enhanced.

Thus, from Table-II, and Table-III, though time taken by Bit-Plane slicing method is highest among the three methods pre-processing using Bit-plane slicing is more accurate as compared to the other methods tested. Most of the Noises from the image were removed irrespective of the image's resolution. Details of the dots were retained and the minimalistic loss of pixels from the Braille dots was observed.

Hence, noise in data and loss of important data while pre-processing was successfully resolved using Bit-plane slicing and Morphological functions (erosion and dilation) and image was pre-processed with the help of Adaptive thresholding Otsu method.

V. CONCLUSION

In this paper, we have attempted to investigate various techniques of preprocessing of image and how these functions respond to various parameters of the equation with respect to the input image. With this trial and error, we reached to a conclusion that for most of the images, bit-plane slicing method was producing the most accurate results for various lighting conditions and resolutions of the input braille image. The major difficulty that led us to tweak the parameters to the finest and also to try various other methods, is the problem with the quality of input image. Low background lighting led to a bad quality image that eventually increases the errors in the pre-processing of the image. Various methods other than bit-plane splicing led to loss of braille dots from the image while removing noise from the image due to improper lighting. We decided to choose bit-plane splicing despite the greater computation time as compared to median and gaussian filters due to the above mentioned reason. Morphological functions like Erosion and Dilation had been used followed by adaptive thresholding Otsu's method for resolving the issues and complete the pre-processing of image.

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