ROBUST BRAILLE RECOGNITION SYSTEM USING IMAGE PRE-PROCESSING AND FEATURE EXTRACTION ALGORITHMS

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ABSTRACT

Braille Character Recognition (BCR) is a method to locate and recognize Braille document stored as an image, such as a jpeg, jpg, tiff or a gif image, and convert the text into a coded machine form such as text file. BCR converts the pixel representation of an image into its equivalent character representation. Braille recognition has plenty of benefits which facilitate the work in our daily life as workers in visually impaired schools and institutes. Based on literature review studies and remarks it can be concluded that extracting information from braille paper requires accuracy in pre-processing stage. Another approach is the recommendation of matching and feature extraction that requier to be enhanced for optimal detection. This work is tested with a variety of Braille documents written using English Braille standards. The applied algorithm based on a comparison of Braille character location extraction in each cell with the templates created for each Braille cell. Many digital image processing stages have been implemented on the Braille document that can be imported to the system using scanner or camera. Gray scale conversion, binary conversion, filtering and morphological dilation have been applied in the preprocessing stage which result in enhanced quality of Braille dots. Furthermore, edge detection, image projection and image segmentation of Braille document applied will improve the matching method. The proposed method in this project succeeds effectively extract Braille dots from the paper Braille picture, and compare it with the provided templates of characters and then transform it to English text file. This project development is based on MATLAB 2011 software programming. The implemented algorithm achieved 100% precise results where several cases have been performed with excellent recognition outcomes.

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CHAPTER 1

INTRODUCTION

1.1 Project Overview

Braille Character Recognition (BCR) is a method to locate and recognize Braille document stored in an image, such as a jpeg, jpg, tiff or a gif image, and convert the text into a coded machine form such as text file. BCR converts the pixel representation of an image into its equivalent character representation. Braille recognition has a plenty of benefits which facilitate the work in our daily life as workers in visually impaired schools and institutes. Many schools have a very large collection of paper forms and documents that is used in teaching blind students, in order to search, read or rewrite these documents by existing hand will take a very long time, and it is only natural way of seeking to automate this process (Kato et al., 2007).

Optical Character Recognition (OCR) is a system to convert scanned printed/handwritten image file into readable/editable text document. OCR system received file as an image and convert it by comparing/matching the characters with the set of OCR stored database. There are many important applications using character recognition nowadays such as speed track that have been used by government to track speeding car. This character recognition can be used for blind people to read text. It has open the new light of life to blind community.

The processes of BCR would be to scan the documents and save them in term of images on the computer, and then apply or perform optical Braille character recognition algorithm on the scanned images to extract the textual

information into separate text files. All this stages are designed in MATLAB environment (Yousefi et al., 2001).The project highlights the characteristics of Braille documents and the stages of the automatic reading. It also explores flexibility in recognition of Braille characters and overcome challenges that can be met in preprocessing stages.

1.2 Problem Statement

Based on literature review studies and remarks it can be concluded that extracting information from braille paper requires accuracy in pre-processing stage. Beside that there are still ongoing research and work need to enhance the recognition performance since image taken from braille documents are exposed to high noise ratio. Therefore some treatments through pre-processing methods and other approach proposed is the recommendation matching and feature extraction that still requiring enhanced for optimal detection.

1.3 Motivation

The importance in this work is to ease the interface between visually impaired people, and society and help in office automation with huge saving of time and human effort success. Research on Braille recognition has progressively become one of the hot research areas. Braille recognition not only reduces time in reading or extracting information from Braille document, furthermore, to resolves the cause of people engaged in special education issues, such as school work correcting, papers marking and etc. (Jia et al., 2010).

Previous works point out that the need for Braille reading system to assist blind people in learning Braille, in addition to, the availability of such a system will enhance communication and collaboration possibilities with visually impaired people (Rawan & Tomader, 2011).

Through the time a small quantity of printed books have been available in Braille, in order to copy such books the only method is using the manually transcription which is both costly and time consuming. Moreover by converting such books to text form will also give advantages for handling printed documents and also can be saved in lesser volume than Braille printed one. Besides that, it

can be noted that BCR method will be practical and cost effective in order to be adopted by people who need it. Furthermore, taking the advantages of using it as an easy and efficient method can be considered as a replacement to the manual job (Horst & Patrick, 1997).

Another motivation behind this is by looking to the previous works on the BCR as they recommended that preprocessing and extracting features require more enhancements and modifications to overcome challenges, that's due to the fact that Braille characters have no colors to be easily recognized since they are just a raised dots on the paper as shown in the Figure 1.1 (Horst & Patrick, 1997).

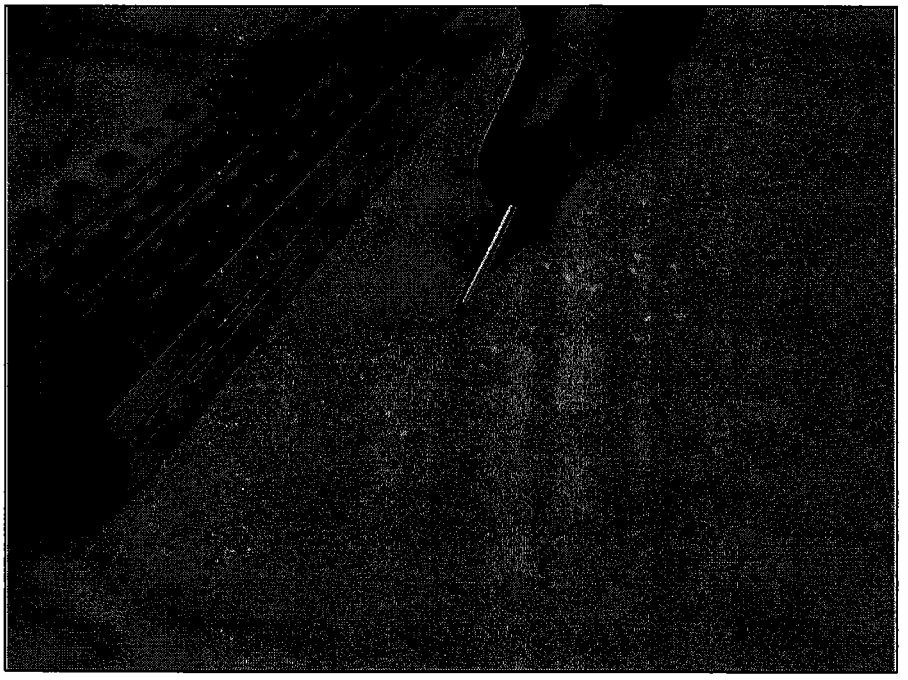

Figure 1.1: Braille Raised Points with the Writing Tools.

Another approach is by making life easier as almost all smartphones carry a megapixel camera, which gives advantages to the system to be set as an application on any smartphone so that Braille document to text can be easily translate without referring to scanners and computers. Such a system can be improved to be built for software applicable and portable in a smartphone application (Horst & Patrick, 1997).

1.4 Objectives

This project presents the idea of transforming Braille characters to normal text. The objectives of the project can be divided in four main points:

- Design a system that recognize Braille characters and convert it to English text based on digital image processing algorithm.
- Enhance the quality of Braille recognition by reducing errors using image preprocessing algorithms.
- Develop a robust extracting and matching algorithm that results in better recognition system.
- Provide a library of MATLAB codes and templates in all necessary stages considered in the design.

1.5 Scope of Study

In terms of scope, the project will take in the ideas extracted from the literature build on Braille Character Recognition "BCR", The project will cover converting the input Braille characters image of full braille page to a computer text file by following several steps of image processing technologies. The design process will have many steps taken in preprocessing the input image by converting it to recognized version by the computer in order to match and compute the correlation between the characters and the datasheet that is predefined for the system. The output of the system will show every step taken in the process ending up with the translation of the Braille characters into an English text form. The project will cover noise removal and feature extraction in order to convert the input Braille characters image line by line to a computer text file by applying Gray scale conversion, binary conversion, filtering, edge detection, image projection and morphological dilation of image pre-processing techniques. The project will not include system capabilities to be real time application.

1.6 Thesis Outlines

The flow of the thesis started from chapter one which discusses the basic overview of braille character and optical recognition, problem statement, objective of converting the braille characters to English text and finally this chapter discusses the scope of the study.

Chapter two which studies the background and general information about Braille and optical recognition. This chapter also reviews basic algorithms of image pre-processing and discusses six different methods by previous researcher developing the Braille character recognition.

The third chapter discusses the overall system methodology process, which includes the BCR pre-processing algorithms and feature extraction tools. Besides that, this chapter covers basic terms and theories of the system design consideration which includes de-noising, edge detection, morphing, extracting and matching.

The fourth chapter present the results of the project, which includes testing many imported images of braille character and applying pre-processing stages on the imported images to get accurate results. Beside that, this chapter covers the discussion of the project, which includes some challenges faced during detection and extraction process and the solutions planned to obtain the best results.

The fifth chapter discussed the conclusion of this project and recommendation on further works and upgrades of the system.

CHAPTER 2

LITERATURE REVIEW

2.1 Optical Recognition History

In 1929, Tausheck found a patent named "Reading Machine" in Germany (Gustav, 1932). This patent produces the concept of Optical Character Recognition "OCR". Basic principal of the patent is template matching which is still used in some applications until today as shown in Figure 2.1.

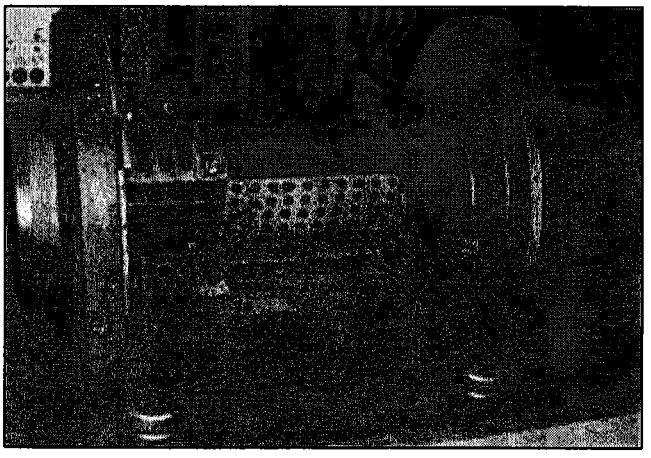

Figure 2.1: A magnetic Digital Storage Drum Memory from 1950s (Bhasker, 2001).

The start of OCR was motivated by the requirement of high speed and electronic data processing. The first OCR equipment installed at the Reader's Digest in 1954 was employed to convert type written reports into computer

readable punched cards (Bhasker, 2001). OCR system became available as software packages for home usage after 1986.

2.2 Introduction of Braille

Information in written form plays an undeniably important role in our daily lives. Recording and using information encoded in symbolic form is essential. Visually impaired people face a distinct disadvantage in this respect. In order to address their need, the most widely adopted writing convention among visually impaired people is Braille. Different attempts have been made to recognize Braille writing system for different languages (Alemu, 2009; Assabie, 2002). As a continuation, this study explores pre-processing and feature extraction modules of English Braille recognizer. This is because of the fact that the performance of the recognizer depends mainly on the pre-processing and feature extraction schemes (Chekol, 2010).

"Access to communication in the widest sense is access to knowledge, and that is vitally important for us. We do not need pity, nor do we need to be reminded that we are vulnerable. We must be treated as equals, and communication is the way we can bring this about" Louis Braille, 1841.

According to latest statistics of the World Health Organization Who more than 285 million people are visually impaired and 7% of them are totally blind (Abdul Malik et al., 2011). Braille method appeared nearly two centuries, and due to changes in laws and regulations it became more prevalent in daily use and it is widely used in almost all countries as a teaching tool to address the special needs of blind students.

Writing is a very effective means of transforming thoughts, ideas, facts, theories to people around the world. It is still a hard task to reach out to all people as some find it necessary to learn Braille for their day to day communication. As it is a necessary tool to reduce the gap between blind people and people around (Shanjun & Kazuyoshi, 2007).

Braille is a method consists of a number of cells each cell has two column consists of three salient points. Blind people can be read through touch by fingers, points in the first column of the cell is 1-2-3 from top to bottom numbers and points in the second column of the cell 4-5-6 from top to bottom. It represents

characters or word or number or punctuation mark or express character or musical special configuration of these letters. In order to prominent and can write in Braille through the Braille machine a machine similar to the normal printing machine can be used, or through the computer, which converts to a regular writing Braille (Al-saleh et al., 2008).

The writing (Braille) on the basis of six key points three on the left and three on the right as shown in Figure 2.2:

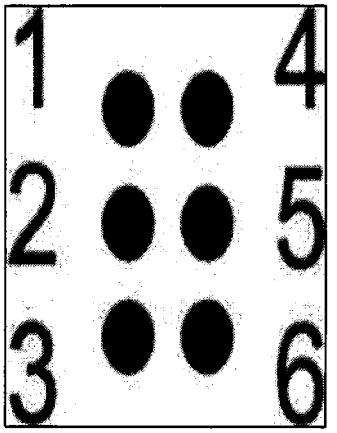

Figure 2.2: Braille Cell (Al-Shamma & Sami, 2010).

Learning the language of braille takes long time for normal people, where good finger sensitivity is important and also to be able to memorize new information, have a good reason for using braille, and have the patience to master a new kind of language. Thus, many researchers came out to solve this issue and to develop a system to make Braille recognized by all people without advance knowledge (Al-Shamma & Sami, 2010).

2.3 Braille Character Recognition.

Many steps are applied in image preprocessing technique such as Gray scale conversion, binary conversion, filtering, edge detection, image projection and morphological dilation. The extraction part is then to be pre-defined in the system to match Braille characters with the equally meaning English letter.

Grade 1 Braille: is the basic representations of letters, where each letter is to be represented by one cell containing two columns each column containing

three rows, where numbers and punctuation and is represented by the following dot combinations as shown in Figure 2.3 (Horst & Patrick, 1997).

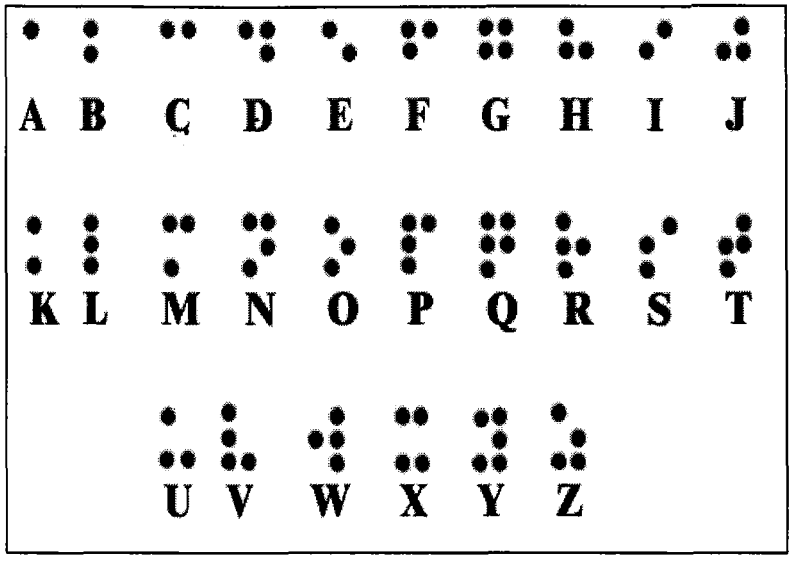

Figure 2.3: Braille Representation for Grade 1 (Horst & Patrick, 1997).

Grade 2 Braille: Since Braille books are so much larger than normal test books a contraction is used to reduce the length of some words. Contractions such as brl for Braille, as well as one character codes for common words such as the, and, and which make it easier and faster for everyone to read a Braille book (Horst & Patrick, 1997).

Table 2.1: Example of Grad 1 and Grad 2 Simplification.

about		ab	
already		alr	

The dimensions of a point according to the Braille and tactile resolution of the fingertips of people has been defined and specified for worldwide use. Horizontal and vertical distance between points in the letter, in addition to, the distances between the cells that represent a word after completion are specified by the Library of US Congress as shown in Figure 2.4 (Horst & Patrick, 1997).

- Dot height is approximately (0.5 mm).
- Horizontal and vertical spacing between dot centers within a Braille cell is approximately (2.5 mm).
- The blank space between dots on adjacent cells is approximately (3.75 mm) horizontally and (5.0 mm) vertically.

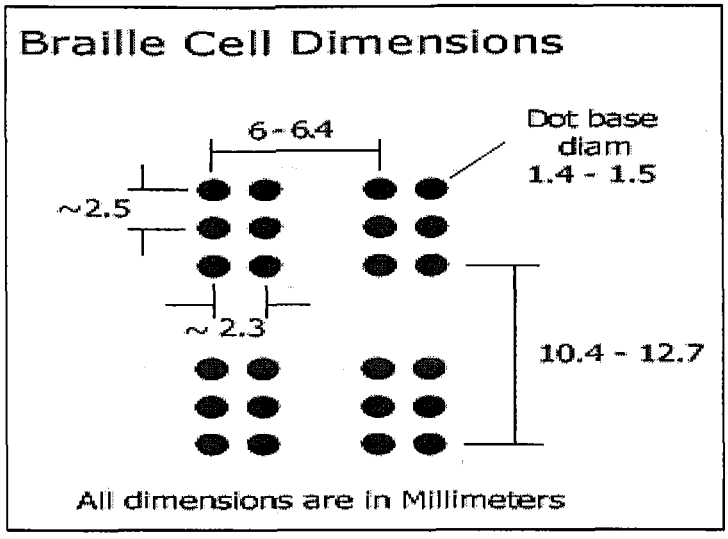

Figure 2.4: Braille Cells Dimensions in Millimeters (Horst & Patrick, 1997).

2.4 The Importance of Braille Recognition System

The importance of Braille recognition System to transform Braille documents to text without any knowledge of Braille reading. Thus the proposed tool is to be used in places where this conversion is necessary. For example, in school teachers need to understand the braille language in order to instruct student. Solving this issue will open up blind schools to a much wider pool of teachers.

Another approach which is more important is ability for blind student to join governmental schools and to be treated as normal student, if it becomes simple for the teacher extract information from braille document and to convert text into braille and vice versa then it will become easy to instruct blind pupils. Nowadays some governmental schools have teacher assistants' who understand braille codes and his main job is to take care of special cases students. Thus, if the ability of translating Braille into text is given to all teachers, the issue will be

solved and much wider blind student can join normal classes (Apostolos & David, 2004).

2.5 Previous Research Work

Many technical report and journal related to this project have been performing before in many different methods. Evaluation of OCR Algorithms for Images with different spatial resolutions and noises was one of the papers done for OCR. These papers are introducing various shaped-based image invariants algorithm for optical character recognitions, 3D object recognitions, and pattern recognitions. Shape-based image invariants can be divided into two different categories boundary based image and region-based image invariants.

A typical way of building an OCR system consist of first training a machine in order to obtain descriptions of what the characters look like and then to compare unknown characters to the previously learned descriptions to obtain the best match. In typical commercial OCR system the training process has been done in advance. The matching procedure usually consists of a preprocessing step, a recognition step and an optional post processing step.

This section study the previous papers on the BCR describing the analysis of the algorithms used and discussing the critical analysis of each design.

2.5.1 A Software Algorithm Prototype for Optical Recognition of Embossed Braille.

The proposed system consists of three components: Half-character detection, half-character recognition, and text file transcription as shown in Figure 2.5 (Wong, 2004).

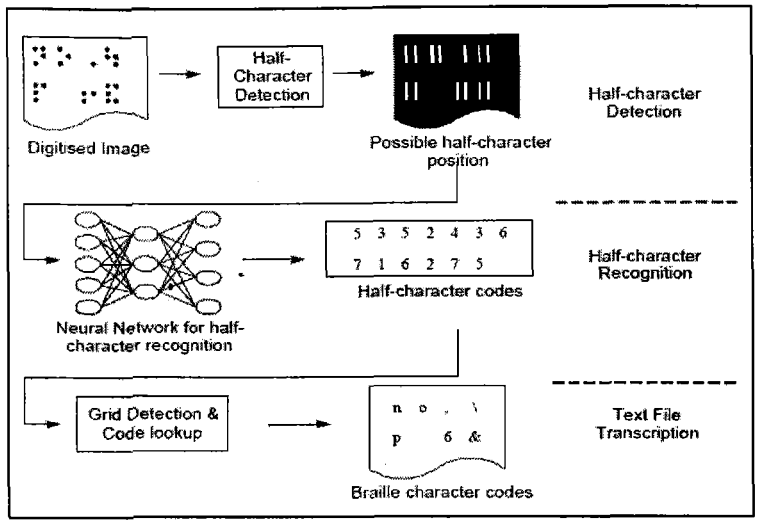

Figure 2.5: Block Diagram for the Proposed System (Wong, 2004).

2.5.1.1 System Analysis

In summary, the work has built on extracting information based on half character for each sample then moving to the second half of the character. The process takes longer time than matching the whole character at ones. This work justifies simply character reading which required well-formed noiseless characters (Wong, 2004). This is because in real life we don't expect Braille document to be 100% well-formed and noiseless.

2.5.2 A Braille Recognition System by the Mobile Phone with Embedded Camera

In this paper, a mobile Braille recognition system is proposed by running a Java programmed application installed in a camera-phone. The aim of the research is to provide a portable and helpful tool to improve the independence of the visually impaired users as shown in Figure 2.6 (Shanjun & Kazuyoshi, 2007).

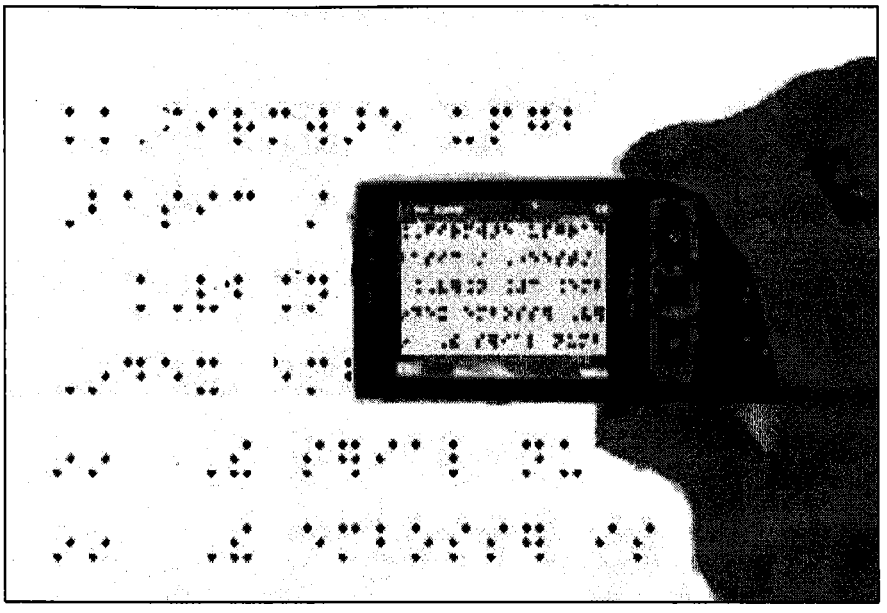

Figure 2.6: Proposed System by the Phone Camera Recognition (Shanjun & Kazuyoshi, 2007).

A photo image using portable phone camera, 320x240 photo size is obtain an input to the java programmed application on the phone, then converting the image into a gray scale of components of red, green and blue. The next step is by segmenting the image by using dynamic threshold method which results in obtaining the dots candidates. The third stage follows by de-noising the input image by filtering the too big or too small blobs. The last step before translating is grouping the dots and characters by aligning into horizontal lines according to vertical positions. At the end the output of the grouping stage will be match with the provided templates and translating the characters to the given language as shown in Figure 2.7 (Shanjun & Kazuyoshi, 2007).

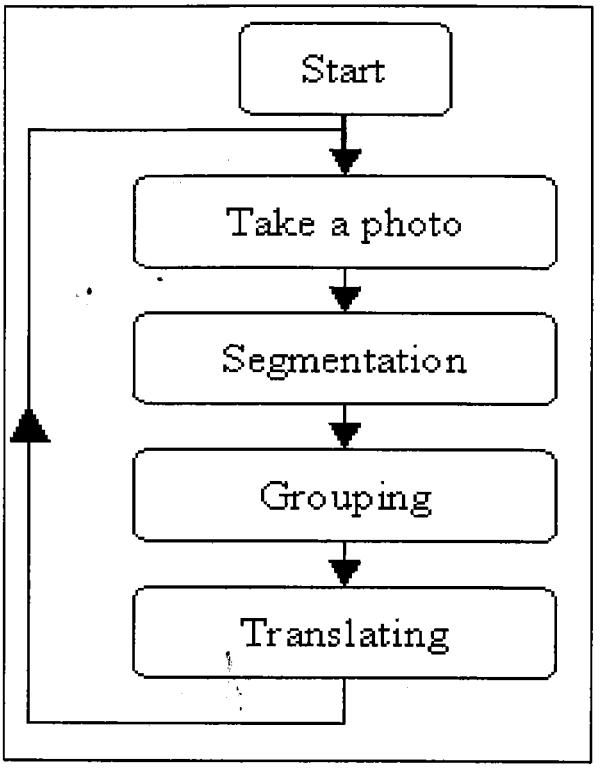

Figure 2.7: Algorithm used in the Braille Recognition System by the Mobile Phone (Shanjun & Kazuyoshi, 2007).

2.5.2.1 System Analysis on Braille Recognition System by the Mobile Phone

The overall work was creative in terms of building the system in portable device such as a phone, but considering that the system is only able to read one line statement each time. Another critical point is the fact that the system doesn't put in consideration the projection of the image, it only consider a fully formed paper on an input to the system (Shanjun & Kazuyoshi, 2007).

2.5.3 The Research on Paper mediated Braille Automatic Recognition Method.

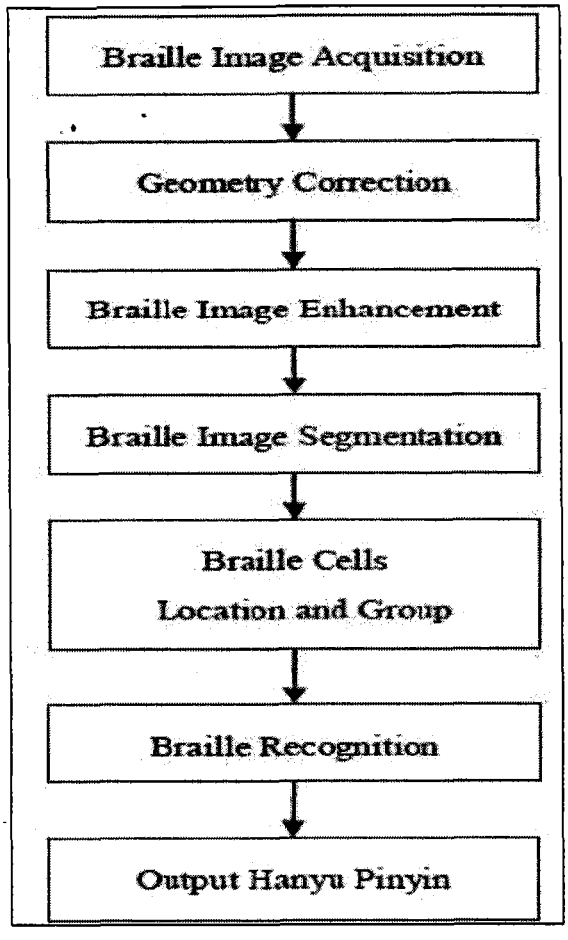

Figure 2.8: The Algorithm Used in the Paper (Jia et al., 2010).

In Braille Recognition system for Image acquisition is a fundamental stage to call the image from the file. Due to high-precision request for image acquisition in Braille recognition, this stage requires somehow precise method to provide high quality and clear embossing Braille image in order to locate and extract the Braille dots in later stages where the concept shown in Figure 2.8. Machine irresolution and human error, predictably, which led to a certain inclination for familiar Braille images in the image acquisition process. Therefore, firstly correct the positions of the Braille document image in forepart of image processing to avoid tilt. Generally, linear regression technique can be used to estimate tilt angle, and then rotate the image either clockwise or counterclockwise by the angle to achieve the objectives and requirements where

the concept shown in Figure 2.8 (Jia et al., 2010). It often makes the image degraded due to many factors in the Braille image collection and transmission process. Jia and Lirong in this work perform histogram equalization method to enhance images. The image histogram is a method of using a graph that count number of pixel graphics, which expressed the gray level relative frequency of all gray level within the limits of the image to the grayscale distribution. This method can also adjust the contrast of gray images, where the image pixels will be evenly distributed throughout the gray scale confine of the image the concept shown in Figure 2.8 (Jia et al., 2010). Image segmentation is the key techniques from image processing to image analysis. There are many types and methods for image segmentation. The quality of segmentation is affected by the different instances. Image segmentation includes four kinds of technologies: Parallel boundary segmentation, Serial boundary segmentation, parallel and serial regional segmentation. The stage of segmentation is very important in term of allocating region of interest in the input image the concept shown in Figure 2.8 (Jia et al., 2010). A Braille cell (character) is six dots combinations arranged in 3 × 2 array. This study found that all of the array arrangement that express Braille characters follow a pre-defined pattern, and the distances in between dots and between each Braille character keep a certain standard the concept shown in Figure 2.8 (Jia et al., 2010). The last stage of matching algorithm is the Braille recognition which shows the process of converting the Braille data to the chosen Chinese Language text. The process of extraction of text from the document is called as document analysis. The recognition process depends greatly on the original document quality and registered image quality, this concept shown in Figure 2.8 (Jia et al., 2010).

2.5.3.1 System Analysis on Research Paper mediated Braille Automatic Recognition Method

In several all the work was very well made but still needs algorithm refinement on extraction to further de-noise and improve accuracy of the Braille extraction to meet recognition requisition (Jia et al., 2010).

2.5.4 Arabic Braille Recognition and Transcription into Text and Voice.

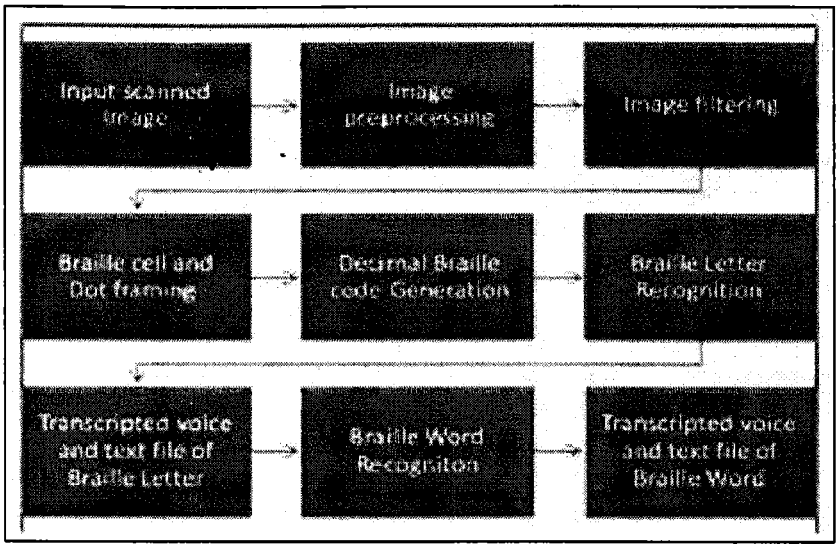

Figure 2.9: Block Diagram of the Implemented Algorithm (Al-Shamma & Sami, 2010).

The paper based on specific standards of Braille Arabic Braille to ensure that the page used for implementation will be compliant, Gray scale and binary conversion using rgb2gray and im2bw MATLAB functions. Canny's edge detector operator was designed to be an optimal edge detector. It takes as input a Gray scale image, and produces as output an image showing the positions of tracked intensity discontinuities. Canny's edge detector method is then used in this work to find the edges looking for local maxima of the slope of the input image. The gradient is designed using the derivative of a Gaussian filter. The method uses two thresholds to sense strong and weak edges, and extract the weak edges in the production if they are attached to strong edges. This method is therefore less likely than others to be deceived by the noise, and more likely to sense true weak edges. Since sharp points are not clearly identified; there is another step in an attempt to increase the contrast of the Braille dots. As mentioned above, the image contains sharp points, but does not include full points, therefore it must satisfy tips to clearly recognize the Braille dots. Then, perform the step function which is used to fill holes using *imfill* MATLAB function and converting to binary image, as shown in Figure 2.9 (Al-Shamma & Sami, 2010).

Then eliminates the filtering function of the binary image for all the connected objects that are less than predefined number of pixels, which results in producing another binary image and micro objects has been filtered. Experimentally found that the number of pixels in the most suitable way is 10 pixels, that is to say that all objects which are pixels or less, have been removed and has not appeared on in the form of points using the *bwareaopen* function of MATLAB.

The next step is the generation of the decimal and Braille code, where it is an important step and it was done by trying each point in the braille cell. The recognition process was active or inactive depending on points by taking the total picture of points and test them either they are active or not. Finally, the letter in Braille was recognized using the matching algorithm (Al-Shamma & Sami, 2010).

2.5.4.1 System Analysis on the Designed Algorithm

Therefore in conclusion of this research work discussed more experiments and supports to apply this implementation on new Braille recognition system which is necessary, strengthen the capacity of the system to be real time application and develop systems and advance applications using a wider range of templates data.

The critical analysis shows that the research work is only limited on well projected document containing no skewness (Al-Shamma & Sami, 2010).

2.5.5 Braille Recognition System – With a Case Study Arabic Braille Documents.

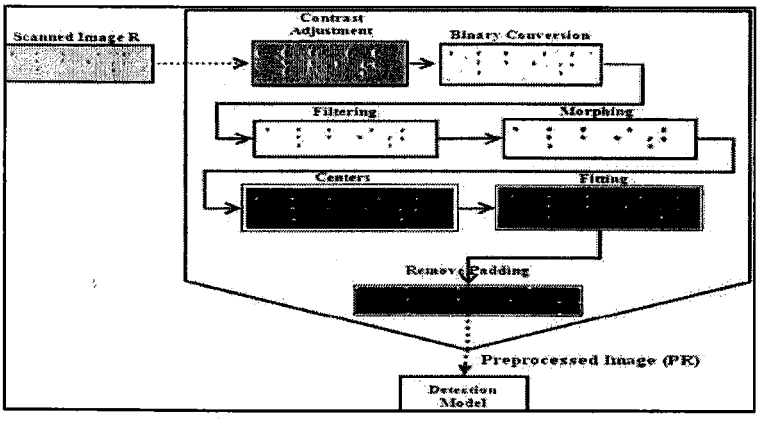

Figure 2.10: The Implemented Algorithm (Rawan & Tomader, 2011).

Rawan and Tomader in their work have followed the same contrast and binary conversion of the image, but then adding median filtering stage to further de-noise the image. The next step is the morphology part to reshape the dots into complete circles where series of erosion and dilation operations using the disk shape was suggested, as shown in Figure 2.10 (Rawan & Tomader, 2011).

After that the process proceeds to the center stage in order to fit the correct position this concept shown in Figure 2.10, then moving to the stage of matching and recognition of this concept. Figure 2.11 shows the distances of dots in the image following a systematic routine.

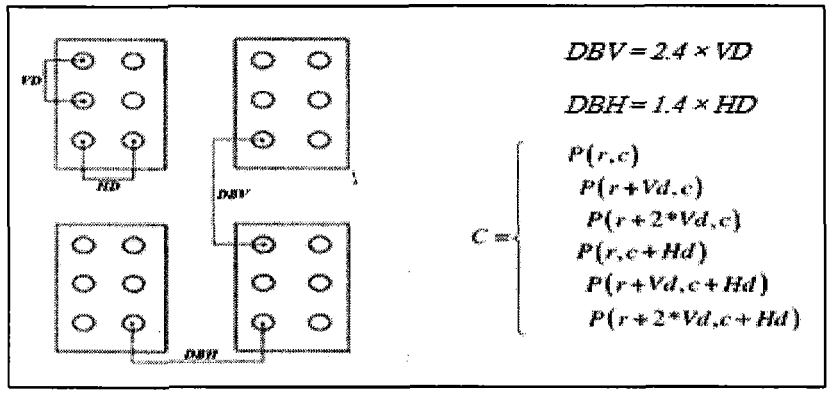

Figure 2.11: The Process of Finding Distances and Building a matching Board (Rawan & Tomader, 2011).

Where,

- VD is vertical dimension between two dots in one column.
- HD is horizontal dimension between two dots in two different columns.
- DBV is the vertical distance between two characters.
- DBH is the horizontal distance between two characters.

2.5.5.1 System Analysis

The overall work was built on a good preprocessing and filtering stages and then high level of system recognition and matching, and this work doesn't illustrate the projection of the document (Rawan & Tomader, 2011).

2.5.6 A robust probabilistic Braille recognition system.

This system was designed base on the projection and skewness of the input image. A set of probabilistic methods to implement BCR are suggested. Two stages are proposed. First stage performs measurements of vertical distances and skewness based on special probability density function to the Braille. The result of this stage shown in Figure 2.12 (c) (Yousefi et al., 2011).

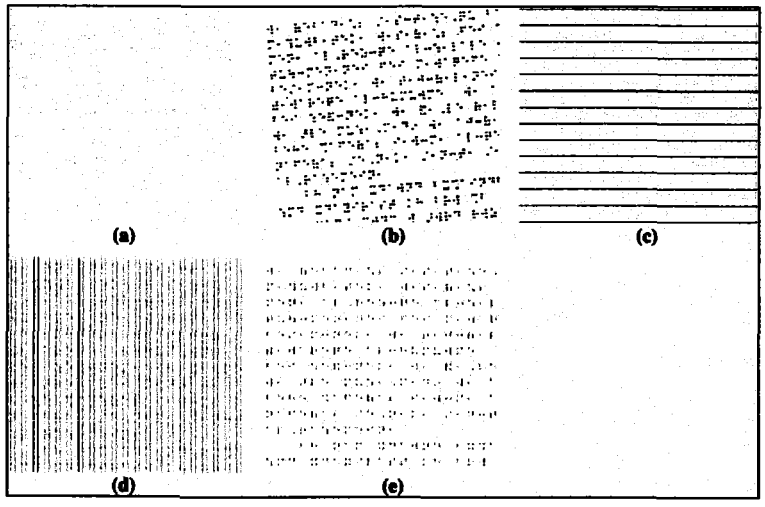

Figure 2.12: (a) A portion of a Braille document with corresponding skewness of 5°, (b) the corresponding binary image, (c) the skewness is corrected and lines are separated, (d) the line parameters are detected, (e) the final estimation of Braille dots (Yousefi et al., 2011).

The second stage was proposed to estimate the horizontal distances from the beginning of this work to the beginning of the first line base using Hidden Markov process. The results of this stage can be seen in Figure 2.12 (d). These horizontal and vertical Braille parameters are suitable to detect all Braille characters, the combination of the stages results in Figure (e) (Yousefi et al., 2011).

2.5.6.1 System Analysis

The work was implemented to illustrate the projection of the input document, but did not briefly discuss the preprocessing and segmentation.

Table 2.2: Literature Review Summary.

Author's Name, Year, Article Name.	**Method**	**Advantage / Disadvantage**
Shanjun, (2007), A Braille Recognition System by the Mobile Phone with Embedded Camera.	The system is designed for visually impaired users with a camera embedded mobile phone at hand, a mobile Braille recognition system is proposed by running a Java programmed application installed in a camera-phone. The image is threshold to pick up the candidate dots of the Braille. Then the candidates are processed to remove noise according to the features of Braille cells. After that, a flexible grid of possible dot location is constructed and is transferred into a vector. Braille Characters are recognized and translated into the equivalent printed text.	- The overall work was creative in terms of building the system in portable device such as a phone - This work was only able to read one line statement each time and the reduction of the noise is 100%. - The critical point of this work that the system does not put in consideration the image projection technique it only consider a fully formed paper to input to the system.
Jia et al, (2010), The Research on Paper mediated Braille Automatic Recognition Method	In this work, mainly studies the paper-mediated Braille automatic recognition method, including the following several parts: Braille feature extraction, Braille cell grouping and	- The total all work was very well made by converting the Braille data to the Chinese Language text. - The recognition process of this work depends greatly

	locating, Braille recognition Finally, convert into Chinese Language text.	on the original document quality and registered image quality and the accuracy of this work is 95% - This work is still need algorithm refinement on extraction to further de-noise and improve accuracy of the Braille extraction to meet recognition requisition.
Wong, (2004), A Software Algorithm Prototype for Optical Recognition of Embossed Braille.	The proposed system consists of three components: Half-character detection, half-character recognition, and text file transcription. This work has built on extracting information based on half character for each sample then moving to the second half of the character.	- The process of this work takes longer time than matching the whole character at ones and 98% accuracy achieved. - This work justifies simply character reading which required well-formed noiseless characters; this is because in real life there is not expect Braille document to be 100% well-formed and noiseless.
This work:	In this project is very well made by applying many techniques, digital image processing stages have been implemented on the Braille document that can be imported to the system using scanner or camera.	- This work covers converting the of full Braille document to a computer text file (English text). - The project will cover noise removal in order to convert the input Braille characters image line by line

	The stages are Gray scale conversion; binary conversion, filtering and morphological and dilation have been applied in the pre-processing stages which result in enhanced quality of Braille dots. Furthermore edge detection, image projection and image segmentation which improve the matching and feature extraction method.	to a computer text file. - The project results in 100 % accuracy and very low processing time.

CHAPTER 3

RESEARCH METHODOLOGY

Based on the literature review discussed in chapter two of this work, the proposed technique will be developed under MATLAB environment, and is divided in too many stages including input image of Braille characters by scanner or camera, converting the image to grayscale, converting image to binary and filtering (the usage of different filters can be chosen to stretch, increase/decrease the contrast of the input image). At the end of this work the image will have better contrast, which in turn will, reduce errors in the dot detection process, applying dilation and morphology, edge detecting, image projection, grid representation (measuring range of plotting, plotting the characters with exact location), then doing some feature extraction ending up with character recognition and matching the predefined character datasheet and finally exporting a translation text file (English text). The overall of braille character recognition system of this work shown in Figure 3.1 and the flowchart of the process as shown in Figure 3.2.

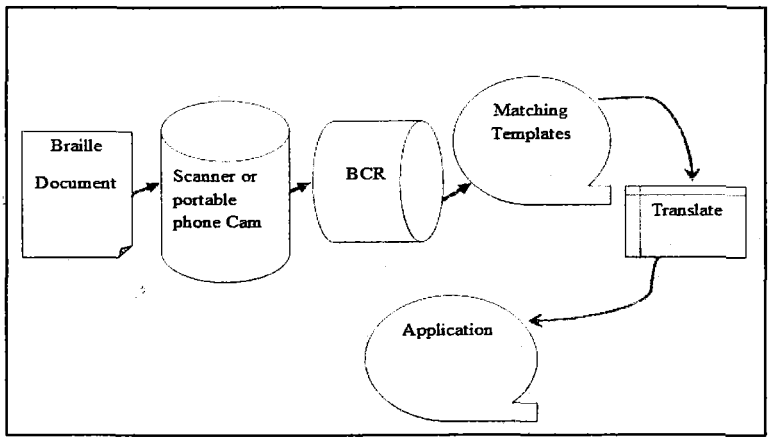

Figure 3.1: Overall BCR System.

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