HAND GESTURE RECOGNITION FOR LAO SIGN LANGUAGE

VIMONHAK SOMBANDITH

A THESIS REPORT SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ENGINEERING IN COMPUTING IN ENGINEERING SYSTEMS
INTERNATIONAL COLLEGE
KING MONGKUT'S INSTITUTE OF TECHNOLOGY LADKRABANG
ACADEMIC YEAR 2016

KMITL-2016-IC-M-11-03

THESIS TITLE Hand Gesture Recognition for LAO Sign Language

STUDENT NAME Ms. Vimonhak Sombandith

STUDENT ID 55601004

DEGREE Master of Engineering

PROGRAM Computing in Engineering Systems (International Program)

ADVISOR Asst.Prof.Dr. Somsak Walairacht

ABSTRACT

The aim of this thesis is to propose a technique for the recognition of Lao alphabet and Lao simple sentences sign language. The technique of image processing that is Histogram of Oriented Gradients (HOG) is applied in order to extract characteristics of the hand images performing each individual alphabet of Lao sign language. The extracted features are then sent for template matching. The similarity between the extracted features and the prototype are measured by using correlation coefficient. While the study of a technique for recognizes Lao simple sentences sign language uses using a Kinect sensor to track human skeleton. By using Kinect sensors, 9 feature joint positions of the human body are tracked. Then, the joint angles between each pair of joint vectors of adjacent joint positions are measured. When the user performs a series of postures representing a simple sentence of Lao sign language, the system records joint angles that are significantly changed from one posture to another posture. A feature joint angle stored in the database is used to recognize the testing sentence's posture. In the experiments the recognition rate for Lao alphabets sign language is 79% and for Lao simple sentences is 75%.

ACKNOWLEDGEMENT

This master thesis would not have been possible without the help, guidance, and support. First of all, my sincere thanks to Associate Professor Dr. Somsak Walairacht for their assistance in this thesis. I appreciate their valuable advice and effort during the course of my work.

Special thank for my scholarship from Japan International Cooperation Agency (JICA) under AUN/SEEDNet project sponsoring my studying at King Mongkut's Institute of Technology Ladkrabang (KMITL). Besides, I would also like to thank lecture and staffs at the International College of KMITL for their lectures and corporation during my study period.

Special thanks to my roommate, my lab mate and another friend in KMITL, I appreciate their friendship and sympathetic help which have made my life here much easier.

Finally, I would like to thank my parent for their patience, continuous encouragement, guidance, love, and support.

Vimonhak Sombandith
Bangkok, Thailand

TABLE OF CONTENTS

Chapter Page

ABSTRACT I

ACKNOWLEDGEMENT II

TABLE OF CONTENTS III

LIST OF TABLES VI

LIST OF FIGURES VII

CHAPTER 1 INTRODUCTION 1

1.1 Background and Significance of the Study 1

1.2 Purpose of the Study 1

1.3 Scope of Works 1

1.4 Thesis Structure 2

CHAPTER 2 RELATED LITERATURE 3

2.1 Sign Language 3

2.2 Lao Sign Language 3

2.3 Image Recognition 5

2.4 Histogram of Oriented Gradients 5

2.5 HOG Feature Descriptor 5

2.6 Computation Histogram of Oriented Gradients 6

2.6.1 Preprocessing 6

2.6.2 Gradient Image Processing 6

2.6.3 Calculated Histogram of Gradients in 8×8 Cells 7
2.6.4 16×16 Block Normalization...8
2.6.5 HOG Feature Vector 8
2.7 The Pearson Correlation Coefficient (*r*)..8
2.7.1 Interpret a Correlation Coefficient 9
2.7.2 Scatterplots of Correlation Coefficients...10
2.8 Kinect camera..11
2.8.1 Microsoft Kinect Features…………………………………………...11
2.8.2 The Kinect Sensor…………………………………………………...12
CHAPTER 3 HAND GESTURE RECOGNITION FOR LAO ALPHABET SIGN LANGUAGE USING HOG AND CORRELATION...13
3.1 System Overview and Experimental Setup...13
3.1.1 System Overview 13
3.1.2 Experimental Setup..14
3.2 Methodology 19
3.3 Experimental Results and Discussions..20
3.4 Conclusion...26
CHAPTER 4 RECOGNITION OF LAO SENTENCE SIGN LANGUAGE USING KINECT SENSOR..27
4.1 Principle and Methodology of Image Recognition System 27
4.1.1 System Analysis...27
4.1.2 Recognition Process...28

4.1.3 Connection Map for Joint Position 29

4.2 Experiments...30

4.3 Results and Discussions 36

4.4 Conclusions 39

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS 40

REFERENCES 41

APPENDIX A 42

AUTHOR BIOGRAPHY..43

LIST OF TABLES

Table **Page**

Table 3.1 Lao consonant chart in a single gesture 14

Table 3.2 Lao consonant chart in combined gestures 16

Table 3.3 Vowel Charts of Lao language in single gesture 17

Table 3.4 Vowel Charts of Lao sign language in combined gestures 19

Table 3.5 Particulars of sample population 21

Table 3.6 Experimental Result of Subjects #1 for LAO Sign Language Alphabets ... 22

Table 3.7 Experimental Result of Subjects #2 for LAO Sign Language Alphabets ... 23

Table 3.8 Experimental Result of Subjects #3 for LAO Sign Language Alphabets ... 24

Table 3.9 Experimental Result of Subjects #4 for LAO Sign Language Alphabets ... 25

Table 3.10 Recognition result 25

Table 4.1 Connection map 30

Table 4.2 Feature postures 31

Table 4.3 Joint angles 32

Table 4.4 Joint angles of sentence expressions 33

Table 4.5 Recognition results 37

LIST OF FIGURES

Figure **Page**

Figure 2.1 The designated Lao national sign language 4

Figure 2.2 Several points are evident from the scatterplots 10

Figure 2.3 Kinect Camera 11

Figure 2.4 Kinect feature 12

Figure 3.1 System Overview 13

Figure 3.2 System Flowchart 20

Figure 3.3 Experiment Result: Lao alphabet sign language 22

Figure 4.1 System Overview 28

Figure 4.2 Recognition process 29

Figure 4.3 Tracked feature joint positions 30

Figure 4.4 Experiment Results: Lao simple sentence sign language 36

Figure 4.5 Experiment Results in the Lao sentences sign language "hello" 37

Figure 4.6 Experiment Results in the Lao sentences sign language "how are you?" . 38

Figure 4.7 Feature posture (a) "Let's eat" and (b) "Do you understand?" 39

LIST OF SYMBOLS

g	Gradient magnitude histogram of the template i
θ	Gradient Orientation
H_i	Histogram of the template i
H_j	Histogram of the template j

LIST OF DEFINITIONS

HOG	Histogram of Oriented Gradients
LSL	Lao sign language
SIM	Similarity measure range

CHAPTER 1

INTRODUCTION

1.1 Background and Significance of the Study

Since people impaired hearing and speaking increase in our society the hand language is necessary and important for these people to communicate each other, to enable the communication with advanced modern deaf can communicate with the ordinary people there are multi-articles released by research design used for these groups of streams translation of language with alphabet aim to upgrade the using hand language of members disabled speaking, in Laos has developed gradually, respectively, as well as building facilities convenient relationship between the deaf, mute suddenly be able to communicate with people in society without restrictions. This article was system design methods to be used to translate alphabet of Lao hand sign language by using technical translating any sign language performed by deaf people in order to communicate with normal people is a crucial issue in Lao society. The number of a professional interpreter for sign language can also be rarely found. Although many research works about this issue had been introduced so far, but it still not has any researcher working specifically on Lao sign language before.

1.2 Purpose of the Study

This thesis aims to present the algorithm to increase the efficiency of the recognition of Lao alphabet sign language. The technique of image processing that is Histogram of Oriented Gradients (HOG), the extracted features measured by using correlation technique. And this article was design system methods to Recognition of Lao Sentence Sign Language by using Kinect Sensor. The features of the Kinect Camera is to detect the images of the movement of body gesture and hand by measuring the value of the angle in each part to analyze the results from the movement gestures.

1.3 Scope of Works

- To propose the recognition system of Lao alphabet sign language.

- To study the technique of image processing that using Histogram of Oriented Gradients and Correlation.
- To study the working principles of Kinect sensor.
- To propose the recognition of Lao simple sentence sign language.

1.4 Thesis Structure

The thesis is organized in five chapters and is briefly summarized as follow.

Chapter 1 presents an overview of the research in this thesis, mainly, its introduction, background of the study and purpose of the study.

Chapter 2 gives a brief introduction to the sign language in section 2.1 and shows some background information on image recognition in section 2.3 and compute histogram of oriented gradients (HOG) in section 2.6. Correlation coefficients are reviewed in section 2.7.

Chapter 3 presents proposed a technique for recognition of Lao alphabet sign language. The technique of image processing, that is a Histogram of Oriented Gradient (HOG), is applied in order to extract a characteristic of the hand image performing individual alphabet of Lao sign language. The extracted features and the prototype features are measured by using correlation technique.

Chapter 4 presents a technique for recognition Lao simple sentence sign language by using a Kinect sensor. By using the Kinect sensor, feature joint positions of the human body can be tracked. After that, the joint angles between each pair of joint vectors of the adjacent joint position are measured. When the user performs a series of posture representing a simple sentence Lao sign language, the system records joint angles that are significantly changed from one posture to another posture.

Chapter 5 summarizes the results of this research and the conclusions from all chapters.

CHAPTER 2

RELATED LITERATURE

2.1 Sign Language

The sign language is the language for the deaf people, composed hand, facial expression and gesture using in the communication of the meaning and transmit the feeling instead of talking. The sign language of each nation is different such as the speaking language which is differently according to the tradition culture and characteristic of geographies such as the sign language of Thai language and American language etc.

The sign language is the language that researcher students of the deaf study branch have been accepted and agreed belong them, that is one language for communicating of meaning between mute and normal people that are called by another name “manual communication”.

The communication of the deaf and mute people cannot communicate with the speaking but their eyes expressions are well normal they can observe the expression and different gesture regularly mobilized. These diverse images are the Medias to make them understand the meaning a little bit or understand not in deep but it was one part that had potential to push the makes effort to use the body gesture and facial expression for express their interior feeling that they have to express correctly their needs to people understand it.

The gesture perform that we can observe is a gesture to be learned from the most nature and from the natural gesture to innovate to the hand gesture one of large part of sign language to be born a gesture using instead of the meaning in the speaking of the mute, really perfect and convenient that we call this language “the sign language”.

2.2 Lao Sign Language

Sign language is a form of communication involving signing, body gesture and nonverbal expression to communicate with others. It is a critical form of communication for a person with hearing impairment, or deaf people, in Lao PDR and around the world. Sign language that spells each alphabet is invented and officially recognized as the designated Lao national sign language as shown in Figure 2.1

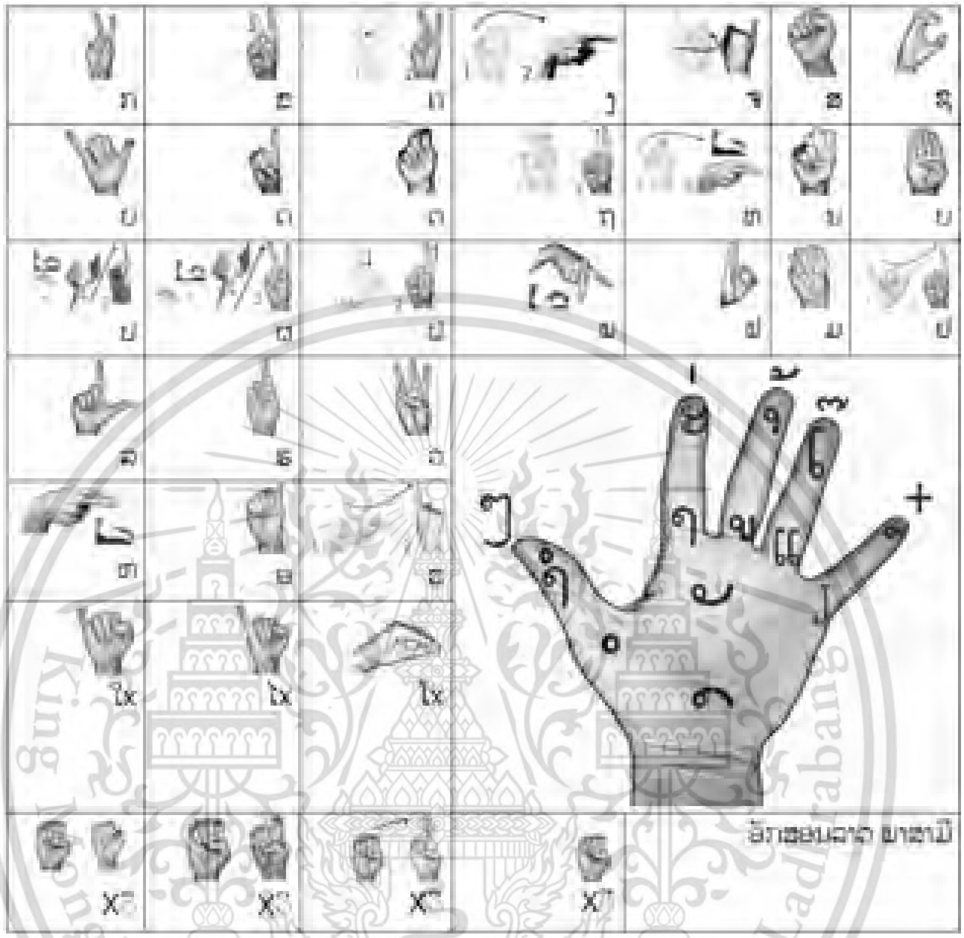


Figure 2.1 The designated Lao national sign language

Electricity and heat production, industry and transport sectors are the main contributors of the total emission. And there are national and international mechanisms, which are currently practicing in order to reduce the emission. For electricity, the trend of renewable and alternative energies have developed and encouraged widely. Those applications of alternative energies are generating electricity and energy from the wind, solar, biofuels, biomass, hydro, geothermal, and marine. Investment of these applications of alternative energies was $ 285. Billions in 2015, which had 5% growth compared to the year 2014 investment and 18% increase for a period of the year 2004 till 2015 (Joseph et al., 2016).

2.3 Image Recognition

Image recognition (sometimes called computer vision) is a technology that strives to acquire process, analyses, and understand images and high-dimensional data from the real world in order to produce numerical or symbolic information. Image recognition– also known as computer vision– is the method of acquiring, analyzing, and understanding images to produce numerical information. In other words, image recognition is a computer’s way of doing what your eye does: see a picture and understand it.

2.4 Histogram of Oriented Gradients

HOG features have been introduced by Navneet Dalal and Bill Triggs, who developed and tested several variants of HOG descriptors, with the differing spatial organization, gradient computation and normalization methods.

The histogram of oriented (HOG) is a definition of feature used in computer vision and image processing for the purpose of object detection. The technique count occurrences of gradient orientation in localized (HOG) of an image.

A feature descriptor is a representation of an image or an image patch that simplifies the image by extracting useful information and throwing away extraneous information. Typically, a feature descriptor converts an image of size width × height × 3 (channels) to a feature vector/array of length n. In the case of the HOG feature descriptor, the input image is of size 64×128×3 and the output feature vector is length 3780. In the HOG feature descriptor, the distributions (histogram) of directions of gradients (oriented gradients) are used as features. Gradients (x and y derivatives) of an image are useful because the magnitude of gradients is large around edges and corners (regions of abrupt intensity changes) and we know that edges and corners pack in a lot more information about object shape than flat regions.

2.5 HOG Feature Descriptor

A feature descriptor is a representation of an image or an image patch that simplifies the image by extracting useful information and throwing away extraneous information. Typically, a feature descriptor converts an image of size width × height × 3 (channels) to a feature vector/array of length n. In the case of the HOG feature

descriptor, the input image is of size 64×128×3 and the output feature vector is length 3780.

The feature vector is not useful for the purpose of viewing the image. But, it is very useful for tasks like image recognition and object detection. The feature vector produced by these algorithms when fed into an image classification algorithms like support vector machine (SVM) produce good results.

In the HOG feature descriptor, the distributions (histograms) of directions of gradients (oriented gradients) are used as features. Gradients (x and y derivatives) of an image are useful because the magnitude of gradients is large around edges and corners (regions of abrupt intensity change) and we know that edges and corners pack in a lot more information about object shape than flat regions.

2.6 Computation Histogram of Oriented Gradients

This chapter has shown the details of calculating the HOG feature descriptor. Calculated internally by OpenCV, MATLAB, and other packages.

2.6.1 Preprocessing

The HOG feature descriptor used for pedestrian detection is calculated on 64×128 patch of an image. An image has may be of any size. Typically patches at multiple scales are analyzed at image locations. The only constraint is that the patches being analyzed have a fixed aspect ratio. In our case, the patches need to have an aspect of 1:2. For example, they can be 100×200, 128×256, or 1000×2000 but not 101×205.

2.6.2 Gradient Image Processing

The step of calculation is the computation of the gradients values we need to first calculate the horizontal and vertical gradients. Specifically, this method requires filtering the color or intensity data of the image with the following filter kernels:

$$[-1,0,1] \text{ and } [-1,0,1]^{T} \tag{2.1}$$

We can also achieve the same results, by using Sobel operator in OpenCV with the kernel. Next, calculate the x and the y gradient images, g_x and g_y from the original image, we can find the magnitude and direction of the gradient using the following formula:

$$g = \sqrt{g^2 + g^2} \tag{2.2}$$

$$\theta = \arctan\left(\frac{g_x}{g_y}\right) \tag{2.3}$$

The calculated gradients are "unsigned" and therefore θ is in the range 0 to 180 degrees.

2.6.3 Calculated Histogram of Gradients in 8×8 Cells

The second step of calculation involves creating the cell histogram. The image is divided into 8×8 cells and a histogram of gradients is calculated for 8×8 cells. At each pixel in an 8×8 cell, we know the gradient (magnitude and direction), one of the important reason to use a feature is that it provides a compact representation. An 8×8 image patch contains 8×8×3 = 192 pixel values. (Magnitude and direction) per pixel which adds up to 8×8×2 = 128 numbers. These 128 numbers are represented using a 9-bin histogram which can be stored, as an array of 9 numbers. Not only is the representation more compact, calculating a histogram over a patch makes this representation more robust to noise. Individual gradients may have noise, but a histogram over 8×8 patch make the representation much less sensitive to noise.

The histogram is essentially a vector (or an array) of 9-bins (numbers) corresponding to angles 0, 20, 40, 60…160. The angles are between 0 and 180 degrees instead of 0 to 360 degrees. These are called "unsigned" gradients because a gradient and its negative are represented by same numbers. Some implementations of HOG will you to specify if you to use signed gradients.

The next step is to create a histogram of gradients in these 8×8 cells. The histogram contains 9 bins corresponding to angles 0, 20, 40 …160. A bin is selected based on the direction, and the vote (the value that goes into the bin) is selected based on the magnitude. If the angle is greater than 160 degrees, it is between 160 and 180, and we know the angle wraps around making 0 and 180 equivalent. The contributions of the entire pixel in the 8×8 cells are added up to create the 9-bin histogram.

2.6.4 16×16 Block Normalization

In the previous step, we created a histogram based on the gradient of the image. Gradients of an image are sensitive to overall lighting. If you make the image darker by dividing all pixel values by 2, the gradient magnitude will change by half, and therefore the histogram value will change by half. Ideally, we want our descriptor to be independent of lighting variations. Before know how the histogram normalized, let's see how a vector of length 3 is normalized. We have an RGB color vector [128, 64, 32]. The length of the vector is $\sqrt{128^2 + 64^2 + 32^2} = 146.64$. This is also called the L2 norm of the vector. Dividing each element of this vector by 146.64 gives us a normalized vector to [0.87, 0.43, 0.22]. Now consider another vector in which the elements are twice the value of the first vector 2 × [128, 64, 32] = [256, 128, 64]. That normalizing [256, 128, 64] will result in [0.87, 0.43, 0.22].which is the same as the normalized version of the original RGB vector. Normalized a vector removes the scale. After known normalize a vector while calculating HOG you can simply normalize the 9x1 histogram the same way normalized the 3×1 vector. A 16×16 block has 4 histograms which can be concatenated to form a 36×1 vector is normalized. The window is then moved by 8 pixels and a normalized 36×1 vector is calculated over this window and the process is repeated.

2.6.5 HOG Feature Vector

To calculate the final feature vector for the entire image patch, the 36×1 vectors are concatenated into one giant vector. There are 7 horizontal and 15 vertical positions making a total of 7×14 = 105 positions. Each 16×16 block is represented by a 36×1 vector. So when we concatenate them all into one giant vector we obtain a 36×105 = 3780-dimensional vector.

2.7 The Pearson Correlation Coefficient (*r*)

The correlation coefficient is a measure of linear correlation (the relationship, in terms of both strength and direction) between two variables. The correlation coefficient is sometimes called "Pearson product-moment correlation coefficient" in honor of its developer, Karl Pearson.

The mathematical formula for computing r is:

$$r = \frac{n\Sigma xy - (\Sigma x)(\Sigma y)}{\sqrt{n(\Sigma x^2) - (\Sigma x)^2}\sqrt{n(\Sigma y^2) - \Sigma y)^2}} \quad (2.4)$$

Where n is the number of pairs of data

- The value of x is such that $-1 \leq \text{r} \leq +1$. The + and – signs are used for positive linear correlations and negative linear correlations, respectively.
- Positive correlation: If x and y have a strong positive linear correlation, *r* is close to +1. An *r* value of exactly +1 indicates a perfect positive fit. Positive values indicate a relationship between x and y variables such that as values for *x* increase, values for *y* also increase.
- Negative correlation: If x and y have a strong negative linear correlation, r is close to -1. An *r* value of exactly -1 indicates a perfect negative fit. Negative values indicate a relationship between x and y such that as values for *x* increase, values for *y* decrease.
- No correlation: If there is no linear correlation or a weak linear correlation, *r* is close to 0. A value near zero means that there is a random, nonlinear relationship between the two variables.
- Note that *r* is a dimensionless quantity; it does not depend on the units employed.
- A perfect correlation of ± 1 occurs only when the data points all lie exactly on a straight line. If $r = +1$, the slope of this line is positive. If $r = -1$, the slope of this line is negative.
- A correlation greater than 0.8 is generally described as strong, whereas a correlation less than 0.5 are generally described as weak. These values can vary based on the “type” of data being examined.

2.7.1 Interpret of Correlation Coefficient

Generally, the correlation coefficient of a sample is denoted by r, and the correlation coefficient of a population is denoted by *p* or *R*.

The sign and absolute value of a correlation coefficient describe the direction and magnitude of the relationship between two variables.

- The value of correlation coefficient ranges between -1 and 1.

- The gestures the absolute value of a correlation coefficient, the stronger the linear relationship.
- The strongest linear relationship is indicated by a correlation coefficient of -1 or 1.
- The weakest linear relationship is indicated by a correlation coefficient equal to 0.
- A positive correlation means that if one variable gets bigger, the other variable tends to get bigger.

A negative correlation coefficient means that if one variable gets bigger, the other variable tends to get smaller.

The Pearson product-moment correlation coefficient only measures linear relationships. Therefore, a correlation of 0 does not mean zero relationships between two variables; rather, it means zero linear relationships. (It is possible for two variables to have zero linear relationships and a strong curvilinear relationship at the same time).

2.7.2 Scatterplots of Correlation Coefficients

The scatterplots bellow how different patterns of data produce different degrees of correlation.

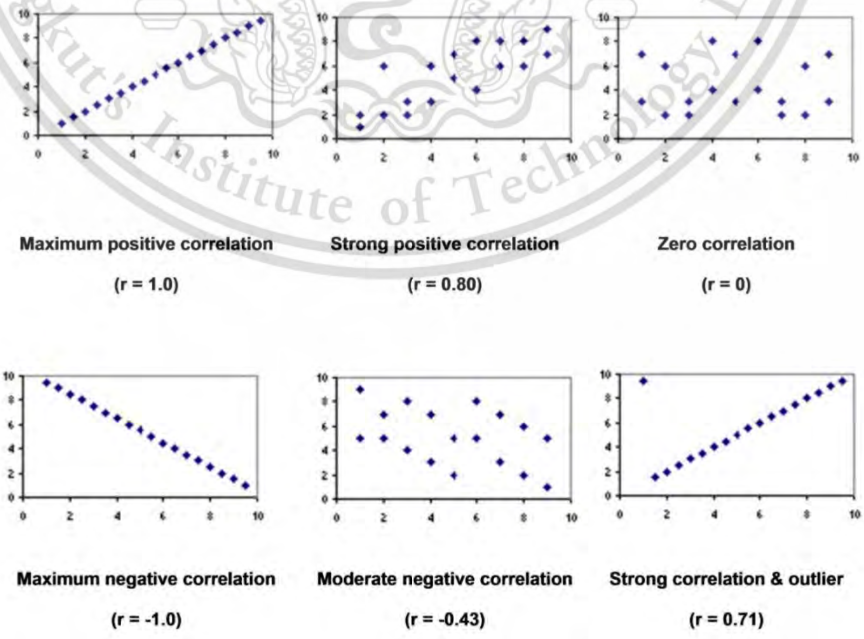


Figure 2.2 Several points are evident from the scatterplots

- When the slope of the line in the plot is negative, the correlation is negative; and vice versa.
- The strongest correlation (r = 1.0 and r = = 1.0) occur when data points fall exactly on a straight line.
- The correlation becomes weaker as the data points become more scattered.
- If the data point falls in a random pattern. The correlation is equal to zero.
- Correlation is affected by outliers. Compare the first scatterplot with the last scatterplot. The single outlier in the last plot greatly reduces the correlation (from 1.00 to 0.71).

2.8 Kinect camera

Kinect is Microsoft's motion sensor add-on for the Xbox 360 gaming console.

- The device provides a natural user interface (NUI) that allows users to interact inutility and without any intermediary device, such as a controller.
- The depth sensors consist of an infrared laser projector combined with a monochrome video data in 3D under any ambient light conditions.
- The sensor is adjustable, and Kinect software is capable of automatically calibrating the player's physical environment, accommodating for the presence of furniture or other obstacles.

Figure 2.3 Kinect Camera

2.8.1 Microsoft Kinect Features

The Kinect Services support the following feature:

- Depth image including player index
- RGB image

- Tilt (Get and set)
- Microphone Array
- Skeleton Tracking

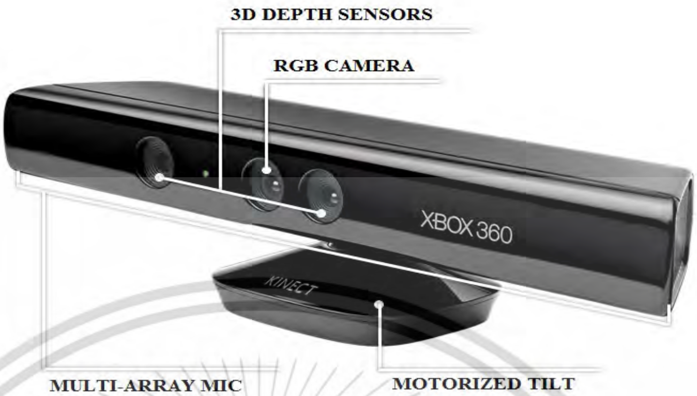


Figure 2.4 Kinect feature

You can specify the resolution of the Depth and RGB cameras independently via a config file, as well as the depth camera mode. The config file also specifies whether you want skeleton tracking to be performed or not. If you do not use the skeleton data, you should not track it because there is a performance overhead. You cannot turn skeleton tracking on once the service is running, so it must be selected is the config file.

2.8.2 The Kinect Sensor

- The Kinect depth sensor range is: minimum 800 mm and maximum 4000mm.
- The Kinect for window Hardware can however be switched to Near Mode which provides a range of 500mm to 3000mm instead of the Default range. If you are using an Xbox Kinect with the Kinect for Windows SDK then Near Mode is not supported.
- The Kinect uses Infrared so it can see through glass. Therefore it cannot be used reliably for obstacle avoidance if you have glass doors. Also because it uses IR, the Kinect will not work in direct in sunlight, e.g. outdoors.

CHAPTER 3

HAND GESTURE RECOGNITION FOR LAO ALPHABET SIGN LANGUAGE USING HOG AND CORRELATION

This chapter present proposed a technique for recognition of Lao alphabet sign language. The technique of image processing, that is a Histogram of Oriented Gradient (HOG), is applied in order to extract a characteristic of the hand image performing individual alphabet of Lao sign language. The extracted features and the prototype features are measured by using correlation technique.

3.1 System Overview and Experimental Setup

3.1.1 System Overview

The overview of the proposed system is shown as in Figure 3.1. A deaf person is sitting in front of Kinect camera with about 30-50 centimeters away. He or she is asked to perform sign language of Lao alphabet one by one. The system extracts hand feature by using HOG. The recognized alphabet is shown on displaying monitor by considering the correlation coefficient with the prototypes in the database.

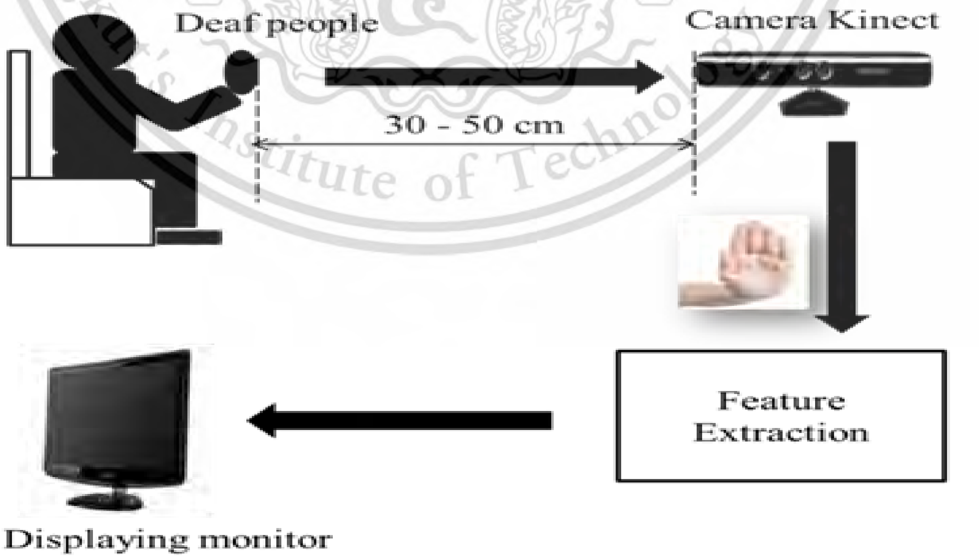


Figure 3.1 System Overview

3.1.2 Experimental Setup

In the experiment, 4 different subjects are asked to perform hand gesture of all 54 Lao alphabets in one set. Each subject repeatedly performed 10 sets in which it becomes the total of 540 gestures. The table below shows the Lao consonant and vowel charts

Table 3.1 Lao consonant chart in a single gesture

No.	Character	Posture
1	ш	
2	Ш	
3	э	
4	ю	
5	я	
6	ё	
7	8	

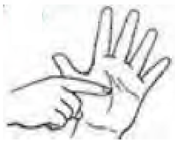
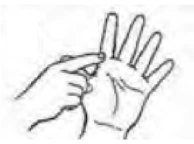
No.	Character	Posture
8	₣	
9	℡	
10	⅛	
11	⅜	
12	Ⅰ	
13	⅞	
14	Ⅱ	
15	Ⅳ	
16	Ⅴ	

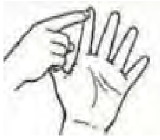
Table 3.1 (continued)

Table 3.2 Lao consonant chart in combined gestures

No.	Character	Posture 1	Posture 2
1	щ		
2	ъ		
3	ы		
4	ь		
5	⁵		
6	⁷		
7	₤		
8	Pts		
9	№		
10	⅝		
11	VI		

Table 3.3 Vowel Charts of Lao language in single gesture

No.	Vowel	Posture
1	'	
2	n	
3	ℓ	
4	^{3}iii	
5	1	
6	^{3}ΔX	
7	^{3}Δ	
8	^{3}viii	
9	^{3}IX	
10	X	

11	Ⅷ	

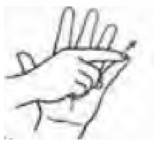
No.	Vowel	Posture
12	$^{3}{}_{2}$	
13	^{3}vii	
14	^{3}vi	
15	$^{3}{}_{3}$	
16	□	
17	●	
18	$^{3}{}_{4}$	
19	Ŧ	
20	^{3}ix	
21	^{3}″	

Table 3.3 (continued)

Table 3.4 Vowel Charts of Lao sign language in combined gestures

No.	Vowel	Posture 1	Posture 2
1	^{3}iv		
2	^{3}v		
3	^{3}ii		

3.2 Methodology

Figure 3.2 shows the flowchart of the proposed system. Images of the user performing sign language are captured by the Kinect camera with a resolution of 640×480 pixels. Streaming of image frames is recorded at 30 fps frame rate. Then, each image frame is cropped and resized to 64×128 pixels as a patch of the image.

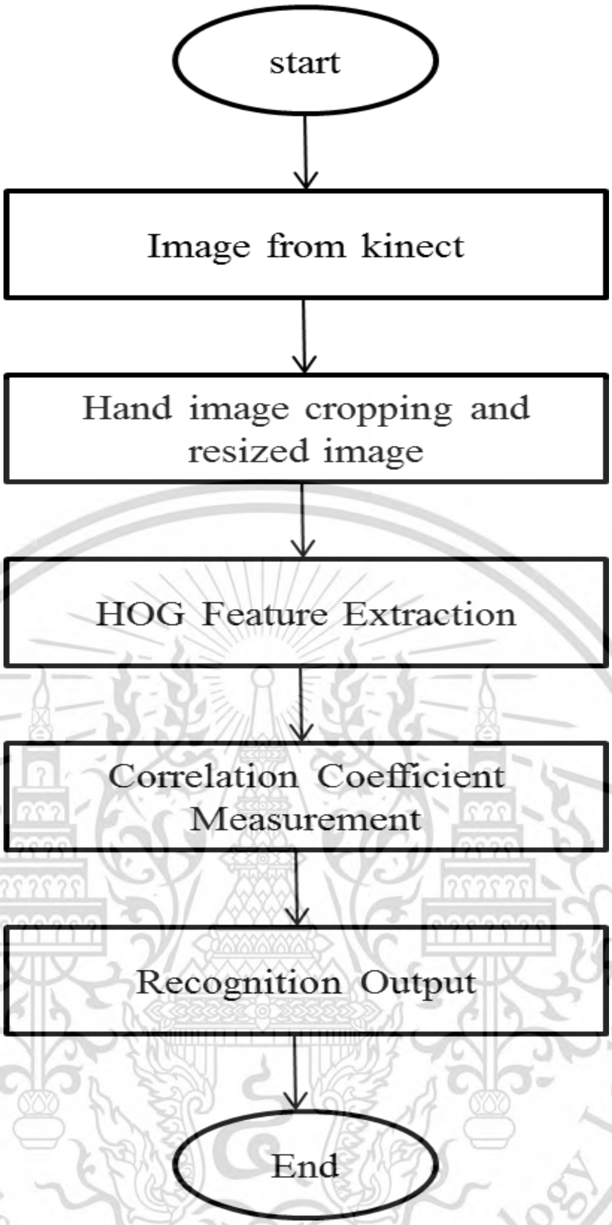
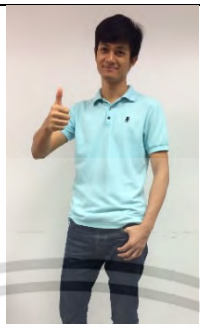


Figure 3.2 System Flowchart

3.3 Experimental Result and Discussion

The table below showing the Particulars of sample population, we tested the system with four ordinary people, even if they did not know the sign language. But practiced for almost 3 weeks.

Table 3.5 Particulars of sample population

	1st subject	2nd subject	3rd subject	4th subject
				
Name	Vimonhak Sombandith	Saysamone Soysouvanh	Phosy Panthongsy	Phimmasone Thammavongsy
Age	28	28	25	26
Gender	Female	Male	Male	Male
Education	Master of Engineering in Computing in Engineering System	PhD student in Electrical Engineering	PhD student in Electrical Engineering	Master student in Computing in Engineering System

In the experiments, Lao alphabets are performed 4 subjects, with different of the shape of their hands, the size of their hands and also the skin color. However, the environment factor, such as room lighting, the distance between the experimenter and the Kinect, and so on, are controlled. For training the system, within 1 set of 54 alphabet letters. In order to evaluate the performance of the system, each subject performs each alphabet letter 10 times and an average of recognition rate is computed.

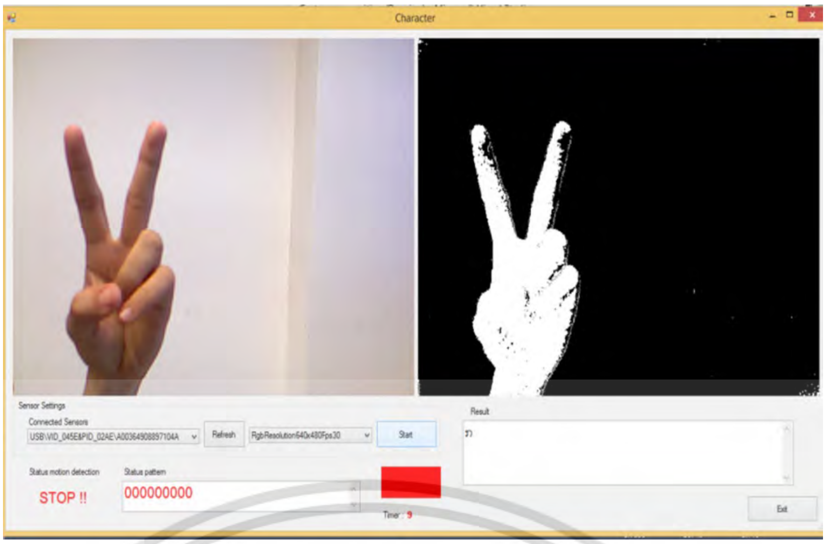


Figure 3.3 Experiment Result: Lao alphabet sign language

Table 3.6 Experimental Result of Subjects #1 for LAO Alphabets Sign Language

Alphabet	1st		2nd		3rd		4th		5th		6th		7th		8th		9th		10th		Correct	Incorrect
ກ	113000000	ຂ	0000000000	ກ	380022000	ຄ	0000000000	ກ	410000000	ກ	2020000000	ກ	0000000000	ກ	3822202020		1400000000	ກ	380000000	ກ	7	3
ຂ	0011015120	ຂ	1020102000		0100110010	ຂ	001100150	ຂ	1500151501	ຂ	0011001515	ຂ	00151001110	ຂ	1500110011	ຂ	0011001100	ຂ	15001500	ຂ	9	1
ຄ	9002200000	ຕ	2002200220	ຄ	2200220022	ຄ	0020022020	ຄ	0036036360		3636362222		022002200	ຄ	2200220022	ຄ	0022002200	ຄ	2200220022	ຄ	8	2
ງ	233344334	ງ	333124312		8334433312	ງ	433122134		334433440	ງ	489334433	ງ	1233443344	ງ	3312449933		4973344334	ງ	3312493744		6	4
ຈ	635566566	ຈ	556655665	ຈ	5566556656	ຈ	2457665556	ຈ	2323232323		1455665566	ຈ	5566556655	ຈ	6556623236	ຈ	5566523655	ຈ	6556655665	ຈ	9	1
ສ	1477777777	ສ	1422325555	ໃ	1477777723	ສ	2377777777	ສ	1477232323	ໄ	1423232323	ໄ	1477777777	ສ	9232377237		1497777777	ສ	4177777777	ສ	6	4
ຊ	3888888888	ຊ	988888888	ຊ	1488888888	ຊ	9888888888	ຊ	3888888888	ຊ	3888888888	ຊ	3888888888	ຊ	3888888888	ຊ	3888888888	ຊ	1088888888	ຊ	10	0
ຍ	1938999999	ຍ	1499999999	ຍ	9999999999	ຍ	9999999999	ຍ	9999999999	ຍ	9999999999	ຍ	9999999999	ຍ	9999999999	ຍ	9999999999	ຍ	9999999999	ຍ	10	0
ດ	1010101010	ດ	1010101010	ດ	281111010		156101010	ດ	101112828		3710101010	ດ	1010101010	ດ	1110101010	ດ	1010101010	ດ	1010101010	ດ	8	2
ຕ	11_11_11_	ຕ	11_11_11_	ຕ	11_11_11_	ຕ	11_11_11_	ຕ	11_11_11_	ຕ	11_11_11_	ຕ	1411_11_		11_11_11_	ຕ	11_11_11_	ຕ	11_11_11_	ຕ	9	1
ຖ	11_11_111	ຖ	11_11111_1	ຖ	111_11_111	ຖ	11_1111_1	ຖ	111_151111		11_115115		11_11_1515		111_11_111	ຖ	11_11_1515		1511_11_11		5	5
ທ	11_112121		21212111_	ອ	12122121		121211_12		1211_1212		11_1211_		11_11_1212	ທ	11_121212		11_11_444		1211_11_12	ທ	2	8
ນ	333331717	ນ	1719311_		2411_11_	ຕ	11_11_11_	ຕ	11_11_11_	ຕ	292911_		11_11_3333	ນ	271711_11_	ຕ	1727113317		111_11_11_	ຕ	2	8
ບ	3813131313	ບ	1313131313	ບ	4113131313	ບ	1313131313	ບ	1319191931	ຣ	1319191319		1313131313	ບ	1313131313	ບ	1919194444		3813131313	ບ	7	3
16151615	149151514	ປ	159141415	ປ	1414141515	ປ	1414151599	ປ	1414151514	ປ	1414151599	ປ	14141599	ປ	9151469		1461111515		11_11_11_		7	3
ຜ	014140214		229141400	ຜ	141422200	ຜ	1414001414	ຜ	014140014	ຜ	002727927		2714140014	ຜ	014140014	ຜ	0991490099		1400001429		6	4
ຝ	1616111616	ຝ	1516161116	ຝ	1116161515	ຝ	151616115	ຝ	1616151615		1516131116	ຝ	116161122	ຝ	1622151516		1616151515		1012316160		6	4
ພ	1414141414	ພ	14141446	ພ	1414144623	ພ	4623464646		1414141414	ພ	1414141414	ພ	1414141414	ພ	1414141414	ພ	1414141414	ພ	1414141414	ພ	9	1
ຟ	1616161616	ຟ	1616161616	ຟ	1616161616	ຟ	1616161616	ຟ	1616161616	ຟ	1616161616	ຟ	1616161616	ຟ	1616161616	ຟ	1616161616	ຟ	1616161616	ຟ	10	0
ມ	2917171717	ມ	1717171717	ມ	1721722229		2929232317		1717171717	ມ	1717171717	ມ	1717171717	ມ	1717171717	ມ	1717171717	ມ	1717171717	ມ	8	2
ຢ	9911991191	ຢ	9911991199	ຢ	9911991199	ຢ	9911991199	ຢ	9911991199	ຢ	9911991199	ຢ	9911991199	ຢ	9911991199	ຢ	9911991199	ຢ	9911991199	ຢ	10	0
ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	10	0
ຣ	1919191919	ຣ	1919191919	ຣ	1919191919	ຣ	1919191919	ຣ	1919191919	ຣ	1919191919	ຣ	1919191919	ຣ	1919191919	ຣ	1919191919	ຣ	1919191919	ຣ	10	0
ວ	2020202020	ວ	2020202020	ວ	2020202020	ວ	149202020	ວ	1220202020	ວ	2020202020	ວ	2020202020	ວ	2020202020	ວ	2020202020	ວ	2020202020	ວ	10	0
ຫ	121244444		1212121212	ຫ	1444121212	ຫ	1212121212	ຫ	1212121212	ຫ	1212121212	ຫ	412121212	ຫ	612121212	ຫ	412121212	ຫ	1212121212	ຫ	9	1
ອ	2121212121	ອ	2121212121	ອ	2323212321		7777232323		2121212121	ອ	2121212121	ອ	2121212121	ອ	2121212121	ອ	2121212121	ອ	2121212121	ອ	8	2
ຮ	1212222212	ຮ	121222224	ຮ	1212222212	ຮ	12222212	ຮ	1212222212	ຮ	124222212	ຮ	1212222212	ຮ	1212222212	ຮ	142222212	ຮ	1212222212	ຮ	10	0
ໃx	923232323	ໃx	2323232323	ໃx	2323232323	ໃx	2323232323	ໃx	2323232323	ໃx	2923232323	ໃx	2323232323	ໃx	9999999999	ຍ	1423232323	ໃx	923232323	ໃx	9	1
ໄx	9999999999	ຍ	5999999555	ຍ	5555514555		1423235555		5555555555	ໄx	5555555555	ໄx	5555555555	ໄx	1355555555	ໄx	2513131313		5555555555	ໄx	5	5
ໂx	2424242424	ໂx	2424242424	ໂx	2424242424	ໂx	2424242424	ໂx	248882424		824242424	ໂx	2424242424	ໂx	2424242424	ໂx	2424242424	ໂx	2424242424	ໂx	9	1
xິ	2626262525	xິ	261112526		2625126261		2825262625	xິ	2525262625	xິ	2525262625	xິ	2525262625	xິ	2525262625	xິ	2525262625	xິ	2525262625	xິ	8	2
xີ	2727252517	xີ	2525272725	xີ	1725252727	xີ	726262727		77252627		2525272725	xີ	2525272725	xີ	2525272725	xີ	2525272725	xີ	2525272727	xີ	8	2
xຶ	2552828775		2526282855		2925252828	xຶ	52535552525		725262626		2625262828		2525282825	xຶ	5525252828	xຶ	5525552828		2525282819	xຶ	4	6
xື	2525252525	xື	252526225		2513251325		1325252626	xື	2525252525	xື	2525252525	xື	1313252525	xື	1313252525	xື	2525252525	xື	2626262626		6	4
xງ	888292929	xງ	2929292929	xງ	2929292929	xງ	2929292929	xງ	2929292929	xງ	2929292929	xງ	2929292929	xງ	1434342929		3434292929	xງ	2929292929	xງ	9	1
xຳ	3131303030	xຳ	3030303030	xຳ	3030303030	xຳ	3030303030	xຳ	3030303030	xຳ	3030303030	xຳ	3030303030	xຳ	3030303030	xຳ	3030303030	xຳ	3430303030	xຳ	10	0
xໍ	3131313131	xໍ	3131313131	xໍ	3131313131	xໍ	3131313131	xໍ	3131313131	xໍ	3131313131	xໍ	3131313131	xໍ	3131313131	xໍ	3131313131	xໍ	3131313131	xໍ	10	0
xົ	3232323232	xົ	3232323232	xົ	3232323232	xົ	3232323232	xົ	3232323232	xົ	3232323232	xົ	3236363636		3236363632		3232323232	xົ	932323236		7	3
xັ	33_33_33_	xັ	33_33_33_	xັ	33_33_33_	xັ	33_33_33_	xັ	33_33_33_	xັ	33_33_33_	xັ	33_33_33_	xັ	33_33_33_	xັ	33_33_33_	xັ	33_3733_		9	1
xາ	3434343434	xາ	3434343434	xາ	3434343434	xາ	3737373737	xຸ	3737373737	xຸ	3837373434	xຸ	3437373434	xາ	3434343434	xາ	3434343434	xາ	3737343434	xາ	7	3
xະ	3535353535	xະ	3535353535	xະ	3835353535	xະ	3030303030		3835383535	xະ	3529383838		2938383838		3535353535	xະ	3030303030		2938383435		5	5
x່	3636363636	x່	3636393939	xູ	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	3638383836		8	2
xຸ	3734373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	10	0
xູ	3838383838	xູ	3838383838	xູ	3838383838	xູ	3838383838	xູ	3838383838	xູ	3838383838	xູ	3838383838	xູ	3838383838	xູ	3838383838	xູ	3838383838	xູ	10	0
x້	3938383839		3839394239		3939393936	x້	3939393939	x້	3939393939	x້	3939393939	x້	3939393939	x້	3939393939	x້	3939393939	x້	3939393939	x້	8	2
ແx	4140404040	ແx	4040404040	ແx	4040404040	ແx	4040404040	ແx	4040404040	ແx	4040404040	ແx	3840404040	ແx	4041414141		4041414141		4141414040		7	3
ເx	4141414141	ເx	4141354138		3838383841		4141414141	ເx	4141414141	ເx	4141414141	ເx	4141414141	ເx	4141414141	ເx	4141414141	ເx	4141414141	ເx	8	2
xຽ	4343414140		4041413243		4343434343	xຽ	4141414141		4133_33_		4034404040		4343434343	xຽ	3641434343	xຽ	4343434343	xຽ	4343434343	xຽ	5	5
xຼ	4444141414		4444444444	xຼ	4444444444	xຼ	4444444444	xຼ	4444444444	xຼ	4444444444	xຼ	4444444444	xຼ	4444444444	xຼ	4444444444	xຼ	4444444444	xຼ	9	1
x໊	4545454545	x໊	4545454545	x໊	4545454545	x໊	4545454545	x໊	4545454545	x໊	4545454545	x໊	4545454545	x໊	4545454545	x໊	4545454545	x໊	4545454545	x໊	10	0
x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	10	0

Table 3.7 Experimental Result of Subjects #2 for LAO Alphabets Sign Language

Alphabet	1st		2nd		3rd		4th		5th		6th		7th		8th		9th		10th		Correct	Incorrect
ກ	00000000	ກ	90000000	ກ	91414141	ຄ	20000000	ກ	34000000	ກ	41000000	ກ	30000000	ກ	30222000	ຄ	90000000	ກ	90014141	ຜ	7	3
ຂ	9010000100		2001020010		0001110011	ຂ	1000111000	ຂ	1000111001	ຂ	1000111000	ຂ	1000101010		1000111000	ຂ	1000011115	ຂ	0102221001	ຄ	6	4
ຄ	2220000000	ຄ	0000220000	ຄ	0000002222	ຄ	0002222000	ຄ	2002200022	ຄ	0262222222		2220000222	ຄ	2222000022	ຄ	2000222000	ຄ	2720000222	ຄ	9	1
ງ	3315444415	ງ	3334443334	ງ	2121213344	ງ	3344213444	ງ	3214421213		334412133	ງ	1112121211		334433443	ງ	3344333443	ງ	3344334433	ງ	8	2
ຈ	6555566666	ຈ	5666615158		2323555566	ຈ	6555556666	ຈ	652355555		6655155615	ຈ	6255556615	ຈ	551556156		155561515		1555161515		5	5
ສ	14777777	ສ	77777777	ສ	77777777	ສ	23777777	ສ	23777777	ສ	11777777	ສ	34777777	ສ	23777777	ສ	47777555	ສ	42177777	ສ	10	0
ຊ	14888888	ຊ	14888888	ຊ	88888888	ຊ	88888888	ຊ	18888888	ຊ	88888888	ຊ	88888888	ຊ	86888812	ຊ	34888888	ຊ	34888888	ຊ	10	0
ຍ	34999999	ຍ	99999999	ຍ	36999999	ຍ	34999999	ຍ	99999999	ຍ	36999999	ຍ	34999999	ຍ	99999999	ຍ	99999999	ຍ	99999999	ຍ	10	0
ດ	27101010	ດ	14101010	ດ	9101010	ດ	14101010	ດ	9101010	ດ	1101010	ດ	10101010	ດ	9101010	ດ	27101010	ດ	1412727		9	1
ຕ	11_11_11_	ຕ	11_11_11_	ຕ	11_11_11_	ຕ	292111_		292111_11_		142111_11_		11427931		11_11_111	ຖ	2911_99111	ຍ	11_11_11_	ຕ	4	6
ຖ	111_11_101		111_11_10		11_11_111	ຖ	111_11_111	ຖ	111_11_111	ຖ	11_11_1111	ຖ	111_11_101		1011_11_10		1011_11_10		1011_11_10		4	6
ທ	1211_61212		1211_11_12	ທ	1211_1212		1211_11_12	ທ	1211_11_12	ທ	1211_1212		1211_11_12	ທ	1211_11_12	ທ	1211_1212		1211_11_12	ທ	6	4
ນ	333333333	ນ	391793333	ນ	933333333	ນ	318332117		171732121		217777317		318317173		171717333	ມ	173317173		173333333	ນ	4	6
ບ	813131313	ບ	131313131	ບ	34131313	ບ	14131313	ບ	13131313	ບ	13771313	ບ	29131313	ບ	27131313	ບ	13131313	ບ	29181313	ບ	10	0
ປ	1414141515	ປ	1514141415	ປ	159141414		1514141415	ປ	1514141415	ປ	1591499111	ຢ	1591491414		1414141515	ປ	1514141415	ປ	1499141415	ປ	7	3
ຜ	4214142720		0141414000	ຜ	2421481414		4114141140	ຜ	0814141400	ຜ	2141414002	ຜ	2141414241		414646468		9148814841		246141414		4	6
ຝ	1416161610		1016161610		1616161010		1116161611	ຝ	1811616161	ຝ	1168881616	ຝ	4116161610	ຝ	1010188816		2929161616		111168888		4	6
ພ	299149999	ຍ	1414141414	ຍ	1414141414	ຍ	149991414		2914141414	ຍ	1414141414	ຍ	914141414	ຍ	1429141414	ຍ	1429141414	ຍ	1414141414	ຍ	9	1
ຟ	1416161616	ຟ	4541161616	ຟ	1416161616	ຟ	1617161616	ຟ	1616161616	ຟ	1616161616	ຟ	4629161616	ຟ	1617161616	ຟ	1316161616	ຟ	1316161616	ຟ	10	0
ມ	2417171717	ມ	1729171717	ມ	1714171717	ມ	2929292929	ງ	2917292929		2917929917		175292917		2917171717	ມ	1717171717	ມ	51711_1717	ມ	6	4
ຢ	1099991111	ຢ	1599991111	ຢ	199991515		1999911111	ຢ	999991515		1999991010		1099991111	ຢ	119999910	ຢ	1099999101	ຢ	1099434343		6	4
ລ	1418181818	ລ	18181818	ລ	243181818	ລ	2914231414	ພ	2329141414	ພ	1418181818	ລ	1814291818	ລ	1418181818	ລ	1418181818	ລ	1418181818	ລ	8	2
ຣ	1119191919	ຣ	1917171919	ຣ	1914191919	ຣ	1914191919	ຣ	2919191919	ຣ	190192819		199382819		1917281919	ຣ	1428191919	ຣ	1938191919	ຣ	8	2
ວ	1420992020		1420202020	ວ	029202020	ວ	201492020		2920202020	ວ	2014202020	ວ	2020202020	ວ	2920202020	ວ	2020000920		9142029920		6	4
ຫ	141212129	ຫ	121229444	ອ	12124121212	ຫ	2912121212	ຫ	412121212	ຫ	1412121212	ຫ	1244441244		129121229		294121212	ຫ	2211224112		6	4
ອ	921212121	ອ	21821219	ອ	9189992121		9999992121		2121212121	ອ	2121212121	ອ	2129212121	ອ	2121212121	ອ	2199219999	ຍ	999219999	ຍ	6	4
ຮ	1212122222	ຮ	2221121212		2212122222	ຮ	2215121212		2212121222	ຮ	222212124	ຮ	2212121222	ຮ	2212121222	ຮ	2212121222	ຮ	2212121222	ຮ	8	2
ໃx	8523232323	ໃ	245232323	ໃ	2323232323	ໃ	2323232323	ໃ	235552323	ໃ	235552323	ໃ	2323232323	ໃ	2323232323	ໃ	2317232323	ໃ	16232232323	ໃ	10	0
ໄx	9555555555	ໄ	5555555555	ໄ	5185432323	ໃ	2399955555	ໄ	5185955555	ໃ	915923523		5555232355	ໄ	5555555555	ໄ	2923235555		5555232355	ໄ	6	4
ໂx	624242424	ໂ	2424242424	ໂ	724242424	ໂ	246242424	ໂ	2415242424	ໂ	2429122424		824242424	ໂ	2418242424	ໂ	2424242424	ໂ	2424242424	ໂ	9	1
xິ	2525262626	xິ	2625262625	xິ	2525252626	xິ	2526262626		2625262626		2626262626		2626262626		452525255		1625252525		2626262526		3	7
xີ	2525252727	xີ	627272725	xີ	2525252727	xີ	2525256666		2526272625	xີ	11262726255	xີ	1717172617		252527617		2525272725	xີ	5235232323		6	4
xຶ	2525252828	xຶ	1917252525		1923255555		2525252828	xຶ	2825222222		2555201910		2525252019		281928512		25174224223		2528252516		2	8
xື	1355555555	ໃ	5535252525	xື	252729290		1715262527		2525252529	xື	2929252626		2525252525	xື	2525252525	xື	2525252525	xື	1425252525	xື	6	4
xງ	3229884529		2929292929	ງ	2917292929	ງ	2929292929	ງ	2929292929	ງ	3029292929	ງ	382984529		2929292929	ງ	2930292929	ງ	292984545		7	3
xຳ	2929308737		3718303012		3045454529		3030303030	xຳ	3836302442		3024483024		3024303030	xຳ	3030303030	xຳ	8292436824		2930303030	xຳ	4	6
xໍ	3131313131	xໍ	3117383131	xໍ	3131313131	xໍ	3030212430		3037373030	xຳ	3031313131	xໍ	3030303030	xຳ	2929292929	ງ	3230313131	xໍ	3130313131	xໍ	6	4
xັ	3232323232	xັ	3232323232	xັ	932363232		3232323232	xັ	3236323232	xັ	3232323232	xັ	3232323232	xັ	3232323232	xັ	932323232	xັ	329323232	xັ	9	1
xົ	33_33_33_	xົ	33_33_33_	xົ	33_33_33_	xົ	33_414141		33_33_33_	xົ	33_33_33_	xົ	33_33_33_	xົ	303733_37		33_33_33_	xົ	33_33_33_	xົ	8	2
xາ	3430303030	xຳ	2930303029	xຳ	3437373734	xຸ	3434343737	xຸ	3437373734	xຸ	3434343434	xາ	3737343434	xາ	3434373737	xຸ	3737373737		3737373737		2	8
xະ	2838383839		3030303030		3535353535	xະ	353535335	xະ	3535353535	xະ	3835353538	xະ	3835353535	xະ	35353535335	xະ	3835353535	xະ	3838383835		7	3
x່	3638383636		3636393939		363636336	x່	3939393636		3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	7	3
xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	10	0
xູ	3838353535		3535353535		3838383838	xູ	3838383838	xູ	4141353838		3535414141		3838383838	xູ	3838383838	xູ	3838383838	xູ	3535414138		5	5
x້	4242423939		3938383942		3939393939	x້	3939393939	x້	3939393939	x້	3636424239		4242393942		3939393939	x້	3939393939	x້	4239393939	x້	6	4
ແx	3737374141		3737414141		4040404040	ແx	3737404040	ແx	3740404037	ແx	4343434040		3737404343		4343434040		3737404040	ແx	4040404040	ແx	5	5
ເx	3841414141	ເx	4138414141	ເx	4144414141	ເx	4444414444		4141414138	ເx	3838414141	ເx	4141414141	ເx	3841414141	ເx	4441414141	ເx	4144444141		8	2
xຽ	4343434343	xຽ	4043434343	xຽ	4343434343	xຽ	4343434343	xຽ	4444434343	xຽ	4343434343	xຽ	4343434343	xຽ	4343434343	xຽ	4343434343	xຽ	4343434343	xຽ	10	0
xຼ	4545414144		4141444441		4445414444		4545414144		4444444444	xຼ	4544444444	xຼ	4144444444	xຼ	41444444444	xຼ	4544444444	xຼ	4444444444	xຼ	6	4
x໋	4545454545		4545454545		4545454545		4545454545		4545454545		4545454545		4545454545		4545454545		4545454545		4545454545		10	0
x໊	4242424242	x໊	4242424242	x໊	4242424242	x໊	4242424242	x໊	4242424242	x໊	4242424242	x໊	4242424242	x໊	4242424242	x໊	4242424242	x໊	4242424242	x໊	10	0

Table 3.8 Experimental Result of Subjects #3 for LAO Alphabets Sign Language

Alphabet	1st		2nd		3rd		4th		5th		6th		7th		8th		9th		10th		Correct	Incorrect
ກ	0200000000	ກ	1422000000	ຄ	2700000000	ກ	2700000000	ກ	0000000000	ກ	0000000000	ກ	0000000000	ກ	3800000000	ກ	0000000000	ກ	0000000000	ກ	9	1
ຂ	0011100011	ຂ	100011111	ຂ	1000111111	ຂ	1000011111	ຂ	1010051111	ຂ	1115111_10		0000111111	ຂ	1111_00011	ຂ	1011_00011	ຂ	1101010001	ຂ	9	1
ຄ	002200026	ຄ	2000222220	ຄ	2000222222	ຄ	200022222	ຄ	2000122200	ຄ	0100099999		0009992000		900000939	ກ	0002020999		0222000222	ຄ	6	4
ງ	3334444444	ງ	441212333	ງ	293312433		333444477	ງ	3344334433	ງ	3344331244	ງ	3344334417	ງ	3174433443	ງ	1717171733		4212121222		7	3
ຈ	5552727272		6662355527	ຈ	55527272927		6667755527	ຈ	6661616555	ຈ	611_2711_5		5556272766	ຈ	6555527127		662855527	ຈ	27555272766	ຈ	6	4
ສ	7733377777	ສ	7777777777	ສ	7777777777	ສ	9777777777	ສ	7777777777	ສ	1477777777	ສ	1477777777	ສ	2977777777	ສ	2977777777	ສ	2977777777	ສ	10	0
ຊ	298888888	ຊ	888888888	ຊ	298888888	ຊ	298888888	ຊ	298888888	ຊ	1488888888	ຊ	3888882488	ຊ	2988888888	ຊ	3888888888	ຊ	2988888888	ຊ	10	0
ຍ	9999999999	ຍ	1499999999	ຍ	4699999999	ຍ	9999999999	ຍ	2999999999	ຍ	9999999999	ຍ	6999999999	ຍ	3899999999	ຍ	9999999999	ຍ	2999999999	ຍ	10	0
ດ	1410101010	ດ	1010101010	ດ	1710101010	ດ	1010281010		1310101010	ດ	1410101010	ດ	2710101010	ດ	2710101010	ດ	610101010		1010101010	ດ	8	2
ຕ	11_11_11	ຕ	2911_11_	ຕ	11_11_11_	ຕ	11_11_11_	ຕ	1311_11_	ຕ	1411_11_	ຕ	11_11_11_	ຕ	11_11_11_	ຕ	2911_11_	ຕ	2911_11_	ຕ	10	0
ຖ	11_11_1111	ຖ	11_11_1111	ຖ	11_11_1111	ຖ	11_11_1111	ຖ	11_11_1111	ຖ	111_11_111	ຖ	11_11_11_1	ຕ	111_11_111	ຖ	111_11_111	ຖ	11_11_111	ຖ	9	1
ທ	11_11_1212	ທ	11_11_1212	ທ	11_11_1212	ທ	11_11_1212	ທ	11_11_1212	ທ	11_11_1212	ທ	11_11_1212	ທ	11_11_1212	ທ	1211_1224		11_11_1212	ທ	9	1
ນ	173333333	ນ	3333333333	ນ	333333333	ນ	33333311_	ນ	11_3171717	ມ	3171733177		3331717317	ມ	173333333	ນ	317717333		2331723323		5	5
ບ	1313131313	ບ	3113131313	ບ	3813131313	ບ	1313131313	ບ	1313131313	ບ	131313133	ບ	1320202020	ວ	1313131313	ບ	1316131313	ບ	1413131313	ບ	9	1
ປ	1515151414	ປ	1515151414	ປ	111151514	ປ	1515151414	ປ	1415151514	ປ	1515151414	ປ	1515151414	ປ	215151514	ປ	1515151414	ປ	1427111511		9	1
ຜ	000141414	ຜ	000141414	ຜ	4141412222		002141414	ຜ	1441272000		0001414142	ຜ	2722222222		4300221414	ຜ	142200014	ຜ	1422700014	ຜ	7	3
ຝ	1616111116	ຝ	1616161117	ຝ	7716777773		1623711_		1616161111	ຝ	167771616		161616111	ຝ	161671111	ຝ	1616161111	ຝ	1616161111	ຝ	7	3
ພ	1414141414	ພ	1429141414	ພ	1429141414	ພ	2914141414	ພ	1414141414	ພ	149142714	ພ	1414141414	ພ	1414141414	ພ	1314141414	ພ	1414141414	ພ	10	0
ຟ	1616341216		1616161616	ຟ	1316161616	ຟ	1616161616	ຟ	1616161616	ຟ	1617121212	ຫ	3016161616	ຟ	1616161616	ຟ	1617161616	ຟ	1616161616	ຟ	8	2
ມ	1711_11_	ຕ	1717171717	ມ	1717171717	ມ	1717171717	ມ	1717171717	ມ	1717171717	ມ	1717171717	ມ	1717171717	ມ	1717171717	ມ	1717171717	ມ	9	1
ຢ	4999271111	ຢ	9999111199	ຢ	9999111130	ຢ	9991111199	ຢ	9991111999	ຢ	9991111199	ຢ	9991111199	ຢ	9991111199	ຢ	9991111199	ຢ	999911111	ຢ	10	0
ລ	2918181815	ລ	1818181818	ລ	1818181818	ລ	3829181818	ລ	182991899		1818181818	ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	9	1
ຣ	1919191919	ຣ	1919191919	ຣ	1911111911		1915191919	ຣ	1919191919	ຣ	919191919	ຣ	191711119		1915191919	ຣ	1919191919	ຣ	194000019		7	3
ວ	2020202020	ວ	2020202020	ວ	120202020	ວ	200202020	ວ	2020202020	ວ	2020202020	ວ	2020202020	ວ	2020202020	ວ	1420202020	ວ	2020202020	ວ	10	0
ຫ	1212121212	ຫ	1212121212	ຫ	1214121212	ຫ	1222121212	ຫ	1212121212	ຫ	2912121212	ຫ	1212121212	ຫ	1212121212	ຫ	1212121212	ຫ	2112121212	ຫ	10	0
ອ	321113333	ນ	2121212121	ອ	2121212121	ອ	214611_11_		2121212121	ອ	2121212121	ອ	2121212121	ອ	2121212121	ອ	2121212121	ອ	2121212121	ອ	8	2
ຮ	12222212	ຮ	2212121222	ຮ	1212122222	ຮ	2212121222	ຮ	1212122213		1322221212	ຮ	2241211212		2241212222	ຮ	412221222	ຮ	2212121222	ຮ	8	2
ໃx	2323232323	ໃx	239232323	ໃx	23999929		2317232339		3423232323	ໃx	2323232323	ໃx	2323232323	ໃx	236882323	ໃx	232392323	ໃx	2323232323	ໃx	8	2
ໄx	5555555555	ໄx	555555555	ໄx	5555517555		5171755517		555555175	ໄx	1455555555	ໄx	1455555555	ໄx	5511_55555		511_555555		11_11_511_		5	5
ໂx	2424242424	ໂx	2424241212		2924242424	ໂx	2424242424	ໂx	2424242424	ໂx	2424242424	ໂx	2424242424	ໂx	2424242424	ໂx	2424242424	ໂx	2424242424	ໂx	9	1
xິ	2528262625	xິ	2525252625		2525262626	xິ	2625252626	xິ	2525262625	xິ	2525262625	xິ	2525262626	xິ	2526262626		2525262626	xິ	2626252526	xິ	8	2
xີ	2525252727	xີ	2525272725	xີ	2525272725	xີ	2525252727	xີ	2525272725	xີ	2525272725	xີ	2725252727	xີ	2525272725	xີ	2525272725	xີ	2727252527	xີ	10	0
xຶ	5552755555		2525282825	xຶ	282877777		252528287	xຶ	252528111	xຶ	25252828	xຶ	251282825	xຶ	251282828	xຶ	2811111255		2525181825	xຶ	7	3
xື	2525252525	xື	2525252525	xື	2516161625		2513131313		2525252525	xື	2525252525	xື	2725252525	xື	2525252525	xື	2525252525	xື	2513131313		7	3
xາ	2929292929	xາ	2929292929	xາ	2929292929	xາ	2929292929	xາ	2929292929	xາ	2929292929	xາ	2929292929	xາ	292182929		2929292929	xາ	293129299		8	2
xຳ	3030303030	xຳ	3030303030	xຳ	3030304444		3030303030	xຳ	3030303030	xຳ	3030303030	xຳ	3030303030	xຳ	3088303030	xຳ	303035352		3030343429		7	3
xໍ	3131313131	xໍ	3130303030		3030303131	xໍ	3131313131	xໍ	3131313134	xໍ	3434343431		3030343431		1431343434		3131313131	xໍ	3131313131	xໍ	6	4
xັ	3232323232	xັ	3232323230	xັ	3232323232	xັ	3032323232	xັ	3232323230	xັ	3232303030	xຳ	3032303232	xັ	3232303232	xັ	3232323232	xັ	3030323230		8	2
xົ	33_33_33_	xົ	33_33_33_	xົ	33_33_33_	xົ	33_33_33_	xົ	33_33_33_	xົ	33_3233_	xົ	33_3233_	xົ	242433_33_	xົ	33_33_33_	xົ	323233_24		9	1
xໆ	3434343434	xໆ	3430313030		306373730		3434343434	xໆ	3434343434	xໆ	343443434	xໆ	3434343434	xໆ	3434343434	xໆ	3434343434	xໆ	3434313131		7	3
xະ	3535353535	xະ	3535353535	xະ	3535353535	xະ	3030353535	xະ	3535353535	xະ	3838383829	xູ	3535353535	xະ	3535353535	xະ	3535353535	xະ	3535353535	xະ	9	1
x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	2936363636	x່	10	0
xຸ	3030373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3740373737	xຸ	3737373737	xຸ	10	0
xູ	3838383838	xູ	3838383838	xູ	3834343439		3439383838	xູ	3434383838	xູ	3838383838	xູ	3838383838	xູ	3838383838	xູ	2934343430		3838383838	xູ	8	2
x້	3939393939	x້	3939393939	x້	3939393939	x້	3939393939	x້	3939393945	x້	4539393939	x້	39393639		3939393939	x້	3939393939	x້	3939393939	x້	9	1
ແx	2940404040	ແx	4040404040	ແx	4040404029	ແx	02929292940		4040404029	ແx	4140414141		4140414141		2940404040	ແx	4040403940	ແx	4040404040	ແx	7	3
ເx	4141414141	ເx	4141414141	ເx	4141414141	ເx	4141414141	ເx	4141414141	ເx	4141414141	ເx	3841414141	ເx	4141414040	ເx	4141413535	ເx	3535354040		9	1
xຽ	4343434343	xຽ	4343434343	xຽ	4343434343	xຽ	4343434343	xຽ	4343434343	xຽ	4343434343	xຽ	4343434343	xຽ	4343434343	xຽ	4343434343	xຽ	4444444040		9	1
xຼ	4044444444	xຼ	4444444044	xຼ	4444404044		4444444444	xຼ	4444444444	xຼ	4444444444	xຼ	4444444444	xຼ	44444343		4444444444	xຼ	4444444444	xຼ	8	2
x໊	4545454545	x໊	4545454545	x໊	4545454545	x໊	4545454545	x໊	4545454242	x໊	42454541		4545454545	x໊	4545454545	x໊	4545454545	x໊	4545454545	x໊	9	1
x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	4242363631		4242424242	x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	9	1

Table 3.9 Experimental Result of Subjects #4 for LAO Alphabets Sign Language

Alphabet	1st		2nd		3rd		4th		5th		6th		7th		8th		9th		10th		Correct	Incorrect
ກ	1000000000	ກ	0000000000	ກ	0000000000	ກ	000002400		0000000000	ກ	0000000000	ກ	0000000000	ກ	0000200000	ກ	0000000000	ກ	0000000000	ກ	9	1
ຂ	0000000001	ກ	11515001111	ຂ	120200111	ຂ	100111111	ຂ	100010115	ຂ	1020202010		111100011	ຂ	1222220001	ຄ	1220001111	ຄ	1200011111	ຂ	6	4
ຄ	2200200022	ຄ	0000000000	ກ	387002220	ຄ	000000200	ກ	000200000	ກ	4300222200	ຄ	0000200000		0002222200	ຄ	2022220044	ຄ	4400022220	ຄ	3	7
ງ	233344443	ງ	1717334444	ງ	4343434444		192533124		433744433	ງ	4377733430		9293334929		7033334444	ງ	3334444437	ງ	2711_11_	ຕ	5	5
ຈ	6255556666	ຈ	666225566	ຈ	6225527666	ຈ	2222555666	ຈ	2755226627	ຈ	5552766666	ຈ	5552766666	ຈ	6513131322		5551666666	ຈ	6555666666	ຈ	9	1
ສ	7777777777	ສ	7777777777	ສ	7777777777	ສ	7777777777	ສ	7777777777	ສ	7777777777	ສ	7777777777	ສ	7777777777	ສ	7777777777	ສ	7777777777	ສ	10	0
ຊ	8888888888	ຊ	2388888888	ຊ	8888888888	ຊ	8888888888	ຊ	3488888888	ຊ	8888888888	ຊ	8888888888	ຊ	8888888888	ຊ	2488888888	ຊ	8882482424		9	1
ຍ	1999999999	ຍ	9991999999	ຍ	9999999999	ຍ	9999999999	ຍ	9999999999	ຍ	9999999999	ຍ	9999999999	ຍ	9999999999	ຍ	9919999999	ຍ	9999999999	ຍ	10	0
ດ	2810101010	ດ	1010101010	ດ	1010101010	ດ	1010101010	ດ	2828101010	ດ	1010101010	ດ	1010101010	ດ	1010101010	ດ	1028281028		2810101010	ດ	9	1
ຕ	711_77797		11_11_11_	ຕ	11_11_11_	ຕ	11_11_11_	ຕ	11_11_11_	ຕ	11_11_11_	ຕ	11_11_11_	ຕ	11_11_11_	ຕ	11_11_11_	ຕ	11_11_312		8	2
ຖ	111_11_11	ຖ	11_1100110	ຂ	11_111111	ຖ	11_11_110		11_11_100	ຂ	011_11_111	ຖ	11_11_1111	ຖ	11_1011120		1111_1110	ຖ	11_111101	ຖ	6	4
ທ	711_11_412	ທ	1211_11_12	ທ	1211_11_12	ທ	1211_11_12	ທ	1211_11_12	ທ	1211_11_5		1111_1212		1211_11_5		1111_11_12	ທ	1211_11_12	ທ	7	3
ນ	3333333333	ນ	3333333333	ນ	3333333333	ນ	3333333333	ນ	3283333333	ນ	3333333333	ນ	3333333333	ນ	3317333333	ນ	3333333333	ນ	3333333333	ນ	10	0
ບ	1313131313	ບ	1313131313	ບ	1313131313	ບ	1313131313	ບ	1313131313	ບ	1313131313	ບ	1313131313	ບ	1313131313	ບ	1313131313	ບ	132672613		9	1
ປ	1514141415	ປ	1514141111		1414141015	ປ	1514141515	ປ	1514141515	ປ	101414215	ປ	1514141515	ປ	1514141515	ປ	1014141510		151414610		7	3
ຜ	011414000	ຜ	0141400000	ຜ	1414000009	ຜ	141400000	ຜ	141400000	ຜ	141400000	ຜ	141400000	ຜ	1462000000	ກ	1414000000	ຜ	1414000009	ຜ	9	1
ຝ	1616211100	ຝ	1616191111	ຝ	1616160010		01616115	ຝ	1616111313	ຝ	1616111311	ຝ	161611110	ຝ	1316161131	ຝ	116161111	ຝ	161611111	ຝ	9	1
ພ	4614141414	ພ	1414141414	ພ	1414141414	ພ	1414142714	ພ	1414141414	ພ	2714141427	ພ	2727141427		2727271427		1414142727	ພ	1414141427	ພ	8	2
ຟ	816161616	ຟ	1616161616	ຟ	1616161616	ຟ	1616161616	ຟ	1616161616	ຟ	1616161616	ຟ	1616161616	ຟ	1616161616	ຟ	1616161616	ຟ	1616161616	ຟ	10	0
ມ	1717171717	ມ	1717171717	ມ	1717171717	ມ	1717171717	ມ	1731717317	ມ	1717171717	ມ	1717171717	ມ	1717171717	ມ	1717171717	ມ	1717171717	ມ	10	0
ຢ	1991181011	ຢ	1829999111	ຢ	1991101101	ຢ	991111199	ຢ	191111199	ຢ	1199111119	ຢ	9111010199	ຢ	2999111111	ຢ	991111199	ຢ	9911111199	ຢ	10	0
ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	1818181818	ລ	10	0
ຣ	1919191919	ຣ	1919191919	ຣ	1919191919	ຣ	1919191919	ຣ	1919191919	ຣ	1919191919	ຣ	1919191919	ຣ	1910191919	ຣ	1919282919	ຣ	1919191919	ຣ	10	0
ວ	2020202020	ວ	2020202020	ວ	2020202020	ວ	2020202020	ວ	2020202020	ວ	2020202020	ວ	2020202020	ວ	2020202020	ວ	2020202020	ວ	2020202020	ວ	10	0
ຫ	1212121212	ຫ	1212121212	ຫ	1212121212	ຫ	1212121212	ຫ	1212121212	ຫ	1212121212	ຫ	1212121212	ຫ	1212121212	ຫ	1212121212	ຫ	1212121212	ຫ	10	0
ອ	2121212121	ອ	2121212121	ອ	2121212121	ອ	2121212121	ອ	2121212121	ອ	11_212111_		11_11_2121		2121212121	ອ	2121212121	ອ	2121212121	ອ	8	2
ຮ	3027221222		1212222222	ຮ	3712122222	ຮ	1212222222	ຮ	1212222222	ຮ	2412122222	ຮ	2212122222	ຮ	1212222222	ຮ	1212222212	ຮ	1212222622	ຮ	9	1
ໃx	10	ໃx	525552323		2314253823		2525252323		232324038		5238232323	ໃx	2323232323	ໃx	2323232323	ໃx	2323232323	ໃx	2323232323	ໃx	6	4
ໄx	5555555555	ໄx	5555555555	ໄx	5555999955		5555555555	ໄx	5555555555	ໄx	555551920		4020555555	ໄx	4020555555	ໄx	52401912255		5555555555	ໄx	7	3
ໂx	824242424	ໂx	2424242424	ໂx	2424242424	ໂx	2424242424	ໂx	2424242424	ໂx	2424242424	ໂx	2424242424	ໂx	2424242424	ໂx	2424242424	ໂx	2424242424	ໂx	10	0
xິ	2525262625	xິ	2525262625	xິ	2525262626	xິ	2526262626		2626252526	xິ	2525262625	xິ	2525262625	xິ	2525262625	xິ	2525262625	xິ	2525262626	xິ	9	1
xີ	2626262625	xີ	131335555		2525232525		2525272725	xີ	2525272725	xີ	2525272725	xີ	2525272725	xີ	2525272725	xີ	2525272725	xີ	2525272725	xີ	7	3
xຶ	2525282825	xຶ	2525282819	xຶ	2525282825	xຶ	2525282825	xຶ	2525282825	xຶ	2525282825	xຶ	2525282825	xຶ	2825252828	xຶ	1919251928		7725258825	xຶ	9	1
xື	2525252525	xື	2525252525	xື	2525252525	xື	2525252525	xື	2525252525	xື	2525252525	xື	2525252525	xື	1438252525	xື	2525252525	xື	2525252525	xື	10	0
xຽ	2929292929	xຽ	3131313131	xໍ	2934343434	xໆ	2931292929	xຽ	2929292929	xຽ	2929312931		3131313131	x່	2929292929	xຽ	2929292929	xຽ	2929292929	xຽ	6	4
xຳ	3030303030	xຳ	3030303030	xຳ	3030303030	xຳ	3030303030	xຳ	3030303030	xຳ	2930302929		2930303029	xຳ	3030302930	xຳ	3030303030	xຳ	3030313130		8	2
xໍ	3131313131	xໍ	3131313131	xໍ	3131313131	xໍ	3131313131	xໍ	3131313131	xໍ	3131313131	xໍ	3131313131	xໍ	3131313131	xໍ	3131313131	xໍ	3131313131	xໍ	10	0
xົ	3432323232	xົ	3432323232	xົ	3232323232	xົ	3232323232	xົ	3232323232	xົ	3232323232	xົ	3232323232	xົ	3232323232	xົ	3232323232	xົ	3232323232	xົ	10	0
xັ	33_33_33_	xັ	33_33_33_	xັ	33_33_33_	xັ	33_33_33_	xັ	33_33_33_	xັ	33_33_33_	xັ	33_33_33_	xັ	33_33_33_	xັ	33_33_33_	xັ	33_33_33_	xັ	10	0
xາ	3434343434	xາ	3434343434	xາ	3434343434	xາ	3434343434	xາ	3434343434	xາ	3434343434	xາ	3434343434	xາ	3434343434	xາ	3434343434	xາ	3434343434	xາ	10	0
xະ	3835383835	xຸ	4535353535	xະ	3535353535	xະ	3535353535	xະ	3535353535	xະ	3535353535	xະ	3535352935	xະ	3535353535	xະ	3535353535	xະ	3529293535	xະ	9	1
x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	3636363636	x່	10	0
xຸ	33_3733_		33_33_33_		4137404037		4040403737		3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373737	xຸ	3737373744	xຸ	6	4
xູ	3841414138		4141383838	xູ	3838383838	xູ	3838383838	xູ	38353838	xູ	3838383838	xູ	3838383838	xູ	3838383838	xູ	3838383835	xູ	3838383838	xູ	9	1
x້	4239393939	x້	3939393939	x້	3939393939	x້	3939393939	x້	3939393939	x້	3939393939	x້	3939393939	x້	3939293939	x້	3939393939	x້	3934343439		9	1
ແx	4140404040	ແx	4040404040	ແx	4040404040	ແx	4141404040	ແx	4040404040	ແx	4040404040	ແx	4040404040	ແx	4040404040	ແx	4040404040	ແx	4040404040	ແx	10	0
ເx	4141414141	ເx	4141414141	ເx	3841413841		3838413838		38414111941		4141414141	ເx	4141414141	ເx	4141414141	ເx	4141414141	ເx	3838383841		6	4
xໆ	2643434343	xໆ	4343434343	xໆ	4343404032		433442219		4343434332	xໆ	4141404343	xໆ	4343434343	xໆ	8244343441		4343434343	xໆ	4343433232	xໆ	7	3
xຼ	4043434343	xໆ	4444444444	xຼ	4444444444	xຼ	4444444444	xຼ	4443404040	ແx	4040404040	ແx	4444444444	xຼ	4444444444	xຼ	4444444444	xຼ	4444444440	xຼ	7	3
x໊	4242424544	xີ	42454514		3939394545		4545453733	x໊	4545454545	x໊	4545454545	x໊	4545454545	x໊	4529454545	x໊	4545454545	x໊	4539454545	x໊	7	3
x໋	2942424242	x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	4242424242	x໋	10	0

The table below shows the result of the testing experiments and the overall average recognition rate performed by 4 different subjects is about 79%.

Table 3.10 Recognition result

User	User 1	User 2	User 3	User 4	Average
Correct	83.33	84.71	78.82	69.02	78.97
Incorrect	16.67	15.29	30.98	21.03	21.03

3.4 Conclusions

In this chapter proposes a system of recognition Lao alphabet sign language using HOG feature extraction and correlation coefficient measurement technique. Sine some of the alphabets is required to perform a series of gesture, it is resulting in difficulties for the experimenters to maintain a constant speed for performing of hand gesture consistently. However, if available, the system is tested with the deaf people, a promising higher recognition rate could be achieved.

CHAPTER 4

RECOGNITION OF LAO SENTENCE SIGN LANGUAGE USING KINECT SENSOR

In this chapter presents a technique for recognition Lao sentence sign language by using a Kinect sensor. By using the Kinect sensor, feature joint positions of the human body can be tracked. After that, the joint angles between each pair of joint vectors of the adjacent joint position are measured. When the user performs a series of posture representing a simple sentence Lao sign language, the system records joint angles that are significantly changed from one posture to another posture.

4.1 Principle and Methodology of Image Recognition System

4.1.1 System Analysis

Figure 4.1 shows a block diagram of the proposed system. A deaf person is sitting in front of the Kinect camera at about 50 centimeters away. While performing a series of sign language sentence, the camera is recording stream of images. With Kinect's SDK, the joint position of the human body can be tracked. This system requires only sitting posture of the performer in order to translate the performed sign language. The angles between vectors of the adjacent joint position are measured. Sets of joint angles are defined corresponding to the feature postures that explicitly representing a sentence of sign language. Feature postures of sign language can be one, two, or three sets depending on how complex of performing the posture. Features are stored in the database for recognition phase. When feature posture match with the database the system displays translated sign language on the monitor.

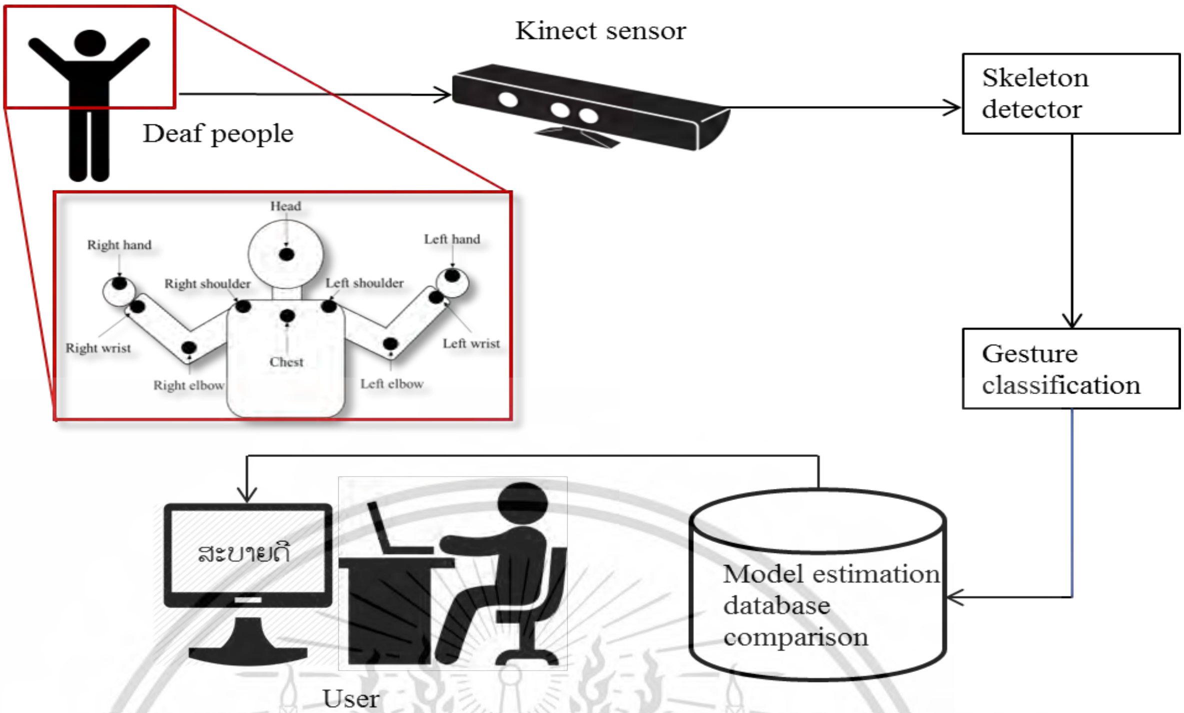


Figure 4.1 System Overview

4.1.2 Recognition Process

Flowchart of the recognition process is shown in Figure 4.2. The system reads a stream of images from the Kinect camera. It then detects the joint positions of the body. The interested joint positions are 10 positions at the head, chest, right shoulder, right elbow, right wrist, right hand, left shoulder, left elbow, left wrist, and left hand. A pair of adjacent joints is connected and represented by a joint vector.

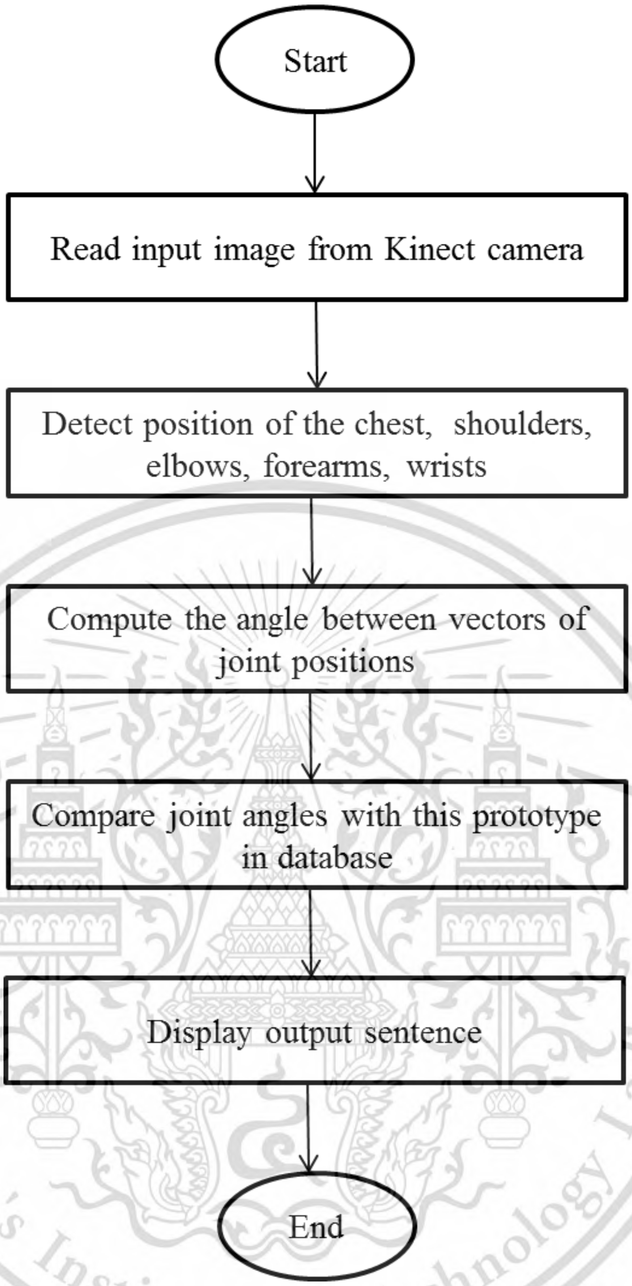


Figure 4.2 Recognition process

4.1.3 Connection Map for Joint Position

The connection map describes the connection of each pair of vectors connected between two adjacent joint positions are shown in Table 4.1 and all joint position are depicted in Figure 4.3.

Table 4.1 Connection map

No.	Joint Position	Vector Connection
1	Head	[1 2]
2	Chest	[1 2], [2 3], [2 7]
3	Right shoulder	[2 3], [3 4]
4	Right elbow	[3 4], [4 5]
5	Right wrist	[4 5], [5 6]
6	Right hand	[5 6]
7	Left shoulder	[2 7], [7 8]
8	Left elbow	[7 8], [8 9]
9	Left wrist	[8 9], [9 10]
10	Left hand	[9 10]

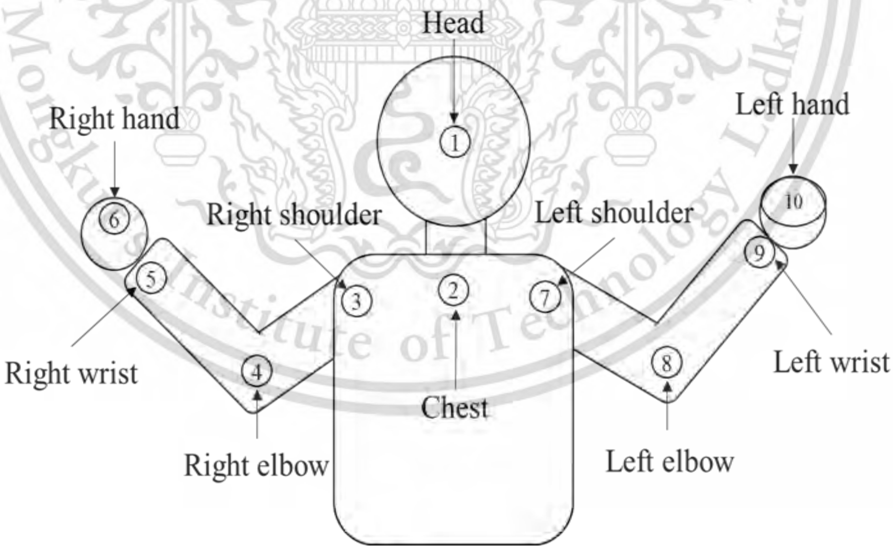
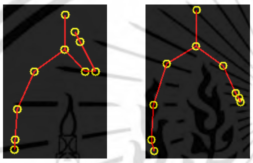
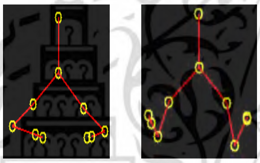
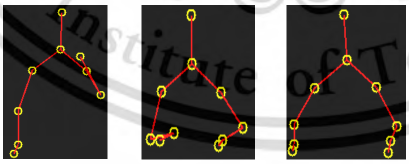
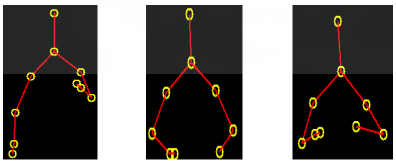
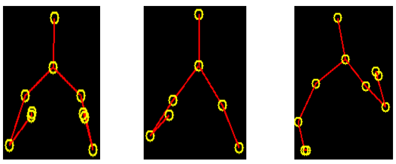


Figure 4.3 Tracked feature joint positions

4.2 Experiments

We had carried out experiments to evaluate the performance of our proposed system. Ten simple sentences of the daily life communication had been used. They are “Hello”, “How are you”, “How are you?”, “I’m fine”, “Where are you going?”, “Have you eaten yet?”, “What is your name?”, “See you again”, “Let’s eat”, “Do you understand?”, and “Thank you”. The sign language of the mentioned sentences had been performed and recorded by the Kinect camera. We had defined set of tracked joint positions as the feature postures representing each sentence. Table 4.2 shows feature posture generated from the experiment.

Table 4.2 Feature postures

No.	Tracked Joint Position	Meaning
1		[illegible] (Hello)
2		[illegible] (How are you?)
3		[illegible] (I’m fine)
4		[illegible] (Where are you going?)
5		[illegible] (Have you eaten yet?)
6		[illegible] What is your name?
7		[illegible] See you again

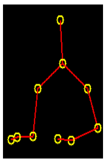
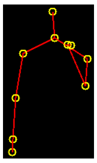
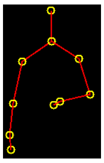
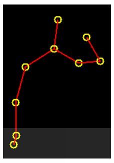
No.	Track Joint Position			Meaning
8				●ĭ̊ĭ ш̊ĭ ●ฆ̈X Let's eat
9				●ฆ̈X ь ŦΔ? Do you understand?
10				шΔцVŦ ′ ь Thank you

Table 4.2 (continued)

From the experiments, all joint positions between the pair of adjacent joint vectors are recorded. Table 4.3 shows experimental data recorded while performing 10 sentences.

Table 4.3 Joint angles

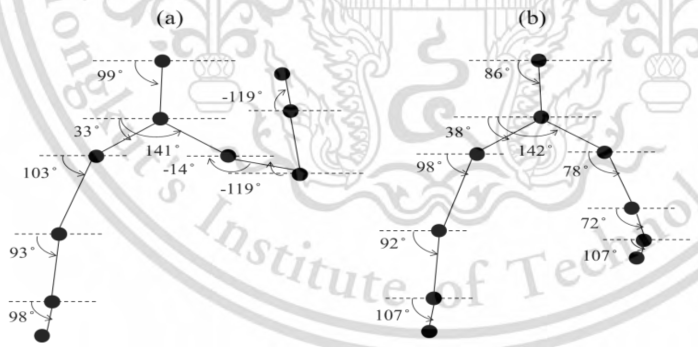
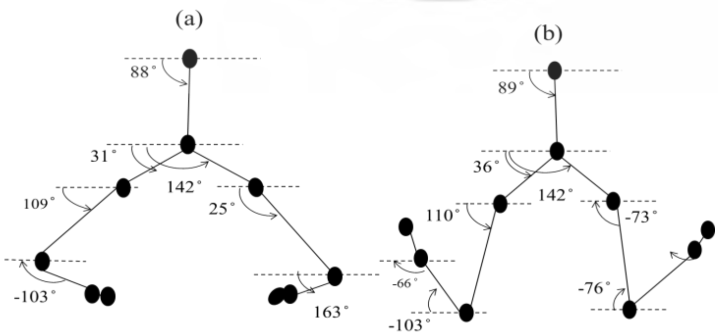
Sentence	Step	Right-hand Side					Left-hand Side			
		(1-2)	(2-3)	(3-4)	(4-5)	(5-6)	(6-7)	(7-8)	(8-9)	(9-10)
ⅢVⅢ Xѳяiii (Hello)	1 2	99 86	33 38	14 78	-119 72	-119 107	141 142	103 98	93 92	98 107
ⅢVⅢ XѳяiŦΔ? (How are you?)	1 2	88 89	31 36	25 -73	163 -76	172 -133	142 142	109 110	-103 -103	-66 -66
цVнoⅢVⅢ Xѳяiii (I'm fine)	1 2	88 89	32 36	27 73	-78 -78	161 99	-172 142	147 109	156 -98	19 -143
●ѷХь VⅢE ′ Ⅲ? (Where are you going?)	1 2 3	91 91 91	30 33 27	86 51 47	-146 150 -142	-142 150 172	148 145 145	98 123 127	79 34 -14	69 34 -14
ш̊ĭ ●ฆ̈X□ⅠзⅢŦΔ? (Have you eaten yet?)	1 2 3	91 87 86	38 42 38	72 51 57	-115 -108 105	-94 -97 97	139 135 144	100 124 125	91 -73 80	112 -62 93
●ѷХ̈ЭⅠVнɪX? (What's your name?)	1 2 3	91 91 87	30 29 30	85 8 73	-147 -167 -165	-126 179 -163	147 150 150	93 98 102	82 -19 6	78 -177 -66

Sentence	Step	Right-hand Side (1-2)	(2-3)	(3-4)	(4-5)	(5-6)	Left-hand Side (6-7)	(7-8)	(8-9)	(9-10)
ҬшЁшЁХ΄К 2 (See you again)	1	90	44	63	-103	-97	136	115	-67	57
	2	87	45	77	-122	-122	135	113	-42	-42
	3	86	34	31	-108	70	147	101	82	76
●ЁшЁ●ајХ (Let's eat)	1	83	40	73	177	86	142	103	163	166
	2	90	38	71	-118	-104	139	100	93	110
	3	87	36	82	134	127	145	100	91	91
●ајХьҒ? (Do you understand?)	1	100	27	-16	-137	-125	145	100	82	86
шҴцѴҒ΄ь (Thank you)	1	86	38	97	-93	-177	143	99	96	103
	2	87	39	70	-169	-108	143	100	91	112
	3	92	54	-32	-122	-126	148	104	98	82

Table 4.3 (continued)

The table below shows the angles between joint vectors with reference to the coordinate system representing a sentence.

Table 4.4 Joint angles of sentence expressions

No	Joint Angles Performing Sentences	Meaning
1		Hello ШИ Хояiii
2		How are you? (ШИ ХояiҒ?)

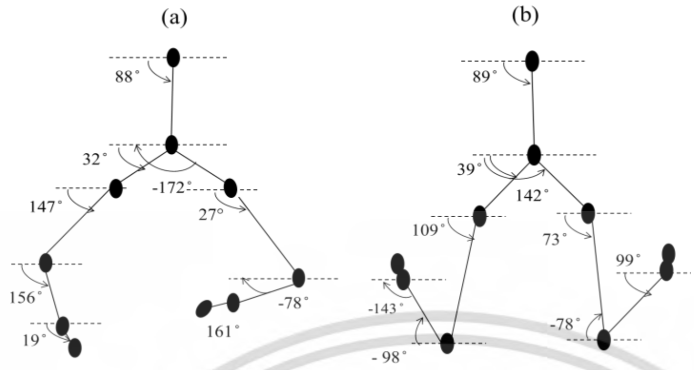
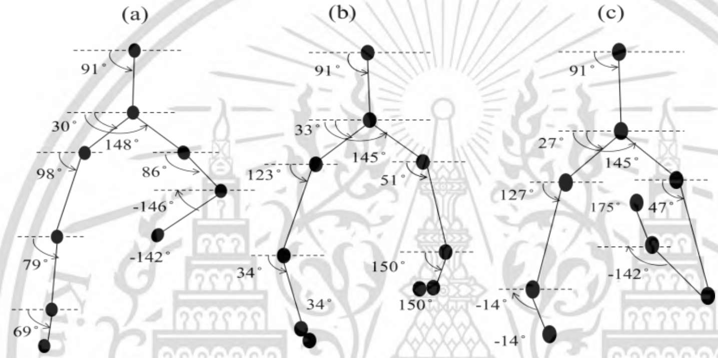
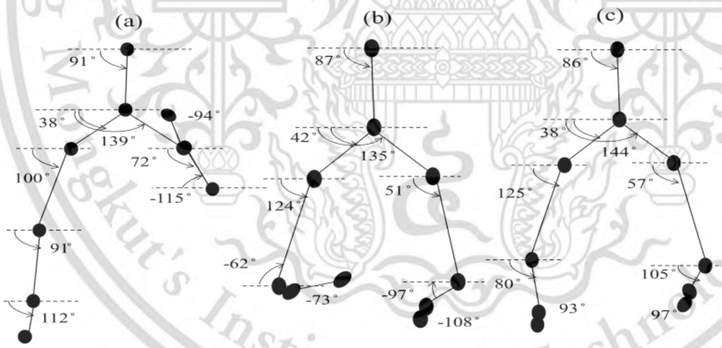
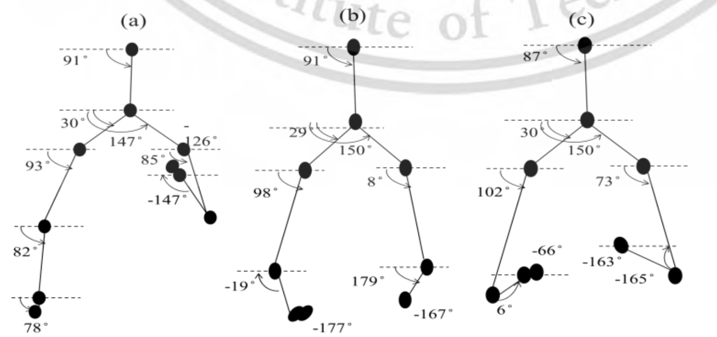
<table>
<tr><th>No</th><th>Joint Angles Performing Sentences</th><th>Meaning</th></tr>
<tr><td>3</td><td>
</td><td>I’m fine
([illegible])</td></tr>
<tr><td>4</td><td>
</td><td>Where are you going?
([illegible])</td></tr>
<tr><td>5</td><td>
</td><td>Have you eaten yet?
([illegible])</td></tr>
<tr><td>6</td><td>
</td><td>What is your name?
([illegible])</td></tr>
</table>

Table 4.4 (Continued)

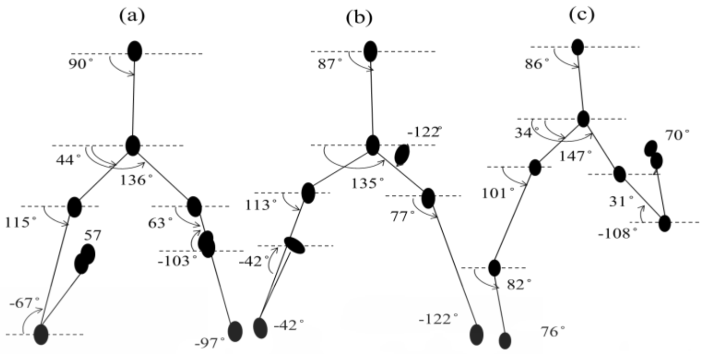
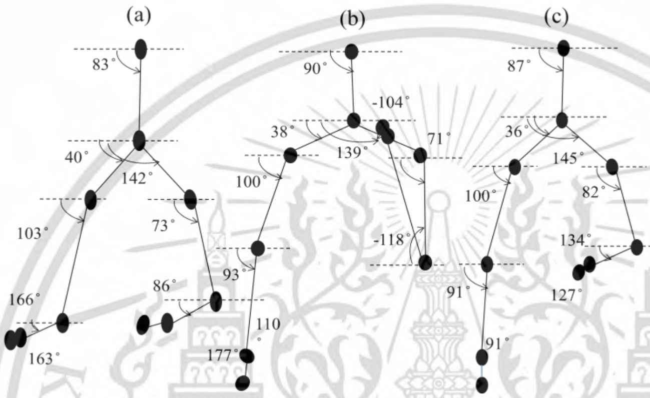
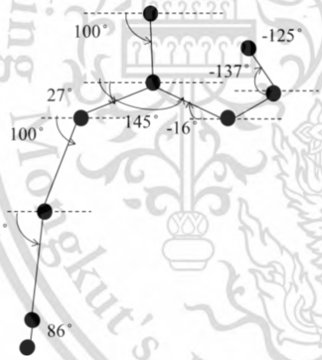
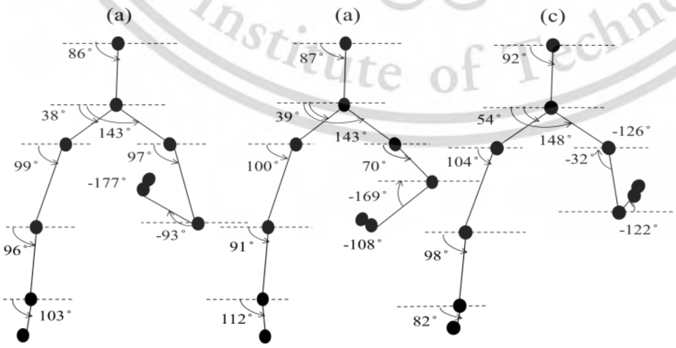
No	Joint Angles Performing Sentences	Meaning
7		See you again ([illegible])
8		Let’s eat ([illegible])
9		Do you understand? ([illegible])
10		Thank you ([illegible])

Table 4.4 (continued)

4.3 Results and Discussions

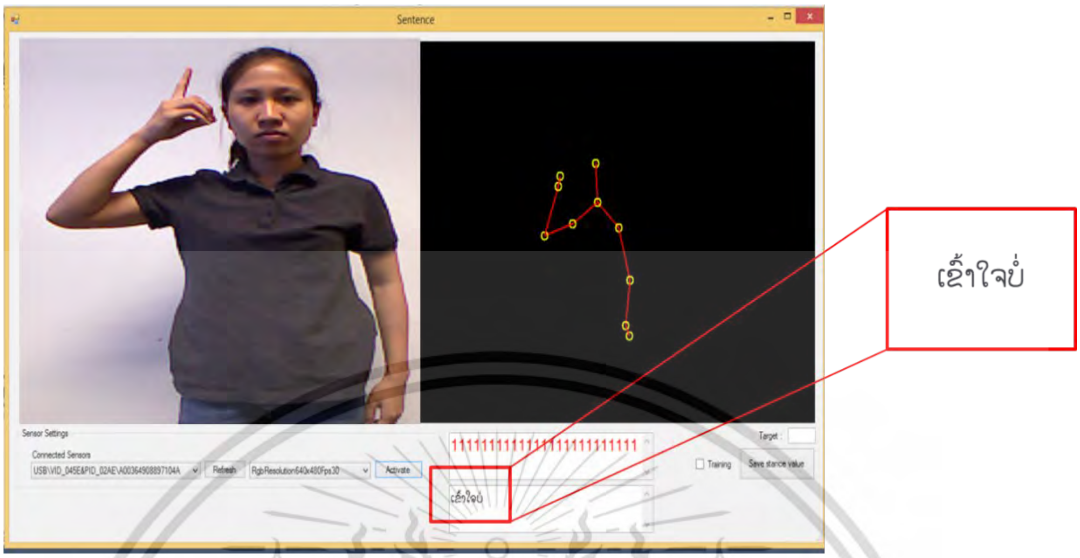


Figure 4.4 Experiment Results: Lao simple sentence sign language

The gestures were repeated for 10 times to validate the accuracy of the proposed systems. The correct percentages of detected gestures matching with their meaning are shown in Table 4.5. As the result, in most of the case of the experimental gestures, we found that it is greatly matched their meaning, except that the sentence of "*ເຊີນກິນເຂົ້າ*" (let's eat) that shows quite low recognition rate. The reason for this is due to the complexity of posture of the sign language. As shown in Figure 4.4, the feature postures required for the sentence of "let's eat" composes of 3 feature postures. While the sentence of "Do you understand?" need only to be 1 feature posture. In addition, the time interval for the system to be able to match feature posture from one to another feature posture must be maintained in the defined range.

Table 4.5 Recognition results

No.	Posture	Correct Result (%)
1	Hello (ꟷ/ꟷ Xoяi)i	90
2	How are you? (ꟷ/ꟷ XoяiꟷΔ?)	90
3	I'm fine (щ\/юꟷ/ꟷ Xoяi)i	90
4	Where are you going? (●ꟷь\/ꟷ′ ꟷ?)	60
5	Have you eaten yet? (шꟷ ●ꟷ□ꟷꟷΔ?)	70
6	What is your name? (●ꟷꟷ\/ꟷX?)	60
7	See you again (Tꟷшꟷ′ K ꟷ)	60
8	Let's eat (●ꟷiшꟷ ●ꟷ	50
9	Do you understand? (●ꟷьꟷΔ?)	100
10	Thank you (шΔц\/ꟷ′ ь)	80

Figure 4.5 Experiment Results in the Lao simple sentences sign language "hello"

TIme	feature mode	(1-2)	(2-7)	(2-3)	(7-8)	(8-9)	(9-10)	(3-4)	(4-5)	(5-6)
1	2 modes	97.578	143.746	28.748	104.263	93.605	92.196	78.87	-125.867	-125.867
		87.036	142.551	38.123	98.257	91.752	107.005	74.643	-73.0281	103.926
2	2 modes	99.835	141.326	33.225	103.791	93.191	98.9	14.2025	-119.855	-119.855
		86.839	142.782	38.07	98.353	92.096	107.005	78.163	-72.636	107.3631
3	2 modes	97.116	142.298	37.957	102.792	93.612	103.93	19.4063	-117.497	-117.497
		86.794	142.926	38.148	98.348	92.067	107.005	78.3424	-71.909	108.09
4	2 modes	97.054	142.111	37.11	102.307	93.985	105.494	23.057	-116.243	-116.243
		86.58	143.267	38.274	98.353	95.077	107.005	78.663	-71.824	108.175
5	2 modes	98.953	140.68	35.721	101.101	93.266	90.065	21.434	-116.4	-116.4
		86.506	143.497	38.137	98.329	95.626	107.005	76.071	-67.03	112.374
6	2 modes	97.561	141.582	37.441	101.232	94.065	90.066	19.047	-116.919	-116.919
		86.703	143.467	38.147	98.379	94.728	107.005	78.686	-70.535	109.464
7	2 modes	95.991	142.586	39.079	101.632	94.277	90.067	17.672	-116.703	-116.703
		86.756	143.175	38.267	98.37	95.249	107.005	78.747	-70.485	109.514
8	2 modes	94.942	142.955	41.23	101.839	94.065	90.067	16.307	-116.925	-116.925
		86.355	142.856	38.668	98.334	95.837	107.005	78.727	-72.489	-24.518
9	2 modes	94.414	143.076	42.42	101.856	94.197	90.067	16.177	-116.903	-116.903
		86.104	142.773	39.322	98.225	95.906	107.005	82.316	-71.057	-73.795
10	2 modes	94.211	142.998	43.115	101.835	94.467	90.067	15.8414	-117.216	-117.216
		86.262	142.79	39.297	98.173	95.897	107.005	82.008	-71.074	-73.727

Figure 4.6 Experiment Results in the Lao simple sentences sign language "how are you?"

Time	feature mode	(1-2)	(2-7)	(2-3)	(7-8)	(8-9)	(9-10)	(3-4)	(4-5)	(5-6)
1	2 modes	87.91	148.142	31.661	158.992	18.709	18.709	25.547	163.423	-172.22
		88.45	142.203	36.351	109.965	-103.552	-66.233	72.701	-76.584	-132.902
2	2 modes	87.832	147.828	32.073	156.529	19.093	19.093	26.941	161.367	-172.229
		89.2	141.838	36.524	109.6	-98.678	-142.712	72.851	-78.335	98.785
3	2 modes	87.57	147.578	31.823	155.891	19.463	19.463	26.264	159.584	-172.229
		89.613	141.493	36.786	113.864	-91.219	90.416	71.784	-83.029	90.352
4	2 modes	88.12	146.972	31.614	155.464	19.884	19.884	42.798	167.594	179.62
		89.457	141.487	36.839	112.671	-91.0324	108.201	71.424	-81.391	108.681
5	2 modes	88.478	146.774	31.95	155.551	20.315	20.315	44.038	172.143	-179.451
		89.43	141.804	36.934	112.508	-92.833	118.853	71.679	-81.983	106.755
6	2 modes	89.493	146.475	31.911	154.743	20.12	20.12	28.169	160.847	179.472
		89.403	141.909	36.685	112.778	-92.358	109.21	71.909	-81.126	107.843
7	2 modes	89.674	146.259	31.145	155.994	21.475	21.475	29.473	158.893	179.62
		89.357	141.904	36.487	111.84	-93.296	114.049	71.685	-81.7	100.855
8	2 modes	89.249	146.275	31.284	155.553	21.453	21.453	47.186	172.4	-175.527
		89.3	142.038	36.325	111.114	-94.41	146.916	71.086	-81.158	115.383
9	2 modes	89.058	146.696	31.274	154.659	21.354	21.354	29.687	158.868	179.62
		88.922	142.098	36.66	110.65	-95.34	167.54	70.909	-81.576	109.139
10	2 modes	88.799	146.822	31.425	154.318	21.189	21.189	44.976	169.943	179.62
		88.854	142.128	36.997	109.62	-96.891	-151.865	71.368	-81.372	116.571

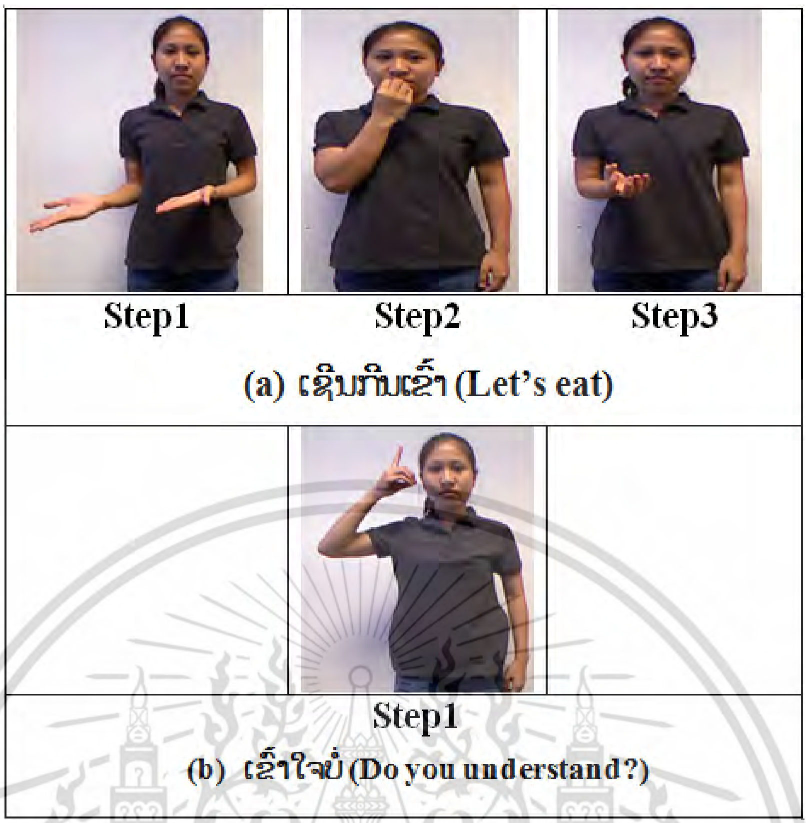


Figure 4.7 Feature posture (a) “Let’s eat” and (b) “Do you understand?”

4.4 Conclusions

This chapter introduces a recognition system of sign language performing daily life simple sentences. The system uses a Kinect sensor camera to tracked joint position on the deaf person’s body while performing sign language. The database of the stores features postures i.e. set of joint angles represented key postures for translating sign language. When the performing sign language matches with the feature posture, the system display output sentence. The accuracy of the system is about 75%. We are investigating to improve the performance of the system so that this system can be useful in the real life usage.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Sign language is one of a powerful means of communication among human. Sign language is an essential and natural expressive mean of communication, especially for the deaf people. This thesis has presented the Hand Gesture Recognition for Lao Alphabet Sign Language using HOG and Correlation, a system of recognition Lao alphabet sign language using HOG feature extraction and correlation coefficient measurement technique. The totals of 54 Lao alphabets are used in the experiments. Four subjects are asked to perform each alphabet of Lao sign language in which each subject had performed totally 540 gestures. The recognition rate of the proposed technique at about 79 % is achieved, and study of Recognition of Lao Sentence Sign Language using Kinect Sensor. By using the Kinect sensor, feature joint positions of the human body can be tracked. Feature joint angles stored in the database is used to recognition the testing sentence's posture. The recognition rate of about 75% is achieved from the experiments performed 10 simple sentences of Lao sign language. Solving this social issue with this system, we hope that it is more or less can help improve the communication between deaf people and normal people, especially in Lao PDR.

REFERENCES

Martin Momona, “Thumb up sign language for Lao”, Memo Books Language Learning Text for Laos, LAO PDR. 2009

Tomas B. Moeslund, Adrian Hilton, Volker Kruger, Leonid Sigal, “Visual Analysis of Humans”, Springer London Dordrecht Heidelberg New York, 2011, ISBN: 978-0-85729-996-3

W. T. Freeman and M. Roth, “Oriented Histograms for Hand Gesture Recognition”, Intl. Workshop on Automatic Face- and Gesture- Recognition, IEEE Computer Society, Zurich, Switzerland, pp. 296-301, 1995.

B. Boufama and M.A. Ali, “Tracking Multiple People in the Context of Video Surveillance”, Image Analysis and Recognition: 4th International Conference, ICIAR 2007, pp. 581-592, 2007

L. Xia, C. C. Chen and J. K. Aggarwal, “Human detection using depth information by Kinect”, CVPR 2011 Workshops, Colorado Springs, 2011, pp. 15-22.

Destelle Francois, Ahmadi Amin, O'Connor Noel E., Moran Kieran, Chatzitofis Anargyros, Zarpalas Dimitrios, and Daras Petros, “Low-cost Accurate Skeleton Tracking Based on Fusion of Kinect and Wearable Inertial Sensors”, 2014 22nd European Signal Processing Conference (EUSIPCO 2014), Lisbon, Portugal, Sept 2014, pp. 371-375

Eugene K. Yen, Roger, and G.Johnston “The Ineffectiveness of the Correlation Coefficient for Image Comparisons,” Form No. 836 R5ST 2629 10/91.

S. Saengsri, V. Niennatrakul, and C. A. Ratanamahatana, “TFRS: Thai Finger-Spelling Sign Language Recognition System”, 2nd International Conference on Digital Information and Communication Technology and its Applications, p. 457-462, 2012.

N.Dalal, B Triggs: “Histogram of oriented gradients for human detection”, 2005 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'05), San Diego, CA, USA, 2005, pp. 886-893 vol. 1.

Jae-Han Park, Yong-Duk Shin, Ji-Hun Bae, and Moon-Hong Bang “Spatial Uncertainty Model for Visual Features using a Kinect™ Sensor”, Vol. 12, pp. 8640-8662, June 2012.

APPENDIX A

List of publications

International Conferences

[1] Vimonhak sombandith, Somsak Walairacht, Aranya Walairacht "Hand Gesture Recognition for Lao Alphabet Sign Language using HOG and Correlation" International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology, ECTI-CON2017, Phuket, Thailand, 27-30 June 2017.

[2] Vimonhak sombandith, Somsak Walairacht, Aranya Walairacht "Recognition of Lao Sentence Sign Language using Kinect Sensor" International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology, ECTI-CON2017, Phuket, Thailand, 27-30 June 2017.

AUTHOR BIOGRAPHY

Author: Ms. Vimonhak Sombandith

Degree: Master of Engineering

Date of Graduation: July 6th 2017

Date of Birth: January 19th 1989

Place of Birth: Vientiane, LAO PDR

Undergraduate and Graduate Education:

Master of Engineering in Computing in Engineering Systems,
King Mongkut's Institute of Technology Ladkrabang, Bangkok, 2016

Bachelor degree in Electronic Engineering,
The National University of Laos (NUOL), the capital of Laos, 2011

Major: Computing in Engineering Systems