DESIGN AND DEVELOPMENT OF PHONEME BASED SIGN LANGUAGE RECOGNITION SYSTEM FOR THE HEARING IMPAIRED

© This item is protected by original copyright

by

RAJKUMAR PALANIAPPAN
0830610328

A thesis submitted in fulfillment of the requirements for the degree of Master of Science (Mechatronic Engineering**)**

School of Mechatronic Engineering
UNIVERSITI MALAYSIA PERLIS

2012

© This item is protected by original copyright

ACKNOWLEDGMENT

I am deeply thankful and grateful to God for His blessings that this research activity is successful and the writing of this thesis is completed.

I would like to express my sincere and profound gratitude to the Vice Chancellor of University Malaysia Perlis, Y. Bhg. Brigedier Jeneral Dato' Prof. Dr. Kamarudin b. Hussin for granting me permission to study in this university.

I would like to express my thanks to the Dean of School of Mechatronic Engineering, University Malaysia Perlis, Associate Prof. Dr. Abdul Hamid Adom for providing support during my research work.

I would like to express my sincere thanks to my co-supervisor Prof. Dr. Sazali Yaacob, Head (Intelligent Signal Processing Research cluster) for his valuable guidance and supervision in the research and preparation of this thesis. His patience and positive attitude foster me in completing my research work.

I would like to thank my main supervisor Associate Prof. Dr. Paulraj M P for his valuable supervision, continuous encouragement, inspiring suggestions and guidance in the research and preparation of this thesis.

I also thank the Ministry of Higher Education, Malaysia for funding this project through FRGS (Fundamental Research Grant Scheme) grant Number-9003-00188.

My sincere thanks to all the members of Intelligent Signal Processing Research Cluster, who have contributed directly and indirectly towards the completion of this research.

Finally, I am grateful to my parents and also my siblings for their love, continuous support and encouragement in completing this research work.

© This item is protected by original copyright

TABLE OF CONTENT

DECLARATION I

ACKNOWLEDGEMENT II

TABLE OF CONTENTS III

LIST OF TABLES X

LIST OF FIGURES XI

LIST OF ABBREVIATIONS XIII

ABSTRAK (BM) XIV

ABSTRACT (ENGLISH) XV

CHAPTER-1 Introduction

1.1 Overview 1

1.2 Problem Statement 3

1.3 Significance of the Study 3

1.4 Research Objectives 4

1.5 Thesis Organization 5

CHAPTER-2 A Review on Sign Language Recognition System

2.1 Introduction 7

2.2 Hearing Impairment and Its Cause 7

2.3 Sign Language 8

2.4 Previous Works in Sign Language Recognition Systems 9

2.4.1 Electromechanical Device based Approaches for Sign Language Recognition Systems 10

2.4.2 Glove based Approaches for Sign language Recognition Systems 11

2.4.3 Vision based Approaches for Sign Language Recognition Systems 12

© This item is protected by original copyright

2.5 Application of Artificial Neural Network in Sign language Recognition 14

2.6 Summary 21

CHAPTER-3 Image Processing and Feature Extraction

3.1 Introduction 22

3.2 Developing Sign Language for English Phonemes 22

3.3 Data Acquisition 23

3.3.1 Selection of Camera 23

3.3.2 Data Acquisition Set up 24

3.3.3 Data Set 25

3.3.4 Subject Requirements During Data Acquisition 25

3. 4 Image Pre-processing 26

3.4.1 Skin Color Segmentation 27

3.4.2 Interleaving Method 28

3.5 Feature Extraction 30

3.5.1 2D-Moments 31

3.5.2 2D- Invariant Moment 32

3.5.3 Combined Blur and Affine Moment Invariants 34

3.5.4 Fourier Descriptor 37

3.6 Methodology 39

3.7 Summary 40

CHAPTER-4 Classification Using Neural Network

4.1 Introduction 41

4.2 Artificial Neural Network 41

4.2.1 Multilayer Feedforward Neural Network 42

4.3 Back Propagation Networks 43

© This item is protected by original copyright

4.3.1 Training Preparations 44

4.3.2 Training Algorithm 46

4.4 Recurrent Neural Network 48

4.5 English Phoneme Sign Classification 49

4.6.1 Implementation of Neural Network for 2D-Moments Features 50

4.6.1.1 Multilayer Perceptron Network Model for 2D-Moments Feature 50

4.4.1.2 Elman Network Model for 2D-Moments Feature 52

4.6 .2 Implementation of Neural Network for 2D-Moment Invariants Features 55

4.6.2.1 Multilayer Perceptron Network Model for 2D-Invariant Moment Feature 55

4.6.2.2 Elman Network Model for 2D-Invariant Moment Feature 57

4.6 .3 Implementation of Neural Network for Combined Blur and Affine Moment Invariant Features 60

4.6.3.1 Multilayer Perceptron Network Model for Combined Blur and Affine Moment Invariant Feature 60

4.6.3.2 Elman Network Model for Combined Blur and Affine Moment Invariant Feature 62

4.6.4 Implementation of Neural Network for Fourier Descriptor Features 65

4.6.4.1 Multilayer Perceptron Network Model for Fourier Descriptor Feature 65

© This item is protected by original copyright

4.6.4.2 Elman Network Model for Fourier Descriptor Feature 67

4.7 Summary 70

CHAPTER-5 Results and Discussion

5.1 Introduction 71

5.2 Sign Language Classification Results Using Feedforward Neural Network Classifier (Non-Interleaving Method) 71

5.2.1 2D-Moments Feature Results Using Feedforward Neural Network Classifier (Non-Interleaving Method) 71

5.2.2 2D-Invariant Moment Feature Results Using Feedforward Neural Network Classifier(Non-Interleaving Method) 74

5.2.3 Combined Blur and Affine Moment Invariant Feature Results Using Feedforward Neural Network Classifier(Non-Interleaving Method) 76

5.2.4 Fourier Descriptor Feature Results Using Feedforward Neural Network Classifier(Non-Interleaving Method) 78

5.3 Sign language Classification Results Using Feedforward Neural Network Classifier(Horizontal Interleaving Method) 81

5.3.1 2D-Moments Feature Results Using Feedforward Neural Network Classifier(Horizontal Interleaving Method) 81

5.3.2 2D-Invariant Moment Feature Results Using Feedforward Neural Network Classifier(Horizontal Interleaving Method) 83

5.3.3 Combined Blur and Affine Moment Invariant Feature Using Feedforward Neural Network Classifier(Horizontal Interleaving Method) 85

5.3.4 Fourier Descriptor Feature Results Using Feedforward Neural 88

© This item is protected by original copyright

Network Classifier(Horizontal Interleaving Method)

5.4 Sign language Classification Results Using Feedforward Neural Network Classifier(Vertical Interleaving Method) 90

5.4.1 2D-Moments Feature Results Using Feedforward Neural Network Classifier(Vertical Interleaving Method) 90

5.4.2 2D-Invariant Moment Feature Results Using Feedforward Neural Network Classifier(Vertical Interleaving Method) 92

5.4.3 Combined Blur and Affine Moment Invariant Feature Using feedforward Neural Network Classifier(Vertical Interleaving Method) 95

5.4.4 Fourier Descriptor Feature Results Using Feedforward Neural Network Classifier(Vertical Interleaving Method) 97

5.5 Sign language Classification Results Using Elman Neural Network Classifier(Non-Interleaving Method) 99

5.5.1 2D-Moments Feature Results Using f Elman Neural Network Classifier(Non-Interleaving Method) 99

5.5.2 2D-Invariant Moment Feature Results Using Elman Neural Network Classifier(Non-Interleaving Method) 102

5.5.3 Combined Blur and Affine Moment Invariant Feature Results Using Elman Neural Network Classifier(Non-Interleaving Method) 104

5.5.4 Fourier Descriptor Feature Results Using Elman Neural Network Classifier(Non-Interleaving Method) 106

5.6 Sign language Classification Results Using Elman Neural Network Classifier(Horizontal Interleaving Method) 108

5.6.1 2D-Moments Feature Results Using Elman Neural Network Classifier(Horizontal Interleaving Method) 109

© This item is protected by original copyright

5.6.2 2D-Invariant Moment Feature Results Using Elman Neural Network Classifier(Horizontal Interleaving Method) 111

5.6.3 Combined Blur and Affine Moment Invariant Feature Using Elman Neural Network Classifier(Horizontal Interleaving Method) 113

5.6.4 Fourier Descriptor Feature Results Using Elman Neural Network Classifier(Horizontal Interleaving Method) 115

5.7 Sign language Classification Results Using Elman Neural Network Classifier(Vertical Interleaving Method) 118

5.7.1 2D-Moments Feature Results Using Elman Neural Network Classifier(Vertical Interleaving Method) 118

5.7.2 2D-Invariant Moment Feature Results Using Elman Neural Network Classifier(Vertical Interleaving Method) 120

5.7.3 Combined Blur and Affine Moment Invariant Feature Using Elman Neural Network Classifier(Vertical Interleaving Method) 123

5.7.4 Fourier Descriptor Feature Results Using Elman Neural Network Classifier(Vertical Interleaving Method) 125

5.8 Results Comparison Between Non-Interleaving and Interleaving Method 127

5.9 Graphical User Interface (GUI) 130

5.10 Summary 131

CHAPTER-6 Conclusion and Recommendation

6.1 Introduction 132

6.2 Conclusion 132

6.3 Research contributions 132

6.4 Recommendation for future works 133

References 135

© This item is protected by original copyright

Appendix A Phoneme Classification 141

Appendix B Gestures used for English Phonemes 142

Appendix C The Parameter of Digital Web Camera 148

Appendix D Mean Phoneme Classification 149

Appendix E Classification Results 157

LIST OF PUBLICATIONS 217

© This item is protected by original copyright

LIST OF TABLES

Table	Title	Page
2.1	List of Previous Works on Sign Language Recognition	16

© This item is protected by original copyright

LIST OF FIGURES

Figure	Title	Page
3.1	Gestures used for creating the sign language	23
3.2	Image Acquisition Device	24
3.3	Experimental set-up	25
3.4	Subject performing a sign	26
3.5	Skin color detected image frame	28
3.6	(a) Segmented Right Hand, (b) Segmented Left Hand	28
3.7	Vertical Maximum Interleaving method	29
3.8	Horizontal Maximum Interleaving method	30
3.9	2D-Moments Feature Plot	32
3.10	2D-Invariant Moment Feature Plot	34
3.11	Combined Blur and Affine Moment Invariant Feature Plot	37
3.12	Fourier descriptor Feature plot	39
3.13	Block diagram of the proposed system	40
4.1	Backpropagation Network Architecture	44
4.2	Internal process of Elman Neural network	49
4.3	Gesture Classification block diagram	50
4.4	MLP Network Model for Right and Left hand Gestures Classification Using 2D-Moments Feature	50
4.5	MLP Network Model for Specific Phoneme Classification Using 2D-Moments Feature	51
4.6	Elman Network Model for Right and Left Hand Gestures Classification Using 2D-Moments Feature	53
4.7	Elman Network Model for Specific Phoneme Classification Using 2D-Moments Feature	54
4.8	MLP Network Model for Right and Left Hand Gestures Classification Using 2D-Invariant Moment Feature	55

© This item is protected by original copyright

Figure	Title	Page
4.9	MLP Network Model for Specific Phoneme Classification Using 2D-Invariant Moment Feature	56
4.10	Elman Network Model for Right and Left Hand Gestures Classification Using 2D-Invariant Moment Feature	58
4.11	Elman Network Model for Specific Phoneme Classification Using 2D-Invariant Moment Feature	59
4.12	MLP Network Model for Right and Left Hand Gesture Classification Using Combined Blur and Affine Moment Invariants	60
4.13	MLP Network Model for Specific Phoneme Classification Using Combined Blur and Affine Moment Invariant Features	61
4.15	Elman Network Model for Right and Left Hand Gesture Classification Using Combined Blur and Affine Moment Invariants	62
4.16	Elman Network Model for Specific Phoneme Classification Using Combined Blur and Affine Moment Invariant Features	64
4.17	MLP Network Model for Right and Left Hand Gestures Classification Using Fourier Descriptor Features	65
4.18	MLP Network Model for Specific Phoneme Classification Using Fourier Descriptor Features	66
4.19	Elman Network Model for Right and Left Hand Gestures Classification Using Fourier Descriptor Features	67
4.20	Elman Network Model for Specific Phoneme Classification Using Fourier Descriptor Features	69
5.1	Comparison of Classification Accuracy (Feedforward Network)	128
5.2	Comparison of Classification Accuracy (Elman Network)	128
5.3	Comparison of Epoch (Feedforward Network)	129
5.4	Comparison of Epoch (Elman Network)	129
5.5	GUI Front-end	130

© This item is protected by original copyright

LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
ASL	American Sign Language
AUSLAN	Australian sign language
BIM	Basha Isyarat Melayu
BP	Backpropagation
DCT	Discrete Cosine Transform
DEC	Digital Equipment Corporation
ENN	Elman Neural Network
GUI	graphical user interface
HCI	Human Computer Interaction
HMM	hidden markov model
IPA	International Phonetic Alphabet
ISL	Indian Sign Language
JSL	Japanese Sign Language
KSL	Korean sign language
KTBM	Kod Tangan Bahasa Melayu
MEMS	microelectronic mechanical system
MLP	Multilayer perceptron
PC	Personal Computer
PSL	Pakistan Sign language
RNN	Recurrent Neural Network
S2V	Sign to voice
TWL	Taiwanese Sign language
USB	Universal Serial Bus
VPL	Visual Programming Language
VSL	Vietnamese Sign Language
WHO	World Health Organization

© This item is protected by original copyright

PENGHASILAN DAN PEMBANGUNAN SISTEM PENGECAMAN BAHASA ISYARAT BERDASARKAN FONEM UNTUK MASYARAKAT CACAT PENDENGARAN

ABSTRAK

Pengecaman bahasa isyarat adalah salah satu cabang penyelidikan pengecaman isyarat yang paling menjanjikan. Bahasa isyarat biasanya dibangunkan untuk masyarakat cacat pendengaran, yang termasuk penterjemah, rakan-rakan dan keluarga orang cacat pendengaran serta orang-orang yang mengalami masalah pendengaran itu sendiri. Tesis ini membincangkan pembangunan system pengecaman bahasa isyarat berasaskan fonem untuk golongan yang terjejas pendengaran. Penyelidikan mengenai pengecaman bahasa isyarat sebelum ini tertumpu pada pengecaman ejaan jari atau pengecaman perkataan yang terpencil. Penyelidikan ini memberi tumpuan kepada pembangunan sistem pengecaman bahasa isyarat untuk mengecam 44 fonem Bahasa Inggeris. Untuk mewakili 44 fonem Bahasa Inggeris tersebut, sebagai langkah pertama, 11 gerak isyarat yang berbeza telah dimajukan. Dengan memilih kombinasi yang sesuai untuk tangan kiri dan kanan daripada 11 gerak isyarat ini, 44 kombinasi isyarat yang berbeza telah dirangka. Pengumpulan data daripada tujuh orang subjek dibuat menggunakan kamera web biasa pada resolusi 640 × 480. Data tersebut diproses dan pengekstrakan ciri-ciri dibuat terhadap kawasan yang disegmen. Algoritma baru bagi pra-proses pencantuman yang telah dicadangkan digunakan dalam pembangunkan sistem pengecaman bahasa isyarat ini dan dibincangkan dalam tesis ini. Rangkaian saraf tiruan (ANN) membolehkan bentuk pengkomputeran alternatif yang cuba untuk meniru fungsi otak. Set ceciri kemudiannya disuap kepada model rangkaian saraf untuk pengelasan isyarat fonem. Satu sistem audio dipasang untuk memainkan perkataan tersebut untuk komunikasi di antara rakyat biasa dan masyarakat cacat pendengaran. Keputusan uji kaji menunjukkan bahawa penggunaan kaedah pra-proses pencantuman dicadangkan menghasilkan ketepatan pengelasan yang lebih baik berbanding dengan kaedah konvensional.

© This item is protected by original copyright

DESIGN AND DEVELOPMENT OF PHONEME BASED SIGN LANGUAGE RECOGNITION SYSTEM FOR THE HEARING IMPAIRED

ABSTRACT

Sign language recognition is one of the most promising sub-fields in gesture recognition research. Sign languages are commonly developed for hearing impaired communities, which can include interpreters, friends and families of hearing impaired people as well as people who are hard of hearing themselves. This thesis discusses the development of a Phoneme based sign language recognition system for the hearing impaired. Previous research on sign language recognition systems have concentrated on finger spellings recognition or isolated word recognition. This research focuses on developing a sign language recognition system for recognizing 44 English phonemes. To represent the 44 English phonemes, as a first step, 11 different gestures were developed. By selecting suitable combination of these 11 gestures for the right and left hand, 44 different gesture combinations were formulated. The signed data are collected from seven subjects using an ordinary web camera at a resolution of 640×480 pixels. The data is preprocessed and features are extracted from the segmented regions of the signed data. A newly proposed interleaving preprocessing algorithm used in developing the sign language recognition system is discussed in this thesis. Artificial Neural Network (ANN) provides alternative form of computing that attempts to mimic the functionality of the brain. The feature set is then feed to the neural network model to classify the phoneme sign. An audio system is installed to play the particular word for the communication between the ordinary people and hearing impaired community. Experimental results show that the use of proposed interleaving method yields a better classification accuracy compared to the conventional method. The vertical interleaving method using combined blur and affine moment invariant features and Elman network yields the maximum classification accuracy of 95.50%.

© This item is protected by original copyright

CHAPTER 1

INTRODUCTION

1.1 Overview

Normal people can communicate their thoughts and ideas to others through speech. However, the only means of communication for the hearing impaired communities is the means of using sign language. A sign language is a language used by the hearing impaired to communicate or convey their thoughts and ideas to others. Hearing impaired people use sign patterns instead of acoustic sound signal to communicate. These sign patterns are obtained by combining hand-shapes, orientation and movement of the hands, arms or body, facial expressions and lip-patterns ("Sign language"). Sign languages are non-verbal visual language, different from the spoken language, but serving the same function. The sign language consists of a vocabulary of signs which are exactly similar in the same way as in the spoken language (Johnston et al., 2007).

© This item is protected by original copyright

Each country and each region has its own sign language. Even a hearing impaired person from one country can't communicate with another hearing impaired person from another country because the signs used in their country are different. Even in the same country there might be a number of different sign languages. In addition, only very few people who are not hearing impaired learn these sign languages. Most of the normal people don't understand these signs, which in turn increase the isolation of the hearing impaired people; they have the constraint of communicating only with their hearing

impaired counterpart by means of the sign language (Harling et al., 1996; Sagawa et al., 1997) .

It is often very difficult for the hearing impaired community to communicate their ideas and creativity to the normal humans. To overcome this communication barrier sign language recognition systems are developed specially for the hearing impaired all over the world for various sign languages.

Vision based sign language recognition has drawn considerable attention from researchers in recent years. The development of sign to voice conversion system will be more useful for the hearing impaired to communicate with the normal people more fluently. Many researchers have developed automatic sign language recognition system for various sign languages. From the previous research works it was observed that the systems proposed by earlier researchers were based on the conversion of an action based verb to an equivalent sign. These systems have the restriction of handling a maximum number of action verbs in the specific language. In order to overcome this limitation, a phoneme based sign conversion system has been formulated. The aim of this research work is to develop a sign language recognition system using neural network model which can visually recognize the English phoneme sign language performed by the signer. The features extracted from the left and right hand gesture signs are used in developing the neural network model. The proposed model is trained and tested for its validation. The proposed system is designed to visually recognize the 44 English phonemes. The proposed system can recognize phoneme signs for any word in English. Since phoneme is directly related to speech, this system gives the hearing

© This item is protected by original copyright

impaired a real life speaking experience. The main motivation and objectives of this research work has been discussed in this chapter.

1.2 Problem Statement

The hearing impaired people always have problems in communicating with normal people. They have problems in conveying their thoughts and ideas to normal people who have very limited or sometimes no knowledge in sign language. This makes the hearing impaired community lose interest in common activities and they avoid communicating with normal people at times and live in isolation. To overcome this situation many sign language recognition systems were developed by researchers but there is still a need for accurately and more effectively recognizing the signs. Currently the systems proposed by earlier researchers are based on the conversion of an action based verb to an equivalent sign. These systems have the restriction of handling maximum number of action verbs in the specific language. This research aims to develop a sign language recognition system for the English phonemes. The proposed system should be easier to use and more user friendly for the hearing impaired people. The proposed system will convert symbolic phoneme sign into equivalent text and voice more accurately and efficiently.

© This item is protected by original copyright

1.3 Significance of the Study

The hearing impaired people are in lack of contact with normal people because of their communication problems. They have problems in conveying their thoughts, ideas and creativity to normal people acoustically. Moreover the lack of sign language knowledge to the normal people makes the hearing impaired people to live in isolation. This research work will be helpful for the hearing impaired community in many ways.

The primary advantage would be the hearing impaired people's communication. The hearing impaired people can communicate with normal people more fluently with the help of such system. The proposed system is developed in such a way that it can be used in other languages too. The system is a phoneme based and uses the 44 English phonemes, hence any word from any language can be developed. This helps the hearing impaired community to use this system to communicate more effectively with their counterparts from other countries too.

© This item is protected by original copyright

1.4 Research Objectives

The purpose of this research is to develop a phoneme based sign language recognition system for the hearing impaired community using neural network. The objectives of this research are as follows.

i. **To develop the sign language and sign language dataset for English phonemes.**

   Developing a sign language is a demanding task in the area of Linguistics. There is no sign language formulated for the English phonemes, in this research the first and foremost objective is to develop the sign language for English phonemes and the data are to be collected using a web camera along with a suitable software interface.

ii. **To develop an interleaving preprocessing method.**

   In image processing, the size of the image plays a major role in reducing or increasing the processing time. In this research it is proposed to develop a simple interleaving preprocessing method which will reduce the processing time and increases the accuracy of the system.

iii. **To develop feature extraction algorithms to extract valuable features from the signed image frames.**

Feature extraction plays an important role in sign language recognition system. There are many types of feature extraction methods used in the previous work. In this research it is proposed to develop simple invariant feature extraction algorithms.

iv. **To develop an intelligent phoneme based sign language classification tool.**

Neural network provides an alternative form of computing that attempts to mimic the functionality of the brain. In this research it is proposed to develop a sign language recognition system using neural network model.

v. **To develop a user friendly graphical user interface (GUI) platform for phoneme based sign language classification**

The development of personal computer (PC) based automatic recognition system for sign language recognition is an important task of this research. It is proposed to develop a GUI for the sign language recognition system.

© This item is protected by original copyright

1.5 Thesis Organization

This thesis explores the topic of sign language recognition system using image and video processing algorithms along with artificial intelligence techniques. The research works carried out in this thesis are presented in six chapters.

Chapter 1 current chapter, provides the introduction of this research and an overview on how the dissertation is organized. The problem statement, Significance of the Study and the research objectives were discussed in this chapter.

The literature reviews on hearing impaired, the causes of hearing impaired, discussions on sign language and various sign language recognition systems developed by previous researchers are presented in Chapter 2. The previous work of sign language recognition is surveyed and discussed.

Chapter 3 describes the development of sign language for phonemes. Experimental protocols, the image processing and feature analysis techniques that are being used in this research are also described.

Chapter 4 presents the concepts of a feedforward neural network model trained by Backpropagation Algorithm and the Elman Network model. The network architecture and the training methods used to develop the phoneme based sign language classification are explained in detail.

© This item is protected by original copyright

Chapter 5 presents the results obtained for the developed system. The results for the different feature extraction methods are discussed. The development of GUI is also presented.

Chapter 6 Summarizes the contribution made in this research and suggestions for future research works are discussed.

CHAPTER 2

A Review on Sign language Recognition System

2.1 Introduction

Gesture recognition is a field where the gesture made by human is recognized using a computer or any other electromechanical device. The primary application of the gesture recognition system is sign language recognition. There are other applications of gesture recognition system, such as human computer interaction (HCI), Remote control, Noisy Environment, Game technology ("Gesture Recognition,"). This chapter begins with the discussions on the causes of hearing impairment and a brief discussion on the various sign language recognition systems developed in the past. The applicability of neural network to this application is also discussed. Finally, at the end of this chapter a summary is presented.

© This item is protected by original copyright

2.2 Hearing Impairment and Its Cause

Hearing impairment is a condition wherein the ability to detect certain frequencies of sound is completely or partially impaired (Umat, 2006). Each human have a hearing level called as the Hearing threshold. The quietest sound level that can be detected by a human is called the hearing threshold. If the hearing threshold is low or null, then it is understood that the person hearing is impaired. Hearing impairment is also termed as deafness and hard-of-hearing. Hearing impairment may be inherited or caused by complications at birth, certain infectious diseases, such as meningitis, use of

ototoxic drugs, and exposure to excessive noise. Around half of all deafness and hearing impairment can be prevented ("Deafness,").

The following are some facts about hearing impairment ("Deafness and hearing impairment,")

i) In 2005, about 278 million people had moderate to profound hearing impairment. 80% of them live in low-and middle-income countries.

ii) Infectious diseases such as meningitis, measles, mumps and chronic ear infections can lead to hearing impairment. Other common causes include exposure to excessive noise, head and ear injury, ageing and the use of ototoxic drugs.

iii) Half of all the cases of hearing impairment are avoidable through prevention, early diagnoses and management.

iv) Current production of hearing aids meets less than 10% of global need. In developing countries, fewer than 1 out of 40 people who need a hearing aid have one.

© This item is protected by original copyright

2.3 Sign Language

Sign language is a form of manual communication which has been developed as an alternative to speech for the hearing impaired people. Wherever hearing impaired communities exist, sign languages develop (Perlmutte). Sign language comprises facial expressions, body movements or body Language, hand shapes, hand positions, hand movements and gestures. Sign language is often used by people who are hearing impaired. There are different sign languages all over the world, just as there are different spoken languages. In the United States, for example, American Sign Language