Fist American Sign Language Recognition Using Leap Motion Sensor

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***Abstract*— The paper aims to solve the problem of the fist signs in American Sign Language because their recognition is not perfect due to the Euclidian distances of the fingertip to palm position used in 3D of those signs are similar, so it is difficult to recognize them. We therefore propose a system of fist American Sign Language recognition with a bare hand in depth plane by using 3D non-contact motion sensor. In this system, two patterns of the polygon area between the consecutive fingertip positions with palm position in depth plane by Shoelace formula are used to identify the fist sign language: 1) six triangles area, 2) one hexagon area, then a decision tree is applied to classify the alphabets. The results showed the 7 alphabets in fist ASL using the researcher's hand. The accuracy of the method proposed is approximately 96.1%.**

Keywords*— *American Sign Language (ASL); Leap Motion Controller (LMC); Fist alphabets; Shoelace formula; Deaf person

I. Introduction

In the world, the number of deaf and hard of hearing persons is approximately seventy million [1] and more than two hundred thousand in Thailand [2]. The deaf persons communicate by sign language. So, the signs are necessary for them. However, a normal-hearing person does not know much in sign language, of course, both normal-hearing and hearing-impaired persons cannot understand each other. Therefore, a researcher has been developed this system to help normal-hearing person understanding; however, the system had a problem with a big size and heavy weight to use a system in daily life and a less accuracy of fist signs because those hand shapes of fist signs are very similar.

As a result of less accuracy of fist signs, deaf person cannot be communicated perfectly. This has brought problem of communication; therefore, a greater accuracy system of fist signs in ASL for daily life is needed.

Many researchers have been working on ASL to improve recognition performance using different sort of devices. In 2012, Kunal Kadam and et al. [3] proposed ASL recognition using microcontroller, glove and flex sensor to measure the change in resistance value. The result showed the accuracy of 94%. However in 2015, Cao Dong and et al. [4] developed ASL alphabet recognition system using Microsoft Kinect, and a latex color glove and joint angle features were applied to recognize 24 static alphabets. The system showed accuracy of 92%; however, this system cannot use in daily life because this device is big. Moreover, Ponlawat Chophuk and et al. [5] developed ASL alphabet recognition using LMC with dot product to calculate a bent finger's angle. The system showed an accuracy of 87.17%. In this system, fist signs were not perfect as LMC cannot predict the position of the finger overlapped by other fingers correctly. Thus, ASL recognition system using the Myo armband that measured 8 channels of EMG signal around the muscles of forearm [6] was proposed by Lucas Silva Figueiredo and et al. Although it can be portable, fist signs were not perfect as the device had moved effect of the EMG signal. The system achieved an accuracy of 41%. So, Deepali Naglot and et al. [7] presented The Euclidian distances between the consecutive fingertip positions to palm position in 3D by LMC. The experimental results showed that the recognition rate reached 96.15%. Nevertheless, N and T alphabets were not perfect because the Euclidian distances of the fingertip to palm position proposed in 3D of those signs are similar, so it is difficult to recognize them.

According to the problem, this paper focuses improving an accuracy of the fist alphabets in ASL by calculating the polygon area between the consecutive fingertip positions and palm position of the right hand in the XZ plane applied by Shoelace formula and a decision tree as the XZ plane can identify the difference of fist signs better than 3D.

The rest of the paper is as follows, an introduction and overview of this system are presented in section I and II respectively. Then, section III shows proposed system. Afterward, section IV presents results for this system. Finally, the conclusion is proposed in section V.

II. Overview of the System

The system was implemented by the laptop (Toshiba L840) [8]. A program was built by Microsoft Visual Studio C++ 2013 [9]. The overview of this system is shown in Fig.1. The first step, fist alphabets were detected by LMC which can detect finger bone and provides palm and tip position of fingers, and used to evaluate and show the signs.

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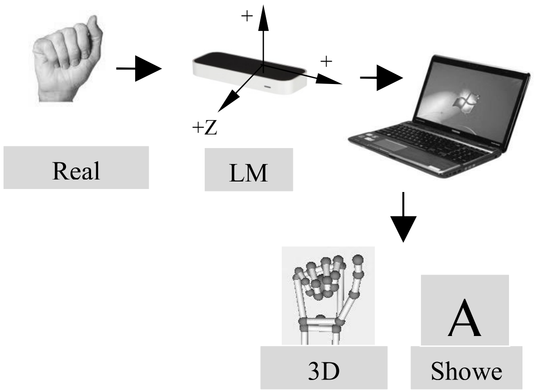


Fig. 1. Overview of the system

A. Leap Motion Controller (LMC)

This device is quite small and simple. It can detect hand and provides motion information such as position. Two cameras and three infrared LEDs is the heart of the device. Therefore, it can create a 3D space. Its sensory field, however, is limited by a narrow dome that extends around and above the sensor 2 feet, 2 feet wide, 2 feet deep and 8 cubic feet [10].

III. Proposed System

The system is designed to recognize the fist signs of American Sign Language with the bare hand. The proposed system consists of captured pose, feature extraction, shoelace algorithm, decision tree and showed signs as shown in Fig. 2.

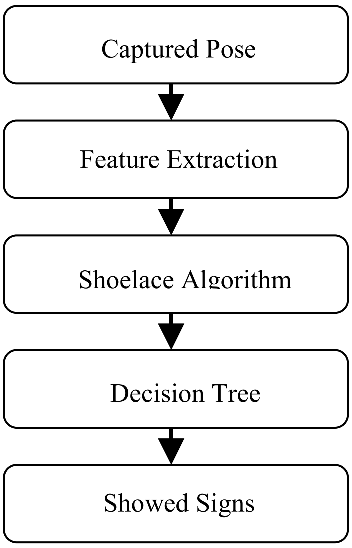


Fig. 2. Overview scheme of the system

A. Captured Pose

In this system, the fist signs of ASL are focused [11]. There are seven signs: A, E, O, M, N, S and T sign as shown in Fig. 3. Moving the thumb position is an indication of fist signs. So, the thumb position can be used for making data to indicate those signs.

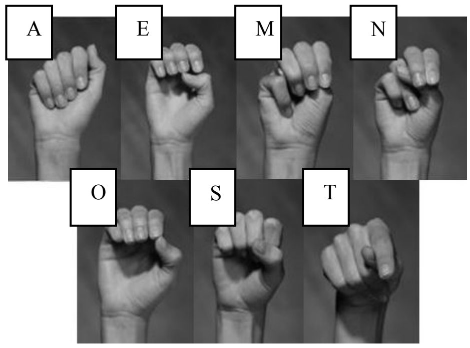
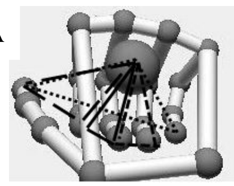
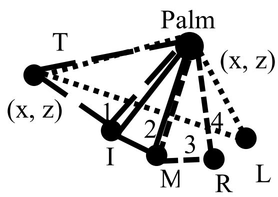
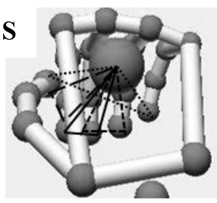
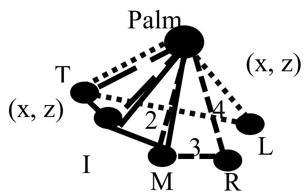
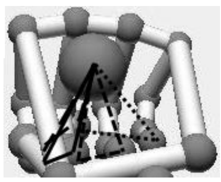
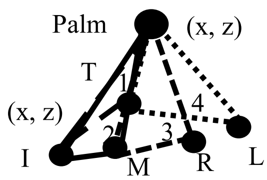


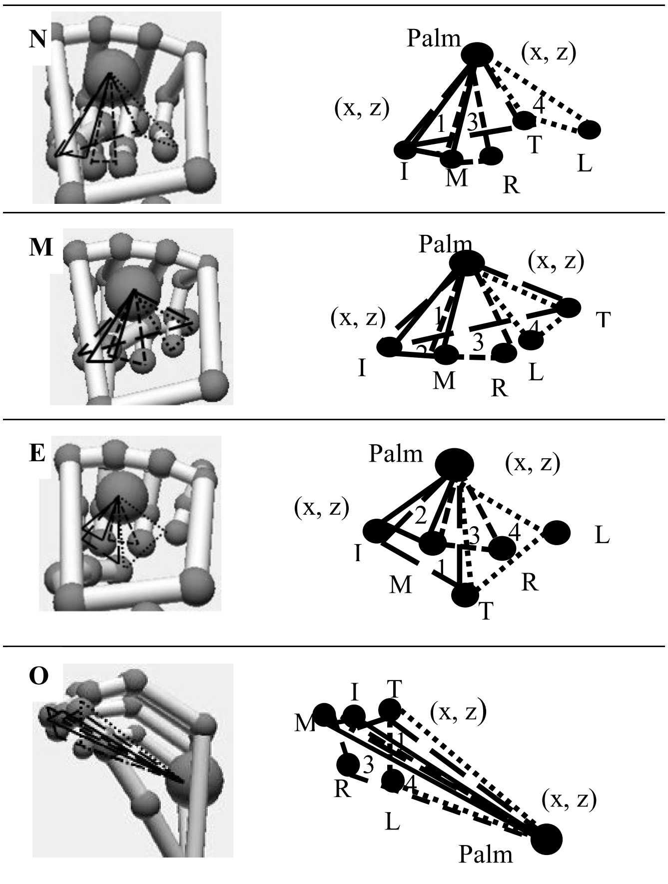
Fig. 3. The fist signs group

B. Feature Extraction

LMC provides motion information such as position. Hence, 5 fingertip position and palm position of the right hand in the XZ Plane are detected for this system. On the left side in Table I is a 3D scale model of the Leap Motion Interactive Controller of fist signs by researcher's hand which consists of A, S, T, N, M, E, and O alphabet. On the right side is feature extraction to make the polygon areas. They are divided into six triangles and one Hexagon area, but we show four types of triangle areas: area '1', area '2', area '3'and area '4' as shown in Table I which T, I, M, R and L stand for Thumb, Index, Middle, Ring and Little fingertip position respectively, and Palm stand for Palm position. Area '1' consists of Palm, T and I , area '2' consists of Palm, I and M, area '3' consists of Palm, M and R, area '4' consists of Palm, T and L, area '5' consists of Palm, T and M, area '6' consists of Palm, T and R, area '7' consists of Palm, T, I, M, R and L.

TABLE I. THE FEATURE EXTRATION OF FIST SIGNS BY AREA SYSTEM: AREA '1'(— —), '2'(———), '3'(- - -) ,'4'(······)

A		
S		
T		



C. Shoelace Algorithm

The algorithm is a mathematical algorithm to determine the area of a simple polygon whose vertices are described by their Cartesian coordinates in the plane. The formula can be represented by the expression [12].

$$A = \frac{1}{2}\left|\sum_{i=1}^{n-1} x_i z_{i+1} + x_n z_1 - \sum_{i=1}^{n-1} x_{i+1} z_i - x_1 z_n\right| \quad (1)$$

Where: A is the polygon area, n is the number of sides of the polygon, and $(x_i z_i), i = 1,2,..,n$ are the vertices. Table II shows the value of the triangle areas and the hexagon area of each sign from person collected the data. There are seven areas of six triangles and one hexagon. From the data of each sign is different, so this data can be used to identify the signs because everyone's hand structure is similar, thus the value areas of '1', '2', '3' and others are the same pattern, but the value areas are different. For example, although a big or small hand is tested, the value of area '1' of an alphabet is more than the area '2'. And you can see that the value of area '1' of the alphabet 'T' is less than the area '2', so the alphabet 'A' and 'B' can identify from the value area

TABLE II. THE VALUE AREA OF TRIANGLE AND POLYGON OF EACH FIST SIGNS IN PROPOSED METHOD

Alphabets	Triangle and polygon area (mm)^2						
	Name of the area						
	'1'	'2'	'3'	'4'	'5'	'6'	'7'
A	659	280	297	1149	921	1053	1210
S	57	284	290	793	409	583	691
T	231	230	275	601	20	319	283
N	492	239	245	410	223	67	11
M	707	259	293	115	508	218	143
E	518	183	243	772	59	331	156
O	627	270	505	1376	922	1223	1291

D. Decision Tree

Decision tree makes classification models in the form of a tree structure. It breaks down a dataset into smaller and smaller subsets [13]. The final result is a tree with decision nodes. For this system, the pattern proposed is shown in Table III. First of all, the pattern used for the proposed method is to arrange the value areas in ascending order, and ignore the value areas. For example, area '7', '6', '4', '5', '1' and '3' are arranged in decreasing order of alphabet 'A'. You can see that each sign is different. So, this pattern can be used to classify the signs, moreover the system can use with everyone's hand. A sample of decision tree of the fist signs is shown in Fig. 4. There are alphabets 'A', 'S', 'T', 'N', 'M', 'E' and 'O'. First of all, the value area '4' > '7' >'5' is defined, then 'A' and 'O' can pass this event, the second event the value area '3' > '1', alphabet 'M' will be shown.

TABLE III. TPATTERN OF PROPOSED METHOD

Alphabets	Area names Arrange the value area in ascending order
A	'7' > '6' > '4' > '5' > '1' > '3'
S	'4' > '7' > '6' > '5' > '3' > '1'
T	'4' > '6' > '7' > '3' > '1' > '5'
N	'1' > '4' > '3' > '5' > '6'> '7'
M	'1' > '5' > '3' > '6' > '7'> '4'
E	'4' > '1' > '6' > '3' > '7' > '5'
O	'4' > '7' > '6' > '5' > '1' >'3'

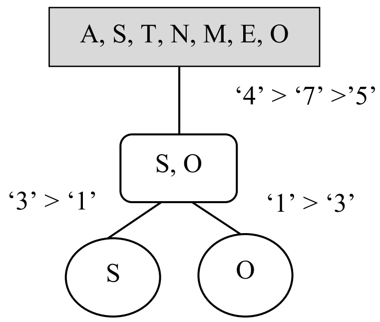


Fig. 4. The sample of decision tree of the fist signs

IV. RESSULTS

The data was collected using 4 persons, and 30 samples of each alphabet are collected. The program is set to detect a new alphabet approximately every 5 seconds. Table IV shows the accuracy of fist signs recognition for 100 times of each alphabet tested by the researcher who has not collected the data. The number of correct signs recognized is represented by the diagonal elements, and misrecognition is presented by the off-diagonal element. Moreover, "None" means that cannot identify the signs. For example, the letter 'O' provides the 94% of correct recognition, while the 6 % of showing no signs is presented. The experimental results, the proposed method achieved a high average accuracy of fist signs.

TABLE IV. THE ACCURACY OF FIST SIGNS RECOGNITION IN PROPOSED METHOD (%)

	A	S	T	N	M	E	O	None
A	100	0	0	0	0	0	0	0
S	0	100	0	0	0	0	0	0
T	0	0	98	0	0	0	0	2
N	0	0	0	95	5	0	0	0
M	0	0	0	4	96	0	0	0
E	0	0	0	0	0	90	0	10
O	0	0	0	0	0	0	94	6
None	0	0	0	0	0	0	0	0

Table V presents the percent accuracy of the fist alphabet, and compares with the previous methods. The previous method [5] obtained the minimum recognition accuracy because LMC cannot predict the finger positions overlapped by other fingers correctly. As result of this problem, fingertip and palm position have been used. In the conventional method [7], some alphabets are greater than the proposed method such as E alphabet because the Thumb position of this alphabet has always been easier to change than others, so the pattern of area value does not seem with the pattern collected. However, the average accuracy of the proposed method is higher than the conventional method.

TABLE V. FIST SIGNS RECOGNITION ACCURACY COMPARISON

Alphabet	**Accuracy (%)**		
	[5]	**Conventional method [7]**	**Proposed Method**
A	100	100	100
E	73.3	100	90
M	23.3	100	96
N	26.6	80	95
O	70	100	94
S	93.3	100	100
T	76.6	60	98
Accuracy Total (%)	66	91.4	96.1

V. CONCLUSION

This paper proposes the way to improve the fist alphabets recognition system in ASL by using 3D non-contact motion sensor. In this system, five fingertip position and palm position of the right hand in the XZ Plane are used to calculate the polygon area by Shoelace formula to identify the alphabet. Then, a decision tree is applied to classify the alphabet for precision. The results showed the fist alphabets using the researcher's hand. The accuracy of this method proposed is approximately 96.1%. In future, we will improve the recognition accuracy of 26 alphabets in ASL and also develop the system for using in daily life.

ACKNOWLEDGMENT

We would like to thank Prof. Dr. Kosin Chamnongthai for his time and effort, Moreover The financial support is provided by Petchra Pra Jom Klao Research Scholarship from King Mongkut's University of Technology Thonburi.

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