A Review of Optical Braille Recognition

Samer Isayed and Radwan Tahboub

Deanship of Scientific Research
Master of Informatics
Palestine Polytechnic University
Hebron, Palestine
{samers, radwant} @ppu.edu

Abstract—The process to take a Braille document image and convert its content into its equivalent natural language characters, is called Optical Braille Recognition (OBR). It involves two main consecutive steps: Braille cell recognition and Braille cell transcription. Braille cell recognition contains few steps including: Image acquisition, Image De-skewing, Image pre-processing, dot recognition, cell recognition and segmentation. Image transcription aims to convert the segmented Braille cell, into its equivalent natural language characters. In this survey we aim to study the earlier works done by other researchers on both Braille cell recognition and transcription.

Index Terms—Braille, Braille Recognition, Image Processing, Neural Network, Support Vector Machine.

1 Introduction

There are approximately 285 million blind and visually impaired people globally, where 39 million are blind and 246 are visually impaired, as stated by World Health Organization in 2014 [1]. Those blind and visually impaired people contribute efficiently to the society, despite their disabilities. But they face a challenge expressing their contributions, because they use a different scripting language, which makes the smooth flow of information between them and the sighted people a stiff challenge. Braille which was founded by a french teacher "Louis Braille" in 1824, is a binary system of reading and writing used by people who are blind, where they feel raised dots on a Braille page with tips of their fingers. The Braille script is made of cells, each cell contains six raised dots that arranged in three rows and two columns as can be seen in Figure 1, these six dots can be *raised* or *flat* according to the Braille character, so these dots are combined to give $2^6 = 64$ different combinations (including the empty Braille character "space").

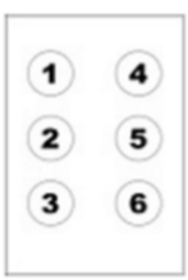


Figure -1
Braille cell

Optical Braille recognition is a computer algorithm, which attempts to automate the process of acquiring and processing Braille documents image, in order to convert it into its corresponding natural language characters, it involves two main steps: segment the Braille characters; and then convert this segmented character into its equivalent natural language character.

The dimensions of a Braille dot have been set according to the tactile resolution of the person's fingertips. The horizontal and vertical distance between dots in a character and the distance between cells that represent a word are known. Dot height is approximately 0.02 inches (0.5 mm); the horizontal and vertical spacing between dot centers within a Braille cell is approximately 0.1 inches (2.5 mm); the blank space between dots on adjacent cells is approximately 0.15 inches (3.75 mm) horizontally and 0.2 inches (5.0 mm) vertically. A standard Braille page is 11 inches by 11.5 inches and typically has a maximum of 40 to 43 Braille cells per line and 25 lines.as shown in Figure 2 [2].

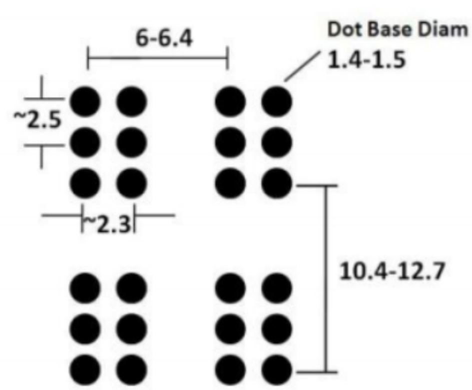


Figure -2
Braille cell dimensions

It is clear that the size of the Braille paper is limited and a method is needed to better utilize the size of the Braille paper, this utilization of the Braille paper can be

978-1-4799-8172-4/15/$31.00 ©2015 IEEE

achieved by forming a double-sided Braille paper, which will contain Braille dots on both sides; with a small diagonal offset between the two sides to prevent interfering between them. This technique is known as *Inter-point Braille*. Figure 3 (a) shows a single sided Braille paper, Figure 3 (b) shows a double sided Braille paper [3].

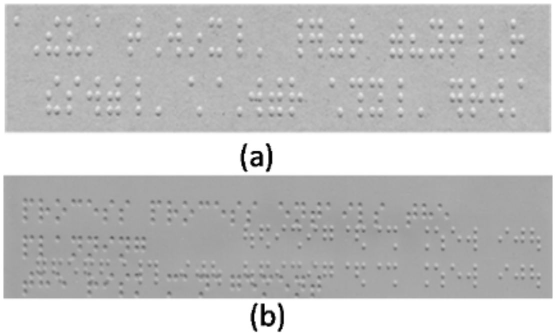


Figure -3
(a) Single sided Braille paper
(b) Double sided Braille paper

The size of a Braille paper can also be utilized by making a cell represents not only a character, but a word or a sentence. So the Braille language consists of three grades: *Grade 1:* in this grade each Braille cell represents a single language character, a word is made up of a combination of Braille cells. *Grade 2:* is like grade 1 but with some abbreviations and contractions. *Grade 3:* is the most complicated grade of Braille which combines complex phrases and sentences. Figure 4 shows grade 1 for English language [4].

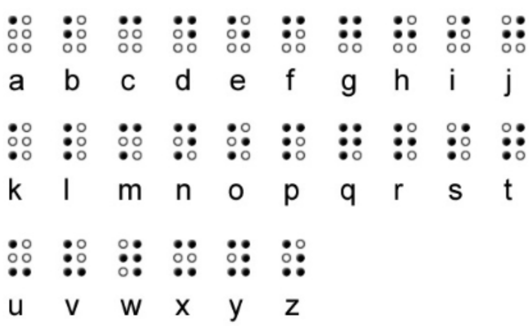


Figure -4
Grade 1 Braille

2 Methodology of optical Braille recognition

In this section we will describe the different techniques used in order to solve the optical Braille recognition system. The general methodology for optical Braille recognition is shown in Figure 5 [5]. It involves a sequence of steps including: Image Acquisition, Image pre-processing, Image segmentation, Dot recognition and Braille cell translation.

2.1 Image Acquisition

Image Acquisition technique is a vital stage of optical Braille recognition system. This stage can be achieved using a

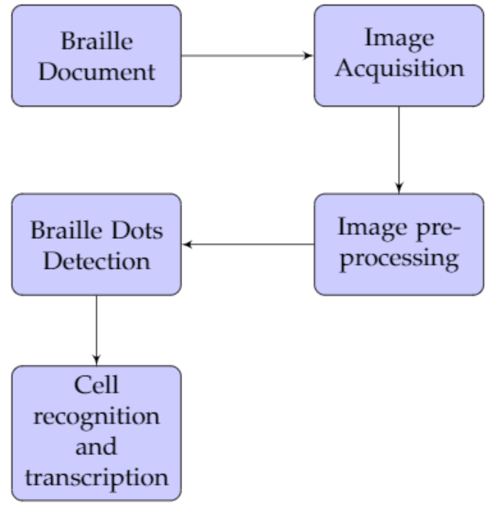


Figure -5
General Methodology

variety of techniques including portable devices; mobile phones; cameras [6], [7] or scanners [2–5], [8–27] or with a special equipments [12], [28]. Most of the researchers use the scanner as there acquisition technique, because it can solve the use of cameras problems in term of complex camera setup, low resolution, illumination problems and the misplacement of Braille dots. The use of scanner gives better results in term of Braille dots alignment and a better resolution. The scanner is attached with a single common light source, that makes the detection of Braille dots in a single side or double sided Braille papers easy.

2.2 Image Pre-processing

The acquired Braille images are still not perfect and it need some enhancements to be processed to the next stage in optical Braille recognition system. This enhancements can be achieved by using a sequence of image pre-processing techniques. Previous researchers focus on using a number of image processing techniques in order to enhance the acquired Braille image includes converting the image from RGB colored image to gray scale image that will make the further processing easy, because the three components of the color (Red, Green, Blue) will be compressed into one component. This process can be done by using the following equation :

$$Y = 0.3 \times R + 0.59 \times G + 0.11 \times B \tag{1}$$

Where R is the red component, G is the green component and B component of the image.

After converting the image into gray scale a noise removal algorithms was proposed using a number of different algorithms, the effort done by previous researchers in term of image noise removal includes increasing the brightness of the Braille image by Kumar et al. [9] and Jie Li et al. [14], while Shreekanth et al. [15] uses the algorithm of median filter; which uses a 3X3 window and then calculate the center pixel value according to the median of the pixels in 3X3 window, salt and peeper noise removal algorithm introduced by Wajid et al. [13]; which can be used to remove unwanted noise.

After noise filtering, another problem has to be solved in image pre-processing before stating with Braille dots recognition. While Braille cell dots are aligned in vertical and horizontal fashion, this alignment of Braille dots can be distributed as shown in Figure 6 (a). This distribution caused either by acquisition error in the acquisition machine or due to human error while acquiring the Braille page. This problem will lead to errors through the later processing stages. This problem is known as *skewing* problem, and it can be solved using a variety of techniques including rotating the image to an angle that rearranges the Braille dots as Figure 6 (b) shows [3].

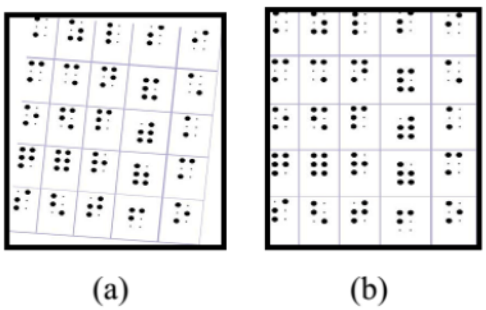


Figure -6
(a) Skewed scanned Braille image
(b) Scanned Braille image after De-skewing process

Other techniques were proposed to solve the image skew angle problem including: *Linear regression method* [26] which aims to find the best line that fit the Braille dots,the form of the linear regression will be $Y = BX + A$. And the value of B can be determined by using the following equation:

$$B = \frac{n\sum_{i=1}^{n} x_i y_i - (\sum_{i=1}^{n} x_i)(\sum_{i=1}^{n} y_i)}{n\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2} \tag{2}$$

Where x_i and y_i represents the the coordinates of the image and n represents the number of pixels in the image.

Another method solves the skewing problem using the *Standard deviation* proposed by Babadi et al. [26] and Hassen et al. [23]. In this method, each time the image is rotated by an angle θ and a new value of $\bar{x}$ and s will be calculated for each row, the best value of θ will be calculated according to the highest value of s. The calculation of the standard equation can be done using the following equations:

$$s = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x - \bar{x})^2} \tag{3}$$

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{4}$$

Also the *Hough transform* algorithm can be used to solve this problem which was introduced by Antonacopoulos and Bridson in [10]. Another technique suggests to use the *sum over rows,* the image was rotated within an angle. And the image was rotated one pixel vertically, sum of rows was calculated each time, the maximum number is obtained when the dots were aligned horizontally this algorithm was introduced by Al-Salman et al. [3], [22].

2.3 Braille Dots Detection

The process of separating the Braille dots from background to then group them into cells will produce a binary image that is essential for the further transcription process. Researches attempt to solve this problem using different algorithms:*static threasholding* was used to detect Braille dots depending on the image histogram, which was introduced by Kumar et al. [9] and Al-Shamma et al. [17]. While Shanjun et al. [6] attempts to solve the problem by using a dynamic local threasholding technique in order to separate dots from background, other researchers who use a double-sided Braille paper attempts to solve the problem by taking the advantage of the shadows presented by the Braille dots in order to divide the Braille image into three classes: {Bright, Dark and Background}. These classes are used to separate the front side Braille dots (verso) and the back side Braille dots (recto) from background. Antonacopoulos et al. [10] and Kumar et al. [9] use a fixed local threasholding to solve the problem in double sided Braille document, Al-Salman et al. [16] uses a static threasholding algorithm by dividing the braille image into three classes (Dark, Bright, Grey) using static values of image gray level. While Shreekanth et al. [15] use the eight connected components based on pixel count in each connected component to solve the problem. A novel dynamic threasholding algorithm introduced by Al-Salman et al. [3], [22] that attempts to estimated threshold values using Between Class Variance with a mixture of Beta distributions, beta distribution is a continuous probability distribution with the probability density function (pdf) defined on the interval from 0 to 1. Each beta distribution can be calculated using the following equation [29]:

$$f(x, \alpha, \beta) = \frac{\Gamma(\alpha + \beta)}{\Gamma(\alpha)\Gamma(\beta)} x^{\alpha-1}(1-x)^{\beta-1} \tag{5}$$

Where α and β determine the shape for the distribution , and there value must be between 0 and 1. Then the histogram $h(x)$ for the image can be determined using the following equation [3]:

$$h(x) = P_1 f(x, \alpha_1, \beta_1) + P_2 f(x, \alpha_2, \beta_2) + P_3 f(x, \alpha_3, \beta_3) \tag{6}$$

And then a new value of threashold T^{new}, i=1,2 is calculated. Another approach was introduced by Morgavi and Morando [20], which identifies the possible dot by using the cross-correlation of the rectangular matrix with the matrix containing the ideal dot. Another efforts in Braille cell segmentation was presented by Wajid et al. [13] that converts the pre-processed Braille image into a column matrix, which can be then used in order to find the start and the end of a Braille cell. Other reaserachers tries to use artificial intelligence algorithms in order to seperate the braille dots from background, Li and Yan in [14], [27] uses Support Vector Machine (SVM) algorithm in order to segment the Braille dots with some positive data samples and some negative data samples .

After noise filtering, some researchers also use different edge detection algorithms; in order to separate the dots from background; the resulting image will be in black and white, and this will decrease the information withing the Braille image which will make the further processing easier, algorithms such as canny edge detection used by Al-Shamma et al. [17] and it gives good results in dots detection, while [25] uses the sobel edge detection algorithm.

Morphology operations including a series of image dilation and erosion was introduced by Shreekanth et al. [15] and Al-Shamma et al. [17]; which can be applied on a binary image in order to remove unwanted noise.

2.4 Cell Recognition and Transcription

The main purpose for this stage is to group and collect the segmented Braille dots into cells, and then to convert that cell into its corresponding natural language character. Most of the researchers efforts in dots recognition and conversion techniques was to use the idea of dividing each cell into *grids* consisting of six parts and corresponding code for each cell was generated according to the presence or absence of a dot in each grid depending on the Braille cell placement which was introduced in section 1. Another approach for cell recognition and transcription was proposed by Shreekanth et al. in [15] and Padmavathi et al. in [4] using an Adaptive Grid Construction method, which can be applied to any Braille document by considering the factors of the Braille image: horizontal projection and vertical projection profiles, the main idea behind their work is to sum the pixels horizontally and vertically to group the Braille dots as shown in Figure 7.

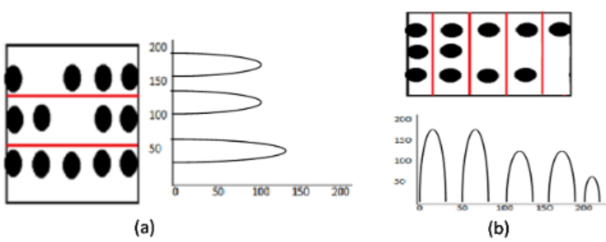


Figure -7
(a) Horizontal projection profiling
(b) Vertical projection profiling

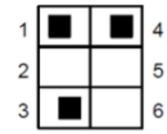
This will give a binary code from each Braille cell. This binary codes is then converted into a decimal code. Zhang et al. [6], Kumar et al. [21], Shreekanth et al. [15] introduces a method for converting this decimal code by using the following expression:

$$\text{Decimal code} = \sum_{i=1}^{6} b_i \times 2^i \tag{7}$$

where b_i represents the Braille dots positions, Figure 8 shows an example for the proposed decimal conversion [5].

3 DISCUSSION AND SUMMARY

In this section, we present a discussion related to the optical Braille recognition methods that we present. First, we make a comparison between the different optical Braille recognition methods, and then a summary table that differentiate different optical Braille recognition algorithms.



(a)

Dot Position	1	2	3	4	5	6
Binary number	1	0	1	1	0	0
Decimal code	13					

(b)

Figure -8
(a) Braille Cell
(b) Equivilent binary and decimal codes

3.1 Comparison of Optical Braille Recognition techniques

In this section, we make a comparison between the methods that we present in this paper. The comparison based on a set of criterias, including: *Image acquisition technique:* shows the image acquisition techniques that were used. *Single side or Double-sided Braille image:* shows the Braille document class that was processed. *Image pre-processing techniques:* lists the set of the image pre-processing techniques that were used. *Braille Dots Detection techniques:* lists the set of the segmentation steps to separate the dots from background. *Transcription techniques:* describes how to obtain the braille cell and translate it into natural language character.

Image Acquisition Techniques: We have found that, the acquisition techniques used are similar with most researchers, most of the researchers use a flatted scanner as there image acquisition technique [2–5], [8–27]; because it can give a good dot placement that can be processed easily in the next recognition steps, it has also the advantage of the shadow created by the scanner source light; which can be then used to detect Braille dots. Some researchers use mobile cameras [6], [7] as image acquisition technique, but it fails to get good quality Braille image. Some researchers use special devices for image acquisition, but it also fails because of the special device availability.

Single side or Double-sided Braille Image: We have found that, more of the researchers use a double-sided which was used in [2], [3], [5], [7], [8], [10], [14–20], [22], [25–27] rather than single side which was used in [4], [6], [7], [9], [11–13], [21], [23], [24] Braille papers as their Braille paper sample, because most of the Braille documents are available in double-sided papers and they find it a challenge separating the front dots from the back dots in a single scan.

Image pre-processing Techniques: We have found that, the image pre-processing techniques used are similar for most researchers, including: converting the Braille image into gray-scale. De-noising the image using some image blur techniques. Correct the skew angle of the Braille image using different algorithms such as Hough Transform and image rotation.

Braille Dots Detection Techniques: We have found that, the Braille dots detection techniques used are similar for most researchers which includes converting the Braille image into binary image by using a threashold, this threashold calculation can be dynamic or static, or by using a multi-

TABLE 1: Comparison between different optical Braille recognition algorithms, in terms of publishing year, image acquisition techniques, Single side or double sided Braille page,Image pre-processing techniques.

Paper	Year	Acquisition technique	Single/double sided	Pre-processing techniques
[6]	2007	Mobile Camera	Single side	Denoisng using connected components converting image into gray scale
[20]	2002	Scanner	Double sided	increase brightness (noise removal)
[21]	2014	Scanner	Single side	RGB to grayscale image noise removal by increase the brightness Morphology operations dilation and erosion
[10]	2004	Scanner	Single side	RGB to grayscale image skew angle correction using hough transform
[14]	2010	Scanner	Double sided	RGB to grayscale image brightness adjustment geometric adjustment
[4]	2013	Scanner & Keypad	Single side	Blur the image to remove noise Morphology operations (openning and closing)
[17]	2010	Scanner	Double sided	RGB to grayscale image

TABLE 2: comparison between different optical Braille recognition algorithms,in terms of Braille Dots Detection techniques, Cell Recognition and Translation, the results and the process speed.

Paper	Dots Detection techniques	Cell Recognition technique	Transcription technique	Results	Speed/page
[6]	Dynamic local threasholding	Placement of braille dots	Binary digital with lookup table	N/A	2 sec
[20]	Cross-correlation approach for dots detection	Multilayer Perceptron Neural Network	Binary digital with lookup table	98%	N/A
[21]	using horizantal and vertical lines(from start of the cell till the end)	combine multiple horizantal and vertical lines to form a character	Binary digital with lookup table	98%	30s
[10]	local dynamic threasholding to separate dots into three classes	placement of Braille dots	Binary digital with 6 bits	95%	N/A
[14]	Binary module by taking a window to crop from the image a sub image the size of a Braille dot SVM classifier to detect dots	placement of Braille dots	searching algorithm and a look-up table	95%	N/A
[4]	Calculate threashold using image histogram	Using horizantal and vertical projection profiling	Binary Vector	98.90%	N/A
[17]	Filling the Braille dots Edge detection using canny edge detector	Placement of braille dots	Decimal code with lookup table	N/A	32.6s using Matlab

level threasholding techniques. Other researchers use class variance with a mixture of Beta distribution for separating the Braille dots from background.

Cell Recognition and Translation: We have found that, the image segmentation techniques, used to detect and group the detected Braille dots. The image processing techniques focus on using the Braille dots placement on the document to combine this Braille dots into cells, other researchers construct a vertical and horizontal projection for that purpose. While other techniques focus on using Neural Network and Support Vector Machine approaches for segmenting the Braille dots. The translation technique used to convert the segmented cell into it's equivalent natural language character are similar with most researchers, most of the researchers use decimal code or binary code with look-up table.

3.2 Summary Table

Table 1 shows the comparison that we have done between different optical Braille recognition algorithms, in terms of publishing year, image acquisition techniques, Single side or double sided Braille page, Image pre-processing techniques used. Table 2 shows the comparison that we have done between different optical Braille recognition algorithms,in terms of Braille Dots Detection techniques, Cell Recognition and Transcription, the results and the processing speed.

4 Conclusion

Optical Braille recognition (OBR) system is able to reduce the gap between blind, visually impaired people and sighted people; the system is able to covert the Braille characters into it's corresponding natural language character. It can help anyone who deals with Blind people and don't know Braille scripting language. From this survey we have found that most of the researchers efforts use *scanner* as there acquisition technique; still no enough research on using mobile camera or standard cameras as acquisition technique. Also there is enough research for most scripting languages including *Arabic* language. Also most researchers focus on using a double-sided Braille document for there conversion. Also there is a lack of research of using *artificial intelligence approaches* such as neural network and support vector machine algorithms. Also there is no benchmark to test the proposed algorithms; researchers uses their own database and Braille image to measure the performance of their algorithms.

References

[1] W. H. Organization. (2014) Visual impairment and blindness. [Online]. Available: http://www.who.int/mediacentre/factsheets/fs282/en/

[2] S. Halder, A. Hasnat, A. Khatun, D. Bhattacharjee, and M. Nasipuri, "Development of a bangla character recognition (bcr) system for generation of bengali text from braille notation," *International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN*, pp. 2278–3075.

[3] A. Al-Salman, A. El-Zaart, Y. Al-Suhaibani, K. Al-Hokail, and A.-A. Al-Qabbany, "An efficient braille cells recognition," in *Wireless Communications Networking and Mobile Computing (WiCOM), 2010 6th International Conference on*. IEEE, 2010, pp. 1–4.

[4] S. Padmavathi, S. S. Reddy, D. Meenakshy *et al.*, "Conversion of braille to text in english, hindi and tamil languages," *arXiv preprint arXiv:1307.2997*, 2013.

[5] Shreekanth.T and V.Udayashankara, "A review on software algorithms for optical recognition of embossed braille characters," in *International Journal of Computer Applications,Volume 81 – No.3, 2013*. IJCA, 2013, pp. 25–35.

[6] S. Zhang and K. Yoshino, "A braille recognition system by the mobile phone with embedded camera," in *Innovative Computing, Information and Control, 2007. ICICIC'07. Second International Conference on*. IEEE, 2007, pp. 223–223.

[7] I. Murray and A. Pasquale, "A portable device for the translation of braille to text," in *Proceedings of the 8th international ACM SIGACCESS conference on Computers and accessibility*. ACM, 2006, pp. 231–232.

[8] A. Al-Saleh, A. El-Zaart, and A. AlSalman, *Dot Detection of Optical Braille Images for Braille Cells Recognition*. Springer, 2008.

[9] Srinath.S and C. R. Kumar, "A novel method for recognizing kannada braille: Consonant vowels," in *International Journal of Emerging Technology and Advanced Engineering, 2008 Certified Journal*. IJETAE, 2013, pp. 596–600.

[10] A. Antonacopoulos and D. Bridson, "A robust braille recognition system," in *Document Analysis Systems VI*. Springer, 2004, pp. 533–545.

[11] L. Wong, W. Abdulla, and S. Hussmann, "A software algorithm prototype for optical recognition of embossed braille," in *Pattern Recognition, 2004. ICPR 2004. Proceedings of the 17th International Conference on*, vol. 2. IEEE, 2004, pp. 586–589.

[12] S. R. Rupanagudi, S. Huddar, V. G. Bhat, S. S. Patil, and M. Bhaskar, "Novel methodology for kannada braille to speech translation using image processing on fpga," in *Advances in Electrical Engineering (ICAEE), 2014 International Conference on*. IEEE, 2014, pp. 1–6.

[13] M. Wajid, M. W. Abdullah, and O. Farooq, "Imprinted braille-character pattern recognition using image processing techniques," in *Image Information Processing (ICIIP), 2011 International Conference on*. IEEE, 2011, pp. 1–5.

[14] J. Li and X. Yan, "Optical braille character recognition with support-vector machine classifier," in *Computer Application and System Modeling (ICCASM), 2010 International Conference on*, vol. 12. IEEE, 2010, pp. V12–219.

[15] V. Udayashankara, "An application of eight connectivity based two-pass connected-component labelling algorithm for double sided braille dot recognition," *International Journal of Image Processing (IJIP)*, vol. 8, no. 5, p. 294, 2014.

[16] A. Al-Salman, Y. AlOhali, M. AlKanhal, and A. AlRajih, "An arabic optical braille recognition system," 2007.

[17] S. D. Al-Shamma and S. Fathi, "Arabic braille recognition and transcription into text and voice," in *Biomedical Engineering Conference (CIBEC), 2010 5th Cairo International*. IEEE, 2010, pp. 227–231.

[18] J.Bhattacharya and G. S.Majumder, "Automatic inspection of braille character: A vision based approach," in *International Journal of computer & Organization trends- Volume1 Issue 3*, 2011.

[19] J. Bhattacharya and S. Majumder, "Braille character recognition using generalized feature vector approach," in *Computer Networks and Intelligent Computing*. Springer, 2011, pp. 171–180.

[20] G. Morgavi and M. Morando, "A neural network hybrid model for an optical braille recognitor," in *International Conference on Signal, Speech and Image Processing 2002 (ICOSSIP 2002)*, 2002.

[21] C. Kumar and S. Srinath, "A novel and efficient algorithm to recognize any universally accepted braille characters: A case with kannada language," in *Signal and Image Processing (ICSIP), 2014 Fifth International Conference on*. IEEE, 2014, pp. 292–296.

[22] A. AlSalman, A. El-Zaart, S. Al-Salman, and A. Gumaei, "A novel approach for braille images segmentation," in *Multimedia Computing and Systems (ICMCS), 2012 International Conference on*. IEEE, 2012, pp. 190–195.

[23] M. Hassen and Y. Assabie, "Recognition of ethiopic braille characters," in *Proceedings of the International Conference on Management of Emergent Digital EcoSystems*. ACM, 2012, pp. 158–165.

[24] A. Mousa, H. Hiary, R. Alomari, and L. Alnemer, "Smart braille system recognizer," *International Journal of Computer Science Issues (IJCSI)*, vol. 10, no. 6, 2013.

[25] C. Ng, V. Ng, and Y. Lau, "Regular feature extraction for recognition of braille," in *Computational Intelligence and Multimedia Applications, International Conference on*. IEEE Computer Society, 1999, pp. 302–302.

[26] M. Y. Babadi and S. Jafari, "Novel grid-based optical braille conversion: from scanning to wording," *International Journal of Electronics*, vol. 98, no. 12, pp. 1659–1671, 2011.

[27] J. Li, X. Yan, and D. Zhang, "Optical braille recognition with haar wavelet features and support-vector machine," in *Computer, Mechatronics, Control and Electronic Engineering (CMCE), 2010 International Conference on*, vol. 5. IEEE, 2010, pp. 64–67.

[28] J. Mennens, L. Van Tichelen, G. Francois, and J. J. Engelen, "Optical recognition of braille writing using standard equipment," *Rehabilitation Engineering, IEEE Transactions on*, vol. 2, no. 4, pp. 207–212, 1994.

[29] P. Blenkhorn, "A system for converting braille into print," *Rehabilitation Engineering, IEEE Transactions on*, vol. 3, no. 2, pp. 215–221, 1995.