ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
FACULTY OF INFORMATICS
DEPARTMENT OF INFORMATION SCIENCE

# RECOGNITION OF AMHARIC BRAILLE

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN INFORMATION SCIENCE

BY

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JANUARY 2009

**Name and Signature of Members of the Examining Board**

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*Dedicated to my family & SubRush!*

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*Teshome Alemu*

*With Blessing!*

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## *Acronyms*

*EABS* *Ethiopian Association for Blind society*

*IEF* *International Eye Foundation*

*OBR* *optical Braille recognition*

*OCR* *optical character recognition*

# Abstract

*According to the International Eye Foundation (IEF) reports, there are currently about 45 million visually impaired people in the world, the vast majority of which has been living in Africa. In Ethiopia, the latest census indicates that there are well over half a million visually impaired individuals including: students, lawyers, teachers, researchers, artists etc. So far, Braille has been the most invaluable means for visually impaired individuals to communicate to the world. Braille called after its inventor Braille Luis is a tactile writing means that consists of six dots arrangement in 2-by-3 matrix in a cell. Societal support is important to rebuild lives devastated by sight loss. These days technology has contributed a paramount value to the society in facilitating two way communications. Recently, optical character recognition (OCR) technique has been implemented for the recognition of Braille documents scanned with standard scanning device.*

*In this study, an attempt has been made in Amharic Braille-to-print documents recognition. To achieve this, various techniques has been reviewed, developed and adopted. The proposed system performs the required recognition in two phases: these are recognition of Braille character and Braille-to-print character. The first phase involves four steps such as thresholding/Binarization, image-segmentation, and feature extraction and recognition. Global-threshold has been implemented to binarize the foreground (content) from the background. As Braille cell are strictly arranged horizontally and vertically, mesh-grid technique has been adopted for segmentation process. With mesh, dots are extracted following the vertical and horizontal grid line. Having done this, in feature extraction the system once again takes advantage of the mesh. So, during this steps dots are further grouped in to cell, which would then recognized with context analysis based on rules defined. To accomplish the first phase Microsoft Visual C++ programming tools has been used.*

*The second phase, deals with classification of Braille-to-print. To this end MATLB's implementation of the feed forward artificial neural network has been utilized.*

*The neural network classifier has been trained on Amharic Braille with Amharic print as the target character. Moreover, the performance of the model has been evaluated with test sets that are prepared from the Braille document.*

*Eventually, the study has shown better performance with all training and test set, with 92.5% accurate.*

# Chapter One

## 1. Introduction

### 1.1 Background

> *"Every day 100 people will start to lose their sight offering practical support and information to anyone with a sight problem. Your support helps us rebuild lives devastated by sight loss."[2].*

According to the International Eye Foundation (IEF) [5] reports, there are currently about 45 million blind people in the world, the vast majority of which has been living in Africa. In Ethiopia, the latest census indicates that there are well over 500,000 blind people in the country.

It is undeniable fact that visually impaired people are part and parcel of the society and play significant role in the society [6] where they live in. So far there are different touch and/or hear means and system created for visually impaired people as a means to reach what the world has in printed document [6]. One of the most valuable and indispensable system is through the use of Braille.

### 1.2 Braille Writing System

Braille is a code which enables visually impaired people to read and write. It was invented by a visually impaired Frenchman, Louis Braille, in 1821 [33][39] [47]. Braille is comprised of a rectangular cell and each cell is made to consist up to six-dots, that makeup up to 63 possible combinations of different characters set or sequences of characters using 1 to 6 dots [6][29][41]. The different arrangement of raised dots in a 3-by-2 Braille is presented in *Figure 1.1*.

Currently there are two types of Braille styles that are commonly used in the world from the English character set, i.e., American Braille and France Braille style [33] [47] . However, most countries adopt

images are noisy the selection of threshold value is problematic so considering a histogram made up of only those pixels that lie at or near the edges of the Braille dots improve the segmentation process [14].

Feature extraction is a representational mechanism of the Braille image. The main function of *feature extraction* is to extract the Braille dots from the binary image and grouping them into cells. In this case, as the shape of a Braille dot is known, the boundary points of the dots can be obtained by the boundary based Chain Code algorithm that detects the boundary coordinates of the Braille dots. So once the coordinates of the dots are detected, the diameter of the dot can also be deduced [14][26].

*Interpretation/Classification:* is the final operation that converts the Braille cells into the respective text (character). It involves grouping the Braille dots into cells and converts them into the text by determining the centriod between dots and the four possible neighbors. Each word is then checked against dictionary. If the word cannot be found, then the word with the highest percentage of similarity will be selected and will be highlighted for later edition [14].

## 1.4 Statement of the Problem

Since the introduction of Amharic Braille in Ethiopia there has been massive Braille documents that have been produced and found at different part of the country: typically AAU Kennedy library at Braille documentation, Sebeta visually impaired school, German Church visually impaired school, Ethiopian Association for Blind society (EABS), Entoto Blind people school and also in different regions of the country (outside Addis Ababa) including the Ethiopian Orthodox Church are worth to mention. Moreover, for a long period of time Braille had been and is an invaluable means for visually impaired individuals [43][47] to document ideas, concepts, knowledge and so on. There are well more than half a million visually impaired individuals [41] that span students to teachers, artists to lawyer, thinker to employee who have and play significant contribution [47] in political, religious, economic and social affair of the society.

There are many visually impaired teachers from elementary to high schools and colleges to universities who have used their Braille as the only means to codify their knowledge. There are visually impaired students in higher education. There are also many visually impaired artists and writer who had and have a lot to share for the societies they live in. However most of their work still remained in their Braille [47] and of course accessed by chance by those who can know, read and write Braille. There are many visually impaired employees' who have been working in governmental and nongovernmental organizations. There are attorney who work around the court area. *But how many of them are really reached to the vision society? How much effort is expected to convert Braille to printed format?* In fact there might be very few attempts that have done in this area to produce the Braille document in printed format either through oral dictation or by vision individuals who have the skill to read and write both Braille and the printed character. Even this is hardly reached to success as the transcription is very cumbersome. According to [36], until recently, creating book in Braille was time taking process. Which would in some cases could take hundreds of hours.

As Nebyuluel [47] notes, unless there is a smooth information flow from visually impaired people to vision and vice versa people do not have the necessary information about visually impaired people. And the work of many visually impaired people would have remained buried [47]. This would create a wide generation gap between the visually impaired and sighted society.

Nebyalule [47], also discuss many issues concerning the visually impaired individuals including: societies' attitude towards them, their competence to learn and accomplish different responsibility citing different talented and competent visually impaired individual from abroad and local, what visually impaired people expect from the society. All the issues discussed forward significant message for the sighted society to give respect, understand their capabilities, and share their feeling creating awareness among society for the wellbeing of the visually impaired and sighted society in general. *In fact there is no one who knows and describe about visually impaired individuals more than them.* So we have to look for means by which the vision society can access their work.

Since 1997, there are a number of research works in the application of OCR technology in one of Ethiopian major language, Amharic. These include the work of worku [42], Ermias [18], Dereje [16], Berhanu [11], Million [31], and Wondwesson [40]. However, all of these research works were conducted on Amharic printed text documents that are either produced manually or typewritten or computer printout.

Literature disclose that different attempt have been done to develop Braille OCR system that work on some language including English, Arabic, Chinese and Indian to facilitate two way communication and knowledge transfer between visually impaired and vision society. However, none of the OCR Braille system developed abroad supports the Amharic Braille.

To the best of the researcher's knowledge, none of the preceding or any other works attempted on Amharic Braille OCR. Hence this study investigates the possibility of developing Braille recognition system for Amharic Language.

## 1.5 Objectives

The general and list of specific objectives of this study are presented below.

### *1.5.1 General objective*

The general objective of this research is to develop Amharic Braille OCR that enable to recognize optically scanned Amharic Braille and convert to the equivalent printed Amharic text character.

### *1.5.2 Specific Objectives*

In attempt to accomplish the aforementioned general objective, the study accomplishes the following specific objectives.

- Review previous related work in the area of Braille recognition so as to understand the domain area and assess different algorithms for Braille image preprocessing, segmentation, feature extraction, classification, and character mapping technique.
- Analyze the features and pattern of Amharic Braille code style for visually impaired individual.
- Understand the application of Neural Network approaches for Braille code recognition.
- Design algorithms required for the various steps (preprocessing, segmentation, feature extraction and classification) involved towards Amharic Braille recognition.
- Test and evaluate the performance of the algorithms developed by collecting sample Amharic Braille documents.
- Make conclusions and forward recommendations based on the test results.

## 1.6 Justification of the study

Awareness among the society about visually impaired people would be more promising if and only if there is two way communication between the visually impaired and vision society. Experience of others country shows that optical Braille recognition has many benefits to Braille users and those who work with them and/or would need to see their work in facilitating communication. It serves as a bridge between visually impaired and vision society. Besides, the outcome of the research would significantly reduce storage space [6][41] as the size and related volume of Braille documents is relatively large as compared to the print document. OCR is an important technology to convert the information contained in Braille into electronic format which would be more useful in information era [6][40] as it preserve Braille out-of-print. Moreover as the reproduction of Braille is cumbersome this research would lay a foundation for future work in order to come up with an applicable Braille OCR system.

So far there are many attempts that have been done to support visually impaired individuals to access many of the printed documents. This attempt is successful in other language in different country through

computer application. To the researcher knowledge, though there are different project started to develop Amharic Embosser, i.e. to transcribe print text to Braille, there is *no full-fledged* program that has successfully completed and working in Amharic Braille. This research is aimed at investigating the possibility of converting optically recognized Braille in to computer understandable format.

Thus, the objective of this research would have significant contribution in making accessible what visually impaired society had and do have for the sighted society creating awareness. This would be the first attempt that would bridge the gap between the two scripturally departed societies: vision and Blind.

## 1.7 Methods

Braille recognition involves various steps of image processing. Research makes available various techniques towards such a problem. Since the main aim of the thesis is to adopt and/or devise algorithms that perform Amharic Braille recognition, various methods of research are reviwed. The following part has been describing research methodologies used.

### *1.7.1 Literature Review*

Related literature on the area of OCR Braille recognition and conversion to print has been thoroughly reviewed from various sources including: articles, books, journals, magazines, proceedings and the Internet. This is done to understand different OCR recognition technology, to map techniques and algorithms so far identified so as to address the related problem domain.

The researcher would believe that this has a paramount significant as the aim of this research is to adapt and/or develop an algorithm that perform the required Braille recognition for Amharic Braille and convert to the corresponding text representation.

### *1.7.2 Implementation Tools*

For the purpose of developing Braille OCR that converts to the equivalent Amharic text, Microsoft visual C++ programming language is used. This is because of the fact that it minimizes the effort required to structure source code which is time-consuming, and delivers increased performance and productivity by enabling developers to leverage existing skills.

The researcher has also used neural network for the purpose of classification of Braille dot for the very reason that it is designed to address problems that are often complex, such as pattern recognition and has the ability to learn from example.

### *1.7.3 Testing procedure*

Testing is an important step to measure the performance of Amharic Braille recognizer that is designed in the present research work. Test is carried out using patterns extracted from the Braille document. Once the network has been trained for Amharic Braille characters, numerals and punctuation marks, the performance of the network tested with total of 550 Braille character.

## 1.8 Scope and Limitation of the Study

The aim of this study is assessing the potential application of OCR technologies to recognize Amharic Braille, so as to help improve the information accessibility between vision and visually impaired society. The scope of the research is limited to converting Amharic Braille character to print character for Single-sided Braille, that are embossed on one side of Braille paper

Given an image of Braille, an attempt has been made in this research work to adopt OCR algorithms for Amharic Braille recognition and apply MATLAB neural network tool to build a model that classify Braille dot into print character. The study has made experiment on the applicability of selected

preprocessing, segmentation, feature extraction, and classification techniques for the recognition of Amharic Braille.

The study planned to perform on all Amharic Braille character, numerals and punctuation marks. However, because of time constraints the current study could not conducted in extended Amharic Braille characters, Ethiopic numerals and some punctuation marks. Besides, Braille character defined with one, two and three cells. Braille character with three cells is not included in the study for the same reason. Moreover, many sample Braille document, with variety of content could not be found as reproduction of Braille is cumbersome.

## 1.9 Application of result

The outcome of the study will have significant contribution to bridge communication gap between the two scripturally separated societies: sighted and visually impaired in teaching-learning process, work area, justice, and art. In many cases different organizations particularly refrain to hire visually impaired individuals as they would have no means to communicate *formally* through written document unless there is someone who mediates in between to transcribe what the visually impaired people produced in to printed format. Student at different level: elementary, high school and higher-education will benefit from the outcome. The outcome also benefit lawyer visually impaired individual in their work environment.

Accordingly, the government and the non-government organizations, and the community at large, will benefit from the research, as the output of the research contributes for developing a practical application.

## 1.10 Organizations of the Study

The paper is organized into five chapters. Chapter one introduces the present research problem, objectives of the study and methodologies adopted. In chapter two an attempt has been made to review literatures in Amharic Braille system, features of Braille character and characteristics of Braille recognition. Review of related research work in Braille problem domain along with the techniques used is also discussed. Chapter

# Chapter Two

## 2. Review Literature

### 2.1 Introduction

Since its invention by French blind man, Louis Braille, Braille has been adapted to nearly every language on earth and remains the major medium of literacy for blind people everywhere [47][33]. For the last many years, restless efforts have also been made to improve the Braille system in every dimension. Their efforts expanded over the last decade with the coming of the computer age.

Literature revealed that since the introduction of OCR technology there have been different attempts to exploit the potential applicability of the technology to Braille document in different part of the world [21]. Though, there has been a great deal of research work conducted on the application of OCR to Amharic printed document [18][31][40], nothing is so far started to exploit the potential applicability of OCR to Amharic Braille documents. Accordingly the work of different researchers in an attempt to Braille recognition from abroad are reviewed in this study. An attempt was made as early as in 1988, by Dubus et al. [41] to design an algorithm which translates relief Braille into an equivalent print character version on paper. And a recent attempt was also made in New Zealand [6], Spain [32] and Tunisia [41], respectively towards the recognition of Braille documents. In this chapter, techniques and approach to Braille OCR is reviewed to show how it is done and what is to be done there by enlighten the direction of the research underway.

To provide an overview of the problem domain, the discussion of Amharic Braille writing system is also presented before the review of Braille OCR system. In addition, Amharic Braille code representations are discussed. This is important in the subsequent discussion of feature extraction of the Braille dot recognition.

## 2.2 Amharic Writing System

According to [10][31], the present writing system of Amharic is taken from Geez (evolved out of Sabaean language) which was brought to the highlands by immigrant from south Arabia in the first century A.D . Geez, which was remained the medium of religious and literary expression in Ethiopia until the 16th century gradually gave way to Amharic.

Before the Amharic characters (Fidel) have got their existing shape and number of symbols, they have gone through a serious of changes by adopting and using the Sabaean and Geez scripts over a long period of time [10][18][31].

By the time Geez was replaced by Amharic, Amharic took, for the purpose of writing, all the 26 symbols which were used in the Geez language. In addition, Amharic has created eight additional symbols to represent sounds not found in Geez [10][31]. This increased the total basic symbols used in Amharic writing system to 34; out of which 33 are core character and 1 is a special character.

### *2.2.1 The Amharic Characters (Fidel)*

Currently, Amharic language consists of 33 core characters each of which occurs in seven orders (one basic form and six non-basic forms), representing syllable combinations consisting of a consonant and following vowel [10][47]. This brought the total number of core characters to 231(33x7). List of these basic characters are shown in *Figure 2.1*.

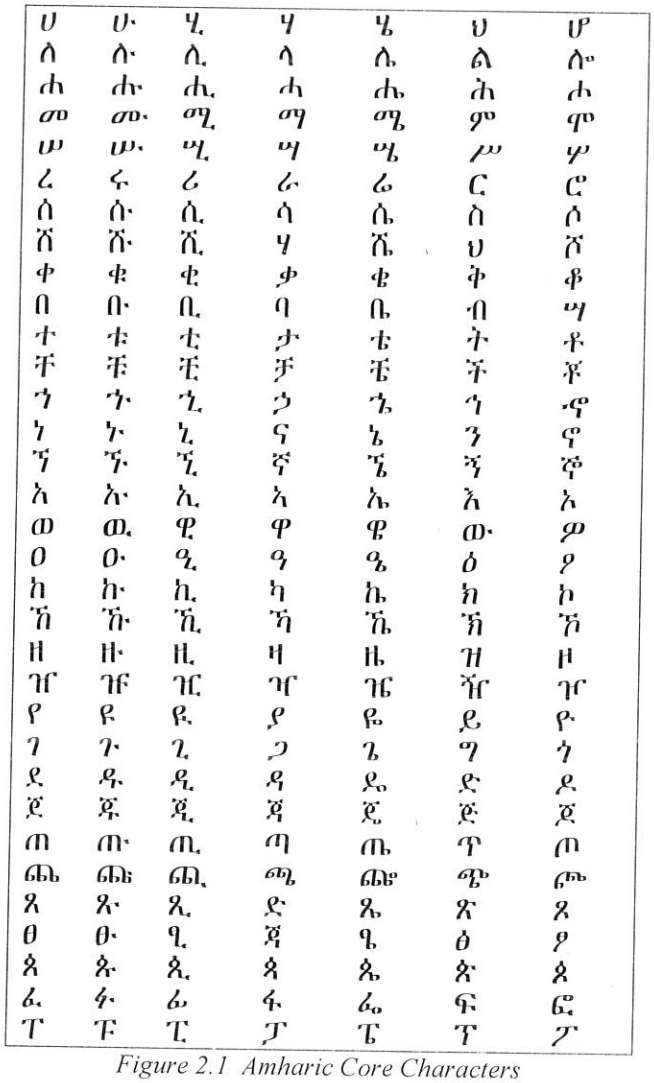


*Figure 2.1 Amharic Core Characters*

In addition to the 231 core characters, there are others, which are indicated below [44][31]:

- Special character (ቨ), which has also seven forms, and has used to represent the 'v' sound of words in Latin-based languages.
- Labialization character, a total of 44 symbols to represent special features. Such symbols include ኳ ሟ ሯ ኗ ቋ ቧ etc.
- Punctuation consisting of word-divider(:) , end of sentence indicator(: : ) , comma(፣) , semi-colon(፤) and other Latin-borrowed symbols like question mark(?), exclamation point(!) , quotes(" "), and parenthesis() [44][31]

- Numerals which consists of symbols for 1 to 9 (፩,፪,፫,፬,፭,፮,፯,፰,፱), for multiple of ten(፲,፳,፴,፵,፶,፷,፸,፹,፺) for 100 (፻) and for 1000(፼) [10] [44] [31].

Hence, the total number of symbols used in Amharic writing system rises to 310, the composition being as presented in ***Table 2.1*** [44][31].

*Table 2.1 The total number of Amharic characters by type*

| No | Type of Amharic characters | No. of characters |
|---|---|---|
| 1 | Core characters(33x7) | 231 |
| 2 | Special characters(1x7) | 7 |
| 3 | Labialized characters | 44 |
| 4 | Punctuation marks | 8 |
| 5 | Numerals | 20 |
| | Total | 310 |

Besides, as noted by [10][31] the original Amharic character set have no symbol for representing zero, negative numbers, decimal points, and mathematical operators for performing arithmetic competitions.

## 2.3 Evolution of the Amharic Braille

The history that would give birth to Braille is rooted deep in times long past after King Louis the Ninth of France suffered a crushing defeat in the Sixth Crusade [39].

As described in section 1.2 of the first chapter, Brail as modern touch education for visually impaired people started in 1917 E.C. Since then, it expands to different parts of the country. In between, many improvements have been made before it takes the current shape of Amharic Braille [44][47].

The first Amharic Braille introduced in Ethiopia was comprehensive and complete. It consider all characters that have similar sound such as (ሀ, ሐ, ኀ), (ሰ, ሠ), (ዐ, ኣ), (ፀ, ጸ) including punctuation marks which are used while reading, and all variants, except the Geez characters (like . Some part of the holy bible: Lukas, Mark gospel, Jhone gospel, Solomon, Mezmure Dave were published by this Amharic Braille and reached to the blind society by the time [47].

In 1944 E.C, the world association of blind society made some change on the earlier Amharic Braille code. The change was made in two parts: the first was made to eliminate the redundant Amharic characters which have similar sound as mentioned above. The second change was made on the numeral parts that replace the Ethiopian numerals with the English numerals. Since this time the modified Braille was distributed to all blind school in Ethiopia by the American missionary and the teachers were announced to adjust their system with the new one [44][47].

Later in 1948 E.C, the Amharic Braille was subjected for improvement for the third times when Sir Cluth Mecanize, the chair person of the world blind society, came to Ethiopia for visit. This time the improvement was made to further reduce the variant of Amharic characters [44][47].

After the 1948 amendment, the 3rd version of Amharic Braille was used for a long time until another attempt was started to modify in the 1980's E.C.

Once again after extended study for 12 years the 4th version of Amharic Braille was published in 1995 by Ethiopian blind society association that was given the mandate to assess many issues to make the appropriate modification on the existing Braille code [44].

The Amharic Braille subjected to many improvements and change as it was designed by the American does not consider many issues set by the world blind association [47]. Some of these rules and procedures which should be considered in adopting Braille to local language are the following [47]:

- Different languages should have similar Braille code. This is not to destroy the cultural nature of the literature of the language and distort the sense and meaning, rather this is to simplify the international publication, to avoid difficulties for those blind who are interested to study different language, and to create common understanding among blind society in the world.
- As per the rule, language that have the same sound or related language that are similar in sound, in character number and type should have similar Braille code structure. However, this does not

imply, those languages that are different should have similar Braille code. For instance, English and European languages like French, Latin, German, etc do have similar foundation in literature. Moreover, they are similar in the number of characters, sounds, thus, have similar Braille code.

As Nebyeleul [47] notes, the Amharic language has its root from Seabian and Arabic and also from different Sematic and kahm language. Hence, according to the rule of the world blind society association, the Amharic Braille should consider those Braille code.

The early Amharic characters adopt the English character which does not represent the right sound. And for the variant of Amharic character assigned the five English vowels such as 'H' to represent the three Amharic character of same sound (ሀ, ሐ, ኀ) [47].

## 2.4 The Amharic Braille Code character

Amharic Braille has been subjected for different improvement since its introduction in Ethiopia. After the last amendment, which was made in 1993E.C, the fourth version of Amharic Braille has been used for a long period of time throughout the county. This part of the study gives detailed description of the fourth version of Amharic Braille code that is in use currently and the focus of the current study. The other three versions of Amharic Braille are given in appendix I, 0, III and IV

### *2.4.1 The Fourth version Amharic Braille*

After 12 years extended study on the third version Amharic Braille code, once again the Braille was revised for the fourth times in 1993E.C. The justification was come from the fact that blind kid should get the Braille simple to learn. Besides, the volume of Braille document, limited combination of dots for characters, and difficulties to present as a legal document was the rational to reconsider for amendment. However, so far nothing is found best for blind than the Braille. The task force which was appointed by the blind association conduct thorough examination on the third Braille version and made improvement around three aspects [44][45]:

- Create equal number of Braille code that match to printed character.
- Modify the punctuation by taking most from the English.
- Include the Amharic numerals.

Accordingly, Braille dot combination has been approved and distributed to be used by different blind institutions has shown in

*Table 2.1*, *Table 2.3* and

*Table 2.2*. To make the representation clear a character "*ሀ*" in Braille would have the following appearance (see ***Figure 2.1***):

1 • o 4  1 o o 4
2 • • 5  2 • o 5
3 o o 6  3 o • 6

*Figure 2.1 sample representation of Braille code*

*Table 2.1Forth version Amharic Braille character*

| 1st form (character) | | Vowel | 6th form (character) | |
|---|---|---|---|---|
| ሀ | 1:2:5 | **2:6** | ሀ | 1:2:5 |
| ለ | 1:2:3 | **2:6** | ል | 1:2:3 |
| ሐ | *1:2:6 | **2:6** | ሕ | *1:2:6 |
| መ | 1:3:4 | **2:6** | ም | 1:3:4 |
| ሠ | 2:3:4 | **2:6** | ሥ | 2:3:4 |
| ረ | 1:2:3:5 | **2:6** | ር | 1:2:3:5 |
| ሰ | *1:4:5:6 | **2:6** | ስ | *1:4:5:6 |
| ሸ | 1:4:6 | **2:6** | ሽ | 1:4:6 |
| ቀ | 1:2:3:4:5 | **2:6** | ቅ | 1:2:3:4:5 |
| በ | 1:2 | **2:6** | ብ | 1:2 |
| ተ | 2:3:4:5 | **2:6** | ት | 2:3:4:5 |
| ቸ | 1:6 | **2:6** | ች | 1:6 |
| ኀ | *1:5:6 | **2:6** | ኅ | *1:5:6 |
| ነ | 1:3:4:5 | **2:6** | ን | 1:3:4:5 |
| ኘ | 3:4:6 | **2:6** | ኝ | 3:4:6 |
| አ | 1:2:3:5:6 | **2:6** | እ | 1:2:3:5:6 |
| ከ | 1:3 | **2:6** | ክ | 1:3 |

| 1st form (character) | | vowel | 6th form (character) | |
|---|---|---|---|---|
| ኸ | 2:3:6 | **2:6** | ኽ | 2:3:6 |
| ወ | 2:4:5:6 | **2:6** | ዉ | 2:4:5:6 |
| ዐ | *1:2:5:6 | **2:6** | ዕ | *1:2:5:6 |
| ዘ | 1:3:5:6 | **2:6** | ዝ | 1:3:5:6 |
| ዠ | 3:5:6 | **2:6** | ዥ | 3:5:6 |
| የ | 1:3:4:5:6 | **2:6** | ይ | 1:3:4:5:6 |
| ደ | 1:4:5 | **2:6** | ድ | 1:4:5 |
| ጀ | 2:4:5 | **2:6** | ጅ | 2:4:5 |
| ገ | 1:2:4:5 | **2:6** | ግ | 1:2:4:5 |
| ጠ | 2:3:4:5:6 | **2:6** | ጥ | 2:3:4:5:6 |
| ጨ | 1:4 | **2:6** | ጭ | 1:4 |
| ጰ | 2:3:5 | **2:6** | ጵ | 2:3:5 |
| ፀ | 1:2:3:4:6 | **2:6** | ፅ | 1:2:3:4:6 |
| ጸ | *2:3:4:6 | **2:6** | ጽ | *2:3:4:6 |
| ፈ | 1:2:4 | **2:6** | ፍ | 1:2:4 |
| ፐ | 1:2:3:4 | **2:6** | ፕ | 1:2:3:4 |
| ቨ | *1:2:3:6 | **2:6** | ቭ | *1:2:3:6 |

* Symbol indicates Braille code change made on this new version.

*Table 2.2 Fourth version Amharic Braille vowels*

| Vowel | 2:6 | 1:3:6 | 2:4 | 1 | 1:5 | Not apply | 1:3:5 |
|---|---|---|---|---|---|---|---|
| Character position | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th |

The sixth variant of the characters are decided to continue without vowel attachment as it has been used in the third version of the Braille. Regarding punctuation mark, codes in ***Table 2.3*** are designed.

Most of the punctuation marks are not new, however much focus had not been given so far. Thus, in the new Braille they are included as most of these symbols feel new by many blind society, according to the revision committee report [44].

*Table 2.3 Amharic Braille punctuation of the last version*

| Punctu. | Braille code |
|---|---|
| . | 3 |
| : | 6 and 3 |
| ÷ | 2:5 |
| / | 5 and 2 |
| - | 4 and 1 |
| :- | 3:6 |
| ፡ | 2 |
| ፤ | 2:3 |
| « | 2:3:6 |
| » | 3:5:6 |
| ’ | 3:5:6 and 3 |

| | |
|---|---|
| ? | 2:3:6 |
| =//= | 6 and 3 |
| X | 1:3:4:6 |
| $ | 4:5 |
| :: | 2:5:6 |
| ! | 2:3:5 |
| … | 3 , 3and 3 |
| ( ) | 2:3:5:6 |
| [ | 6 and 2:3:5:6 |
| ] | 2:3:5:6 and 3 |
| * | 3:5 and 3:5 |

| | |
|---|---|
| _ | 4:6 and 4:6 |
| → | 2:4:6, 2:5 and 2:5 |
| ← | 2:5,2:5 and 1:3:5 |
| ↑ | 4:5:6 and 1:5 |
| ↓ | 4:5:6 and 3:5 |
| እና ወይም | 3:4 |
| | |

**Amharic Numerals**

The Braille revision committee also made change on the numerals part of the Braille code. The need to reexamine this part is that, unlike the Arabic numerals, in Ethiopia there are different publication that uses the Ethiopic numerals such as newspaper and religious books. So, in order to show the numerals are Ethiopic, changes were needed on this part of the Braille. Accordingly, it is designed to use the whole dot (1:2:3:4:5:6) to indicate the numbers are in Ethiopic. Then, this Ethiopic numerals indicator mode followed by the numerals which was used for Arabic numerals are used in the fourth version [44]. Except

the numerals translation mode 3:4:5:6 (for Arabic) and 1:2:3:4:5:6 (for Ethiopic) the same dot combinations were used as given in ***Table 2.4***.

*Table 2.4 Ethiopic, Arabic-Braille characters*

| ⠚ | ⠛ | ⠉ | ⠙ | ⠑ | ⠋ | ⠓ | ⠊ | ⠚ | ⠁ |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 |
| 1 | 1:2 | 1:4 | 1:4:5 | 1:5 | 1:2:4 | 1:2:4:5 | 1:2:5 | 2:4 | 2:4:5 |

## 2.5 Amharic Braille Writing and Reading system

Braille sheet is a thick paper or plastic material designed to withstand the pressure while one write and read the Braille code. The size of the page varies between documents produced by different means. In addition, the color of the paper varies, as it does not play any role in conveying the written information. The majority of Braille sheets, however, are either buff colored or white [6][14][21].

### *2.5.1 Braille writing*

Braille is designed to be read by moving fingertips from left to right across the lines of dots. While writing Braille, move fingertips from right to left instead (on the reverse side), by physically pressing the dots into the paper so that they show up on the other side of the Braille sheet. The different methods used to write Braille, (including the manual) are listed as follows [21][36]:

- Manually, using a handheld stylus (to make the impressions) and a slate (to hold the paper) by physically pressing each dot into Braille sheet.
- With a Braille typewriter, this has one key for each of the six dots in a Braille cell (Mechanical).
- Using Braille printer that attached to computer system (electronic).

Until recently, creating books in Braille was time taking process. This is because translating a book from print to Braille required sighted transcribers to translate the book by hand. Later, improved optical character recognition (OCR) technology with computerized Braille printers has improved this process

### 2.7.1 *Braille character*

In Braille, printed text is represented by Braille characters. Each character is constructed as a set of six points arranged in two columns of three called a Braille cell. The cell has been set according to the tactile resolution of the fingertips of person. Each point position in a cell is identified by a number and can be either raised (a protrusion) or flat. A raised point is also called a Braille dot [44][21].

The dimensions of a Braille dot have strict regular structure. The horizontal and vertical distance between dots in a character, the distance between cells representing a word and the inter-line distance are also specified by the Library of Congress [6][21]. In theory, the dimensions of Braille dots must fall within certain bounds as indicated in *Figure 2.2*. In practice, although most instances of Braille are close to these standards, there are slight variations between Braille produced by different devices [21].

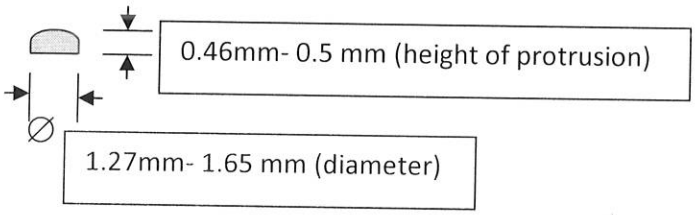



*Figure 2.2 Braille dot dimension specified by library of Congress*

Each Braille character is a unique combination of dots within the cell. Braille cells with six points is widespread; in Ethiopia also this is the Braille cell so far used [44][47]. In this study Braille characters are assumed to be composed of six points for Amharic Braille.

### 2.7.2 *Interpretation of Amharic Braille character*

The Amharic printed word is represented by a set of Braille characters forming a Braille word. The characters inside a Braille word are separated by a distance greater than the horizontal one between points (dots within a cell/character) and less than that between words [21]. The distance between words in a line of Amharic Braille characters consists of one or more space characters. The space character is a Braille cell with no dots (all points are flat).

In English language, another mode symbol is used to indicate the capitalization of a letter. Similarly, mode symbols are used in many languages to denote that a particular accent should be placed on the character that follows [21].

### *Grade 2 Braille/contraction*

The letter-by-letter representation of a word as in grade I Braille leads to the production of quite voluminous Braille documents (a dictionary can occupy a bookcase). In English Braille therefore, attempts have been made to represent frequently occurring letter strings by one or two Braille characters [44][21]. The rule for using them is referred to as grade-2 Braille (also called contracted or literary Braille) [21].

The strings of characters that can be contracted have been selected according to the frequency that they occur and therefore, differ between languages. In English grade 2 Braille, for instance, there are over 200 contractions and short form words [21].

Regarding the Amharic Braille, as indicated by the Braille improvement committee (1995 E.C), the design of Amharic Braille contraction along with some other issues was deferred for some other time, for the reason that issues with the basic Amharic Braille code yet not finalized by the time [44][45]. Except for "ena"/"weyem" there is no grade 2 Braille in Amharic.

## 2.8 Features of Amharic Braille Code

The Amharic Braille character composed of three parts: Braille character for printed symbol, punctuation marks and numerals [44][47].

All basic Amharic character represented with a single Braille character (see

*Table 2.1*). Each Amharic character has seven variant. Except the sixth variant, the remaining sound six sounds add the particular vowel code to get the required sound in a character [44]. For example:

- Braille dot 2:3 is vowel for the first variant in all the character. so to write first form of Fidel ለ (1:2)→ለ(1:2, 2:3)

The Amharic Braille also consists of different punctuation mark. Most of the Braille code for this purpose is taken from English. For those unique to Amharic language, different dot published by the committee (see *Table 2.3*). The majority of the punctuation marks represent by a grade 1 Braille [44][47].

Amharic Braille use two type of numerals: Arabic and Ethiopic. In English Braille the numerals 1, 2… 0 uses the code for a, b…j. The same dot combination is used in Amharic Braille also. The numerals translation mode remains the same in Amharic Braille. For example:

- Arabic Braille numerals mode: 3:4:5:6, and Ethiopic →1:2:3:4:5:6,
- To write 2: 3:4:5:6 and 1:2
- To write ፪: 1:2:3:4:5:6 and 1:2

## 2.9 Nature of Amharic Braille embossed

As describe before, the Amharic Braille, like any other Braille documents, are formed by embossing the dots on the back side of the medium sheet so that they can be read from the facing side. There are also different sized Braille sheet; the size of the page varies between documents produced by different means. In addition, the color of the paper varies, as it does not play any role in conveying the written information [21].

The Braille characters are embossed in lines from the top of the document to the bottom much like printed documents. Braille documents can have the dots embossed on one side or on both. As the volume of Braille documents is quite large, it is advantageous to use both sides of the sheet. However, this is not the

practice with Amharic Braille [21][41].

## 2.10 The Braille OCR system

As pointed out earlier, there has been a great deal of research work done in the field of optical recognition of Braille for automatic reading in different parts of the world. In order to show issues considered in connection to Braille, the next section of the studies discuss important features of embossed Braille document that will be helpful in the subsequent recognition process.

### *2.10.1 Characteristics of Automatic Braille Reading system*

As the Braille documents are not designed to convey any visual information, their color is uniform or not significant. The information is not printed in a contrasting color as does with printed document (ordinary document) [21].

Accordingly, in an attempt to design automatic reading for Braille document the first problem is to identify the tactile information visually. The issue in this case is the separation of the protrusions (called raised dot) on the paper sheet from the flat background [21][36].

Second, the identification of Braille dots from the differences in the intensity of reflected light is not straightforward. As the Braille paper is only used for tactile purposes, the quality of its appearance is not important. Hence, there are sometimes visual imperfections due to small dark fiber usually associated with cardboard and dirty marks that may also be present due to repeated use [21][36].

Moreover, damaged Braille documents with punched holes and less prominent dots due to heavy or repeated use compound the problem and negatively influence, the effect produced by the lighting [21][36].

Notwithstanding the above fact, many of the Braille documents are produced as inter-point (double-sided), which posing another problem on the process of recognition. This complicates the dot extraction stage

because shadows and bright areas are produced from both sides [6][21][36].

Once the Braille dots have been located in the image, the next task is to identify the characters. In a Braille system a character is represented with six dots, which is called cell, arranged in two columns. The problem is to identify which dots belong to which Braille cell. In theory, Braille cells are aligned in the horizontal and vertical directions in the form of a grid. However, noticeable deviations are there due to the production process or distortions introduced in the image of the document [21][26].

Eventually, Braille characters have a more regular structure than printed ones. Their size and style is fixed throughout a document, although there are certain variations between different documents. The spacing between Braille dots is quite regular and can be used to segment characters [6][21]. Nevertheless, Braille characters are not single connected entities and do not have distinguishing structural differences between them (they are all combinations of dots) which affect the recognition and verification process [13][26].

### *2.10.2 Optical Braille recognition system Overview*

For better analysis of the different aspects in existing solutions, as a starting point the basic steps in Braille recognition process considered in five stages including: *Image Acquisition/Digitization, Pre-Processing, Segmentation, feature extraction and recognition [21]*

#### *2.10.2.1 Image Acquisition/Digitization*

The first step towards digital document image processing is obtaining an electronic representation of a document. It is a process of capturing a Braille page and converts into a digitized image array. As it was mentioned above, the nature of this kind of document is quite different from that of a printed one. The protrusions (raised dots) create a light area next to a dark one (shadow) while the gray-level value of the background is somewhere in-between, this is visually examined in single-sided Braille document. This day's, the increasing popularity of flat-bed document scanners has provided a cost-effective and practical alternative to camera for digitization purpose [6][21][23].

#### 2.10.2.2 *Image Pre-Processing*

This stage modify gray-level image of a Braille document and prepare the pixel values of the digitized image for subsequent operations. This includes contrast enhancement and adjustment, skew and noise removal, and edge enhancement (edges sharpening) of the Braille [14][21].

Noises generally manifest themselves as random fluctuations in gray-level values superimposed upon the "ideal" gray-level value, and it usually has a high spatial frequency. Skew may be introduced during image acquisition by not carefully aligning the document or it may arise due to a production fault. Large skew angle negatively influence the recognition process, as the dots will not be aligned in rows as expected [14][21].

Another form of pre-processing is edge enhancement to sharpen the fine details of the image that has been blurred in order to improve the separability between the regions corresponding to dots and the background. The solution include: subtract a locally averaged image from the original in order to eliminate this problem, applying second degree convex two-dimensional function based on a second-degree polynomial function, and median filtering adaptive thresholding process [17][21].

#### 2.10.2.3 *Image Segmentation*

At this stage, the regions in the image corresponding to Braille dots are identified. In a binary image, dots can be identified as small connected components [26]. It should be noted that this situation is valid only when single-sided Braille documents are encountered. In this case, the above approaches are able to identify dots from either the dark (shadow) or the light areas in the image which, after thresholding, are represented as connected components [21].

In a grey-level image, the identification of dot regions needs more careful consideration. It is necessary to have a specification of the image area corresponding to a dot. A dot is represented by a combination of a dark and a light region. The intermediate grey-level pixels of the background surround and, possibly, also

separate the pair. Naturally, the orientation and order of the light-dark pair of regions depends on the direction of the illumination. In images of inter-point Braille documents, however, the protrusions give rise to region pairs in which the order is opposite to that of the region pairs produced by depressions. The consistency of the appearance of gray-levels at the positions of depressions and protrusions renders the use of template matching a possible option [21][36].

#### *2.10.2.4 Feature Extraction and Recognition*

Feature extraction is a representational mechanism of the Braille image. So, the function of feature extraction is to extract the Braille dots from the binary image and grouping them into cells. Then the identity of each of the Braille detected is recognized, but no attempt is made to interpret the Braille character. Since each character is distinguished from the rest by its unique combination of dots, it will suffice to identify the (relative) positions of its dots. Then, the character can be described in terms of the numbers of dot positions.

The first approach is to describe Braille characters as a region in the image; this region is divided into six equal compartments (two across, three down) in which the search for dots is performed. If the exact positions of dots in the image are known, it is easy to check if one of them is included in a compartment.

Alternatively, the region in the image corresponding to a compartment is searched and the number of pixels corresponding to dot components is counted. If the number exceeds a pre-specified threshold then the compartment is considered to contain dots. In any case, the recognized character can now be represented as a binary number with six bits.

In other approaches the Braille characters identified in the image are described explicitly or implicitly by the positions of the rows and the columns of a cell. In these cases it is necessary to check along specified

directions for the existence of dots. This is accomplished with gridlines construction. So the possible positions of Braille dots are determined by the intersections of horizontal and vertical grid lines. The six possible positions of the dots are known for each individual Braille character position in the image. Hence, all the possible character positions are examined.

## 2.11 Review of Braille optical recognition work

This section of the study discusses the work of different researcher in the area of Braille recognition problem domain as it is summarized in Table 2.5.

*Table 2.5 Summary of Braille optical recognition research work*

| Year | Title | Country | Main Approach used | Result | |
|---|---|---|---|---|---|
| | | | | Single | Double |
| 1994 | Optical Recognition of Braille Writing Using Standard Equipment. | Belgium | Digitization-mask method<br>Segmentation-Gridlines<br>Recognition-region based(local correlation) | Test-1 no-error<br>Test-2 99.75%<br>Test-3 unsatisfied | |
| 1995 | A System for Converting Braille into Print.<br>(English language) | England | Recognition-context analysis Based on Finite state approach | - | - |
| 1995 | Analysis of Scanned Braille Documents<br>(English language) | Manchester | Binarization- threshold<br>Dot identification- template matching<br>Segmentation- analysis of character line and horizontal spacing b/n columns of dots<br>Recognition- region based (divided into six compartment) | - | 98.5%<br>97.6% |
| 1996 | A Braille OCR for Blind People (English language) | Spain | adaptive thresholding<br>Mesh-grids<br>Interpretation-Braille Alphabet | - | - |
| 1999 | Regular feature extraction for recognition of Braille<br>(English and Chinese language) | | Binarization-Global threshold<br>Feature extraction- Chain Code algorithm<br>Interpretation-centriod based on boundary coordinates<br>Braille dictionary | - | - |
| 2004 | A Software Algorithm Prototype for Optical Recognition of Embossed Braille (English language) | New Zealand | Binarization- thresholding<br>Recognition-probabilistic neural network<br>Transcription- gridlines | 99% | - |
| 2005 | Image Processing Techniques for Braille Writing Recognition.<br>(English character) | Spain | Tool- MATLAB programming<br>Binarization-dynamic thresholding<br>Segmentation-adaptive Braille grid | - | 99.9% |
| 2007 | An Arabic Optical Braille Recognition System.<br>(Arabic language) | Tunisia | Binarization-global threshold<br>Dot Parts Detection-thresholding<br>Recognition-defined region and horizontal projection | 99% | 99% |

### 2.11.1 Optical Recognition of Braille Writing Using Standard Equipment.

This study is an early attempt to recognition of Braille using a commercially available scanner. The steps followed in the study are summarized as follows.

#### 2.11.1.1 *Image preprocessing*

Braille pages are never perfectly flat. This is due to the tension in the paper caused by the production of the Braille dots. It introduces low frequency distortions (shadows) that can be eliminated by subtracting a local averaged image from the original. The image will be divided in to sub images to minimize the influence of deformation of grids (Local linearization) [21][28]. If the grid is very distorted, the sub images will become small. The calculated grid must be aligned with the main axes of the text. It is possible to work with a rotated grid or to align the complete image to orthogonal axes first. The latter has certain advantages in the organization of the data so this solution was chosen [28].

The Discrete Fourier Transform (DFT) can be used to calculate the rotation angle, but the image's structure causes important and recognizable data peaks in the DFT image to lie too close to the origin. This gives an error on the calculated rotation angle, and a further refinement is necessary. They followed a different approach. Using the deviation over the sum of the rows, the image was slanted over an angle [17][28].

#### 2.11.1.2 *Segmentation*

In the digitized Braille page, dots are represented with light and dark areas. They classify these areas by making a three-value image in which all pixels within a threshold value are made zero. Pixel values above this range are made +1 and below this range -1 (n is typically between 1 and 2, and allows adaptation to different illumination conditions) [28].

The actual center of the dots can be found by correlating the image with a mask as shown in *Figure 2.3*. This mask is an absolute simplification of a Braille dot. The vertical size of the mask depends on the size of the Braille dots and equals the distance between the centers of the dark and light area of an average dot.

After correlation, we obtain an image with five values. Regions with value -2 (recto) and +2 (verso) are called core regions, regions with value +1 (recto) and -1 (verso) are called side-lobes, and 0 is background.

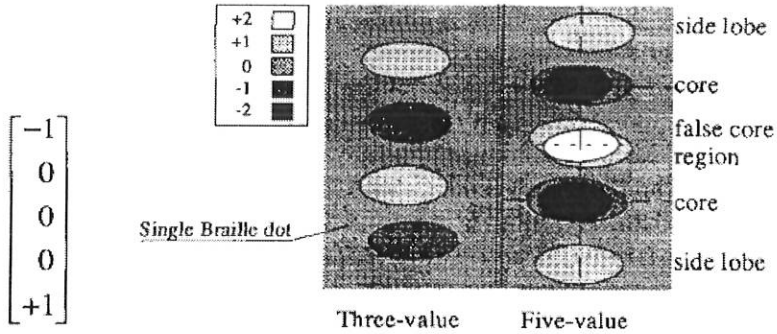



*Figure 2.3 Correlation mask for an image with a distance of five pixels between the center of the dark and light zone[left]and Neighboring dots introduce false core regions or ghost-point[right].*

*(source: Mennens, J., et al, "Optical Recognition of Braille Writing Using Standard Equipment", IEEE transactions of rehabilitation engineering, Vol. 2, No. 4, pp. 210, December 1994. Fig. 6)*

#### *2.11.1.3 Feature Extraction and Recognition*

Grid lines are searched by making histograms of rows and columns in the five-value image. These histograms have five bins (-2, -1, 0, 1, 2) [28].

- Firstly, the histograms for the rows are calculated. When a plot is made of the number of pixels in bin (+2) and bin (-2) (bin-curves), they show maxima where rows of recto and verso dots reside.
- Next, the histograms of the columns are calculated. Because the previously found horizontal grid lines are eligible to contain Braille dots, it is sufficient to consider these lines only in creating the histograms.
- Another improvement was made by making combinations of values found in different bins.
- In the case of recto dots, the presence of pixels with a value -2 was rewarded and the presence of pixels with a value -1 was penalized.
- These pixels are always found around the center of a Braille dot. This procedure will result in narrower peaks.

- After the vertical grid lines are found, the horizontal lines searched again, but in a reduced image that consists of the vertical grid lines only. Because grid lines were calculated separately for each sub image, the data needs to be regrouped in strips, to get an overview of the complete image.

Before we can do any interpretation of the Braille dots, it is a must to find all atoms in the vertical and horizontal grid lines. Distances and tolerances on line positions are always calculated on a local basis, i.e. the routine learns from local conditions to decide where candidate lines can be found [28].

#### *2.11.1.4 Test Results and Summary*

When all atoms are found, a small test (a minimal local correlation) will check for the presence of a dot on the intersection of two lines. These dots are grouped in a binary Braille character set (Binary Braille: each dot is represented by a bit position), which can be translated using an appropriate translation table to any other code [28].

The algorithm was tested on various types of Braille: single-sided and double-sided and every set contained an equal amount of samples. An average error rate of 0.25% on a character basis was reported [28].

Using a commercially available scanner and a set of fairly basic calculation methods to obtain a maximum conversion speed, a text containing Braille characters can be converted to any other character code. The most important characteristic of the routines is that on a local basis, without losing contact with the global context, and try to postpone complex calculations until the data set has been significantly reduced [28].

### *2.11.2 Analysis of scanned Braille documents*

This paper attempted the use of commercially available flat-bed document scanner for the first time to Braille document recognition. It argues that, the use of the camera introduced complexities such as

aberrations, considerable noise and the need for image registration. So to overcome these problems, earlier study used computationally expensive procedures [36].

After the Braille document is scanned, the system proceeds to identify the locations of the protrusions and the depressions. To do this it exploits the differences in grey levels in the image. It uses simple rules to distinguish between Braille dots on the two different sides. Then, the dots of each side are grouped together to form characters which are then recognized and encoded [36].

The system implemented in four steps: image acquisition, identification of Braille dots, segmentation and recognition of the characters.

#### *2.11.2.1 Image Acquisition*

The Braille document was scanned at 100 dpi and a 16 grey level image. Under the scanning configuration used, the grey level values of the background pixels were from 10 to 12. Lighter areas have grey levels with values ranging from 13 to 15, and the darker areas corresponding to shadows had grey level values less than 10 [21][36].

#### *2.11.2.2 Identification of Braille Dots*

The protrusions and the depressions on the surface of the Braille document give rise to differences in the grey levels in the image. In the scanning direction (vertical) the protrusions create a dark area first and then a lighter one. The depressions produce the opposite. (see *Figure 2.4*)

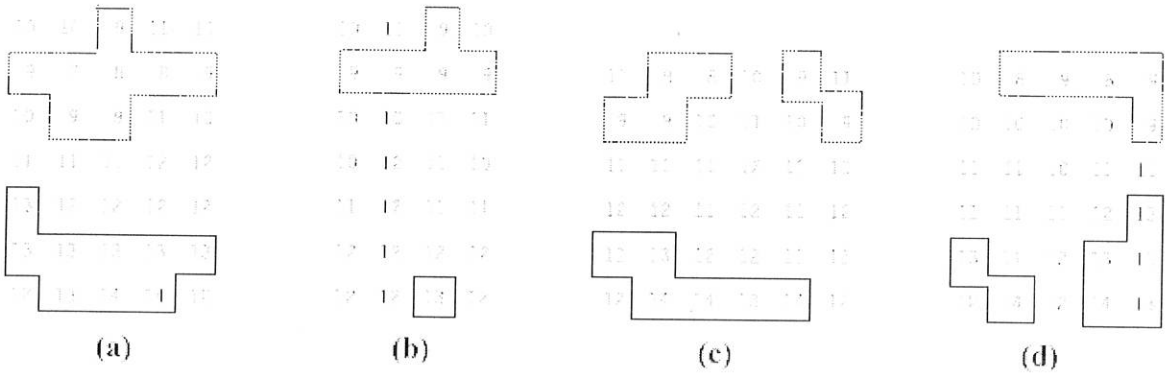



*Figure 2.4 Analysis of scanned Braille documents.*

Since there is such a consistency one could perform a template match to identify the locations of the depressions and the protrusions [21][36].

The algorithm to identify protrusions and depressions continues as follows. Each of the dark regions is considered in turn and a check is made to determine whether a light region exists above it. If it exists within the limits of the expected Braille character height then a depression is found. Otherwise, a check is made to determine whether a light area exists below the dark one. All protrusions and depressions identified are then written onto a new blank image independently. Then, the two images can be analyzed, each as containing only protrusions which form Braille characters [36].

#### *2.11.2.3 Character Segmentation*

The first action to analyze the resulting image from the earlier step is to locate the lines of Braille characters. Each character in a line has three rows where dots may be present. The distance between dots in consecutive rows of the same character line is determined and all the text lines that have dots on all three rows are detected. Then, knowing the average line height, the rest of the text lines together with the blank lines are also detected [21][28].

Having located the lines of Braille, the characters in each line are next segmented. Character segmentation is based on the analysis of the horizontal spacing between columns with dots. The fact that a Braille character may have dots in only one column also contributes to a variety of horizontal spacing in a text line [36].

#### *2.11.2.4 Character Recognition*

Once the position of each Braille character in the image is known, this step is concerned with the recognition of each character and encodes it in a suitable form for further processing. To achieve this, the rectangular area in the image that corresponds to a segmented character is divided into six equal compartments. These are arranged in three rows and two columns and represent the bounds of the expected positions of dots in a Braille character. If there is a dot in any of the compartments then a bit is set in a binary number at the position that corresponds to the number of the compartment. The binary number can then be used to identify the Braille character in the character set used [36].

#### *2.11.2.5 Results and Discussion*

A preliminary result from images of inter-point buff-colored Braille documents was promising. At this experimental stage, an average of just over 98.5% of the protrusions and 97.6% of the depressions are correctly recognized [36].

This paper concentrates on the application of OCR techniques to inter-point Braille documents. As a whole, the approach proofs the feasibility of a cost-effective, fast and easy to use Braille reading system [36].

### 2.11.3 A Braille OCR for Blind people

The purpose of this work was to develop an optical character recognizer (OCR) for the Braille code. The research gone through three main stages, including [23]:

- Processing of the scanned images to locate the positions of the Braille dot.
- Processing of the resulting dot from the previous process for Braille mesh determination.
- Application of the Braille alphabet to convert the located points into an ASCII text.

#### 2.11.3.1 Point Localization

This stage starts with an observed model of the pattern to be recognized. That is, in a double-sided two kinds of points distinguished: mountains (protrusion) and the valleys (depressions). This pattern can be observed in *Figure 2.5* [23][21].

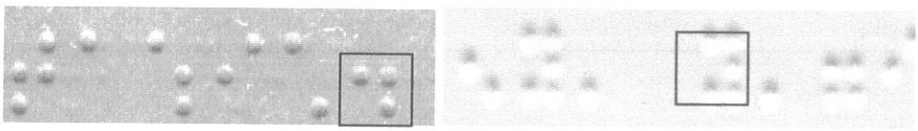


*Figure 2.5 Braille image showing left raised dots (protrusions) and right valley (depressions).*

So at this point in order to convert the zone in to black and white spots, the research applies two adaptive thresholds which are computed from luminance histogram.

Thresholding is an image processing technique for converting a grayscale or color image to a binary image based upon a threshold value. Image thresholding is very useful for keeping the significant part of an image and getting rid of the unimportant part or noise. If a pixel in the image has an intensity value less than the threshold value, the corresponding pixel in the resultant image is set to black. Otherwise, if the pixel intensity value is greater than or equal to the threshold intensity, the resulting pixel is set to white.

Thus, creating a binarized image or an image with only 2 colors (black (0), and white (255). However, this holds true under the assumption that a reasonable threshold value is chosen [15][21].

In the research, the thresholds are computed from the luminance histogram. They are found as the points that leave above/below a given percent of the total area of the histogram [21][23].

Afterwards, compute the centers of the black and white spots and consider them as black and white points. Then, look for couples formed by a white point above and a black point below. And also mark the couples formed by a black point above and a white point below as valley-points. It adjusted the thresholds in the distances necessary for two points to be considered as a couple [23].

The method had two problems: first, some points are lost and second, some false points are produced. The errors are due to spots that are very near to each other and that get joined after the thresholding process (this happens especially when a mountain and a valley are very near). The solution was to put all the intelligence in the next process (the mesh detection), which was able to remove the false points and to find where the points lost [23].

#### *2.11.3.2 Mesh detection*

This process detects the positions and directions of the lines and columns of the text that make up the Braille mesh. A Braille character has a mesh of 6 points. Each point may or may not be active. So having the entire mesh, it is possible to go over it and inspect the presence of spots near each potential point. This algorithm recovers the lost points. However the false points are the one that do not observe the distance rules. The algorithm is such that simply excludes them [23].

The algorithm chooses a starting point and goes moving the standard distances to construct the entire mesh [23]. At this point a key fact is to avoid choosing a false point as the starting one.

Another important issue is to detect the relative position of the starting point in its character that has 6 possible positions; by simply, suppose all the possible positions and then use the method explained above of maximal counts (counts of points found with this suppositions). First, determine to which column (out of 2) belongs the point and then to which row (out of 3) [23].

The final stage is the construction of the entire mesh beginning from the starting point. This movement is accomplished in an adaptive fashion. The method is to move a mesh of size 6 (a one character mesh). After the movement looking for the next character, if there are points near the mesh ones, then, correct the mesh position based on these points. This continues until the right limit of the image [23].

#### *2.11.3.3 Translation into ASCII*

Having done the previous stage, the Braille text now represented as characters of six points (six bits that may be 1 or 0) which are ready to convert into ASCII by applying a Braille alphabet [23].

### *2.11.4 Regular Feature Extraction for Recognition of Braille*

The aim of this paper is to present an automatic system to recognize the Braille pages and convert the Braille documents into English/Chinese text for editing. The proposed System in this study consists of six operations: Scene constraints, Image acquisition, pre-processing, segmentation, feature extraction, and Interpretation [14].

#### 2.11.4.1 *Scene Constraints*

It is a preliminary process to exploits and imposes the environmental constraints such as, illuminate with a yellow polarized light source, placed at an angle about 45 degrees away from the page top [14].

#### 2.11.4.2 *Image Acquisition*

The capturing device used in this experiment is a digital camera, which is placed directly above the Braille. The image captured with 512 * 512 pixel resolution with each pixel representing an 8-bit gray scale value [14].

#### 2.11.4.3 *Pre-processing*

Modify and prepare the pixel values of the digitized image for subsequent operations. The pre-processing operation consists of two sub-operations: noise filtering and edge enhancement [14][21].

A low-pass spatial Gaussian filter is applied to the image to attenuate the high spatial frequency noise from the image while at the same time preserving the detailed edge information of the Braille dots. The objective of edge enhancement is to sharpen the fine details of the image that has been blurred. The process performs two independent filtering operations using convolution Sobel kernels denoted X and Y, the resulting values are obtained by using the convolution formula [14][21]:

output = |convolute(input,X)| + |convolute(input,Y)|

#### 2.11.4.4 *Segmentation*

This step separates the acquired image into foreground (dots), and background regions. This operation also separates the front-faced dots and back-faced dots [14].

the Braille dictionary, and the retrieved characters are grouped into words. Each word is then check against an English dictionary [14].

Using both single-sided and double-sided Braille pages as the specimen, the system had been proved to be 100% and 97% accurate respectively. The system takes advantages of the regular spacing between Braille dots within a cell, and the regular spacing between cells [14].

### 2.11.5 *A Software Algorithm Prototype for Optical Recognition of Embossed Braille.*

The rationale behind this study was that most of the systems developed before concentrated on the translation; however, the formatting of the document is also critical when reproduction is involved [41].

The paper attempted to devise a method of Braille recognition that aims at preserving the formatting of the Braille page, as well as the efficiency and accuracy of the recognition algorithm [41].
The proposed system involves three steps: Half-character detection, half-character recognition, and text file transcription [41]. The block diagram for the proposed system is presented in *Figure 2.6*

- The half-character detection algorithm determines the whereabouts of the characters by detecting the possible dot positions.
- The half-character recognition determines the half-character that the dots represent by using a probabilistic neural network.
- After the half-characters have been recognized, the grid will be determined with the text file transcription algorithm to produce a Braille text file where the formatting is preserved as much as possible.

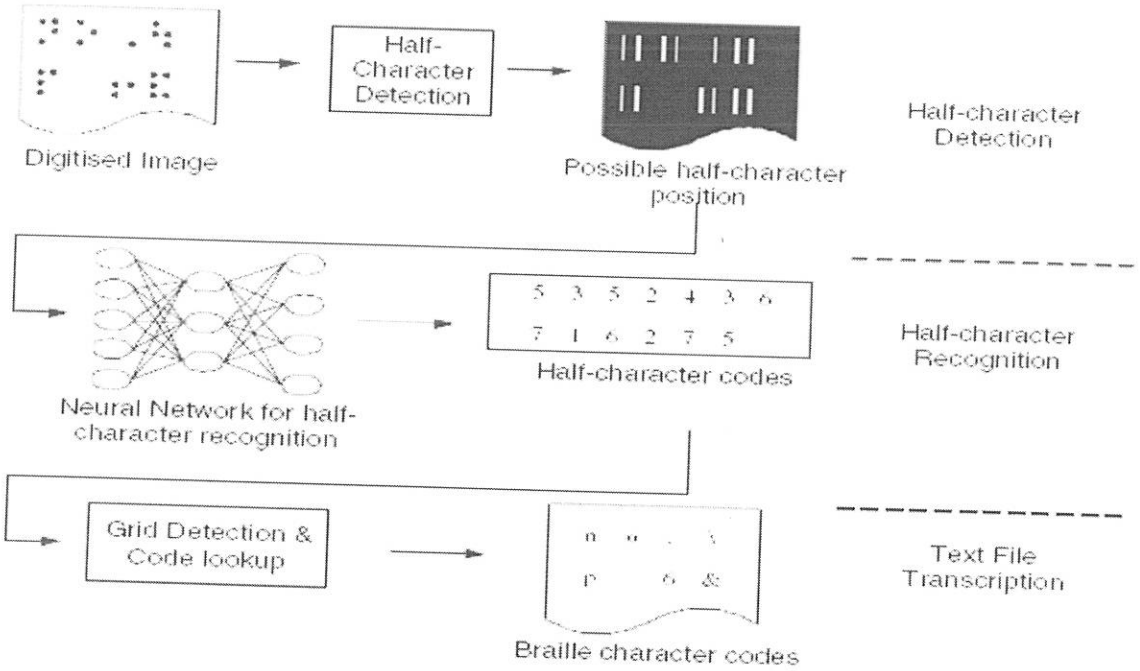



*Figure 2.6 A Software Algorithm Prototype for Optical Recognition of Embossed Braille.*

*(source: Wong, L., W. Abdulla, and S. Hussmann. "A Software Algorithm Prototype for Optical Recognition of Embossed Braille", the 17th conference of the International Conference in Pattern Recognition, Cambridge, UK, pp. 24, August 2004. Fig. 1 )*

### 2.11.5.1 Half-Character Detection

In this step, the row of pixels is changed into a two-tone image to distinguish the pixels that are likely to be part of the shadows of the dots from the others. The result from this process is two-tone images and the position of the character [41].

Compared with the conventional method of using a mask to determine the position of the dots, thresholding and buffering, although it does not give the exact location of the dots, can find the area where processing is needed to determine what character is present [41].

### 2.11.5.2 Half-Character Recognition

In this step further processing is made on the buffered two-tone image to recognize the half-characters detected from the previous step. The half-characters are processed and classified as one of seven possible

arrangements. The seven arrangements come from having three possible dot positions in each half-character, without considering "empty half character". This processing is done by using a probabilistic neural network, with [41]:

#### 2.11.5.3 *Text File Transcript*

This process determines the position of the original parent whole characters. To do this, it takes advantages of the fact that, the Braille format has very strict rules on the spacing

between dots within a character and between neighboring characters, thus these rules can be used to help determine the positions of the characters in the document, as well as whether the half-characters are the left half or the right half [41]. By looking at the distances between the dots, the intra and inter-character spacing were estimated. Using this information a grid was formed to all possible positions for the characters in the document. Once the grid has been estimated, the position of the characters with respect to the image can be used to calculate the positions of the characters in the document [41].

This study proposed an algorithm to optically recognize Braille documents and transcribe documents into a computer file. The algorithm processes the image one row at a time and uses thresholding to pre-process the image. The processed sections that contain the Braille characters are then recognized using a probabilistic neural network. On experiments performed on single sided computer embossed documents, more than 99% accuracy was achieved [41].

### 2.11.6 *Image Processing Techniques for Braille Writing Recognition.*

This study attempts the development of BrailLector, a system able to speak from Braille writing. The system applied dynamic thresholding, adaptive Braille grid, recovery dots techniques and TTS software (Text-To-Speech) presented in *Figure 2.7* [32].

The paper first describes the characteristics of the database created for such purpose, followed by, image processing techniques used for dots detection and recovering. Then, explain the conversion from Braille text to standard text. The proposed system block diagram presented in

### 2.11.6.1 Database

A big database was created in order to check the global system with as many characters (30862) from 26 Braille sheets; to ensure the correct testing of the developed system and a good analysis of the error variance [32].

The mechanism used for image acquisition has been a flat-bed scanner with different resolution than 100 dpi since it uses interpolation methods to resize the input image [32].

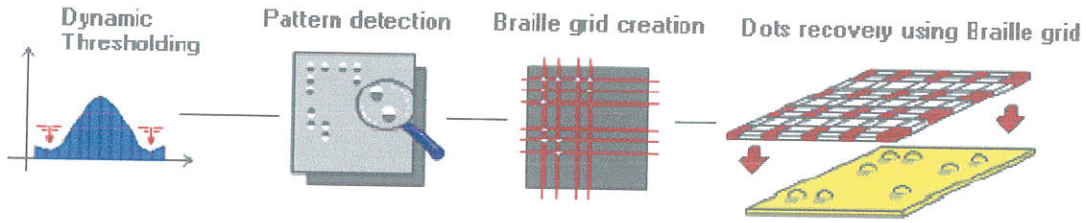



*Figure 2.7 Image Processing Techniques for Braille Writing Recognition*

*(Source: Wong, L., W. Abdulla, and S. Hussmann. "A Software Algorithm Prototype for Optical Recognition of Embossed Braille", the 17th conference of the International Conference in Pattern Recognition, Cambridge, UK, pp. 308, August 2004, Fig.2)*

The different image processing steps of the scanned image for its translation include the following.

### 2.11.6.2 Thresholding

This is a primary process that applies innovative thresholding method to extract the useful information of Braille images. Once the optimum area of Braille spots (to reduce the number of wrong symbols detected)

are known, an iterative algorithm looks for the best threshold according to these areas of Braille dots. This is done, to get the optimum levels to separate black, white and grey [32].

#### *2.11.6.3 Pattern detection block*

After the first step, no useful information is rejected, and in this step it takes advantage of the shadows protrusions which make dot patterns. So this difference facilitates the separation between front and back side dots [32]:

The goal of this secondary process is to separate each side of the document in different images. The algorithm consists of a "shift and overlap" process since it only moves the spots downwards or upwards and carries out a logical and. As it avoids the sequential reading of the image matrix approach was fast, very simple and efficient [32].

Skew detection: this stage applies horizontal histogram and mass centers calculation to detect skew angle and correct by rotating the original image [32].

Problem: all dots are not detected with overlapping process, some of them are missed, either because they are very small or their shadows do not overlap with only 4 pixels. For this reason, a new stage was added to the system: Braille grid [32].

#### *2.11.6.4 Braille grid.*

In order to produce the mesh from the detected dots, they develop adaptive algorithm. The algorithm works as follow [32]:

- Builds columns in a first stage: since distances between points are normalized, the process begins searching for groups of dots in the same vertical plane that respect these distances.

- Then, builds the columns according to the pattern of Braille columns adapting itself to the layout of the document. This result, a flexible mesh that tolerates small differences between columns. The process for the rows is quite similar but in this case the pattern to search is a Braille row.
- Detected columns and rows will be arranged together to create the final structure. As the grid was flexible, it makes suitable for copying Braille sheets without losing the format.

#### *2.11.6.5 Dots recovery using Braille grid*

After mesh building, all valid Braille positions are known; intersections between rows and columns define a valid position for a Braille dot. So in this step [32]:

- First, dilation techniques are used to expand the search zone.
- Then, fit this image on the dots image after thresholding in order to check in detail those positions where dots were not found.
- Only potential positions of dots are checked; this means time saving and efficient search. Original dots will be recovered (they belong to correct Braille positions) and false dots will be discriminated as they are out of the valid places for a Braille dot.

#### *2.11.6.6 From Braille to Normal Text*

In this process the final image that contains the Braille dots represented by spots, is analyzed and text is segmented in rows and characters. Segmentation process takes advantage of the Braille mesh again as it marks all the positions of Braille dots. Every character is converted into a binary number according to the active dots. The process consists of reading character by character and each one of the six positions that make the basic cell. The output of this step is a file with each character coded like a binary number [32].

This paper explained the development of an automatic system for translating Braille text to normal text or voice. To achieve this the system apply, dynamic thresholding and adaptive Braille grid had been used, adding some intelligence to the global process and making it able to detect dots in both sides of the

document with only one scan. It is a robust application with 99.9% of correct symbols. The conversion time is 26 seconds for double-sided documents by MATLAB programming language [32].

### 2.11.7 *An Arabic Optical Braille Recognition System*

This paper looks at developing algorithms to recognize an image of embossed Arabic Braille of both single-sided and double-sided material obtained by a regular scanner; the research was published in 2007 [6].

The research comprises the following steps [6]:

- Capturing an image of a Braille document page using a flatbed scanner.
- Converting the image to a gray color.
- Followed by cropping any white or black frames.
- The result from the previous step is thresholded so that only three classes of regions exist: dark, light and background.
- In case of having a tilted paper, de-skewing is applied using a binary search algorithm.
- Perform initial identification of Braille dots (Having labeled each of the different types of regions)
- Finally, Braille cells recognition.

#### 2.11.7.1 *Image acquisition/Converting the Image to Gray Level*

To reduce complexity the first step in this system converts colored scanned images to gray level so that any pixel value in the image falls within the range 0 – 255 [6][17].

#### 2.11.7.2 *Image pre-processing*

a. Cropping the Image Frame

Images suffer from having either black or white frames that would affect thresholding, so cropped before proceeding forward. To handle the problem, calculate the average gray level for the whole image and then for each of the rows and columns separately [6].

b. Image Thresholding

Once again, at this step the research involved examining each pixel in the 2-D array representing the scanned Braille document and classify in to three categories with threshold:

(1) Gray level pixel elements having values 32 and above are considered bright and given a threshold value +1.

(2) Gay level pixel elements having values 23 and below are considered dark and given a threshold value -1.

(3) Gray level pixel elements having values between 23 and 32 are considered gray and given a threshold value 0.

The algorithm to handle works as follows; after converting the image to gray level and removing highest and lowest values to leave out distinct values, the average gray level for the whole image is calculated. After that both a and b values are calculated according to the following equations [6][17]:

$$a = \text{mean}\ (\ \max(I) + \text{avg}\ )\ /\ 2$$

$$b = \text{mean}\ (\ \min(I) + \text{avg}\ )\ /\ 2;$$

Where:

- a highest value and b lowest value
- I is an array representing the whole image.
- max (I) and min (I) represent the highest and lowest values respectively in each column of the array I.

The classification parameters L and H are calculated according to the following equations:

$$H = \text{avg} + (\ \text{max\_avg} - \text{avg}\ )\ /3;$$

$$L = \text{avg} - (\ \text{avg} - \text{min\_avg}\ )\ /\ 3$$

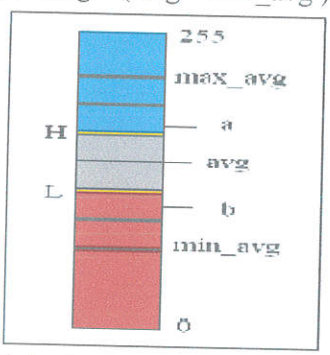



*Figure 2.8 Arabic Braille Recognition proceeding*

# Chapter Three

## 3. Braille Recognition Technique

### 3.1 Introduction

The present research is concerned with the adoption of different Braille image recognition techniques for Amharic Braille documents. For this purpose approach that are used to Braille recognition such as image thresholding/Binarization, segmentation, feature extraction and recognition are reviewed. The part also discusses the neural network techniques to classify the given Braille-to-print character.

### 3.2 Digitization/Image Acquisition

In Optical Braille Recognition (OBR), digitization enables to produce a digital image of the scanned document in the form of bitmap. Currently, there are different alternatives used to digitize Braille document: from digital camera to flat bed scanner, hand held scanner or a sheet-fed scanner. A flat-bed scanner is a cheap alternative which can be used for so many other applications of this sort.

To distinguish the dots adequately, the spatial resolution setting should be between 80 and 200 dots per inch (dpi). This is because, below 80 dpi there is an insufficient amount of information and above 200 dpi the extra amount of information is superfluous. Although 16 grey levels (4 bits) yield acceptable results and minimize the memory space required, the use of 256 (8 bits) is recommended for better results [21] [36].

### 3.3 Binarization/Image Thresholding

In image processing, Binarization is the process of identifying the foreground (black color), which would be the content of the scanned image, from the background (white color). However, the identification of Braille dots from the differences in the intensity of reflected light is not straightforward. There are various

methods that can be used to binarize digitized documents. Among the great deal of techniques thresholding is the simplest and most commonly used approach that applies some value for the purpose. The techniques can be global or local thresholding. Meanwhile there is one outstanding problem, i.e. how to devise an automatic procedure for determining the optimum thresholding level.

In Global thresholding a single threshold value is calculated from the total intensity level of the pixel that forms the image. The resulting threshold value is then applied to the whole image pixel. Accordingly, a given pixel, based on its intensity level compared with the threshold, to set its value [17].

In local thresholding, the threshold value is calculated by considering the intensity of the image pixel in a given area, so we may have different threshold value for different area in the image. The locally calculated threshold value is used to determine the class of that pixel in the local area such as: black or white. However, local thresholding is computationally expensive as it accesses each pixels many times. And it is not recommended in many cases [17].

The global- thresholding algorithm adopted in this study is given in ***Figure 3.1***. The algorithm adopted involves the conversion of color pixel to gray level to reduce computation expense.

```
//Image thresholding algorithm
Let Img is a matrix with same size with Braille bmp image and
Let x and y be horizontal and vertical coordinate independently
Set x=y=0; // set coordinate to first pixel of image
Do
        For each line in Img do
                Read each pixel at Img(x, y) and Convert in to gray-level
                If gray level is less than or greater than the threshold then
                        Set pixel at Img(x, y) as black//content or foreground
                Else
                        Set pixel at Img(x, y) as white//background
While end of Img
```

*Figure 3.1 Global-thresholding algorithm for Braille image*

## 3.4 Image Segmentation

Segmentation refers to the process of separating dots from Braille image that can further be grouped in to a cell. For the Braille recognition problem domain, the point of interest or the low level of abstraction to be extracted is the single dot that could have six alternative positions in a cell.

There is different segmentation technique particularly apply in Braille image such as mesh-grids based or local measure. In local measure, the approach takes advantages of the difference in dots pixel intensity level. The dots produce different color level at the top and bottom. So the dots can be extracted by performing analysis of pixels forming the dot with threshold. However, this is usually is not preferred as it lead to extraction of noise as valid dot. The second technique, mesh-grids, is appropriate and widely applicable in Braille. The technique is preferred since Braille cells arranged strictly following vertical and horizontal layout of the document and does not have unique structure to isolate one combination from the others. Besides segmentation with mesh-grids bring good result for most of the Braille research [23][28][32].

In this regard, different techniques have been devised to solve clustering problem domain in data mining. Among, the existing clustering algorithms the interest is on grid-based methods. Grid is a pattern of straight lines crossing each other which quantizes the space into a finite number of cells. Grid Mesh can be global or adaptive. Grid-based methods have the fastest processing time that typically depends on the size of the grid instead of the data objects. These methods use a single uniform grid mesh to partition the entire problem domain into cells and the data objects located within a cell are represented by the cell using a set of statistical attributes [27].

Adaptive Mesh, on the other hand, is a type of multi-scale algorithm that achieves high resolution in localized regions of dynamic, multidimensional numerical simulations. Its adaptability allows simulating multi-scale resolutions that are out of reach with methods using a global uniform fine grid.

Thus, in global grid, the horizontal and vertical grids are constructed based on a fixed global threshold. Whereas, in adaptive mesh the threshold is determined locally for each dots that runs vertically and horizontally. To determine the size of dots, analysis of the dots profile is important. To this end, each logical line of the Braille is extracted by constructing the horizontal projection. This process is important to determine the height of a single dot, which would be used while constructing the horizontal grids. After line segmentation, vertical projection is performed that result in half-character segmentation (one column of a cell). Then, based on the above information (spacing, dot height and width), a mesh is constructed.

The algorithm first finds optimal starting dot by searching black pixel column wise and start to count if black pixel is found until the next white pixel is found; and do the same for raster line horizontally. The resulting value checked for threshold and then used to complete the horizontal and vertical grids. Global mesh-technique is the preferred approach, if the size of the dots in the image is uniform. However, it has problem if dots size differ from document to document as it apply the same global threshold value to draw all grids line in the image.

In adaptive mesh-grids technique, to draw the horizontal grids the algorithm finds the maximum height of dots from line segmentation. To perform line segmentation, the algorithm scan each raster line of the image horizontally, if black pixel is found, it marks as the beginning of the dots and increment the dot count by one. And then jump to the next raster line to check the presence of black pixel. This continues until no more black pixel is found in the next raster line of the image. Thus, the first black pixel and the first white pixel after the black pixel mark the beginning and the end of that particular dot. Once the dot height is determined for a given dot line, the midpoint is calculated by dividing the dot count value by two. Then, the algorithm sets pixels in raster line that pass through the midpoint coordinate, to some color value to draw the horizontal grids line.

To draw the vertical grids the algorithm scan vertically to find the maximum dot width from half-character segmentation. The resulting value which indicates the width of dot is divided by two to draw the vertical grid at the current height position plus half of the dot width value for that specific vertical line. This

process continues adaptively for the whole image calculating the new dot width to draw the subsequent grids. The advantage of adaptive mesh is that it considers locally the size of dots in drawing each grids line.

***Figure 3.2*** and *Figure 3.3* describe algorithm for horizontal and vertical grids.

```
//Adaptive grids-mesh to construct Horizontal grids line
Let img is matrix same size with Braille image,
Let x and y are coordinates points for width and height of the image.
Do
        For each y where y is less than img height
                If pixel at img(x, y) is black
                        Do while pixel at img(x ,y) is black
                                Increment dotcount by one
                                Go to next row
                        End loop
                Else
                        Jump to next line
                End if
        End for
        If dotcount less than min-threshold
                Continue to next column
        If dotcount greater than min-threshold and less than max-threshold
                Let w=0
                For each w where w is less than img width
                        Draw horizontal grid-line at y-(dotcount/2)
        Else If dotcount greater than max-threshold
                Let w=0
                For each w where w is less than img width
                        Draw horizontal grid-line at y-(3/4)*dotcount
                        Draw horizontal grid-line at y-(1/4)*dotcount
End loop
```

*Figure 3.2 Horizontal Mesh-grids algorithm*

```
//segmentation algorithm based on adaptive mesh-grids
Let img is matrix same size with Braille image
Let x and y are coordinates points for width and height of the image.
//construct vertical grids line
Do
        For each x where x is less than img width
                If pixel at img(x, y) is black
                        Do while pixel at img(x ,y) is black
                                Increment dotcount by one
                                Go to next column
                        End loop
                Else
                        Jump to next line
                End if
        End for
        If dotcount less than min-threshold
                Continue to next line
        If dotcount greater than min-threshold and less than max-threshold
                Let h=0
                For each h where h is less than img height
                        Draw vertical grid-line at x-(dotcount/2)

        Else If dotcount greater than max-threshold
                Let h=0
                For each h where h is less than img height
                        Draw vertical grid-line at x-(3/4)*dotcount
                        Draw vertical grid-line at x-(1/4)*dotcount
End loop
```

*Figure 3.3 Vertical Mesh-grids algorithm*

The algorithm is implemented to tolerate noise in case the two consecutive dots do not have space to delimit the end of the first dot and the beginning of the next dot. Thus, if the size of dot is above the threshold set to single dot size two grids line is drawn, at current height value minus ¾ and ¼ of dot count for the first and the second grids line respectively.

Once the mesh is constructed, segmentation extracts the dot point from the image. The segmentation procedure identifies the foreground, from the back ground based on previously constructed mesh. The algorithm perform search for the foreground pixel with threshold. As the segmentation is based on mesh, search to extract dots are performed around the intersection of the horizontal and vertical gridline.

The segmentation algorithm starts by determining the first intersection point of the mesh on the Braille image. Then the algorithm search pixel color of the foreground (content) with threshold in all direction around the intersection point to declare the presence of valid dot which would be the possible location of the dot.

The threshold can be relaxed to consider the minimum dot size. Accordingly, if the pixel meet the threshold, the (x, y) coordinate values of that point is registered in an array prepared for such purpose. This continues for the whole mesh intersection points and the corresponding (x, y) coordinates is registered if there is a dot on that coordinate.

Finally, the algorithm convert the whole image in to black color and set the dot coordinates value with one pixel of white color.

The segmentation technique which depends on the constructed grids mesh is robust and tolerates noise. This is because the algorithm does not require checking every pixel in the image. Moreover it tolerates noise as the search is made only following the mesh coordinates. The algorithm is described in ***Figure 4.20***

## 3.5 Feature Extraction and Recognition

Feature extraction is a representational mechanism of the Braille image. At this stage the identity of each of the Braille detected is recognized. Since each character is distinguished from the rest by its unique combination of dots, it will suffice to identify the (relative) positions of its dots. Then, the character can be described in terms of the numbers of dot positions.

Since the positions of Braille characters in the image have already been identified, it is straightforward to check for the existence of a dot at each of the six positions of points in a Braille cell.

The first approach is to describe Braille characters as a region in the image; this region is divided into six equal compartments (two across, three down) in which the search for dots is performed. If the exact positions of dots in the image are known, it is easy to check if one of them is included in a compartment along specified directions following mesh grid that has been constructed. The six possible positions of the dots are known for each individual Braille character position in the image. Hence, all the possible character positions are examined. Within each one of them, the intersections of grid lines are considered [21].

So, modification of region based approach is adopted in the current study. The modification is that the six compartment of the cell checked for the presence of a single pixel rather than all pixels in the area. This is because, after segmentation dots has a single pixel representation. Then, context analysis is performed to recognize the cell as part of the Braille character or stand alone as a Braille character.

At this stage feature extraction, takes advantage of the mesh. The algorithm following the mesh access dots on the coordinate point and group into cell. Then, the resulting grouped dots of a cell are checked for its content against the rules defined. The context analysis is used to determine the status of the cell. Accordingly, a cell will have three possible statuses in a Braille character. Depending on the number of cell (one or two) defined for a Braille character, the cell recognized as part of a character or as a character alone. That is once, the feature extraction is performed, which group dots in a cell, up on recognition the cell is recognized as a Braille or part of Braille character. Algorithm adopted for feature extraction and recognition is presented in appendix V.

## 3.6 Artificial neural network

### *3.6.1 Introduction*

An artificial neural network (ANN) is a mathematical model or computational model based on biological neural networks. It can also be referred to as an adaptive statistical model on an analogy with the structure

of the brain. Neural network find application in modeling, patter recognitions, signal processing and control by virtue of an important property; the ability to learn from input data [24]. The following part of the section dedicated to discuss on the concept and issues on neural network.

Artificial neural networks have been studied for more than four decades since Rosenblatt first applied the single-layer perceptrons to pattern-classification learning in the late 1950s. Recently, many researchers apply neural network in the field of computer engineering and artificial intelligence. It has been used in large number of application and has proven to be effective in performing complex function in a variety of fields. These include pattern recognition, classification, vision, control system and predictions [19].

Different definitions are forwarded to neural networks. However for the purpose of this study the one used by Heikin, S, 1999, will be adopted, which views the ANN as a formalized adaptive machine:

> *"An artificial neural network is a massive parallel distributed processor made up of simple processing units. It has the ability to learn from experiential knowledge expressed through inter unit connection strengths, and can make such knowledge available for use."*

### *3.6.2 Basic structure of a neuron*

#### *3.6.2.1 The Human brain*

Artificial Neural Networks were inspired by biological findings relating to the behavior of the brain as a network of units called neurons. The human brain is estimated to have around 10 billion neurons each connected on average to 10,000 other neurons. The neural model comprises the basic structure of the human brain shown in ***Figure 3.4*** .The tree like structure called the **Dendrite.** The neurons collect signals from other neurons through these dendrites. The neuron send out spikes of electricity activity through a long, thin stand known as **axon,** which split into thousands of branches .At the end of each branch, a structure called a **synapse** converts the activities from the axon into electrical effects that inhibits or excites activity in the connected neuron .When a Neuron receives excitatory input that is sufficiently large

compared with its inhibitory input, it ends a spike of electrical activity down its axon. Learning occurs by changing the effectiveness of the synapse so that the influence of one neuron on another changes.

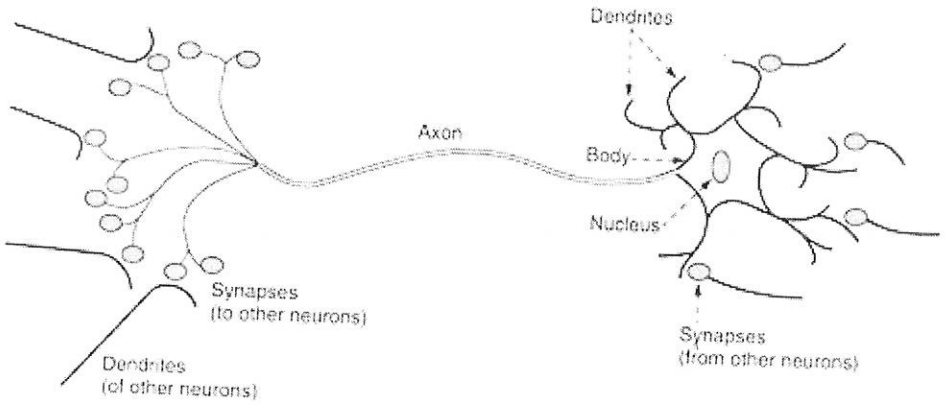



*Figure 3.4 The Biological Neuron Model*

The biological neuron model is the foundation of an artificial neuron. It simulates the four basic components of the natural neuron: Dendrite**, soma, axon, and synapses**.

In the neural network literature, the unit analogous to the biological neuron is referred to as a processing elements [**PE**] or units. A processing element has many input path and combines, usually by a simple summation, the values of these input paths.

When creating a functional model of the biological neuron, there are three basic components of importance. First, the synapses of the neuron are modeled as weights. The strength of the connection between an input and a neuron is noted by the value of the weight. Negative weight values reflect inhibitory connections, while positive values designate excitatory connections [24]. The next two components model the actual activity within the neuron cell. An adder sums up all the inputs modified by their respective weights. This activity is referred to as linear combination. Finally, an activation function controls the amplitude of the output of the neuron. An acceptable range of output is usually between 0 and 1, or -1 and 1.

Mathematically, this process is described in ***Figure 3.5***.

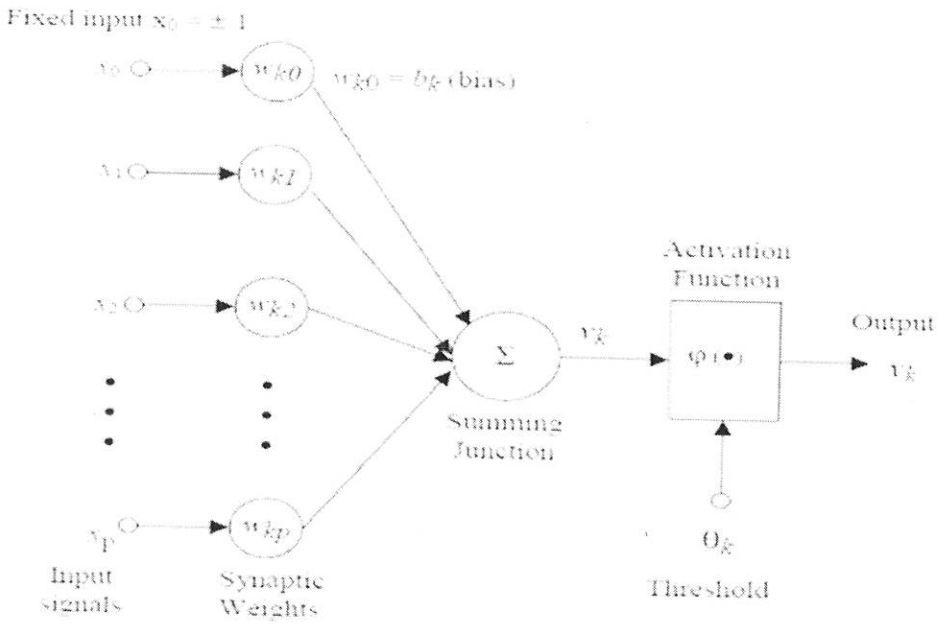



*Figure 3.5 Artificial Neural Network Model*

From this model the interval activity of the neuron can be shown in ***Equation 3.1***:

$$v_k = \sum_{j=1}^{p} w_{kj} x_j$$

*Equation 3.1 Weight Summation function for Neural Network*

The output of the neuron, $V_k$, would therefore be the outcome of some activation function on the value of $V_k$.

### 3.6.3 *Component of Neural Network*

There are seven major components that make up an artificial neural network such as: Weighting Factors, summation function, transfer function, scaling and limiting, output function Error function and Back-propagated value and learning function [8]. These components are valid where the neuron is used in any layer: input, output or is in one of the hidden layers.

### *3.6.3.1.1 Weighting Factors*

A neuron usually receives many simultaneous inputs. Each inputs has its own relative weight, which gives the input the impact that it needs on the processing element's summation function. Weights are adaptive coefficient within the network that determines the intensity of the input signal in the artificial neuron. They are the measures of an input's connection strength. This strength can be modified in response to various training sets and through its learning rules.

### *3.6.3.1.2 Summation function*

The first step in processing element's operation is to compute the weighted sum of all of the inputs. Mathematically, the inputs and the corresponding weight are vectors which can be represented as $(X_1,X_2,X_3.....X_m)$ and $(W_1,W_2, W_3.....W_m)$.The total input signal is the dot , or inner product of these two vectors .The result is a single number ,not a multi-element vector.

The summation function can be more complex that just the simple input and weight sum of product .The input and weight coefficients can be combined in many different ways before passing onto the transfer function. The specific algorithm for combining neural input is determined by the chosen network architecture and paradigm.

### *3.6.3.1.3 Transfer Function*

The result of the summation function, almost always the weighted sum ,is transferred to a working output through an algorithmic process known as the transfer function .In transfer function ,the sum total can be compared with some threshold to determine the neural input .If the sum is greater than the threshold value, the processing elements generate a signal. If the sum is less than the threshold, no signal is generated. Both types of response are significant.

### *3.6.3.1.4 Scaling and Limiting*

Once the transfer function has completed, the result can pass through additional processing such as scaling and limiting. This scaling simply multiplies a scale factor times the transfer value, and then adds an offset. Limiting is the mechanism, which insures that the scaled result does not exceed an upper or lower bound. This limiting is in addition to the hard limits that the original transfer function may have performed. And such type of scaling and limiting is mainly used in topologies to test biological neuron models.

#### *3.6.3.1.5 Output Function*

Each processing element is allowed to output one signal, which it may send to hundreds of other neurons. This is just like the biological neuron, where there are many inputs and only one output. Normally, the output is directly equivalent to the transfer function's result. Some network topologies, however, modify the transfer result to incorporate competition among neighboring processing elements. Neurons are allowed to compete with each other, inhibiting processing elements unless they have great strength. Competition can occur at one or both of two levels. Which determines neuron that will be active, or provide an output; and help to determine which processing elements will participate in the learning or adaptation process.

#### *3.6.3.1.6 Error function and Back-propagated value*

Artificial neuron's error is calculated as the difference between the current output and the desired output, in most learning networks. This raw error is then transferred by the error function to match the particular network architecture. The artificial neuron's error is then typically propagated into learning functions of another processing element. This error term is sometimes called the current error.

The current error is typically propagated backward to a previous layer. Yet, this back propagated value can be either the current error, the current error scaled in some manner or some desired output depending on the network type. Normally, this back-propagated value, after being scaled by the learning function, is multiplied against each of the incoming connection weight to modify them before the next learning cycle.

### 3.6.3.2 Learning functions

The purpose of the learning function is to modify the variable connection weights on the inputs of each processing elements according to some neural based algorithms. This process of changing the weights of the input connections to achieve some desired result could also be called adaptation functions, as well as the learning mode.

### 3.6.3.3 Type of Activation Function

#### *3.6.3.3.1 The activation function*

The activation function Φ (.) performs a mathematical operation on the signal output. As mentioned above, the activation function acts as a squashing function, such that the output of a neuron in a neural network is between certain values (usually 0 and 1, or -1 and 1). In general, the most commonly used activation functions are three, which are described below.

First, there is the Threshold Function, also known as Heaviside function, which takes on a value of 0 if the summed input is less than a certain threshold value (v) and the value 1 if the summed input is greater than or equal to the threshold value shown in ***Equation 3.2***.

$$\varphi(v) = \begin{cases} 1 & \text{if } v \geq 0 \\ 0 & \text{if } v < 0 \end{cases}$$

*Equation 3.2 Threshold Function*

Secondly, there is the Piecewise-Linear function. This function again can take on the values of 0 or 1, but can also take on values between that depending on the amplification factor in a certain region of linear operation given in Equation 3.3.

$$\varphi(v)=\begin{cases}1 & v\geq\frac{1}{2}\\ v & -\frac{1}{2}>v>\frac{1}{2}\\ 0 & v\leq-\frac{1}{2}\end{cases}$$

*Equation 3.3 Piecewise Linear Function*

Thirdly, there is the sigmoid function. This function can range between 0 and 1, but it is also sometimes useful to use the -1 to 1 range. An example of the sigmoid function is the hyperbolic tangent function. The sigmoid function is strictly continuous function, which can be differentiable. This property makes it appropriate for use in neural network trained by back-propagation shown in Equation 3.4

$$\varphi(v)=\tanh\left(\frac{v}{2}\right)=\frac{1-\exp(-v)}{1+\exp(-v)}$$

*Equation 3.4 The Sigmoid Function*

Some more types of activation function are also used in different areas of application of ANN .The choice of the activation function mainly depends on the distribution of the target value, which is generated by the output units. For continuous valued targeted with a bound range, the sigmoid function are preferable, provided that either the output or the target to be scaled to the range of the output activation function [37].

### 3.6.3.4 The network Architecture

Artificial neural networks have simple structures and are designed to mimic the function of the biological neurons. The principal importance of a neural network lies on their interconnections. The natural connection of a human brain is too complex to be implemented directly in neural network. The structures, therefore studied so far are simple and easy to be implemented in digital computers.

Architecture of a neural network is the specific arrangement and connection of the neurons that are organized in the form of layers, make up the network. It is defined by a number of layers, the number of units per layers, and the interconnection pattern between layers. In general, ANN has a similar structure of topology, basically, these are three types of layers each consisting of a group of neurons.

- The input layers consist of neurons that receive input from the external environment
- The output layers consist of neurons that communicate the output of the system to the user or external environment
- One or more hidden layers between the output and input layers

When the input layer receives the input, its neurons produce output; this becomes input to the next layer of the system. The manner in which the neural network is structured is internally linked with the learning algorithm used to train the network [24].

#### *3.6.3.4.1 Single layer feed forward networks*

A feed forward network is a network where the neurons on the first layer send their output to the neurons on the second layer, but they do not receive an input back from the neurons on the second layer.

In other works the network is strictly feed forward. A network with the input and output layer only is called single-layered network.

#### *3.6.3.4.2 Multi layer feed forward networks*

The multilayer feed forward networks or the multilayer preceptron, are generalization of the single layer perceptron. It includes one or more hidden layers each with their respective number of neurons as shown in Figure 3.5. The function of the hidden neurons is to intervene between the external input and the network output in some useful manner.

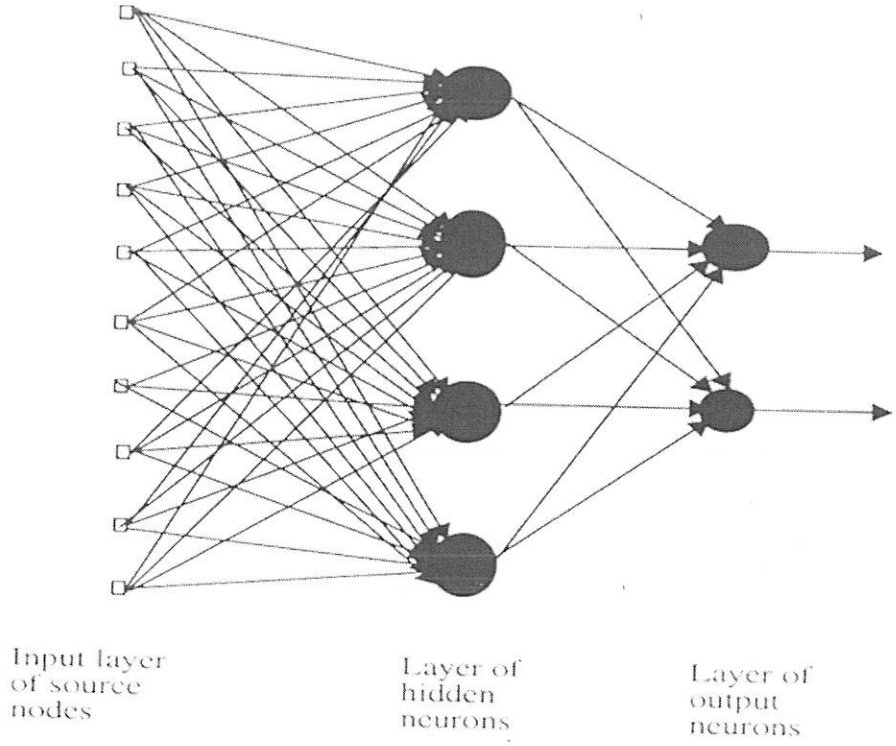



*Figure 3.6 Feed Forward Neural Network*

### *3.6.3.4.3 Recurrent networks*

A Recurrent networks, which is sometimes referred to as feedback networks can have a signal traveling in both direction by introducing loops in the network. There may, exist one or more such loops as shown in ***Figure 3.7***. In these networks a neuron of layer after receiving input from another layer, send its output back to the previous layer neurons. Recurrent network are said to be dynamic in that their state is changing continuously until they reach an equilibrium point [34].

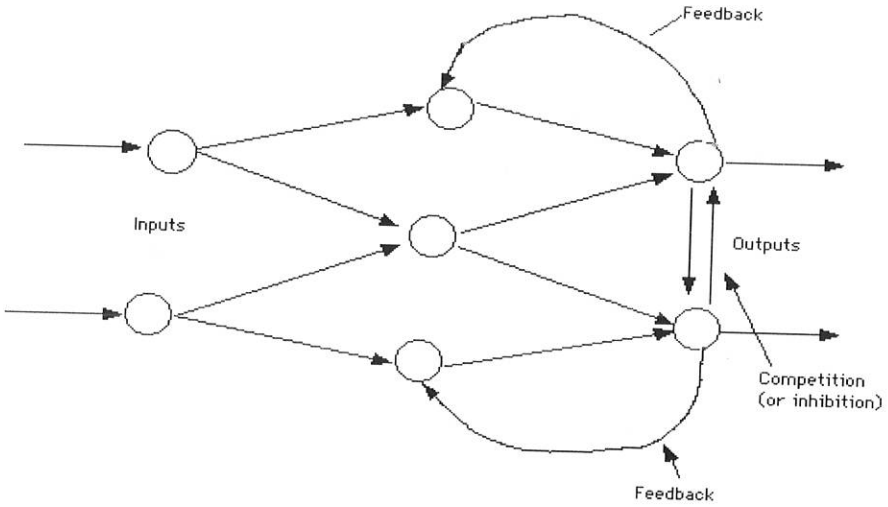



*Figure 3.7 Simple Networks with Feedback and Competition.*

### 3.6.3.5 The learning process

The process of adjusting the weight to make the network learn the relationship between the input and target is called learning. The connection between neurons in a neural network is given adjustable weights or measure of importance. To be more precise a definition of learning that is adapted from Mendal and McClaren [1970] is given by [24] as follows:

> *"Learning is a process by which the free parameters of a neural network are adopted through a process of stimulation by the environment in which the network is embedded. The type of learning is determined by the manner in which the parameters changes take place."*

The process of making the network to learn the solution to a problem follows a set of well defined rules called the learning algorithms. Many learning algorithms have been invented to help find an optimum set of weight that result in the solution of the problem. In general, all the learning methods of an adaptive network can be classified into two major categories.

### *3.6.3.5.1 Supervised learning*

In Supervised learning the neural networks are trained to produce desired outputs in response to sample inputs, making them particularly well suited to modeling and controlling dynamic systems, classifying noisy data, and predicting future events. Most commonly, neural network use supervised training. These input-output pairs are provided by an external teacher or by the system containing the network. For this reason it is also called learning with a teacher. The actual output of the net may or may not match the desired output, depending on the weight at the particular moment. In all cases the training algorithms modifies the weights with the idea that the next time the net sees the same input pattern, it will more closely reproduce the target output pattern as its actual output.

### *3.6.3.5.2 Unsupervised learning*

In Unsupervised learning the neural networks are trained by letting the network continually adjust itself to new inputs to find pattern or regularity in the input data. So the network is not trained towards specific outputs. It is self-organizing learning process that does not require external teacher. Once, the network has become tuned to the statistical regularities of the input data. It develops the ability to form internal representation for encoding feature of the input and thereby to create new classes automatically [9].

**Learning rate**

It is rate at which the artificial neural network learns and it depends on the several controllable factors. In selecting the approach, there are many tradeoffs to consider. Obviously, a slower rate means of a lot more time is spent in accomplishing the off-line learning to produce an adequately trained system. With the transfer learning rates, however, the network may not be able to make the fine discriminations possible with a system that learns more slowly.

Generally, several factors besides time have to be considered when discussing the offline training test. Network complexity, size, architecture, type of learning rule or rules employed and desired accuracy must

be all considered. These factors play a significant role in determining how long it will take to train a network.

Usually learning rate is positive and between zero and one. If the learning rate is greater than one, it is easy for learning algorithms to overshoot in correcting the weights and the network will oscillate. Small values of the learning rate will not correct the current error quickly, but if small steps are taken in correcting errors, there is a good chance of arriving at the best minimum convergence.

#### 3.6.3.6 Learning laws

Many learning laws are in common use. Most of these laws are some sort of variation of the best known and oldest learning law [8].

##### *3.6.3.6.1 Hebb's Rule*

The first learning rule was introduced by Donald Hebb. His basic rule was: if a neuron receives an input from another neuron and if both are highly active, the weight between the neuron should be strengthened.

##### *3.6.3.6.2 Hopfield Law*

It is similar to the Hebb's rule with the exception that it satisfy the magnitude of strengthening or weakening. It states,"if the desired output and the input are both active or both inactive, increment the connection weight by the learning rate, otherwise decrement the weight by the learning rate".

##### *3.6.3.6.3 The Delta Rule*

This rule is the further variation of the Hebb's rule. It is one of the most commonly used rules. The delta rule works in the way that the delta error in the output layer is transferred by the derivative of the transfer function and is then used in the previous neural network to adjust input connection weights. In the other words, this error is back-propagated in to the previous layers one layer at a time. The process of back-

propagating the network errors continues until the first layer is reached. This rule changes the synaptic weight in the way that minimizes the mean squared error of the network.

#### *3.6.3.6.4 The Gradient Descent Rule*

This rule is similar to the delta rule in that the derivative of the transfer function is still used to modify the delta error before it is applied to the connection weights. Here, however, an additional proportional constant tied to the learning rate is appended to the final modifying factor acting upon the weight. This rule is commonly used, even though it converges to a point of stability very slowly.

### 3.6.3.7 Multilayer Feed forward neural networks

Multilayer feed forward neural network or multilayer perceptron network [MLP] is the most popular neural network type. It has been applied successfully to solve some difficult and diverse problems by training them in supervised or unsupervised manner with a highly popular algorithm known as *error back-propagation algorithm.*

The typical network has an input layer, at least hidden layer and an output layer. There is no limit on the number of hidden layer but most application use just one or two.

### 3.6.3.8 Back-propagation

Training a neural network is the process of setting the weight on the inputs of each of the units in such a way that the network best approximates the underlying function. Back-propagation is the most commonly used method for training multilayer feed forward neural network. This training scheme is used for adjusting the connection weight of each unit in such a way that the error between the desired output and the actual output is reduced. More clearly, the neural network adjusts the connection weights to each unit, beginning with the connection between the last hidden layer and the output layer. After the network has made adjustment to this set of connection, it calculates error values for the next pervious layer and makes

adjustments. This scheme was developed independently by Webros, Parker, Rumehart, Hinton and Williams [8].

The role of a training algorithm is to set the network's weight and threshold so as to minimize predictive error by the network. The historical cases gathered are used to automatically adjust the weights and thresholds in order to minimize this error. This process is equivalent to fitting the model represented by the network to the training data available. The error of a particular configuration of the network can be determined by running all the training cases through network, comparing the actual output of generated with the desired or targeted output. The difference is combined together by an error function to give the network error. The most common error function is the sum squared error, where individual error of output on each case squared and summed together [30].

The error back-propagation method can be applied to any feed forward network with differentiable activation function. The requirement of differentiability of the activation function is based on the following reason; as mentioned before, the difference between the response of an output unit and expected response is the error made by the network. The unit of the output layer uses this error directly to correct their connection weights, but this is not the same for the units of the hidden layer since they are not in direct contact with the error. As a result the unit of hidden layers needs to estimate their error using error back-propagation method. The amount of error made by the network is first converted into an error signal that is proportional to the rate of change of the nonlinear activation function. In fact, this implies that we want the correction to be proportional to the rate of change of the activation function.

The ultimate purpose of error correction learning is to minimize the cost function based on the error signals, such that the actual response of each output neuron in the network approaches the target response

for that neuron in some statistical sense [24]. The algorithm for feed-forward network is given in ***Figure 3.8***.

### 3.6.3.9 Application of neural networks

When the result of the model is more important than understanding how the model works, neural network are good choices for most classification and prediction tasks. Neural network actually represent complex mathematical equation, with lots of summation, exponential function and many parameters. Neural network do not work well if there are many hundreds or thousands of input feature. Large numbers of feature make it more difficult for the network to find patterns and can result in long training phases that never converge to a good solution [12].

Neural network have a broad applicability to real world business problems .They have already been successfully applied in many industries and in pattern recognition in image processing.

***Input:*** *The training samples, samples; the learning rate, **l**; a multilayer feed-forward network, network.*
***Output:*** *A neural network trained to classify the samples.*
***Method:***

1) *Initialize all weights and biases in network;*
2) ***While*** *terminating condition is not satisfied{*
3) ***for*** *each training sample **X** in samples{*
4) *// Propagate the inputs forward:*
5) ***for*** *each hidden or output layer unit **j***
6) $I_j=\sum_i w_{ij}O_i + \theta_j$;*//compute the net input of unit **j***
7) ***for*** *each hidden or output layer unit **j***
8) $O_j=1/(1+e^{-I_j})$;*// compute the output of each unit **j***
9) *//Back propagate the errors:*
10) ***for*** *each unit **j** in the output layer*
11) $Err_j=O_j(1-O_j)(T_j-O_j)$;*//compute the error*
12) ***for*** *each unit **j** in the hidden layer*
13) $Err_j=O_j(1-O_j)\sum_k Err_k w_{jk}$;
14) ***for*** *each weight $w_{ij}$ in network:*
15) $\Delta w_{ij}=(l)Err_jO_i$;*//weight increment*
16) $W_{ij}=w_{ij}+\Delta w_{ij}$;*}//wight update*
17) ***for*** *each biase $\theta_j$ in network{*
18) $\Delta\theta_j=(l)Err_j$;*//bias increment*
19) $\theta_j=\theta_j+\Delta\theta_j$;*}//bias update*
20) *}}*

*Figure 3.8 Feed-forward algorithms for neural network.*

# Chapter Four

# 4. Experimentation

## 4.1 Introduction

Braille is an invaluable means to visually-impaired to interact with the real world. Different attempt has been made to recognize Braille writing system in different language. In this study effort has been made to recognize Braille document for Amharic language. This chapter provides detailed performance analysis of the Amharic Braille recognizer developed in the present study.

The proposed system starts with acquisition of the Braille documents which is usually called digitization. The Digitization of Braille documents is performed with flat-bed scanner (at 200 dots per pixel resolution), which is the chipset and commonly used device for such study. After the digitization process, the image is processed to identify the foreground (content) from the background; this process is called image Binarization or thresholding. In this study, global-Thresholding technique is applied for Binarization process, since the technique is well known and commonly used approach particularly for image that has uniform color intensity such as Braille document. Threshold value has been set based on the color frequency through experimentation.

During segmentation the binarized image is further processed to locate the position of potential Braille dots. In the study segmentation algorithm is developed for identification of the dots following the gridline constructed vertically and horizontally with the dots pattern. The first step construct mesh grids considering the Braille dots, then segmentation performed by searching the black pixel with threshold around the mesh coordinate. Eventually, the procedure identifies dots in one-pixel white color with black background. The advantage of gridlines is that dots search only made on coordinates. This reduces the computation time. The resulting image is then fed to the feature extraction procedure to extract the

patterns of each Braille cell. At this stage, the mesh comes into the picture to group the dots in to cell. And context analysis is made to recognize the Braille character. In this regard, it reduces the computation time as it does not consult all the pixels of image. Besides, Braille character mainly uses one and/or two cells to represent the corresponding print character. Further analysis is made on the cell content, since in some case two Braille cells represent one print character. So to determine a cell is part of a particular character a context analysis is preferred based on rules. Eventually, the extracted patterns are created and stored with one and two cells in a file to prepare for further processing using neural network. In recognition (classification) of Braille-to-print, neural network is applied. This is because, neural network is widely applied in different problem domain as it is robust to tolerate error and learn from example. Accordingly, the feed-forward neural network is created with multilayer fully connected perceptron. The block diagram in Figure 4.1 shows the proposed system as seven steps process along with the corresponding tools applied in each steps.

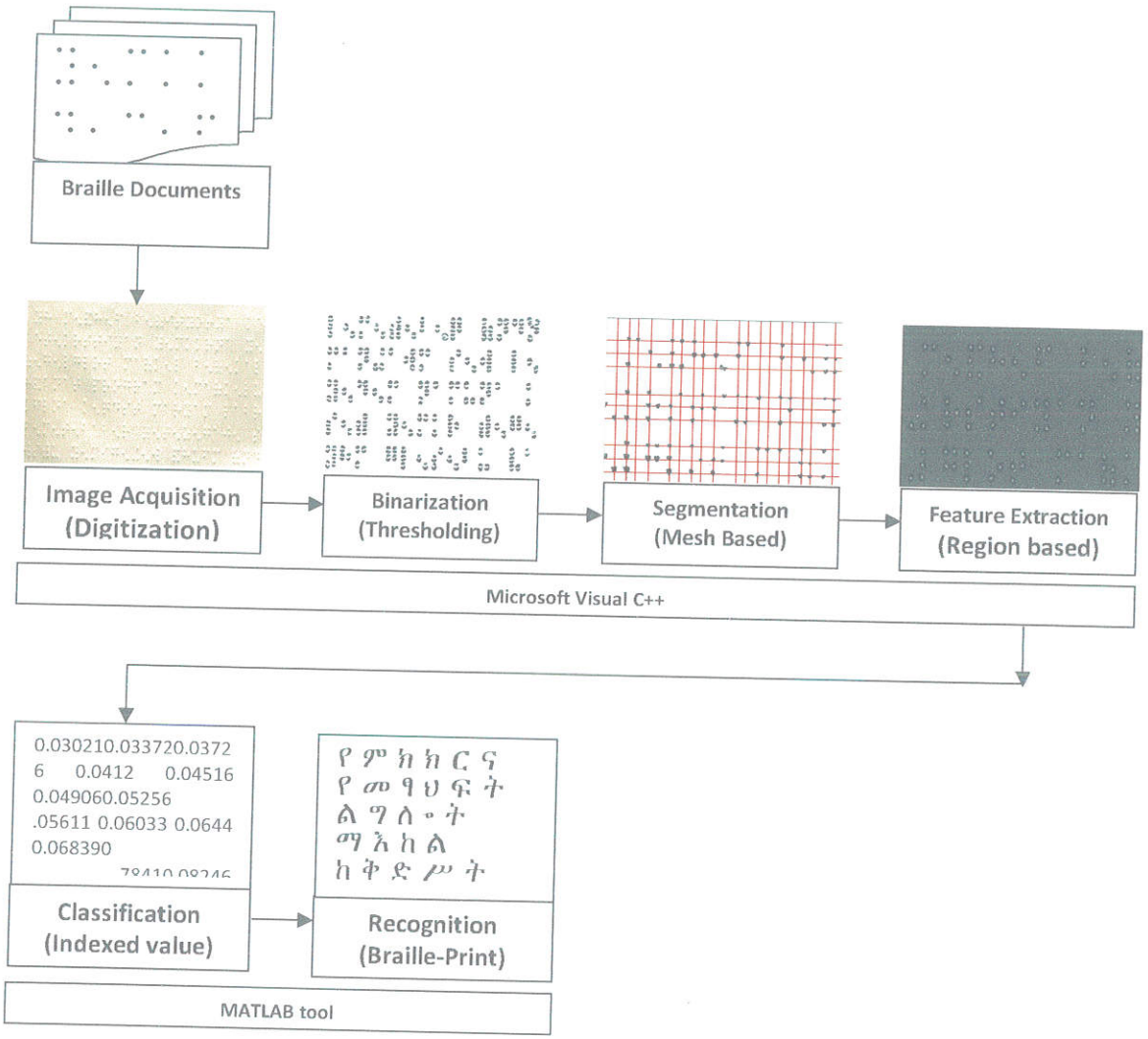



*Figure 4.1 Block diagram of the Amharic Braille Recognizer.*

## 4.2 Data Collection

Braille document has been collected mainly from German school and AAU-Kennedy library. The documents include both manually produced and typewritten. As the Braille can be plastic and/or paper sheet, both were collected, most of which is typewritten. In addition, considering color variation in the present study documents with white and light yellow has been selected. This is done because the intensity of pixel in Braille image varies from one color to another, it tremendously affect the noise level. Added to digitized documents, the size of the page varies between documents produced by different means. For the purpose of this study the standard sized Braille, 11 x 11.5 inch, which is dominantly used at different

center, is selected. As indicated in the literature Braille can be produced on one side or double side of the document. For the reason that, most Amharic Braille documents are single-sided, the study is limited to investigate single-sided embossed Braille sheet. The details of sample Braille document collected for experimentation are given in ***Table 4.1*** .

*Table 4.1 Summary of Amharic Braille documents collected for the study*

| Braille property | Description |
|---|---|
| Braille sheets | 10 sheet |
| Total number of characters | 4500 |
| Mean number of character per sheet | 450 |
| Digital format | Gray scale/Color |
| Resolution (horizontal and vertical) | 200 dpi |
| Image size Kbytes(on average) | 2.75MB |
| Braille type | Single sided – grade 1 |
| Image format Bitmap ('bmp') | Bmp |
| Document size(Horizontal x vertical) | 11inches x 11.5inches |

## 4.3 Digitization/Image Acquisition

In Optical Braille Recognition (OBR), digitization enables to produce a digital image of the scanned document in the form of bitmap. A flat-bed scanner, with hp photo and imaging program, has been used for digitization process. This is because it is a cheap alternative which can be used for so many other applications of this sort.

The Braille document is scanned with 200 dots per inch (dpi) resolution which is recommended to get good quality image. With this configuration, Braille documents that are collected for the present study are scanned and prepared for subsequent processing.

The document scanned with color and gray level, which is examined visually to get better image. Sample digitized image is shown in ***Figure 4.2*** (left for gray and right for color).

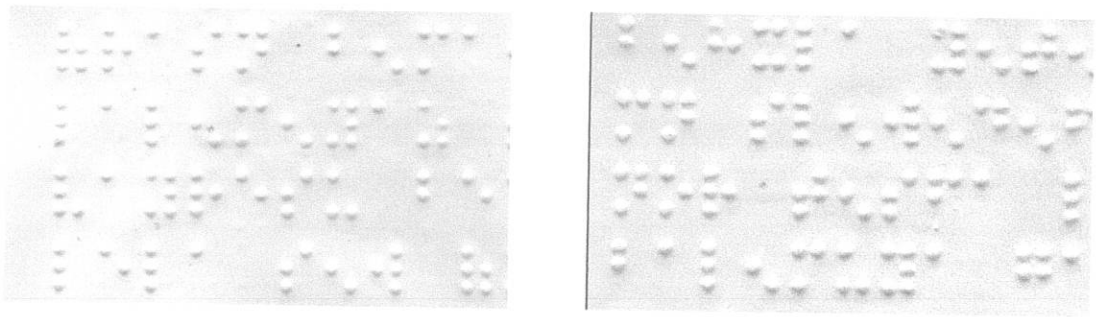


*Figure 4.2 Braille document image (left with gray level scale and right with color)*

## 4.4 Binarization/Image Thresholding

In image processing Binarization is the process of identifying the foreground (black color), which would be the content of the scanned image, from the background (white color). Binarization has been performed by thresholding approach, which can be global or local. For the problem at hand, a global thresholding technique has been selected for the reason that it is simple to use and computationally less expensive than local thresholding technique. Moreover, the Braille image has uniform color which is appropriate for global thresholding.

In this research, initial attempt has been made to develop a program coded in visual C++ studio. And the algorithm produces satisfactory result with typical Braille image. To set the threshold value, image pixel-level frequency has been examined for both gray-level and color image. ***Table 4.2*** shows the frequency of a typical Braille image pixel intensity, for colored and gray-level image along with the corresponding histogram graph given in ***Figure 4.3***.

*Table 4.2 Frequency distribution of colors (left for gray-level image and right for color image)*

| Gray-level | Frequency |
|---|---|
| 92 | 1 |
| 124 | 1 |
| 132 | 13 |
| 140 | 68 |
| 148 | 628 |
| 156 | 2101 |
| 164 | 5954 |
| 172 | 12200 |
| 180 | 19702 |
| 188 | 29625 |
| 196 | 42194 |
| 204 | 61493 |
| 212 | 154388 |
| 220 | 1143817 |
| 228 | 1729945 |
| 236 | 379544 |
| 244 | 101286 |
| 252 | 92507 |
| 254 | 1839 |
| **Total color** | **19** |

| Color-level | Frequency |
|---|---|
| 101 | 1 |
| 118 | 27 |
| 135 | 1023 |
| 152 | 5470 |
| 169 | 2892 |
| 173 | 3304 |
| 180 | 14767 |
| 191 | 1727 |
| 194 | 6223 |
| 197 | 29385 |
| 202 | 32767 |
| 203 | 21542 |
| 207 | 15762 |
| 213 | 139651 |
| 220 | 19513 |
| 224 | 64455 |
| 228 | 442743 |
| 232 | 651437 |
| 236 | 505634 |
| 246 | 121213 |
| 253 | 84585 |
| 254 | 76546 |
| **Total color** | **22** |

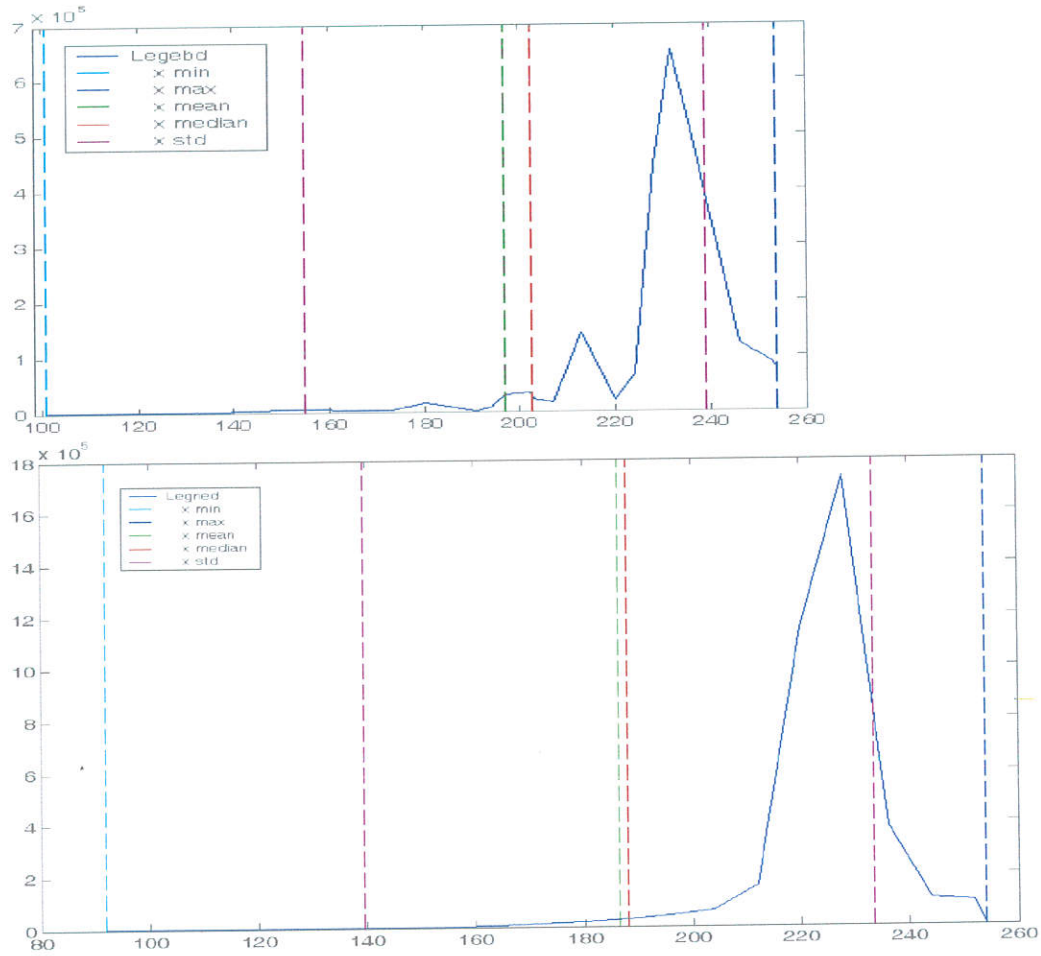



*Figure 4.3 Frequency distributions of colors for Braille image (Top- color Braille image, and Bottom-Gray level image)*

In setting threshold, a preliminary analysis of relevant picture statistics with a series of experiments is performed in which the threshold image is examined as the threshold is adjusted, and the best result is ascertained visually [17].

Accordingly, based on the frequency distribution different experiments have been conducted with three different thresholds. The thresholds that has been considered include value less than, less than or greater than, and greater than the maximum frequency for both type of image. And from experience a better image result is found from the gray level image. It is also observed from experiment that the noise level increase with color image than for same image in gray level. The resulting images based on the three thresholds are given in the following part.

### 4.4.1 *Binarizing Gray Image*

To binarize gray image, one-threshold value and two-threshold value are tested.

**Image with two-threshold value:** From experience for gray image the best image (see ***Figure 4.4***) with less noise is resulted with threshold value: less than or equal to 202 or greater than or equal to 247 color values.

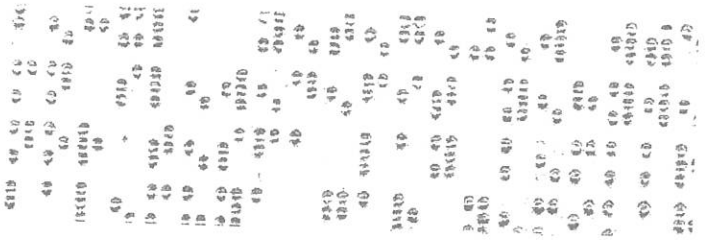


*Figure 4.4 Gray-level image after threshold (color value <=202 or color value >=247)*

**Image with one-threshold value:** sample gray-image result based on less than (see ***Figure 4.5***left-image) and greater than (see ***Figure 4.5*** right-image) from the maximum frequency:

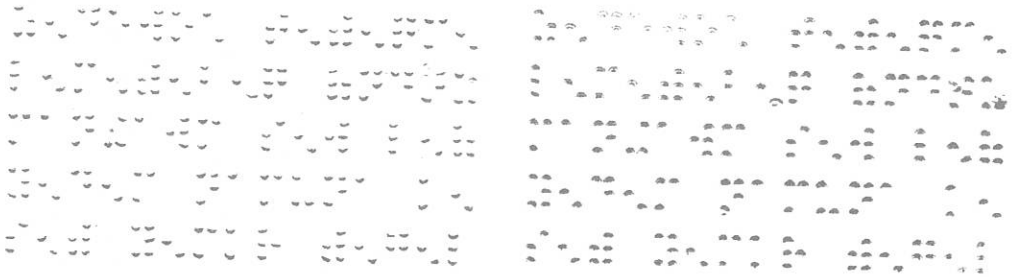


*Figure 4.5 Binarized gray-level image (left- Color value less than 202, and right- with Color value greater than 247)*

The resulting images from the above process work well for further processing. However, with two threshold values the resulting image produce a single- dot (two black areas) separated by white color in between. Sample image is shown in ***Figure 4.6***.

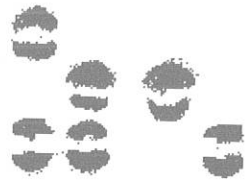


*Figure 4.6 Result of Binarization with two threshold value.*

Image shown in ***Figure 4.6*** is resulted because the raised part of the Braille dot produce two different intensity at the top and bottom part of a dot (protrusions) for light reflected while digitizing the document. This image is important to separate double-sided Braille document in to two: front and back side. This study does not consider this image further, since the scope of the study is focused on single-sided Braille.

### *4.4.2 Binarizing Color image*

An attempt is also made to binarize color image as described below.

**Image with two-threshold value:** ***Figure 4.7*** given below show sample result from color image. Color Image Binarization has been performed with threshold value less than or equal to 203 or greater than or equal to 254 color value.

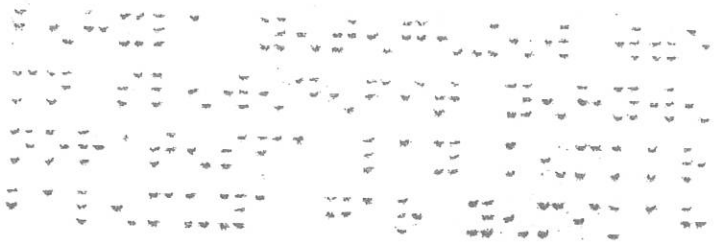


*Figure 4.7 Color-level images after threshold*

Visual examination of the resulting image show that with color image there is a possibility of losing valid dot point as the dots size is relatively small and the noise level is relatively high. This requires advanced image preprocessing techniques. Hence, in this study the one with gray-level image is considered for further processing.

The program which is coded in visual C++ environment performs the Binarization with threshold value. The algorithm mainly performs two things: first converts each pixel in to gray-level, and then compare the resulting color value with the threshold to set the pixel in one of the two colors (black and white).

```
RGBQUAD color; //store RGB value
COLORREF ColVal;//store graycolor value
                color.rgbRed=pDC->GetPixel(b,a);
                color.rgbGreen=pDC->GetPixel(b,a);
                color.rgbBlue=pDC->GetPixel(b,a);
//convert color value to graylevel

ColVal=(color.rgbRed * 77 + color.rgbGreen * 150 + color.rgbBlue * 29 + 128)/256;
```

*Figure 4.8 Ms-visual C++ code to extract the RGB of image pixel and convert to gray-level*

To accomplish this, color variable is declared as RGBQUAD, which allow extracting the RGB (red, green and blue) value of a pixel in visual C++. Then the Red, Green, and Blue value of the pixel are stored independently in a color variable declared as COLORREF as given in ***Figure 4.8*** along with the formula for computing colval (color value).

The global- threshold algorithm perform well on a clean Braille image. However, most of the Braille is degraded in quality, and the noise level affect to the extent of missing some valid dot and/or separating overlapping dots.

The following are some of the challenge worth mentioning while performing the Binarization experimentation which increases noise level.

- First as the Braille document has uniform color it makes difficult to find a value that particularly locate the area of the dot (see ***Figure 4.9*** (b)).
- Because of repeated use and bend, image is distorted. As a result the binarized image is suffered in scattered type of noisy. This condition is clearly visualized in *Figure 4.9* (a).

- Preparation of image, layout, arrangement and reflection of light affect the digitization process too (see *Figure 4.9* (c)). To get clear image decreasing/increasing the threshold will diminish the size of the dots.

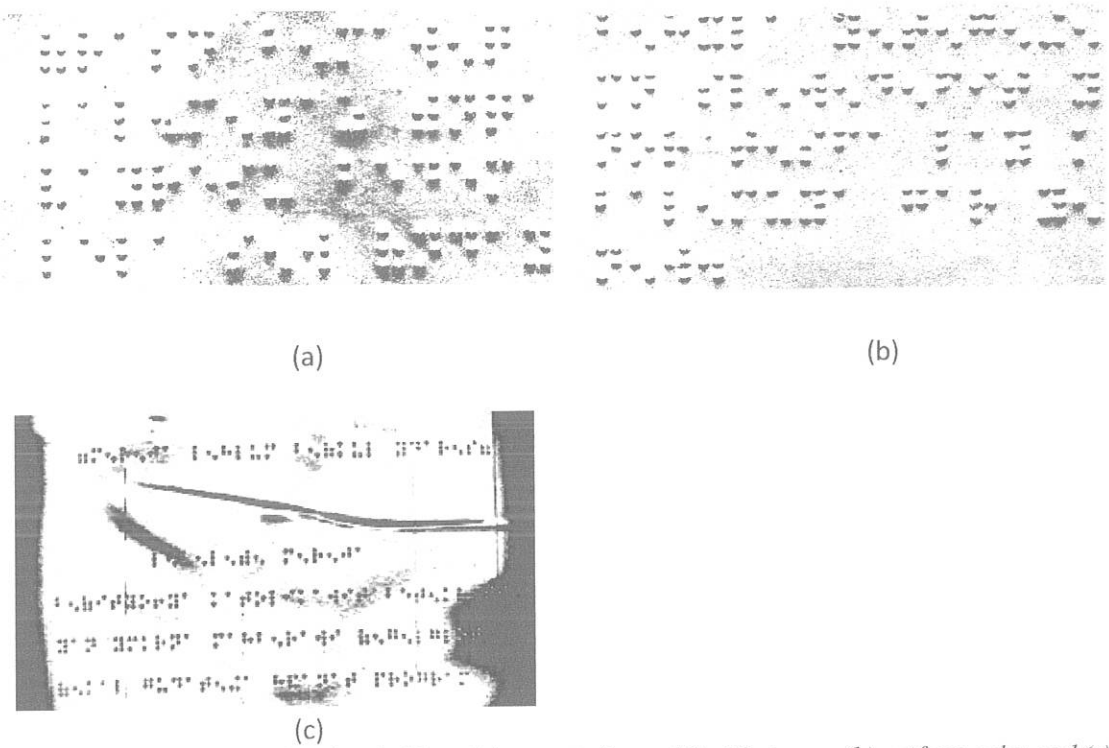



*Figure 4.9 Noisy image after thresholding ((a) repeatedly used Braille image, (b) uniform color and (c) light effect).*

In such a case attempt was made to make some adjustment on the threshold (by decreasing or increasing). The action would bring some improvement in decreasing the scattered noise, but still this will happen at the cost of losing some valid dots as shown in ***Figure 4.10***.

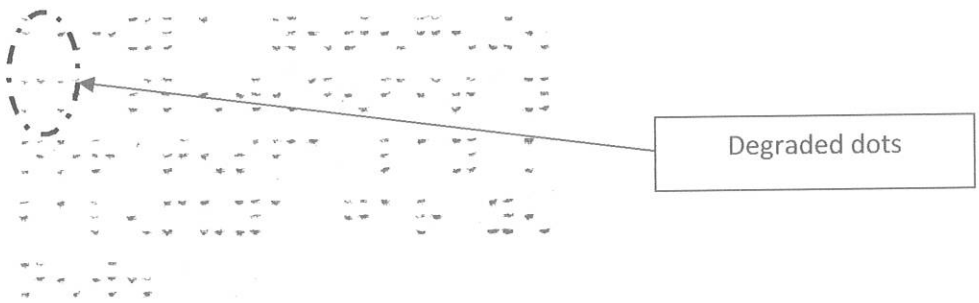



*Figure 4.10 Result of Binarized image after reducing the threshold (Image with reduced threshold)*

At this point, a second attempt is made to binarize the image using image manipulation program. This is done with some image in which high level of noise was resulted. Though there are different image processing programs the researcher prefers GIMP2.6 tool because it is found to work well for the intended purpose and available free. The resulting image is saved with two tone color value. ***Figure 4.11*** shows the final binarized Braille image.

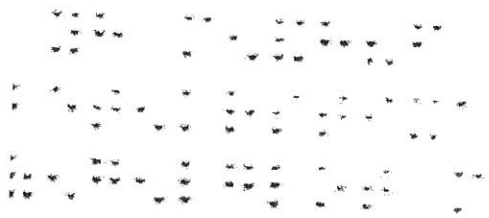


*Figure 4.11 Sample binarized which is used for further recognition.*

After the Binarization, or sometimes called thresholding, the scanned image has the feature that the foreground (content of the image) is represented by black color and background with white color. This output of the Binarization module will be fed to the next level of processing, which is image segmentation.

## 4.5 Image Segmentation

As indicated previously, segmentation refers to the process of separating dots from Braille image that can further be grouped in to a cell. These cells further grouped to form character, words or any strokes in Braille. For the Braille recognition problem domain, the point of interest or the low level of abstraction to be extracted is the single dot that could have six alternative positions in a cell as depicted in ***Figure 4.12***. This could be:

Column 1 and Row 1: Dot 1
Column 1 and Row 2: Dot 2
Column 1 and Row 3: Dot 3
Column 2 and Row 1: Dot 4
Column 2 and Row 2: Dot 5
Column 2 and Row 3: Dot 6

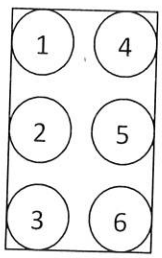



*Figure 4.12 Braille cell with dots position*

In this research segmentation is performed in two steps: In the first step gridlines mesh is constructed; and then dots are searched following the grids mesh with threshold. The technique is preferred since Braille cells follow strict layout in horizontal and vertical line and does not have unique structure to isolate one combination from the others. Besides segmentation with mesh-grids bring good result for most of the Braille research [23][28][32].

In this study, both global and adaptive, mesh techniques has been tested to select a method with best result. In using global mesh, the horizontal and vertical grids are constructed based on a fixed global threshold. Whereas, in adaptive mesh the threshold is determined locally for each dots that runs vertically and horizontally.

To illustrate, after the Binarization process is over, horizontal and vertical projection profile of the image has been performed. This process is used to determine the height of a single dot, which would be used to set the threshold. Based on analysis of horizontal projection profile, a threshold value of ten (10) has worked well to isolate Braille dot lines (dot height). After line segmentation, vertical projection is performed that result in half-character segmentation (one column of a cell). With vertical projection, a threshold of 12 works well to isolate dot (dot width). ***Figure 4.13*** describes the result of vertical and horizontal projection.

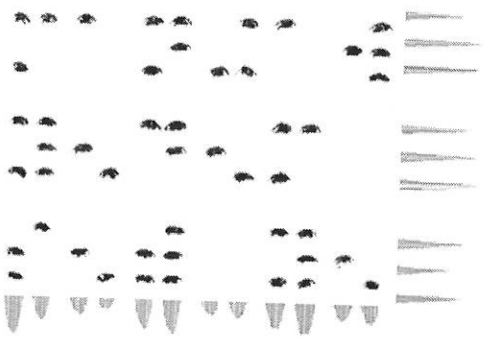


*Figure 4.13 Horizontal and vertical projection for Braille image.*

Based on the above information (spacing, dot height and width), a mesh is constructed. At this moment initial attempt has been made to test the global mesh that performs in the following ways.

The algorithm first finds optimal starting dot by searching black pixel column wise and start to count if black pixel is found until the next white pixel is found; and do the same for raster line horizontally. The resulting value checked for threshold and then used to complete the horizontal and vertical grids. So, each vertical grids line is constructed leaving 10 pixels for inter dots (within a cell) spaces and 14 pixels for intra dots (between cells) spaces. After vertical grids, the horizontal grids line is constructed with 10 pixel inter dots spacing (with in a cell) and 10 pixel intra dots spacing as shown in ***Figure 4.17***. Inter and intra dot spacing is described in ***Figure 4.14***.

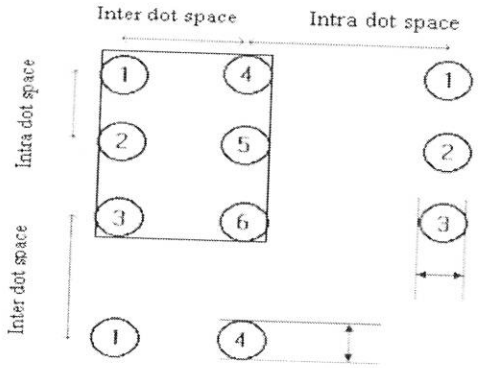



*Figure 4.14 Inter and intra dot spacing in Braille*

Once the optimal starting dot for vertical grids is determined, the subsequent possible vertical grids continue for the width of the Braille image with threshold value. ***Figure 4.15*** shows the vertical grids line drawn for a given Braille image.

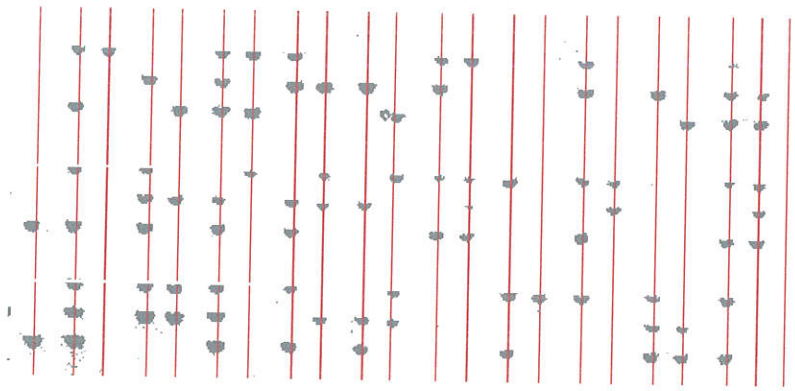


*Figure 4.15 Vertical grids line based on threshold value (10 pixels for dot within a cell and 14 pixels for dots between cells).*

On the other hand, the horizontal histogram is drawn to determine the height of dots, distance between dots of same character and next dot line. Through experimentation the value is set to 15, 10, and 18 for dot height, space between dot with in a cell and space between dots of different cells, respectively. A sample Braille image with horizontal line is given in ***Figure 4.16*** below.

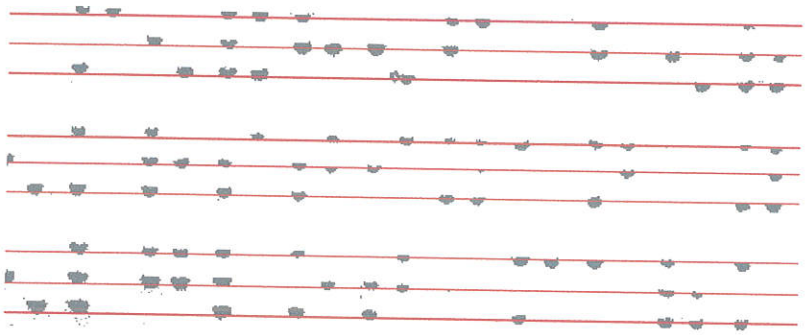


*Figure 4.16 Horizontal grids line based on threshold value (10 pixels for dot within a cell and 18 pixels for dots between cells).*

The algorithm constructs the mesh grid well. A typical Braille image with global grids is shown in ***Figure 4.17***.

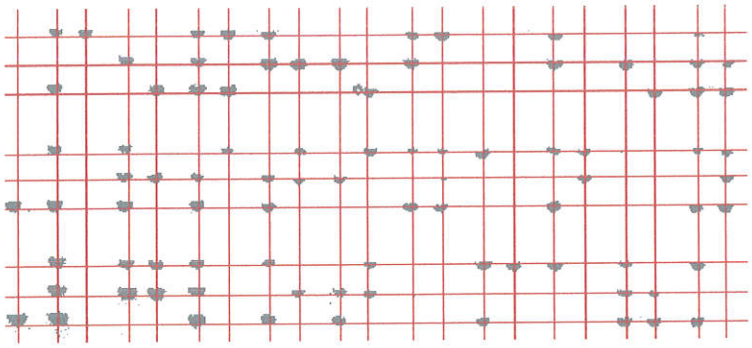


*Figure 4.17 Braille image with Global grids*

However, experience with different images show that dots on the Braille image do not always have the same size (height and width). Some documents show well formed dots while others consist of very small dots. Moreover the dots collection in a given Braille image does not have uniform size. While constructing mesh for such image, experimentation show that the grids line deviation increase as it moves to the right horizontally and to the bottom vertically. ***Figure 4.18*** is a typical example in such condition.

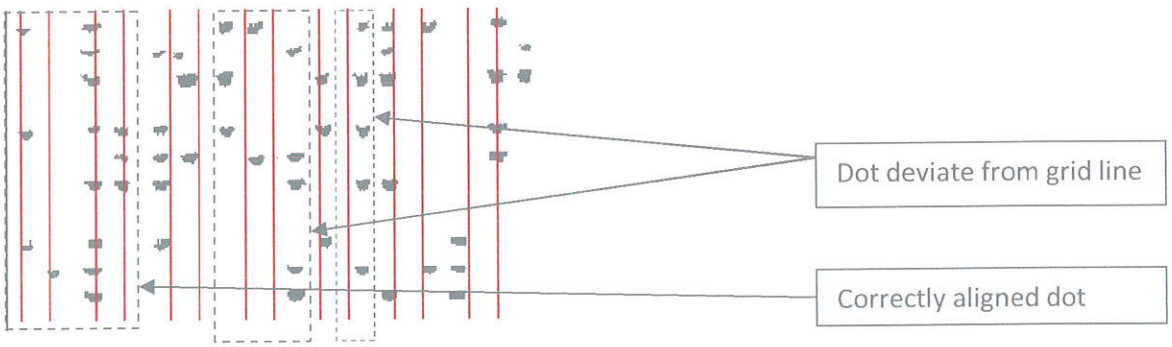



*Figure 4.18 Deviation of grids line towards the right ends*

At this point adaptive algorithm is developed to construct the grids line with the intension to come up with better result. This time, the algorithm calculate dots size and spacing locally (adaptively) to draw the subsequent vertical and horizontal grids.

The algorithm for grids formation is described in section 3.4. To draw the horizontal grids the algorithm finds the maximum height of dots from line segmentation. To perform line segmentation, the algorithm scan each raster line of the image horizontally, if black pixel is found, it marks as the beginning of the dots and continue until the next white pixel is found. Once the dot height is determined for a given dot line, the

midpoint is calculated. Then, red line is drawn that pass through the midpoint coordinate.

To consider overlapping dots, a threshold value of 35 pixel dot size has been set experimentally. Thus, in this situation the dot count is checked if it is more than the size of the threshold. If the result is true, accordingly two grids line is drawn, at current height value minus ¾ and ¼ of dot count for the first and the second grids line respectively. Overlapping dots are shown in ***Figure 4.19***.

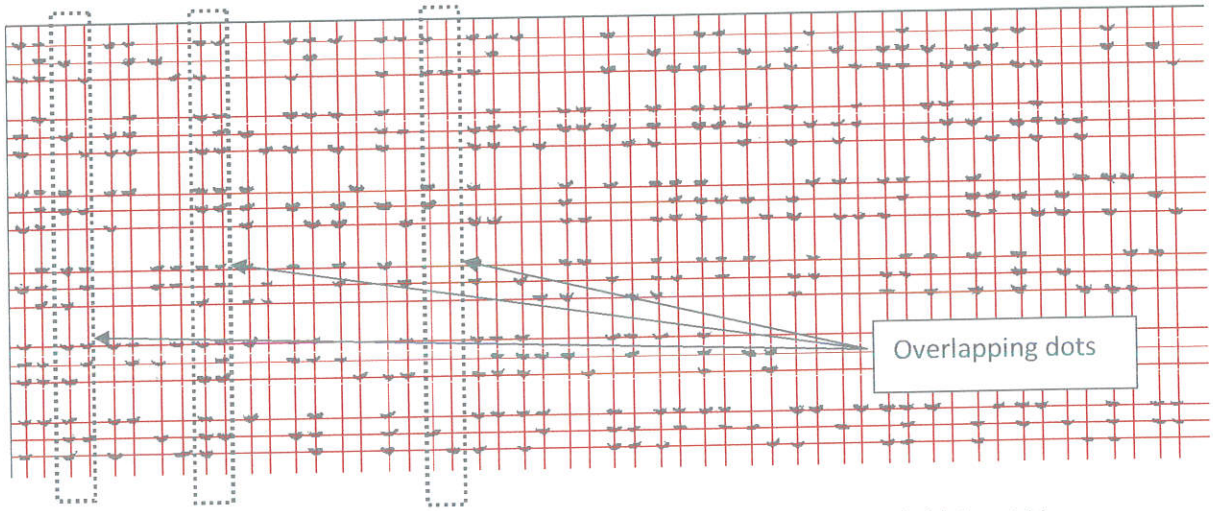



*Figure 4.19 A scenario that shows grids for overlapping dots considering the threshold dot width*

To draw the vertical grids the algorithm scan vertically to find the maximum dot width from half-character segmentation. The resulting value which indicates the width of dot is divided by two to draw the vertical grid at the current height position plus half of the dot width value for that specific vertical line. This process continues adaptively for the whole image calculating the new dot width to draw the subsequent grids. Part of mesh implementation for horizontal grids is given in *Figure 4.20*

```
bool hit=FALSE;int dotWidth=0,h=0,DotSpace=0,b=0
for(int a=0;a<bm.bmWidth;a++)
{       //count max dot height for dot line
        for( b=0;b<bm.bmHeight;b++)
        {       if(pDC->GetPixel(a,b)==0)//check black pixel
                {
                dotWidth++;hit=TRUE;break;
                }
        }
        if(hit)
        {
                hit=FALSE;continue;
        }
        else if(!hit && dotWidth<=5 && dotWidth>0)//eliminate noise
        {       for(int x=a-dotWidth;x<a;x++)
                        for(int c=0;c<bm.bmHeight;c++)
                                dc.SetPixel(c,x,RGB(255,255,255));
                dotWidth=0;
        }
        else if(!hit &&(dotWidth>5)&& dotWidth<=20)
        {int d=a+1, thr=a-(dotWidth/2);
        for(int c=0;c<bm.bmHeight;c++)
        {
                dc.SetPixel(thr,c,255);//set pixel to red color
        }dotWidth=0;
        bool b_dot=TRUE;DotSpace=0;
        //check space between two dots in a line,
        while((dc.GetPixel(d,0)==RGB(255,255,255)||dc.GetPixel(d,0)==255)&& b_dot)
        {DotSpace++;
                for(int z=1;z<bm.bmHeight;z++)
                        if(dc.GetPixel(d,z)!=RGB(255,255,255)&& dc.GetPixel(d,z)!=255)
                        {
                                b_dot=FALSE;break;
                        }d++;}
        if(DotSpace>=40)//if space b/n two dots >=40 draw additional line
        {       int thr=a+12;
                for(int c=0;c<bm.bmHeight;c++)
                {dc.SetPixel(thr,c,255);} DotSpace=0;
        }}
        else if(!hit && dotWidth>30)
        {int thr=a-dotWidth, thr_1=(a - dotWidth*(3/4)), thr_2=(a - dotWidth/4);
        for(int c=0;c<bm.bmHeight;c++)
        {
                dc.SetPixel(thr_1,c,255);
                dc.SetPixel(thr_2,c,255);
        }dotWidth=0;}
}
```

*Figure 4.20 Horizontal mesh implementation*

As the adaptive mesh take in to consideration the maximum dot height and/or dot width for horizontal and vertical grids line respectively, none of the dots will bring significant deviation from the line. Even the small dots fall adjacent either above or below the grids line. Sample image taken during the experimentation is given in ***Figure 4.21***.

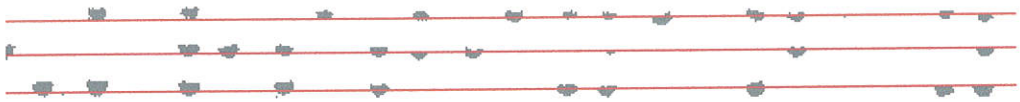


*Figure 4.21 Horizontal gridline for Braille image*

At this stage it is worth to mention some problem investigated during experimentation of adaptive mesh in different Braille image. The algorithm is developed on the assumption that there is a minimum of one dot down the image vertically. And the algorithm draws vertical line only for the presence of valid dots to that specific half-character. However, experience shows that some Braille image consists of one or two line of character. Accordingly, there is a probability of missing dot in any of half character down the column. This condition is undesirable as a Braille character should have 2 columns by 3 rows structure. The problem also affects the feature extraction, which would be the forth coming phase in the study. So, further modification is made to mesh program to draw ideal grid lines where valid dots are missed vertically in half-character. To correct the problem one module (see ***Figure 4.22***) is added to check if the distance between the two dots in a line is within the range of the threshold for dot space within a character. If the spaces fail to meet the criteria, the algorithm draw a hypothetical vertical line considering the dot distance which is set experimentally to be 12 pixels from the first dot. To draw the line the algorithm check the white space between two dots is greater than 40 pixels (which is set experimentally).

```
if(DotSpace>=40){int thr=a+12;
        for(int c=0;c<bm.bmHeight;c++)
                dc.SetPixel(thr,c,255);
                DotSpace=0;
        }
```

*Figure 4.22 Visual C++ code to draw hypothetical vertical grids line*

This is important as each Braille character is written within two columns and three rows. Braille image with ideal vertical grid is given in ***Figure 4.23***.

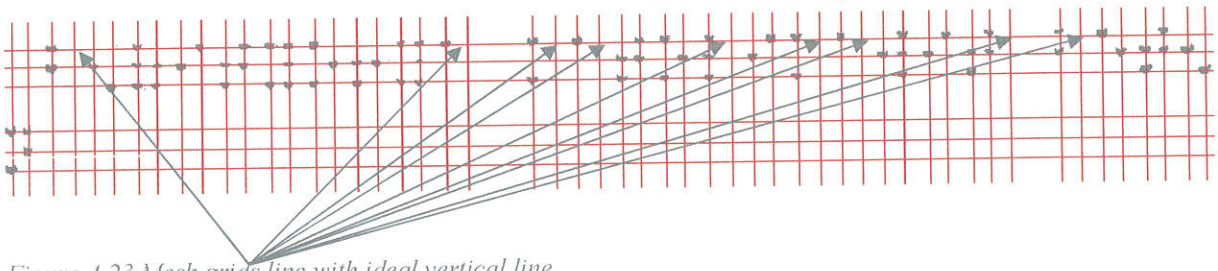


*Figure 4.23 Mesh grids line with ideal vertical line.*

```
int dot[2000][2],dotcount,h ,k,w,da;//da index of array
bool hit=FALSE;
do{
        if(dc.GetPixel(0,h)==255)//check vertical mesh grids
        {
                do{
                        if(dc.GetPixel(w,0)==255){//chkec horizontal mesh 255 is red color value
                                for(int z=h-5;z<=h+5;z++){
                                        for(int y=w-5;y<=w+5;y++)
                                                if(pDC->GetPixel(y,z)==0)
                                                        dotcount++;}
                                if(dotcount>=10)
                                {dot[da][0]=w; dot[da][1]=h; dotcount=0; da++;
                                }w++;
                        }
                }while(dc.GetPixel(w++,0)!=255&&w<bm.bmWidth);
                w=0;h++;
        }
}while(dc.GetPixel(0,h++)!=255&&h<bm.bmHeight);
for(int i=0;i<bm.bmHeight;i++)//convert background in to black!!
        for(int j=0;j<bm.bmWidth;j++)
                if(dc.GetPixel(j,i)!=0)
                        dc.SetPixel(j,i,0);
k=0;
while(dot[k][0]) //set dot with white color pixel on black background!!!
{       dc.SetPixel(dot[k][0],dot[k][1],RGB(255,255,255)); k++;
}
```

*Figure 4.24 Implementation of mesh based segmentation*

Once the adaptive mesh is constructed, segmentation extracts the dot point from the image. The segmentation procedure identifies the foreground, from the back ground based on previously constructed

mesh. The program search black pixel around the intersection of the horizontal and vertical line to segment dot.

The segmentation given in ***Figure 4.24*** algorithm starts by determining the first intersection point of the mesh on the Braille image. Then the algorithm search black pixel in all direction around the intersection point to declare the presence of valid dot which would be the possible location of the dot. The search made within the area of 5 pixel to the left, right, top, and bottom from the intersection point. And a threshold value is set experimentally to10 and more black pixels to announce valid dot. The value is relaxed to consider the minimum black pixel a Braille dot may contain and the red pixel of the grids line that cross the dots. If the black pixels meet the threshold, the (x, y) coordinate values of that point is registered in an array prepared for such purpose. This continues for the whole mesh intersection points and the corresponding (x, y) coordinates is registered if there is a dot on that coordinate. This step is important to clearly display the dot with single white pixel on black background as shown in the picture below. Finally, the algorithm convert the whole image in to black color and set the dot coordinates value with one pixel of white color. To set the white pixel that represents the presence of dot, (x, y) coordinate value is taken from previously registered array. Sample result of the segmentation algorithm is given in ***Figure 4.25***.

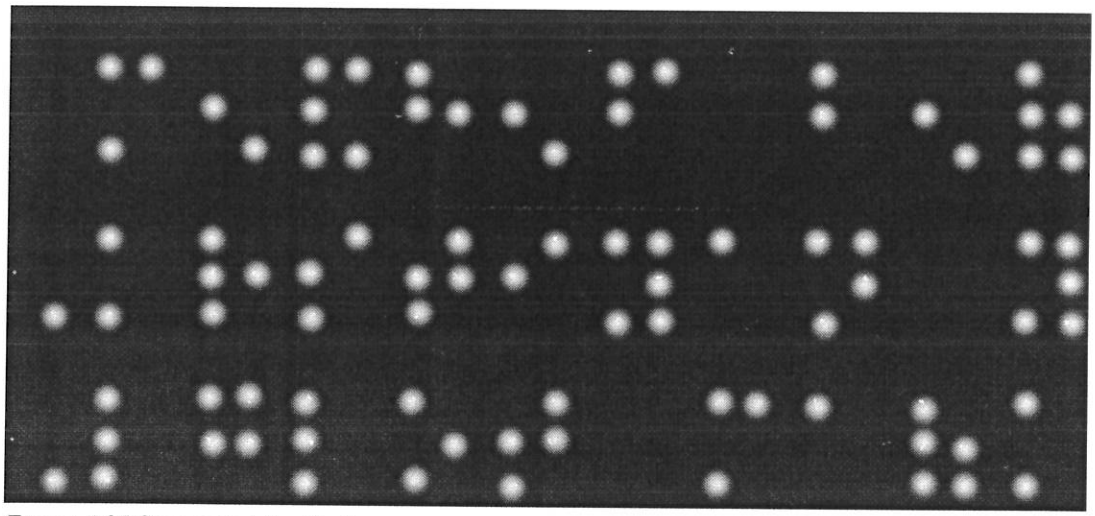


*Figure 4.25 Segmented Braille image*

The segmentation module which depends on the constructed grids mesh is robust and tolerates noise. This is because the algorithm does not require checking every pixel in the image; instead only potential dots areas are checked for the threshold value; there by also reducing the computation time. Moreover black pixels which are found outside the mesh coordinates are not checked. This provides the program to tolerate noise. The algorithm is found effective for different Braille image with varieties of dot size. And performs well with clean image and tolerates some scattered noise.

Once the segmentation has completed, the resulting image is used to further process dots by grouping in to Braille cell to draw patterns for Amharic Braille code.

## 4.6 Amharic Braille Feature Extraction and Recognition

It is discussed in the literature review section 2.7 that a Braille character is made up of six dots arranged in two column and three rows. Dot on the six possible place can be turned on (raised) or flat to create Braille character. Depending on the type of print character used in Amharic language, one cell (six dots), two cells (12 dots) or/and rarely three cells (18 dots) may be used in Braille writing system for the corresponding character in print. That is why the Braille documents blamed to be bulky and take much volume in hard copy version. The following part describe which type of print character requires one, two

and/or three cells; and decisions made to determine the number of cells used to represent print equivalent to come up with standard input for the network.

Amharic Braille, like the print Amharic writing system applies all the basic characters with their six forms (34 x 6). While all the basic forms (34) are represented with a single Braille cell, the rest requires two cells (the first cell indicating the basic form, and the second cell the vowel (sound) for one of the six forms). To illustrate the situation, sample character is given in that shows Braille code and print. ***Table 4.3*** shows one-to-one mapping between Braille-to-print characters. In the following illustration to represent dots in a cell, the dot position is labeled with number 1 through 6. And to represent the dot is active for a particular label binary digit 1 will be used.

*Table 4.3 Basic Amharic Braille character with one cell*

| 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|
| 1 | 1 | | | 1 | | ሀ |
| 1 | 1 | 1 | | | | ለ |
| 1 | 1 | | | | 1 | ሐ |
| 1 | | 1 | 1 | | | መ |
| | 1 | 1 | 1 | | | ሠ |
| 1 | 1 | 1 | | 1 | | ረ |

To write the first forms for character in ***Table 4.3***, we use two cells as shown in ***Table 4.4***:

*Table 4.4 First variant of basic Amharic Braille character with tow cells.*

| 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | 1 | | | 1 | | | | 1 | ሀ |
| 1 | 1 | 1 | | | | | 1 | | | | 1 | ለ |
| 1 | 1 | | | | 1 | | 1 | | | | 1 | ሐ |
| 1 | | 1 | 1 | | | | 1 | | | | 1 | መ |
| | 1 | 1 | 1 | | | | 1 | | | | 1 | ሠ |
| 1 | 1 | 1 | | 1 | | | 1 | | | | 1 | ረ |

This indicates that the majority of the Amharic print characters require two cells with the exception of the 34 basic form characters.

With regard to numbers, the Amharic Braille applies both Ethiopic and Arabic numerals system. Both numerals system require two Braille cells for their representation. The difference however, is on numeral

symbol dot combination that precedes the numbers. The numerals mode defined for Ethiopic number is "111111", while "001111" used for Arabic numbers (see section *2.4.1* for more). Accordingly, the first cell in numerals defines the numerals mode (Ethiopic or Arabic) and the second cell defines the numbers (0-9). Table 4.5 and Table 4.6 illustrate the numerals writing system in Braille for Ethiopic and Arabic numbers respectively:

*Table 4.5 Arabic Braille numerals with two cells.*

| 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 2 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 3 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 4 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 5 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 6 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 7 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 8 |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 9 |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 |

*Table 4.6 Amharic Braille numerals with two cells.*

| 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | ፩ |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | ፪ |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | ፫ |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | ፬ |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | ፭ |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | ፮ |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | ፯ |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | ፰ |
| 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | ፱ |
| 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | ፲ |

The Amharic Braille also applies different punctuation marks used in print Amharic language. These days there are 41 punctuation marks that can be used in Braille writing. Except three rarely used punctuation marks, (indicated in *Table 4.8* ), all punctuation marks require one or two Braille cell (see *Table 4.7*).

*Table 4.7 Lists of punctuation marks with one and two cell.*

| 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 | Symbol description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | Space |
| 0 | 0 | 1 | 0 | 0 | 0 | | | | | | | . Point |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | : colon |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | / forward slash |
| 0 | 0 | 1 | 0 | 0 | 1 | | | | | | | -hyphen |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | --- |
| 0 | 1 | 0 | 0 | 0 | 0 | | | | | | | ' single quote |
| 0 | 1 | 1 | 0 | 0 | 1 | | | | | | | «» |
| 0 | 1 | 0 | 0 | 1 | 1 | | | | | | | :: full stop |
| 0 | 1 | 1 | 0 | 1 | 1 | | | | | | | () Brackets |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | [ opening square bracket |
| 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | ] closing square bracket |
| 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | __ underline |
| 0 | 0 | 1 | 1 | 0 | 0 | | | | | | | And/or |
| 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | Poem symbol |
| 0 | 0 | 1 | 0 | 0 | 1 | | | | | | | Return symbol (የመመለሻ) |
| 0 | 0 | 0 | 1 | 0 | 0 | | | | | | | የማጥበቅ ምልክት |
| 0 | 0 | 0 | 0 | 1 | 1 | | | | | | | Repeated page indicator |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | የዳሽ ምልክት በቃላት መካከል |

*Table 4.8 punctuation marks that defined in three Braille cell.*

| 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | →Right arrow |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | ←Left arrow |
| 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | |

Based on the above fact, the researcher made some analysis as to which character type to include and how many Braille cell to use to create a standard input for neural network in the forth coming procedure.

In this study, all sort of Braille character are not considered. The reason is that except the basic Amharic character with their six forms and Arabic numerals, most of the punctuation marks and Ethiopic numerals are rarely apply in the Braille writing. To justify the reason, some of the Braille documents gathered for the purpose of this study are reviewed to see the frequency of punctuation mark used in the documents.

So far the Braille image passed through different image processing steps to segment the content from the background and represent as a single pixel based on the mesh-grids. During feature extraction further processing is performed to group dots in a cell. Then, the content of the cell analyze to recognize as

Braille characters.

As described previously, Braille character is described as a region in the image, this region is divided into six equal compartments (two across, three down) in which the search for dots is performed. The possible positions of Braille dots are determined by the intersections of horizontal and vertical grid lines.

Having grouped dots in a cell, its content has been analyzed with rules defined. The context analysis has performed to determine the status of dots in a cell. Based on the result, the cell can be recognized as Braille character alone or part of a Braille characters. This is because depending on the context, a Braille character may have one or two cells.

To prepare two different patterns input for neural network, a program is developed that represent Braille character as six and twelve dots. The program converts dots in a cell as binary digits. One (1) is assigned to indicate the presence (active) of dots and zero (0) is assigned for the absence (flat) of dots in a cell.

This is done following the algorithm described in appendix V. The extracted dots are grouped as one and two cells to prepare two different patterns for the neural network in the forth coming step. To do this the program scan one cell at a time, following the grids line coordinates constructed previously. The first cell may define the basic Amharic Braille character (prefix), number mode or punctuation mark; and the next six bit (suffix) defines the corresponding vowel, number or punctuation mark for particular character.

Once the dots in a cell accessed, to decide the status and the position (from two cells), the content has been checked for three criteria: Braille vowel, numerals and punctuation. Then the algorithm continues to check the next possible cell, if this is found to be among the six vowels, it will be registered as suffix of the previous cell. This is preferred because the sound cell in Amharic Braille cannot be found before the basic character. To make the concept clear the Amharic Fidel "ሀ" which is the sixth form of "ሀ"represent without vowel as "110010". To write the remaining variant, however we need to add additional cell for the vowel as given in *Table 4.9*:

*Table 4.9 Two cell Braille-print character representation*

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ሀ | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| ሁ | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| ሂ | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| ሃ | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| ሄ | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| ህ | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ሆ | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |

On the other hand, if the cell status is vowel, or is preceded by number mode or punctuation mark (suffix); the content fills the second cell (second 6 dots of cells). Moreover to give room for some Braille code that does not considered in this study: such as the remaining punctuation mark and extra Amharic character, all other cell that fail to meet the above criteria, are labeled as others cell content with value different from previously used (binary digit). The algorithm adopted for feature extraction and recognition is described in appendix V.

## 4.7 Amharic Braille-print character recognition using ANN

So far, all the potential Braille character features are extracted and stored to file with 6 and 12 bit that can be turned on(1) or off(0) in any combination. This section, that depend on the result of the previous steps, describes how the artificial neural network is created, trained and tested to classify an inputs pattern as one of the target output results. The overall task of the recognizer is to be able to classify pattern extracted (input, Braille character) into one of the possible target values (print character). For the purpose, the study apply MATLAB neural network tool box, which is the most commonly used tool in Neural Network researches such as creating recognizer. Thus, the next part of the study discusses in detail how the network is designed, created, trained and tested within the facilities and the functionalities of the MATLAB tool.

### *4.7.1 Artificial Neural Network Architecture*

The first step to application of neural network to solve a specific problem is designing the architecture of the network. In this study, the architecture of the neural network created for the recognition problem is a multilayer perceptron that accepts the binary representation of Braille character as input vector. The binary representations of Braille character as input vector are created from Amharic Braille alphabet in two standards (6 bits and 12 bits) that have equal number of input nodes to the corresponding input layer of the network. Another input is prepared with 6 bits and 12 bits each from the Braille document. The two inputs with two different standards are prepared representing the Braille character for training and testing the network.

The diagram in ***Figure 4.26*** is designed to describe the architecture of the recognition system starting from the Braille character input to the print character recognition phase. The diagram depicts the two parts in the recognition process. The first part ends with the extraction of Braille character as binary digit which is accomplished with Ms-visual C++. The next part recognizes the print character which is accomplished with MATLAB tool.

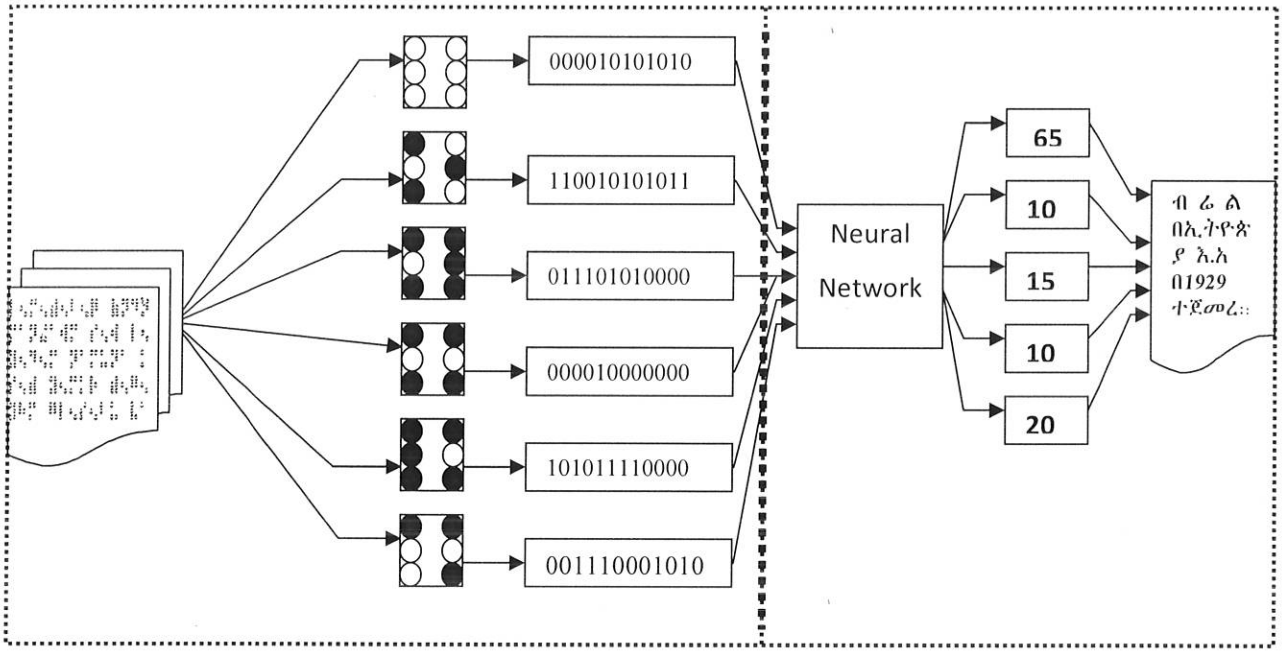



*Figure 4.26 Amharic Braille-print recognition network architecture*

### *4.7.2 The Neural Network*

A feed-forward neural network with back propagation algorithm organized into three layers is created. The topology, or structure, of this network is typical of networks used for prediction and classification. The approach adjusts the strength of connection between nodes at different layers after computing the error between the desired and the actual output of the network on each steps of training. Supervised learning is used, where the desired output of the network for the known patterns of input is fed to the network during training. Accordingly, the network takes inputs, perform some operation and provide the output using the feed forward approach. Then the mean squared error between the desired and the actual output is calculated. If this value is found to be greater than the threshold the error propagates back to adjust the weights of each connection in the course of finding the optimal weight for each connection.

The network is designed with two possibilities with respect to the number of nodes at the input layer: 6 and 12 nodes. The binary representation of the input character extracted and created in excel file is fed to the network after some rearrangement of the rows and columns of each patterns.

### *4.7.3 Braille Character Input Method for the Neural Network*

In MATLAB tool, to train the network the input pattern is first rearrange into column vector which contain elements equal to the number of neurons at the input layer. Accordingly, binary representation of the Braille characters is created in a file as 6 and 12 bits pattern of Braille characters. The input is converted in to one column vector where each preceding column of the character matrix will be appended one after the other.

*Table 4.10 Sample Amharic characters with same ASCII value*

| | Latin | ASCII | | |
|---|---|---|---|---|
| ሄ | X@ | 88 | 64 | 152 |
| ኇ | ~ | 152 | | 152 |
| ቤ | u? | 117 | 63 | 180 |
| ዝ | ´ | 180 | | 180 |
| ጎ | %< | 37 | 60 | 97 |
| ር | a | 97 | | 97 |

Before making decision on output nodes it is worth to mention that all Amharic print characters (target) do not be represent with one ASCII- code value. Examples of such character are given in ***Table 4.10***. This situation results, two different Amharic characters to have same value (when convert to decimal and add), which would bring confusion on later conversion to print. So, to come up with uniform mapping, the character is assigned index starting from 1 to 34, and 1 to 267 for the four different input set mentioned in section 4.7.5 and this value is converted between the value 0 to 1 to fit the network output with Min-max normalization formula.

$$V' = \frac{V - min_A}{max_A - min_A} (new\_max_A - new\_min_A) + new\_min_A$$

*Equation 4.1 Min-max normalization formula*

Thus, the number of nodes at the output layer is decided to be one. After deciding on the possible number of nodes at each layer, the next phase is creating the network and proceeding with the training part, which is discussed in the subsequent part.

### 4.7.4 *Creating the Neural Network*

At this stage, everything is ready for creating and training the network. This part devoted to describe how the network is created. As indicated earlier, a feed-forward back-propagation network is created with gradient-decent momentum training and adaptive learning rate. Training the network with two parameters momentum and learning rate is important for two reasons. First, learning rate is used to specify how the weights are adjusted after calculating errors on the output layer. Likewise, the purpose served by the momentum parameter is that, once the learning network knows to which direction to move on the learning curve, we can adjust the speed of the network for faster convergence. The principle is that, once the direction of convergence of the learning model is known moving fast towards the minima point will speedup the learning process which helps to minimize the total time required by the network to learn different patterns. In addition to fast convergence, the momentum will help the network not to get stuck at local minima. A local minimum is a point in the learning curve where the network error is minimum only to the points in its vicinity and not to the total learning curve.

With too low momentum constant the network will be slow and may get stuck in local minima. On the other hand, if it is set to large value, the network will have less probability of getting trapped in local minima and will converge fast, but it may also oscillate from one point to the other in the curve without touching the global minima.

Training dataset 4: contains 267 records for basic Amharic character (38 x 7), numerals and punctuation marks (19), each with 12 bit (2 cells) and with the corresponding print character ASCII-code.

To train the network, different network parameters such as: goal, epochs, learning rate are adjusted as per the performance of the network (see ***Table 4.11***), and then input patterns along with matrix of target values fed to the network for training.

*Table 4.11 Training parameters for the proposed network*

| functions: | parameters: |
|---|---|
| adaptFcn: 'trains' | goal: 0.001 |
| performFcn: 'mse' | lr: 0.2 |
| trainFcn: 'trainlm' | show:50 |
| | epoch: 1000 |

The line of instruction to perform the training is:

***{AmharicBrailleNet, tr}=train (AmharicBrailleNet, BrailleInput, PrintTarget);***

***Where : AmharicBrailleNet*** is the neural network created in the previous section, ***BrailleInput*** is matrix where each column represents one Braille character from the dataset and ***PrintTarget*** is pattern of target output for each corresponding input.

Accordingly, to train the network the three Braille character input file along with the corresponding target character file is given to the neural network. Then, it has been repeatedly trained with the original dataset and with different noise pattern which are randomly generated by the training module. And there is 50 iteration, which makes a total of 700 for each character pattern, which are provided in the training set. The random noise is set to 0.03 and 0.05.

### *4.7.6 Testing the Neural Network*

Once training the artificial neural network is performed, it is required to test the performance of the network model with different test cases. In this study, testing is conducted in two steps:

- Test 1: contains a total of 100 characters with two cells.
- Test 2: contains a total of 350 characters with two cells.
- Test 3: contains test 2 and additional 100 characters set.

Accordingly, test set 1, test set 2 and test set 3 have been given to Model-1, Model-2 and Model-3 respectively. The performance of the neural network for the three test dataset is given below in ***Table 4.13***.

*Table 4.13 Performance rates for test dataset*

| Network | Performance /Rate of Recognition | |
|---|---|---|
| | Test Set size | Test Set |
| Model -1 with 238 | 100 | 96 % |
| Model -2 with 257 | 350 | 94 % |
| Model -3 with 267 | 450 | 92.5 % |

The performance of the network is decreased with the test set. This is because there are some characters found in the test document for which the network did not trained. This includes the excluded punctuation marks and numerals.

Finally, from the three models the researcher selects the one with 92.5% performance. The rational is that this model trained with training set contained in the other two models plus additional numerals set. And as discussed in above the majority of the error attribute to numerals and punctuation marks. However, for the remaining dataset the three network models are produced similar performance. So it would be better to consider the one that consider wide variety of character than the one with less character set. The artificial neural network algorithm, adapted for the study is presented in ***Figure 3.6***.

[12]. Berry, M. a. "Mastering Datamining: The art and science of Customer Relationship Managment." NewYork: John Wiley and sons inc. 2000

[13]. Blenkhorn, P., "A System for Converting Braille into Print", IEEE Transactions on Rehabilitation Engineering, Vol. 3, No. 2, pp. 215-221, June 1995

[14]. C. Ng and V. Lau, "Regular feature extraction for recognition of Braille", In Proceedings of Third International Conference on Computational Intelligence and Multimedia Applications, ICCIMA'99, pp. 302-306, 1999.

[15]. Cambridge University. (1998). Optical character recognition.

[16]. Dereje Teferi, "Optical Character Recognition of Typewritten Amharic Text. (Masters Thesis). Addis Ababa, School of information Studies for Africa, Addis Ababa University, 1999.

[17]. E. R. DAVIES. "Machine Vision, Theory Algorithms Practicalities." Elsevier Third Edition. 2003

[18]. Ermias Ababe, "Recognition of Formatted Amharic Text Using Optical Character Recogniton". (Masters Thesis). Addis Ababa, School of Information Studies for Africa, Addis Ababa University, 1998.

[19]. Fauset, L. "Foundation of Neural Network." New Jersey: Prentice-Hall. 1994

[20]. Getaneh Hamid. "Provision of Special Needs Education for the Blind in Sebbeta and Walaita Schools." (Masters Thesis). Addis Ababa University. 1999.

[21]. H. Bunke and P.S.P. Wang. "Handbook of character recognition and document image analysis. ", 1997

[22]. Hentzschel, T. W., and P. Blenkhorn. "An Optical Reading Systems for Embossed Braille Characters using a Twin Shadows Approach", Journal of Microcomputer Applications, pp. 341-345. 1995.

[23]. Hermida, X. F., et al. "A Braille OCR for Blind People. ", Proceedings of ICSPAT-96. Boston (U.S.A.).October, 1996.

[24]. Hykin, S. "Neural Network-A comprehensive foundation. ", Upper Saddle River,NJ: Prentice Hall. 1999

[25]. Id21, Institute of Development Studies University of Sussex Bringhton BN1 9RE, UK. "Breaking barriers Building access for disabled people." Available at: http://www.id21.org/insights/insights55/insights55.pdf

[26]. J. Mennens, L. V. Tichelen, G. Francois, and J. Engelen. "Optical recognition of Braille writing using standard equipment." IEEE Transactions on Rehabilitation Engineering, 2(4): pp. 207–212, December 1994.

[27]. Jiawei Han et al. "Data Mining: concepts and Techniques." 2001

[28]. Mennens, J., et al, "Optical Recognition of Braille Writing Using Standard Equipment", IEEE transactions of rehabilitation engineering, Vol. 2, No. 4, pp. 207-212, December 1994.

[29]. Mennens, J., et al, "Optical Recognition of Braille Writing", IEEE, pp. 428-431, 1993

[30]. Michael J.A. Berry, Gordon S. Linoff. "Data Mining Techniques for Marketing, Sales, and Customer Relationship Management Second Edition." Wiley Publishing, Inc. 2004.

[31]. Million Meshesha, "A Generalized Approach to character Recogniton of Amharic Texts", (Masters Thesis). Addis Ababa, School of information Studies for Africa, Addis Ababa University, 2000.

[32]. Néstor Falcón et. al. "Image Processing Techniques for Braille Writing Recognition." EUROCAST, LNCS 3643, pp. 379 – 385, 2005.

[33]. New York institute for special Education. "History of Braille." Blindness Resource Center, 2008. Available at : http://www.nyise.org/blind/barbier2.htm

[34]. Perlovsky, L. I. "Neural Network and Intellect: Model Based Concept." New York: Oxford University Press. 2001

[35]. Radial basis networks (neural network toolbox): Probabilistic neural networks. [Online] Available: http://www.mathworks.com/access/helpdesk/help/toolbox/n net/radial10.shtml#2412, c_1994-2003. The MathWorks, Inc.

[36]. Ritchings R.T et. al. "Analysis of scanned Braille document." World scientific Publishing co. pp 413-421. 1995

[37]. Sarles, W. Retrieved 10 11, 2008, from Neural Network-FAQ ,periodic posting to the usenet news group comp.ai.neural-net: 1997 Available at: ftp://ftp.sas.com/pub.neural/FAQ.html

[38]. Statsoft. Retrieved 11 02, 2008, from Neural Network: 2003 http://www.statsoftinc.com/textbook/steneunet.html

[39]. Wikipedia free. Braille Available at htttp:// www.wikipedia.com.

[40]. Wondwossen Mulugeta. "OCR for Special type of Handwritten Amharic text ("YEKUM TSIFET"). " (Masters Thesis). Addis Ababa, Department of information science, Addis Ababa University, 2004.

[41]. Wong, L., W. Abdulla, and S. Hussmann. "A Software Algorithm Prototype for Optical Recognition of Embossed Braille", the 17th conference of the International Conference in Pattern Recognition, Cambridge, UK, pp. 23-26, August 2004.

[42]. Worku Alemu. "The application of OCR techniques to the Amharic script." (Mastrs Thesis). Addis Ababa, school of Information Studies for Africa, Addis Ababa University. 1997

[43]. በልዩ ትምህርት ቡድን ሥ/ት/ዝ/ጥናትና ምርምር ኢንስቲትዮት:: የብሬል ማስተማሪያ የመምህሩ መመሪያ:: አዲስ አበባ 1991::

[44]. በኢትዮጵያ አይነስውራን ብሔራዊ ማህበር 12ኛ ዙር ስራ አስፈፃሚ ኮሚቴ የተቋቋመው የአማርኛ ብሬል አሻሻይ ኮሚቴ:: የአማርኛ ብሬል አሻሻይ ኮሚቴ ዘገባ:: ታህሳስ 19 እና 20 ቀን 1995 ዓ.ም. ለተጠራው አገር አቀፍ ጉባኤ የቀረበ:: 1995

[45]. ጌታነህ አበበ:: የአማረኛ ብሬል ከነሀሴ 24-28/1991 በሰበታ እውራን ት/ቤት አውደ ጥናት የቀረበ:: :: በአፀደ ሕፃ/ልዮና መ/ተ/ሥ/ት/ዝ/ዋና ክፍል:: ሥ/ትም/ዝ/ክ/ም/ኢንስቲትዮት:: 1984

[46]. ጌታነህ አበበ። የአማረኛ ብሬል ንባብና ጽሕፈት መማሪያ የመምህሩ መመሪያ። በአዐደ ሕፃ/ልዮና መ/ተ/ሥ/ት/ዝ/ዋና ክፍል። ሥ/ትም/ዝ/ክ/ም/ኢንስቲትዮት። 1984

[47]. ነብየልዑል ዮሃንስ ዘመነ ብርሃን አዲስ አበባ ብርሃንና ሰላም ማተሚያ ቤት 1954።

# Appendix

## I. The first version of Amharic Braille

***Table I.1*** *List of vowels for first version Braille*

| Vowels | 1:4 | 2:5 | 3:6 | 1:5 | 2:4 | 2:6 | 2:6 |
|---|---|---|---|---|---|---|---|
| Variant | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th |

***Table I.2*** *List of vowels for first version Braille*

| | | | |
|---|---|---|---|
| ሀ | 1:2:4 | ኸ | 2:3:4 |
| ለ | 1:4:5 | ወ | 2:3:4:5 |
| ሐ | 1:2:4:5 | ዐ | 1:6 |
| መ | 1:2:5 | ዘ | 1:4:6 |
| ሠ | 2:4:5 | ዠ | 1:3:4:6 |
| ረ | 1:3 | የ | 1:4:5:6 |
| ሰ | 1:2:3 | ደ | 1:5:6 |
| ሸ | 1:2:3:6 | ጀ | 1:2:4;6 |
| ቀ | 1:3:4 | ገ | 1:2:4:5:6 |
| በ | 1:3:4:5 | ጠ | 1:2:5:6 |
| ተ | 1:3:5 | ጨ | 1:2:3:5:6 |
| ቸ | 1:3:5:6 | ጰ | 2:4;5;6 |
| ኀ | 1:2:3:4 | ፀ | 2:4:5:6 |
| ነ | 1:2:3:4:5 | ጸ | 1:3:6 |
| ኘ | 1:2:3:4:5:6 | ፈ | 1:3:4:5:6 |
| አ | 1:2:3:5 | ፐ | 2:3:4:5:6 |
| ከ | 1:2:6 | | |

***Table I.3*** *List of first Version Extended Amharic Braille Character*

| | |
|---|---|
| ቈ | 1:2:3:4:6 2:3:4 |
| ኰ | 1:2:3:4:6 1:3:4 |
| ጎ | 1:2:3:4:6 1:2:3:4 |
| ጐ | 1:2:3:4:6 1:2:4:5:6 |

# II. The second version Amharic Braille (1945)

***Table II.1*** *List of second version Basic Amharic Braille character*

| | 1st | | 7th | | 1st | | 7th | |
|---|---|---|---|---|---|---|---|---|
| ሀ | 1:2:5 | ሀ | 1:3:4:6 | ኸ | 2:3:6 | ኽ | 5 2:3:6 | |
| ለ | 4:5:6 | ል | 1:2:3 | ወ | 2:4:5:6 | ዉ | 2:4:6 | |
| ሐ | Not apply | | | ዐ | Not apply | | | |
| መ | 1:3:4 | ም | 2:3 | ዘ | 1:3:5:6 | ዝ | 2:3:4:6 | |
| ሠ | 2:3:4 | ሥ | 5 | ዠ | 3:5:6 | ዥ | 5:6 | |
| ረ | 1:2:3:5 | ር | 1:2:5 | የ | 1:3:4:5:6 | ይ | 1:4:5:6 | |
| ሰ | Not apply | | | ደ | 1:4:5 | ድ | 1:4:5:6 | |
| ሸ | 1:4:6 | ሽ | 1:5:6 | ጀ | 2:4:5 | ጅ | 1:2:6 | |
| ቀ | 1:2:3:4:5 | ቅ | 4:6 | ገ | 1:2:4:5 | ግ | 2:3:5:6 | |
| በ | 1:2 | ብ | 4:5 | ጠ | 2:3:4:5:6 | ጥ | 1:2:3:5:6 | |
| ተ | 2:3:4:5 | ት | 123456 | ጨ | 1:4 | ጭ | 3:6 | |
| ቸ | 1:6 | ች | 2:5 | ጸ | 2:3:5 | ጽ | 3:4:5:6 | |
| ኀ | Not apply | | | ፀ | 1:2:3:4:6 | ፅ | 3:4:5:6 | |
| ነ | 1:3:4:5 | ን | 1:2:4:6 | ጸ | Not apply | | | |
| ፐ | 3:4:6 | ፕ | 2:6 | ፈ | 1:2:4 | ፍ | 5 1:2:4 | |
| አ | 3 | እ | 3:4 | ፐ | | | | |
| ከ | 1:3 | ክ | 3:5 | | | | | |

***Table II.2*** *List of vowels for second version Braille*

| Vowel | none | 1:3:6 | 2:4 | 1 | 1:5 | none | 1:3:5 |
|---|---|---|---|---|---|---|---|
| Variant | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th |

# III. The third version Amharic Braille (1949E.C)

**Table III.1** *List of vowels for third version Braille*

| Vowel | 2:6 | 1:3:6 | 2:4 | 1 | 1:5 | Independent | 1:3:5 |
|---|---|---|---|---|---|---|---|
| Character Variant | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th |

**Table III.2** *List of third version Basic Amharic Braille character*

| 6th | | 6th | |
|---|---|---|---|
| ሀ | 1:2:5 | ኸ | 2:3:6 |
| ለ | 1:2:3 | ወ | 2:4:5:6 |
| ሐ | Not apply | ዐ | Not apply |
| መ | 1:3:4 | ዘ | 1:3:5:6 |
| ሠ | 2:3:4 | ዠ | 3:5:6 |
| ረ | 1:2:3:5 | ደ | 1:3:4:5:6 |
| ሰ | Not apply | ጀ | 1:4:5 |
| ሸ | 1:4:6 | ገ | 2:4:5 |
| ቀ | 1:2:3:4:5 | ጠ | 1:2:4:5 |
| በ | 1:2 | ጨ | 2:3:4:5:6 |
| ተ | 2:3:4:5 | ጰ | 1:4 |
| ቸ | 1:6 | ጸ | 2:3:5 |
| ኀ | Not apply | ፀ | 1:2:3:4:6 |
| ነ | 1:3:4:5 | ፈ | Not apply |
| ኘ | 3:4:6 | ፍ | 1:2:4 |
| አ | *1:2:3:5:6 | ፐ | 1:2:3:4 |
| ከ | 1:3 | | |

*** Symbol indicates Braille code change made on the new version.**

**Table III.3** *List of third Version Extended Amharic Braille Character*

| Amharic irregular character | | |
|---|---|---|
| ቈ | 1:3 | 2:4:5:6 |
| ኰ | 1:2:3:4:5 | 2:4:5 |
| ጎ | 1:2:5 | 2:4:5:6 |
| ጐ | 1:2:4:5 | 2:4:5:6 |

# IV. The fourth version Amharic Braille (1949E.C)

***Table IV.1*** *List of fourth Version Amharic Braille punctuation marks*

| Punctu. | Braille code |
|---|---|
| . | 3 |
| : | 6 and 3 |
| ÷ | 2:5 |
| / | 5 and 2 |
| - | 4 and 1 |
| :- | 3:6 |
| | 3:6 and 3:6 |
| | 5 and 2:3:5 |
| ፡ | 2 |
| ፣ | 2:3 |
| « | 2:3:6 |
| » | 3:5:6 |
| | 6 and 2:3:6 |
| ’ | 3:5:6 and 3 |
| ? | 2:3:6 |
| :: | 2:5:6 |
| ! | 2:3:5 |
| … | 3 , 3and 3 |
| ( ) | 2:3:5:6 |
| [ | 6 and 2:3:5:6 |
| ] | 2:3:5:6 and 3 |
| * | 3:5 and 3:5 |
| _ | 4:6 and 4:6 |
| → | 2:4:6, 2:5 and 2:5 |
| ← | 2:5,2:5 and 1:3:5 |
| ↑ | 4:5:6 and 1:5 |
| ↓ | 4:5:6 and 3:5 |
| | 5:6 |
| | 4 and 3:4:5 |
| እና ወይም | 3:4 |
| | 3:4:5 and 3:4:5 |
| | 6 and 3 |
| | 2:6 and 3:5 |
| | 3:6 |
| | 4 |
| | 5:6 |
| | 5 |
| | 2:5 and 2:5 |
| =//= | 6 and 3 |
| | 4:5:6 and 4:6 |
| | 4:5:6, 4:6 and 46 |
| X | 1:3:4:6 |
| $ | 4:5 |
| | 3:6, and 3:6 |
| | |

## V. Feature extraction Algorithm

```
Let cell_1 and cell_2 are array to store  prefix and suffix of a character respectivelly
Let BraillChar is an array defined to store a character containing cell_1 and cell_2
Let hordotArr is an array to store vertical cordinate point of grids intersection of image
Let VerdotArr is an array to store horizontal cordinate point of grids intersection  of image
Let temp is an array to store current six dot as binary digit
Let img is matrix same size as image
Let dotColor is one pixel representation of dot at mesh cordinate
While h in hordotArr not null
        For each w in VerdotArr
                If pixel at img(w,h)equals to dotColor //First column dot position 1 2 3 starts here
                        set temp[0]=1
                else
                        set temp[0]=0
                end if
                if pixel at img(w,h++)equals to dotColor
                        set temp[1]=1
                else
                        set temp[1]=0
                end if
                if pixel at img(w,h+2)equals to dotColor
                        set temp[2]=1
                else
                        set temp[2]=0
                end if
                if pixel at img(w+1,h)equals to dotColor//Second column dot – 4 5 6 starts here
                        set temp[3]=1
                else
                        set temp[3]=0
                end if
                if pixel at img(w+1,h+1)equals to dotColor
                        set temp[4]=1
                else
                        set temp[4]=0
                end if
                if pixel at img(w+1,h+2)equals to dotColor
                        set temp[5]=1
                else
                        set temp[5]=0
                end if
                If isVowel(temp)equals to true//check content of a cell
                        If BrailleChar cell_1 not empty
                                buffer temp to cell_2
                        Else
                                buffer zero to cell_1
                                buffer temp to cell_2
                //vowel comes after consonat cell otherwise that is wrong starting
                        End if
```

*Continued in the next page...*

```
                Else if isnumberMode(BTemp)equals true or isPunctuationMarkPfix(BTemp) equals true
                        buffer temp to cell_1
                        buffer zero to cell_2
                        go to next cell //untile checkes next cell cell_2 set to default zero
                Else if BrailleChar cell_1 not null AND isnumberMode(cell_1)is true
                        buffer temp to cell_2
                        go to next BrailleChar
                Else if isconsonant(temp)is true
                        buffer temp to cell_1
                        buffer zero to cell_2
                        Go to next cell
                Else if isvowel(temp)is true and isPunctuationMarkPfix(BTemp)not true
                        buffer temp to cell_2
                Else
                        buffer unknown to cell_1
                        buffer unknown to cell_2
                        increment BrailleChar  and Go to next cell
                End if
        End for loop
end while
while BrailleChar not null //write BrailleChar to file
        write cell_1,cell_2 to file
end while
//function implementation
Begin function isnumberMode(integer temp) //chech the current cell content is number mode
let numMode array for number mode//{0,0,1,1,1,1}
        for each x,y in numMode, temp
                if x not equals y
                        return false
        return true
function end
Begin function isVowel(temp) //check the curent cell content is vowel and return
let vowel is an  array for braille
character//{0,1,0,0,0,1};{1,0,1,0,0,1};{0,1,0,1,0,0};{1,0,0,0,0,0};{1,0,0,0,1,0};{1,0,1,0,1,0}
let hit is boolean
        for each cell in vowel
                set hit false
                for each x,y in cell,temp
                        if x equal y
                                set hit true
                        else
                                go to next cell//break inner loop
                if hit true
                        return true
        return false
function end
Begin function isPunctuation(temp) //check cell content is one of punctuation mark prifix cell
let PuncMarkS is an array for punctuation prifix//{0,0,1,0,0,0;0,1,0,0,0,0;0,0,1,0,0,1;0,1,1,0,1,1;0,0,0,1,0,1;0,0,1,1,1,0}
        for cell in PuncMarks
                set hit false
                for x,y in cell,temp
                        if x equals y
                                set hit true
                        else
                                go to next cell//break inner loop
                if hit is true
                        return true
        return false
function end
```

**Figure V.1** Feature extraction algorithm based on grids-mesh and contextual approach

# VII. Sample Braille Image

***Figure VII.1*** *Sample Braille image with Gray-color*

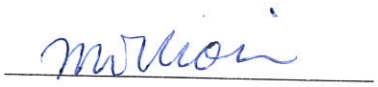
## Declaration

I, the undersigned, declare that this thesis is my original work and has not been presented as a partial degree requirement for a degree in any other university and that all sources of materials used for the thesis have been duly acknowledged.

Teshome Alemu

March 2009

The thesis has been submitted for examination with my approval as university advisor



Dr. Million Meshesha

March 2009