MALAYSIAN SIGN LANGUAGE RECOGNI TION FRAMEWORK BASED ON SENSORY GLOVE

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ABSTRACT

The purpose of this study was to propose a low-cost and real-time recognition system using a sensory glove, which has 17 sensors with 65 channels to capture static sign data of the Malaysian sign language (MSL). The study uses an experimental design. Five participants well-known MSL were chosen to perform 75 gestures throughout wear sensory glove. This research was carried out in six phases as follows: Phase I involved a review of literature via a systematic review approach to identify the relevant set of articles that helped formulate the research questions. Phase II focused on the analysis of hand anatomy, hand kinematic, and hand gestures to help understand the nature of MSL and to define the glove requirements. In Phase III, DataGlove was designed and developed based on the glove requirements to help optimize the best functions of the glove. Phase IV involved the pre-processing, feature extraction, and classification of the data collected from the proposed DataGlove and identified gestures of MSL. A new vision and sensor-based MSL datasets were collected in Phase V. Phase VI focused on the evaluation and validation process across different development stages. The error rate was used to check system performance. Also, a 3D printed humanoid arm was used to validate the sensor mounted on the glove. The results of data analysis showed 37 common patterns with similar hand gestures in MSL. Furthermore, the design of DataGlove based on MSL analysis was effective in capturing a wide range of gestures with a recognition accuracy of 99%, 96%, and 93.4% for numbers, alphabet letters, and words, respectively. In conclusion, the research findings suggest that 37 group's gestures of MSL can increase the recognition accuracy of MSL hand gestures to bridge the gap between people with hearing impairments and ordinary people. For future research, a more comprehensive analysis of the MSL recognition system is recommended.

RANGKA KERJA PENGECAMAN BAHASA ISYARAT MALAYSIA BERDASARKAN SARUNG TANGAN SENSORI

ABSTRAK

Objektif kajian ini adalah untuk mencadangkan satu sistem pengecaman kos rendah yang berfungsi dalam masa sebenar dengan menggunakan sarung tangan sensori yang mempunyai 17 penderia dengan 65 saluran untuk merakam data isyarat statik bagi bahasa isyarat Malaysia (BIM). Kajian ini menggunakan reka bentuk experimental melibatkan lima peserta yang mempunyai pengetahuan tinggi dalam bahasa insyarat Malaysia untuk menggunakan 75 gerak isyarat tangan dengan sarong tangan sensori. Kajian ini dijalankan dengan melibatkan 6 fasa seperti berikut. Fasa I melibatkan soroton literatur melalui pendekatan soroton sistematik untuk mengenalpasti set artikel yang releven untuk membina soalan-soalan kajian. Fasa II memberi fokus terhadap analisis anatomi tangan, kinematik tangan, dan gerak isyarat tangan untuk memahami sifat semula jadi BIM dan untuk mendefinasi keperluan sarung tangan yang dicadangkan. Dalam Fasa III, DataGlove direka bentuk dan dibangunkan mengikut keperluan sarung tangan dalam mengoptimakan fungsi sarung tangan yang dicadangkan. Fasa IV melibatkan pra-pemprosesan, pengekstrakan ciri, dan klasifikasi data yang dikumpul dari DataGlove dan gerak isyarat tangan BIM yang telah dikenal pasti. Satu dataset BIM berdasarkan penderia visi yang baru diperoleh dalam Fasa V. Fasa VI memberi fokus terhadap proses penilaian dan pengesahan dalam fasa pembangunan, di mana kadar ralat digunakan untuk menilai prestasi sistem dan satu lengan humanoid 3D digunakan untuk mengesahkan penderia yang dipasang pada sarung tangan berkenaan. Dapatan kajian menunjukkan terdapat 37 corak umum gerak isyarat tangan BIM yang sama. Tambahan lagi, reka bentuk DataGlove berdasarkan analisis BIM adalah berkesan dalam merakam pelbagai gerak isyarat dengan ketepatan pengecaman setinggi 99%, 96%, dan 93.4% untuk nombor, huruf abjad, dan perkataan, masing-masing. Sebagai rumusan, dapatan kajian ini mengesyorkan agar gerak isyarat BIM umum boleh digunakan untuk meningkatkan ketepatan pengecaman gerak isyarat BIM untuk merapatkan jurang antara mereka yang mempunyai masalah pendengaran dan orang awam. Untuk kajian akan datang, analisis yang komprehensif perlu dijalankan terhadap sistem pengecaman BIM.

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LIST OF ABBREVIATIONS

3D	Three Dimensions
ACC	Accelerometer
ASL	American Sign Language
ADC	Analog-to-Digital Converter
ArSL	Arabic Sign Language
AI	Artificial Intelligence
ANN	Artificial Neural Networks
ASLR	Auto Sign Language Recognition
BIM	Bahasa Isyarat Malaysia
BN	Bayesian Network
CSL	Chinese Sign Language
CRF	Conditional Random Field
DOF	Degree of Freedom
FSR	Force Sensing Resistor
FSL	French Sign Language
GLCD	Graphical Liquid Crystal Display
Gyro	Gyroscope
HMM	Hidden Markov Models
HCI	Human-Computer Interaction
(ISL)	Indian Sign Language
IMUs	Inertial Measurement Units
JSL	Japanese Sign Language
k-NN	K-Nearest Neighbor

LED	Light-Emitting Diode
LDA	Linear Discriminant Analysis
ML	Machine Learning
MAG	Magnetometer
Mag	Magnetometer
MSL	Malaysian Sign Language
MS	Manual Signals
MCU	Microcontroller Unite
MEMS	Micro-electro Mechanical System
ME	Movement Epenthesis
EMG	Multi-Channel Electromyography
NN	Neural Network
NMS	Non-Manual Signals
PSL	Pakistan Sign Language
PaHMM	Parallel Hidden Markov Models
PSL	Polish Sign Language
PIC	Programmable Intelligent Computer
SD	Secure Digital
SL	Sign Language
SLR	Sign Language Recognition
SEE	Signing Exact English
SVM	Support Vector Machine
TSL	Taiwan Sign Language
TOF	Time of Flight

LIST OF GLOSSARY

Term	**Definition**
Abduction-Adduction	Movements of limbs and other body parts toward or away from the centerline of the body (a line that runs up and down to the centre of the human body) are termed adduction and abduction, respectively. Adduction is the movement of a body part toward the body's midline.
BIM	The main language of the deaf community of Malaysia. BIM has many dialects, differing from state to state
DataGlove	A device is worn as a glove equipped with sensors and another instrument, which allows the manual manipulation of gesture recognition.
Deaf	Lacking the power of hearing or having an impaired hearing (or unable to hear or pay attention to something.)
Digit	A finger, thumb, or toe.
Disabled Person	A person is having a physical or mental condition that limits their movements, senses, or activities.
Dumb	Temporarily unable or unwilling to speak.
Finger Bend	Shape or force (Finger straight) into a curve or angle.
Finger Flex	The action of bending or the condition of being bent, especially the bending of a limb or joint.
Finger Twisting	Twist around one's finger. Also, turn, wind, or wrap around one's finger.
Flexion-Extension	Motion, the process of movement, is described using specific anatomical terms. The move includes movement of organs, joints, limbs, and particular sections of the body. The terminology used describes this motion according to its direction relative to the anatomical position of the joints.
Inertial Measurement Unit	Is an electronic device that measures and reports a body's specific force, angular rate, and sometimes the magnetic field surrounding the body, using a combination of

	accelerometers and gyroscopes, sometimes also magnetometers.
Micro-electro Mechanical System MEMS	Micro-Electro-Mechanical system is the technology of microscopic devices, particularly those with moving parts. It emerges at the Nano-scale into nanoelectromechanical systems and nanotechnology.
Mute	Refraining from speech or temporarily speechless.
Ordinary Person	A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.
Sensory Glove	An input device for human-computer interaction worn like a glove. Various sensor technologies are used to capture physical data such as bending of fingers.
Sign Language	A system of communication using visual gestures and signs, as used by deaf people.
Speechless	Unable to speak, especially as the temporary result of shock or strong.

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION AND RESEARCH BACKGROUND

1.1 Introduction

This chapter outlines our work by providing a brief background on the research direction, clarifying the problem of research followed by the ambitions and motivation of this research, which is accomplished by achieving the research objectives.

In next Section 1.2, a brief background regarding the research topic is presented. In Section1.3, display the problems identified that drawn the direction of this work. In Section 1.4, and Section 1.5, research objectives and research questions are reported respectively. The scope of this study is presented in Section 1.6. Finally, outline the main structure of the thesis are briefly stated in Section 1.7.

1.2 Problem Background

Individuals with special needs suffer discrimination and different barriers that restrict their participation in various community activities. Due to the lack of proper human communication, they are deprived of their rights to living, move or even working independently. Human communication is a two-way process of reaching mutual understanding, in which participants not only exchange information, news, ideas and feelings but also create and share meaning. In general, communication is a means of connecting people. Regrettably, a large number of people with special needs suffer from extreme poverty and neglect (Aguiar et al., 2016). Disability complexity relies on the type and degree of disability. Interventions to overcome disability-related problems are multiple and systematic and vary according to the context. This work is concerned with persons to possess hearing and speech impairment (deaf and dumb).

According to the statistics of the World Federation of the Deaf and the World Health Organization, approximately 70 million people in the world are deaf-mute. 360 million people are deaf, and 32 million of these individuals are children (organisation; Fact sheet Updated February 2017 ;). The majority of speech- and hearing-impaired people cannot read or write in regular languages. Sign language (SL) is the native language used by the deaf and mute to communicate with others. SL relies primarily on gestures rather than voice to convey meaning. It combines the use of fingers, shapes, hand movements, and facial expressions (V. Sharma, Kumar, Masaguppi, Suma, & Ambika, 2013). Sign language suffers from several defects, in particular, a considerable number of hand movements, limitation in the language vocabularies, and learning difficulties. Furthermore, SL is not a common way to communicate ordinary people (wherein, it is the primary communication way among disables). Therefore, disabled people face severe difficulties in communicating with others. This communication barrier adversely affects the life and social relationships of deaf people (Bhatnagar, Magon, Srivastava, & Thakur, 2015). Thus, disables need medium (e.g., translator device) to communicate with ordinary people. Several researchers and developers are exploring techniques to allow communication between disables and original people (i.e., vision-based sign language translators, sensor-based sign language translators, etc.). Sensor-based glove seems to be a more practical solution by which disables wore a sensory glove that can read the gestures and translate it into words. Several benefits of using such device, particularly, less complexity with data processing (Tanyawiwat & Thiemjarus, 2012), no limitations on movements (i.e. sitting behind a desk or chair). Also suite with different environment (i.e. hand shape recognition is not affected by the background condition) (Kanwal, Abdullah, Ahmed, Saher, & Jafri, 2014; Vutinuntakasame, Jaijongrak, & Thiemjarus, 2011), lightweight (i.e., SLR-based glove device is wearable, high mobility and comfortable) (Arif, Rizvi, Jawaid, Waleed, & Shakeel, 2016; Fu & Ho, 2007). Apart from that, such a recognition system can be employed to learn SL for both dumb and ordinary people (Sriram & Nithiyanandham, 2013). Furthermore, a number of applications are currently involved in gesture recognition systems such as SLR, substitutional computer interfaces, socially assistive robotics, immersive gaming. Also, virtual objects, remote control, medicine-health care, gesture recognition of hand/body language, etc. (Bedregal & Dimuro, 2006; Borghetti, Sardini, & Serpelloni, 2013; El Hayek, Nacouzi, Kassem, Hamad, & El-Murr, 2014; Hoque et al., 2016; Phi, Nguyen, Bui, & Vu, 2015; Pławiak, Sośnicki, Niedźwiecki, Tabor, & Rzecki, 2016). These benefits are described in detail in Section 2.5.1.

1.2.1 Sign Language

In the world, almost every country has its official sign language (Vijay, Suhas, Chandrashekhar, & Dhananjay, 2012), for instance, American Sign Language (ASL) (Kadam, Ganu, Bhosekar, & Joshi, 2012), Arabic Sign Language (ArSL) (Tubaiz, Shanableh, & Assaleh, 2015), French Sign Language (FSL) (Kadam et al., 2012), Japanese Sign Language (JSL) (Sagawa & Takeuchi, 2000), Polish Sign Language (PSL) (Oszust & Wysocki, 2013), and others. Similarly, in Malaysia, the official sign language is the Malaysian Sign Language (MSL), also known as Bahasa Isyarat Malaysia (BIM). BIM was developed in the 19th century. This language has been inherited from old ASL (Majid, Zain, & Hermawan, 2015). In this work, the Malaysian sign language (MSL) has been explored due to the lack of studies directed in this field.

SL is a visual-spatial language based on positional and visual components, such as the shape, location, and orientation of the fingers and hands alongside with arm and body movements. These components are used together to convey the meaning of an idea. The phonological structure of SL generally has five elements as shown in Figure 1.1.

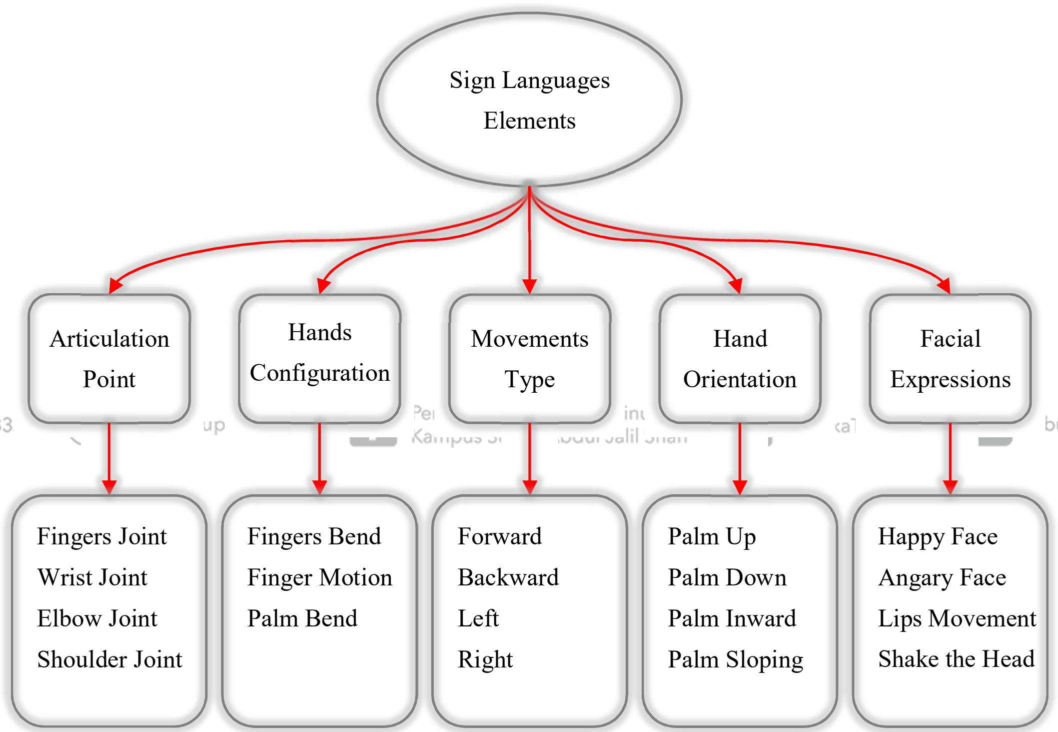

Figure 1.1. The Essential Elements Related to Sign Language Gesture Formation

Each gesture in SL is a combination of five mentioned blocks. These five blocks represent the valuable elements of SL and can be exploited by automated intelligent systems for SL recognition (Shortly SLR) (Ramli, 2012).

1.2.2 Sign Language Recognitions

Language is a way of communication among human. Different communities used different languages. When a person from a particular community wants to contact a person from other community, he/she are required to use either common language where both understand or using translators to communicate. Similarly, sign language is the way of communication among deaf /dumb people., A translators are required to shorten the gap between deaf and ordinary people. One of the critical interventions is SLR systems that are utilised to translate signs performed by deaf and dump people into text or speech. These translators are established to allow communication with those who do not know these signs (Anderson, Wiryana, Ariesta, & Kusuma, 2017). Towards this end, there are three types of translators suggested in the academic literature, sensor-based sign language recognition, vision-based sign language recognition and hybrid of sensor-vision sign language recognition as shown in Figure 1.2.

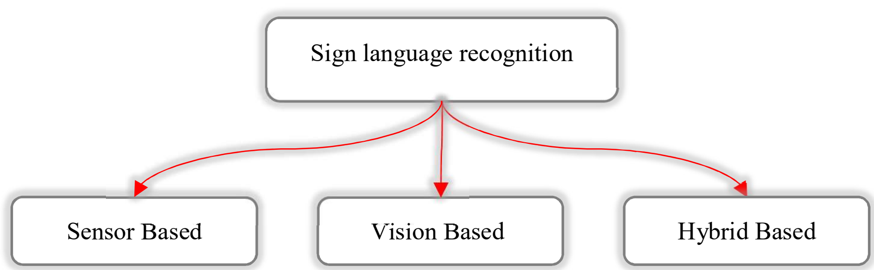

Figure 1.2. Sign Language Recognition Approaches

SLR systems based on the sensory glove are among the most significant endeavours aimed at procuring data for the motion of human hands. The use of a specific type of instrumented gloves that are fitted with various sensors, namely, flexion (or bend) sensors, accelerometers (ACC), proximity sensors, and abduction sensors, is an alternative approach that enables to acquire gesture-related data as shown in Figure 1.3.

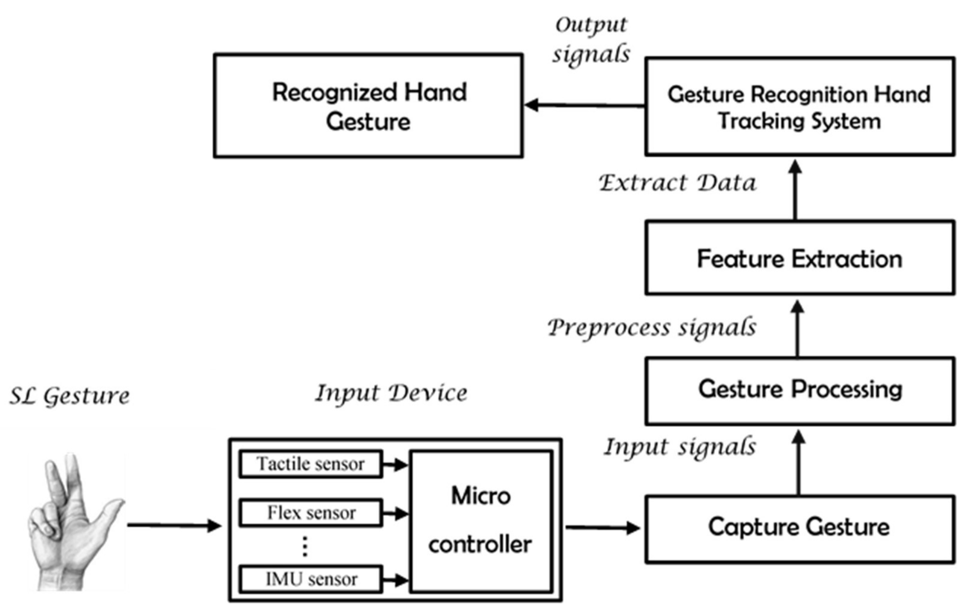

Figure 1.3. The Main Phases Concerning Collecting and Recognizing SL Gestures Data using The Glove-Based System

These sensors are used to measure the bend angles for fingers, the abduction between fingers, and the orientation of the wrist. Degrees of Freedom (DOF) that can be realised using such gloves vary from five to twenty-two, depending on the number of sensors embedded in the glove. A significant advantage of glove-based systems over vision-based systems is that gloves can directly report relevant data (degree of bend, pitch, etc.)

in terms of voltage values to the computing device (Vijayalakshmi & Aarthi, 2016), thus eliminating the need to process raw data into meaningful benefits.

Vision-based systems use cameras as primary tools to obtain the necessary input data as shown in Figure 1.4. The main advantage of using a camera is that it removes the need for sensors in sensory gloves and reduces the building costs of the system. Cameras are quite cheap, and most laptops use a high specification camera because of the blur effect performed by a web camera. However, despite the high specification camera, which most smartphones possess (Anderson et al., 2017), there are various problems of adopting vision based SLR. In particularly, the limited field of view of the capturing device, high computational costs (Alvi et al., 2004; Kumar, Gauba, Roy, & Dogra, 2017), and the need for multiple cameras to obtain robust results (due to problems of depth and occlusion) (Erol, Bebis, Nicolescu, Boyle, & Twombly, 2007; Luqman & Mahmoud, 2017). These issues create barriers when it comes to real-time recognition systems. By contrast, vision-based systems need to apply specific tracking and feature extraction algorithms to raw video streams, thereby increasing the computational overhead (Chouhan, Panse, Voona, & Sameer, 2014; Phi et al., 2015).

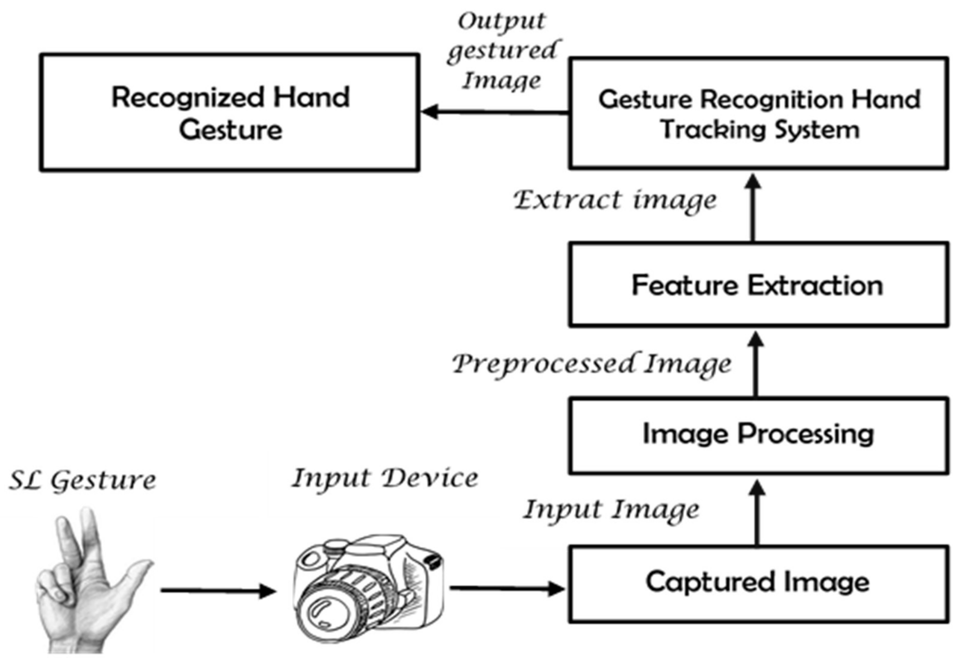

Figure 1.4. A Flow Chart of The Processing Steps Used in The Vision-Based System for SLR (Vijayalakshmi & Aarthi, 2016)

The third method of collecting raw gesture data employs a hybrid approach that combines glove and camera-based systems. This approach uses mutual error elimination to enhance the overall accuracy and precision. However, not much work has been carried out in this direction due to the cost and computational overheads of the entire setup. Nevertheless, augmented reality systems produce promising results when used with a hybrid tracking methodology (Bhatnagar et al., 2015). On the other hand, SLR research has a possible influence on human-computer interaction (HCI), where the two types of languages (signed and phonetic), can in principle be used as an interface to interact with computers (Kumar et al., 2017; Majid et al., 2015).

With the scope of Malaysian sign language, there is a severe lack of work in solving this humanitarian problem. In particular, there are a minimal number of articles published to address the issue of Malaysian sign language gestures recognition, where only three studies in the literature covered in the scope of this research. In general, quite a few scholarly articles have been published on the problem of recognising the sign language of BIM on various aspects.

1.3 Problem Statement

Several challenges related to the development of sensory DataGlove sign language recognition approaches are reported in the academic literature. Each challenge associated with some issues and aspects, which are summarised in Figure 1.5, and explained in the following:

The first challenge is related to glove design and usage. Several problems related to glove designs and human usage. For instance, performing a particular sign for multiple time by the same user results different values (Oz & Leu, 2007). Also, hand size differences between users (Dipietro, Sabatini, & Dario, 2008), position of sensors, material and usage of the gloves effect the accuracy (Borghetti et al., 2013; Kau, Su, Yu, & Wei, 2015).Furthermore, finger verity of length required changing the position of sensors or pre-calibration process whenever the user changed (Khan, Gupta, Bailey, Demidenko, & Messom, 2009; Oz & Leu, 2007; Kau et al., 2015), trade-off between the number of sensors, accuracy of recognition and data processing complexity (Ibarguren, Maurtua, & Sierra, 2010; Kanwal et al., 2014).

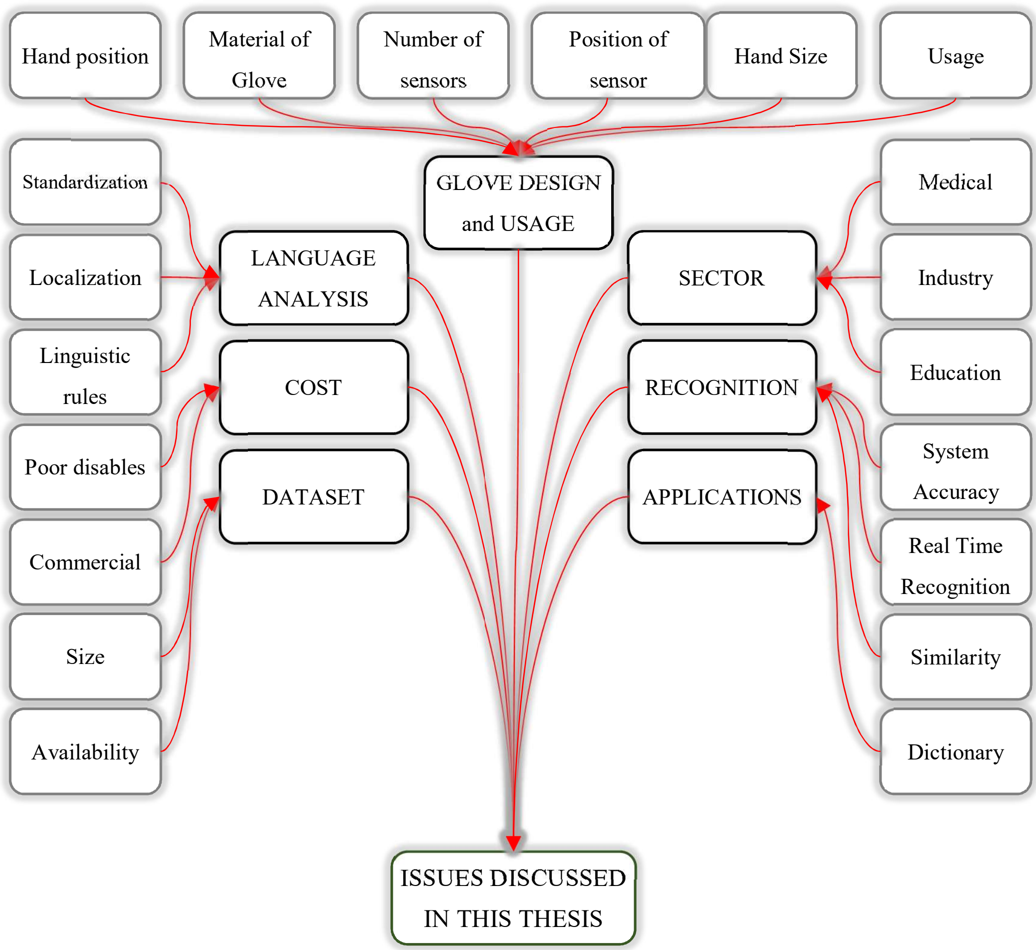

Figure 1.5. Summary of Issues Discussed in This Thesis

Type of sensors is another issue related to the glove design. There are two issues related to sensor type. The first issue is to utilize the available sensors and exploring newly available sensors in the market to improve the accuracy (Abhishek, Qubeley, &

Ho, 2016; Harish & Poonguzhali, 2015). The second issue is related to the quality of the sensors which needs more test and performance analysis (Fu & Ho, 2007; Ibarguren et al., 2010).

The second challenge is related to the cost. Two cost aspect related to the cost challenge, the first aspect is associated with the cost of the gloves where the commercial gloves price between 1,000$ to 20,000$ (Adnan et al., 2012; El Hayek et al., 2014; Phi et al., 2015), perhaps one of the main barriers of not having much research on BIM. The users relate the second issue to glove usage. Because of the cost, the new technology might help rich people rather than poor people (Bajpai, Porov, Srivastav, & Sachan, 2015; Kau et al., 2015). Therefore, there is a need of low-cost development of sensory DataGlove sign language recognition system (Abualola, Al Ghothani, Eddin, Almoosa, & Poon, 2016; S. F. Ahmed, Ali, & Qureshi, 2010; Vijay et al., 2012).

The recognition system is another challenge related to the accuracy of. There are three issues related the recognition accuracy, glove performance, real-time recognition, and signs similarities respectively. Standard evaluation procedure of glove performance is yet to be reported. Therefore, a clear procedure to evaluate the overall system might contribute to the advancement of DataGlove development (Dipietro et al., 2008). Similarly (Ibarguren et al., 2010). While system accuracy is measured with small scale data in term of number and complexity (Fu & Ho, 2008). The second issue is related to real-time recognition. Real-time recognition is another issue when it comes to recognition accuracy (Ibarguren, Maurtua, & Sierra, 2009). Practically, the real-time application is preferable towards developing a final product; however, the accuracy is still a barrier of developing such approach (Bajpai et al., 2015; Gupta, Singh, Pandey, & Solanki, 2015). The last issue related to the accuracy is the similarity between the signs, e.g., in the ASL alphabet, the letters “N,” “M,” “T,” and “S” are signed with a closed fist (Bui & Nguyen, 2007). Another example is the gesture of “V” and “U” character, which produces an error (Abualola et al., 2016).

Perhaps, sign language analysis is one of the fundamental challenges when a large-scale project aims to develop sign language recognition proposed. There are three issues summarised from the academic literature with the scope of sign language analysis (i.e., grammatical rules, localisation, and standardisation). Grammar and grammatical rule have been widely discussed in academic literature. Structure of words, sentence, and phrases that consist of gestures are required to be investigated (Dipietro et al., 2008; Tanyawiwat & Thiemjarus, 2012; Zhang et al., 2011). It should be noted that different sign language has different linguistic rules (Kadam et al., 2012; Pradhan, Prabhakaran, & Li, 2008). In addition to that, understanding the gestures angles, orientations and other features alongside with the sensors that can acquire the relevant data per sign is necessary to develop a robust SLR system (Das, De, Paul, Chowdhury, & Neogi, 2015). Extra features acquired from extra sensors can help to recognize two different signs with a similar shape (e.g., letters 'U,' and 'V') (Aguiar et al., 2016). Other sensors can be located at the arm joint and shoulders to distinguish more complicated signs (Ibarguren et al., 2010; Lei & Dashun, 2015; Oz & Leu, 2011; Pradhan et al., 2008; Swee, Ariff, Salleh, Seng, & Huat, 2007). Therefore, a combination of different types of abduction can capture more complicated gestures (Al-Ahdal & Nooritawati, 2012; Bhatnagar et al., 2015; Elmahgiubi, Ennajar, Drawil, & Elbuni, 2015; Fu & Ho, 2008; Sadek, Mikhael, & Mansour, 2017; Sriram & Nithiyanandham, 2013). However, using lightweight and fewer sensors helps to simplify the hardware complexity (Arif et al., 2016). Localization means investigating local sign language to elaborate and analyze this particular sign language towards standardizing gesture and group it afore developing SLR system (Arif et al., 2016). While generalizing (i.e., globalize) the glove is yet a far target required long exploration (Trottier-Lapointe et al., 2012).

Investigate the available of dataset shows a lack of large-scale data size and availability of dataset. This challenge burden the researchers from developing new recognition algorithms. In addition to that, to develop a recognition system, researchers are required to develop the gloves or using commercial gloves, and thus researchers are avoiding the complexity of such projects (Kanwal et al., 2014). Available datasets utilized in the academic literature are either small size or limited to a few gestures (Arif et al., 2016). In other hand, the availability of large scale dataset can save time and efforts to develop accurate SLR algorithms (S. Ahmed, Islam, Zishan, Hasan, & Islam, 2015; Ani, Rosli, Baharudin, Abbas, & Abdullah, 2014; Borghetti et al., 2013; Chouhan et al., 2014; Das et al., 2015; Gupta et al., 2015; Shukor et al., 2015).

Other minor challenges are related to the gloves applications such as using SLR to teach the sign language (Arif et al., 2016). Teaching disable persons (Abdulla, Abdulla, Manaf, & Jarndal, 2016), gesture recognition technology can be utilized in machine maintenance (López-Noriega, Fernández-Valladares, & Uc-Cetina, 2014; Pradhan et al., 2008; Tanyawiwat & Thiemjarus, 2012), virtual reality sector (e.g. wearable mouse glove, wearable keyboard-glove, virtual musical appliances, computer games, simulated environment, etc.) (Luqman & Mahmoud, 2017), medical industry, such as telesurgery (Das et al., 2015; Kau et al., 2015) and finally, develop a dictionary for sign language (Kosmidou & Hadjileontiadis, 2009).

Concerning MSL, very few articles are reported in the academic literature. Out of 71 articles published with the scope of sensory DataGlove sign language recognition there are only three articles discussed the development of Malaysian sign language recognition system (one development article and two frameworks) (Shukor et al., 2015; Swee, Ariff, et al., 2007; Swee, Salleh, et al., 2007). Several issues reported in these articles. In particular, these articles developed in small scale test, no dataset publicly published associated with these articles, glove tested is limited to tilt sensor to measure finger angle, no sign language analysis was provided, glove limited to SLR while the accuracy was high due to the number of signs used during the experiment (as few as nine signs). Therefore, there are several lacks on the development of Malaysian sign language recognition.

This research is an attempt to discuss comprehensive Malaysian sign language recognition with several aspects reported in Figure 1.5.

1.4 Research Objective

The main research objective is to develop an intelligent gesture recognition framework based on a sensory approach for MSL by capturing hand orientation with detect finger bend. The purpose is to build a translator system to assist the deaf to communicate with ordinary people. Towards this end, this research proposed the following objectives:

1. To analysis hand gestures of Malaysian sign language based on anatomy, kinematic and configuration of hand.
2. To design and develop a DataGlove module for Malaysian sign language based on the requirement resulted from objective two.
3. To design and develop a recognition approach for Malaysian Sign Language static gestures performed by the proposed DataGlove module.
4. To design and develop a dataset of MSL signs using DataGlove to construct the guideline dictionary.

1.5 Research Questions

This research attempts to answer some research questions formed from analysing the academic literature. The proposed questions are associated with the relevant objectives as reported in Table 1.1.

Table 1.1

The Six Main Question of the Research

Research Questions	Research Objectives
Q1: Is it possible to module Malaysian sign language into patterns and groups based on kinematic, anatomy and configuration of hand?	Obj1: To analysis hand gestures of Malaysian sign language based on kinematic, anatomy and configuration of hand.
Q2: Does the position of sensors in the glove produce data value? Q3: What is the optimal glove design in term of sensor position, sensor number, sensor type and the combination of sensors?	Obj2: To design and develop a DataGlove module for Malaysian sign language associated with the second objective.
Q4: Does the proposed design of sensory glove is capable of improving the recognition accuracy rate for Malaysian Sign Language?	Obj3: To design and develop a recognition approach for Malaysian Sign Language static gestures performed by the proposed DataGlove module.
Q5: Does construct a dataset of Malaysian sign language using sensory glove is an achievable task?	Obj4: To design and develop MSL signs dataset-using DataGlove in order to construct the guideline dictionary.

1.6 The scope of the Study

The approach utilised in this work to collect signs data is the sensor-based DataGlove, wherein a glove containing a variety of sensors is developed to perform particular functions. This function reads a Malaysian Sign Language posture. Figure 1.6, shows a diagram of the main points of study scope.

- Only signs that are executed with a single hand will be handled in the performance experiments and database creation. Therefore, the glove is designed to acquire the right-hand data.
- As for the gesture, signs involved in this experiment do not interfere with the movement in its formation; in other word, static gestures are targeted in this work.
- The system is designed to distinguish only static, isolated words of Malaysian Sign Language.

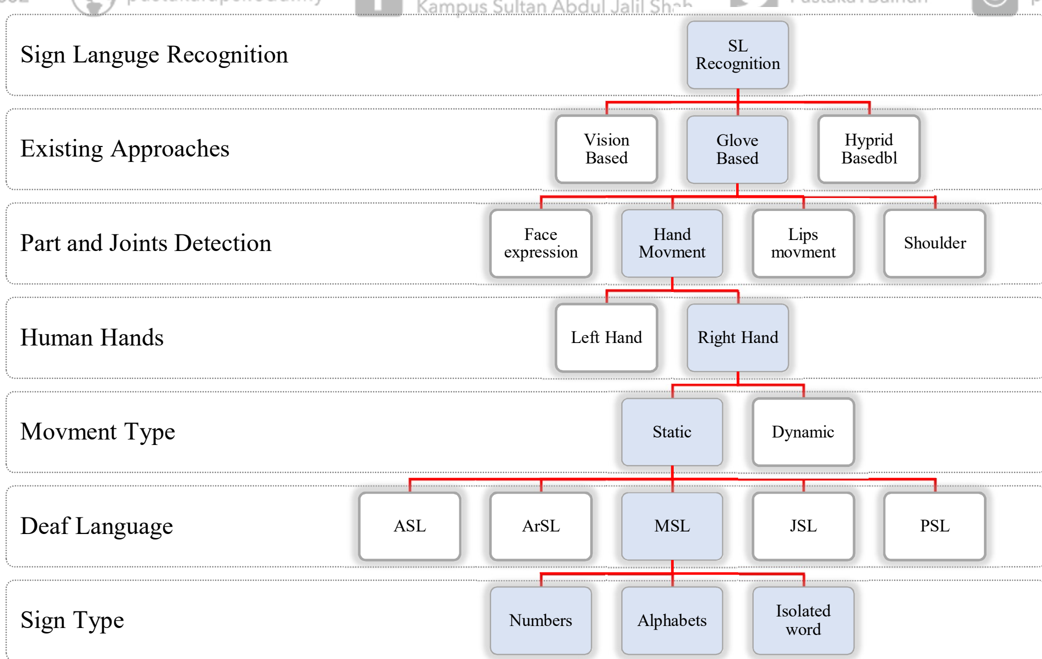

Figure 1.6. The Scope of Study Diagram; only The Shapes That are Painted Light Blue is Related to This Study

1.7 Thesis Layout

This search composed of eight chapters and Table 1.2 presents the primary goal of each chapter, while Figure 1.7 illustrates the surmised of the main point, which discussed in each chapter.

Chapter one: In Chapter 1, a brief introduction and overview of the research are provided. The problem statement, identify the research objective, the scope of the work, are present also followed by thesis layout.

Chapter Two: In Chapter 2, an in-depth investigation was conducted about the previous studies reported in the SLR field, which based on sensor approach. A systematic review protocol is developed to collect the relevant articles from the academic literature. Selected articles are then reviewed to extract the challenges and produce a taxonomy for the research resources.

Chapter Three*:* In this chapter, the research methodology is designed and discussed to develop a framework for Malaysian SLR. This research is outlined in six phases represents the research objectives — one objective per chapter.

Chapter Four*:* The description of the MSL analysis module is provided in Chapter 4. The objective behind developing MSL analysis is to identify the constraints that may have influential on hand poses through hand anatomy, analysis MSL context, parameters, hand attributes, and related academic literature to this purpose.

Chapter Five: Sensors testing, performance analysis and benchmarking of the various sensors were presented in Chapter 5. The evaluation method of DataGlove performance is developed and followed by the DataGlove validation.

Chapter Six: In this chapter, experiments and performance analysis of various DataGlove designs are presented. Furthermore, highlighting the purpose of each sensor used and issues discussed. Finally, new DataGlove is designed, developed and evaluated.

Chapter Seven: In this chapter, database importance, dataset creation, as well as the methodology of building the DataGlove dataset of MSL, are reported. Similarly, the development of vision-based dataset is reported in this chapter.

Chapter Eight: The summary of the research finding, contribution, review of claims and comparative analysis of the research outputs are reported in Chapter 8. Research limitation, further research proposals, and the conclusion are also presented.

Table 1.2

List of the Goals of the Thesis Chapters

Chapter	Research Goals
One	Introduces the research topic, brief background, of the problem statement, and research objectives and define the scope of this research.
Two	Surveys the literature in SLR area, taxonomised the information, identifying gaps in current knowledge, showing the weaknesses, challenges, and points of view and critically analyses the gathered information.
Three	Present the theories underpinning this research, research strategy, and the materials and technique applied.

(continue)

Table 1.2 *(continued)*

Chapter	Research Goals
Four	To underline the relation between the kinematic hand model and SL postures, analysis of important hand attributes. In addition to discovering the relationship between the signs and extract patterns of the formation of the signs
Five	Select the suitable sensors for developing data glove based on evaluation and benchmarking
Six	Developing a new design of DataGlove for SLR based on sensor approach. Also, develop a recognition approach for static gestures of MSL.
Seven	Create dataset belonged to MSL and collected by using new DataGlove.
Eight	Summary of the main findings, research contributions, study limitations, and future work, of this research

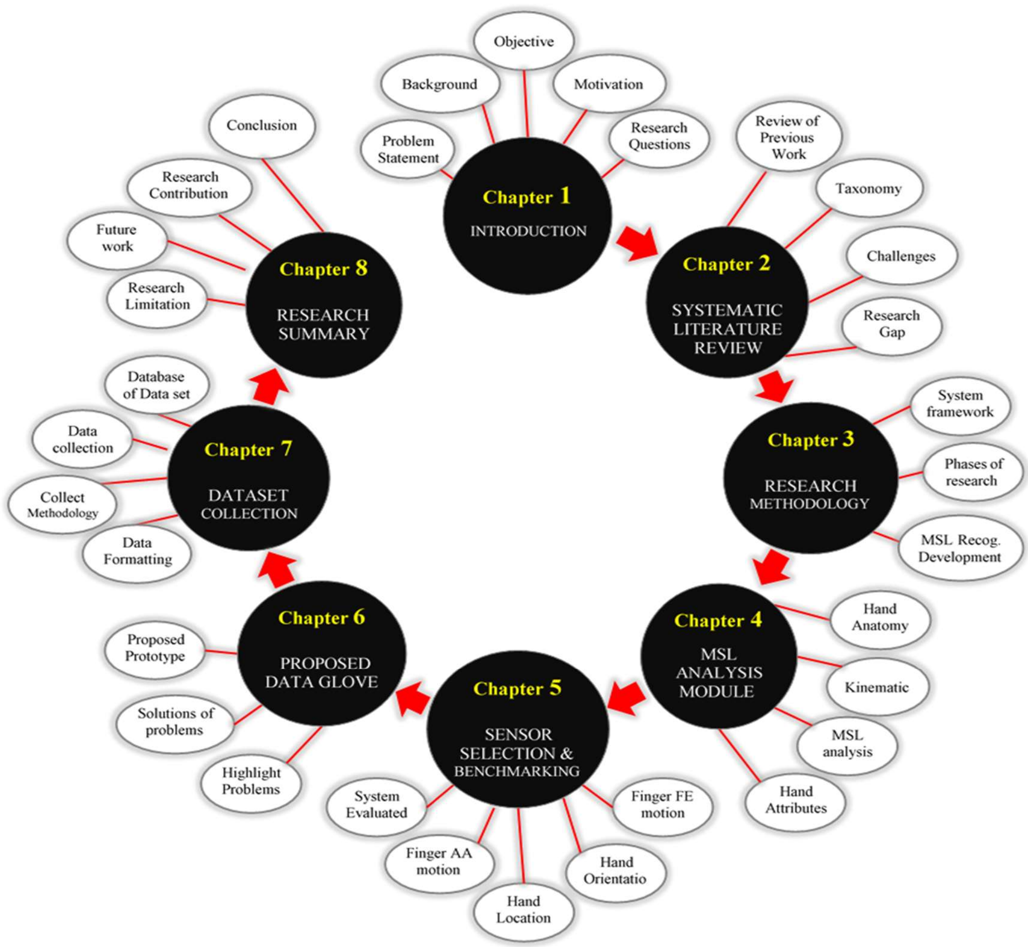

Figure 1.7. Thesis Layout and Summarised Main Points of Each Chapter