INVESTIGATION OF DATA GLOVE GRASPING FEATURES: SUM OF MOVEMENT AND AREA UNDER CURVE

by

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ABSTRAK

Perkembangan teknologi yang pesat pada era ini telah menghasilkan perubahan dalam interaksi antara manusia dan komputer (HCI). Sarung tangan maklumat adalah salah satu penderia teknologi yang terhasil dari kemajuan HCI. Sarung tangan maklumat menyediakan maklumat yang penting mengenai genggaman jari bagi HCI dengan menyediakan data jari yang dibengkokkan. Sepanjang zaman ini, pelbagai prototaip sarung tangan maklumat telah dicipta oleh penyelidik untuk aplikasi HCI. Sarung tangan UniMAP atau GloveMAP adalah antara salah satu contoh prototaip sarung tangan maklumat yang menggunakan penderia mudah lentur untuk mengesan pergerakan jari. GloveMAP mampu untuk membekalkan hasil voltan seiring dengan tahap pembengkokkan jari yang amat penting dalam mereka-ciptaa plikasi HCI. Walaubagaimanapun, pemerolehan maklumat daripada sarung tangan maklumat perlu diproses dan dianalisis untuk melatih computer supaya berupaya untuk mengesan aktiviti menggenggam jari dengan berkesan. Oleh itu, suatu penyiasatan direka untuk menyiasat beberapa kaedah pengekstrakan ciri dengan bantuan pengunaan pengelompokan jenis dipantai dan tidak dipantau. Selain itu, hasil voltan GloveMAP juga akan diringkaskan kepada nilai sudut bengkokan jari. Tujuan utaman kajian ini adalah untuk mengenalpasti objek yang digenggam dengan menggunakan pengekstrakan ciri dan teknik pengelompokan. Pengelompokan K-means dan Linear Discriminant Analysis (LDA) digunakan bersama dengan berbagai teknik pengekstrakan ciri untuk mendapatkan kadar pengecaman objek. Sudut cerunan (θ), panjang cerunan (ℓ), varians (σ^2), purata ($\bar{x}$), penengah (m), sisihan piawaian (σ), dan teknik pengekstrakan ciri yang dicadangkan iaitu jumlah pergerakan (*SuM*) dan ruang dibawah lengkung (*A*) diproses bersama dengan teknik pemilihan ciri untuk memilih ciri-ciri yang sesuai untuk pengecaman objek. Diakhir kajian, kadar pengecaman untuk pengelompokan k-means dan LDA. Keputusan eksperimen menunjukkan bahawa LDA mencapai sehingga 88.4% kadar pengecaman menggunakan ciri *SuM* dan *A*, manakala k-means mencapai sehingga 85.0% kadar pengecaman menggunakan ciri *SuM* dan *A*.

Investigation of Data Glove Grasping Features: Sum of Movement and Area Under Curve

ABSTRACT

The rapid development of technologies that are emerging during this era produces the evolution of human-computer interaction (HCI). Data Glove is one of sensor technologies resultant from HCI advancement. Data Glove provides vital information of finger grasping activities for HCI by providing physical data of finger bending. Over the centuries, various prototypes of data glove have been design by researcher for HCI application. UniMAP Glove or GloveMAP is an example of data glove prototype that utilize flexible bending sensor to track fingers movement. GloveMAP is capable to provide a voltage output proportional to degree of finger bending. This information is essential in designing the HCI application. However, data acquisitions from GloveMAP need to be processed and analysed in order to effectively train the computer to recognize the finger grasping information. Thus, an experiment is design to study several feature extraction methods with the assist of supervised and unsupervised clustering. Besides that, GloveMAP voltage output will be simplified into angle information. The purpose of this research is to recognize the grasping objects by using suitable feature extraction and clustering techniques. K-means and Linear Discriminant Analysis (LDA) clustering are used along with several feature extraction techniques to obtain the objects recognition rate. Angle of slopes (θ), length of slopes (ℓ), variance (σ^2), standard deviation (σ), mean ($\bar{x}$), median (m)and the proposed feature extraction method sum of movement (*SuM*) and area under curve (*A*) are process with the feature selection method to select the best features for the recognition process. Throughout the end of research, recognition rate for K-means and LDA clustering is compared. The experimental results show that LDA achieved over 88.4% recognition rate using *SuM* and *A* as feature, meanwhile k-means achieved over 85.0% recognition rates using *SuM* and *A* feature.

CHAPTER 1

INTRODUCTION

1.1 Background and Motivation

Nowadays, technology advancement is essential as its provide industrial competitiveness, advancements in agriculture, boosting education and scientific research, evolution of communication and making every aspect of life easier, better and fulfil basic human need. Robotic is one of the results of technologies advancements. These technologies can be used as human replacement in dangerous environments and manufacturing processes, and can resemble humans in behaviour, appearance and perception. Robot can learn to adapt a specified task given that it is equipped with suitable sensor or control algorithm and taught to use the information.

Robot usually equips with robotic hand to simulate the basic of human hand function handling and holding objects. Even though robot capable on function of handle and holding objects, it has a limitation on the capability of distinguishing the grasping objects contrast to the human capability. This limitation makes the flaw in robotic design especially toward designing an artificial intelligence robot. Therefore, an experiment must be design to train the system in order to recognize the grasping object. However, the information of human finger must be captured in order to acquire the necessary information for computer learning process. Thus, the data glove device emerged as solution on tackling this problem. Yet, currently marketed data glove is not affordable by everyone as the price is around RM4000 per unit (Fifth Dimensional

Technology, 1995). This problem turns out to motivate us on using the designed data glove named as UniMAP Glove (GloveMAP) for Human-Computer Interaction.

Human-Computer Interaction (HCI) is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them (Hewett et. al, 1992). According to Harper, HCI is an understanding and designing of differences relationship between human and computer (Harper,Rodden, Rogers,Sellen, 2008). This relationship could occur at various features such as command line, menus, natural language, direct manipulation, and form fill (Bechhofer, 2010). Through direct manipulation, gesture of human body that contains meaningful information will be interpreted through pointing device/graphical display (Billinghurst, 2011; Bechhofer, 2010). The examples application of HCI is as proposed by (Pavlovic, Rajeev,Huang, 1997). They presented the survey of several other approaches for vision-based gestural interfaces. Meanwhile, (Tan,Nijholt, 2010)presented the capability to performing the brain-based gestural interfaces for HCI interaction. Data Glove is another example of gestural interfaces using hand-based interaction. Data Glove regularly used for Virtual Reality (Sayeed,Kamel, Besar, 2007) and hand gesture application (Ishikawa, Matsumura, 1999;Saengsri,Niennattrakul, Ratanamahatana, 2012; Jiangqin, Harbin, Wen, Yibo, Wei, Bo, 1998; Swee, Ariff, Salleh, Siew, Leong, 2007).

GloveMAP is another form of data glove prototype used to capture physical data of human hand (Adnan, Khairunizam, Shahriman, Ali, Ayob, Aziz, 2012a). GloveMAP utilized the capability of flexible bend sensors to acquire finger movement information while performing grasping activities. This grasping activity produce a signal trajectory accordance to the grasping objects. Based on the criteria of produce signal, a feature extraction technique is used to extracted GloveMAP feature. Beforehand, the

GloveMAP output will be filtered to remove the noise produced in electrical component resulted from thermal motion of electrons. GloveMAP output are in-form of voltage over time and varies according to the surface of flexible bending sensor. The resistivity of the sensor is change when bending the flexible bend sensor due to the increasing of distance between each of carbon element inside the thin strip of flexible bend sensor. Since GloveMAP output are in the form of voltage, the output is considered difficult to understand compared to output in the form of angle. Thus, the produced voltage is converted into angle by using polynomial method (Ali, Khairunizam, Shahriman, Juliana, Aziz, 2013).

Afterward, feature extraction method will be employ to extract relevant information from GloveMAP voltage signal. Feature extraction is a process of representing entire GloveMAP produce signal into a set of information therefore reduces the processing power and algorithm requirement for signal processing. Sum of movement, statistical feature, signal slopes and area under curve are among the used feature for GloveMAP feature extraction. The obtained feature will be classified afterwards using classification method such as k-means and Linear Discriminant Analysis (LDA).

Classification analysis is widely used in machine learning and data mining. Classification analysis can be separated into two processes; supervised learning and unsupervised learning. Supervised is a learning method that target or explanatory variable (feature) are well defined while unsupervised is a learning method that target variable are unknown (Härdle, 2014). K-Means is an example of unsupervised learning method while LDA is supervised learning method. Classification technique is important in data analysis especially in classifying an unknown object based on a set of feature provided.

1.2 Problem Statement

1) Output signal in-form of voltage required knowledge on voltage signal. While in medical, the flexure of human finger is usually representing in angle term. Therefore, voltage information must be manipulated in order to represent voltage into a more understandable information.
2) Grasping activities while wearing GloveMAP produce voltage over time information. This data requires an understanding of the signal analysis in order to extract feature of the signal. Meanwhile, statistical feature extraction usually employed by previous researcher to accomplish this problem. Thus, a signal analysis experiments must be design in order to investigate the capability of newly proposed feature extraction method to represent the entire voltage over time signal into a set of feature.
3) Computer basically does not recognize the input data provided by GloveMAP. In fact, the computer needs to be taught to learn about the grasping object. However, in order to train the computer, multivariate information is required. A set of mathematical algorithm often used to manipulate multivariate data into the desired outcome. Classification is an example of mathematical algorithm intent toward classifying a grasping object. Therefore, several classification processes are used to classify GloveMAP output into similar group or cluster.

1.3 Objective

The objectives of this research are as follow:

1) To construct voltage output into angle conversion.

    - GloveMAP output currently in-form of voltage over time. These outputs are considered as difficult to understand for some user without signal analysis background. Hence, GloveMAP voltage output will be representing into angle information.

2) To extract feature for grasping object analysis.

    - Including the entire GloveMAP voltage output into classification algorithm can increase the processing time, increase the complexity of algorithm and also decrease the capability of the classification algorithm. Therefore, the GloveMAP voltage output will be represent into a set of feature using appropriate feature extraction method.

3) To classify grasping signal by using classification technique.

    - Classification can be separated into two learning method; supervised learning and unsupervised learning. Both have its own advantage in data classification. K-means and LDA is selected for GloveMAP output assessment.

4) To recognize the grasping objects by referring to the outcome from classification training.

    - Outcome variable obtain from K-means and LDA classification learning process will be used to recognize the grasping object.

1.4 Scope

The scopes of this research start with collecting data obtain from GloveMAP output. Then, the GloveMAP output will be represent into angle information by constructing the correlation between voltages and angle using polynomial regression. Next, the voltage signal will be analysed to select several features for classification process. To achieve this goal, the classification method of k-means and LDA will be developed. After that, a selection of eight objects for grasping analysis will be carried out with each object are repeat trials for 20 times. The collected data will be used for training and testing for both LDA and k-means classification. Finally, recognition rate for both classifiers are compared.

1.5 Project expectation

The project is expected to achieve a higher recognition rate on newly introduced feature extraction method for data glove HCI application. The proposed feature extraction method must capable to provide higher recognition rate on recognizing the grasping objects. Hence, along with a new feature extraction method, several conventional feature extraction techniques are used with classification method for recognizing the grasping object while wearing the GloveMAP. The project long term goal is aim toward designing a robotic hand that is capable to recognize the grasping object without using vision sensor. Thus, this project will serve as an introduction in designing intelligence system for artificial intelligence robotic.

1.6 Thesis Organization

This thesis consists of five chapters and organized as followed. First chapter highlight some introduction, problem statements, objectives of the research and scope of the research.

Chapter 2 presents the literature review of data glove, previous works of data glove, grasping analysis, feature extraction and classification method. Chapter 3 describes the flow of the research which consist of data glove data acquisition, angle conversion, feature extraction, feature selection and classification method.

Experiment setup and results are presented in chapter 4, where a series of experiment have been conducted including the conversion of input voltage into angle, feature selection method, classification using k-means and LDA and result discussion. Chapter 5 conclude the main contribution of the research and some recommendations for future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Nowadays, advancement of technology, allowed the possibility of HCI. The creation of programmable device or computer cause the barrier between human and technology diminish. These types of interaction were once considered as a dream of many researchers. The development of computer allowed the innovation of various applications and devices to support human need. However, there still a room for improvement in order to reduce the obstruction between human and computer. For instance, computer which lacks of the sense of perception compared to human vision, hear, taste, smell, and touch. Computer had a problem to identify sense of taste and smell without proper algorithm involved.

However, over the years many researchers started to show interest on solving the problem of HCI. Human vision is imitated by the invention of tool that records images. The series of recorded images capture in rapid succession then create an illusion of moving image or video (Ascher, Pincus, 2007). Even though the vision of human eyes much further sophisticates, video capturing device allowing the HCI based on vision sense as demonstrated by (lannizzotto, Costanzo, Lanzafame, La Rosa, 2005). However, vision is limited with recognizing object within a dim environment and only if the object is not obstructed with solid obstacle. The most well-known solution toward solving vision problems is the innovation of data glove.

Data Glove is tool design to capture physical information of it wearer. Various prototypes of data glove have been designed in order to obtain the information of hand and finger. The used of data glove enable the transformation of HCI. Advancement of HCI paired with data glove allowing user to control robotic hand essentially toward Tele-Robotics, handling industrial robot hand, and humanoid robotic hand (Kuklinski et. al, 2014). Utilizing data glove capability, sign language recognition for muted person, hand diagnosis, and glove based rehabilitation for stroke patient were also possible (Rahman, Hoque, Zinnah, Bokhary, 2014). Besides from controlling robotic hand and usage on medical field, data glove also enables the innovation of controlling virtual reality application for education, control character animation directly, and as a gaming controller (Cao, Gao, Wang, Li, 2016).

Recognizing objects using data glove are not merely as easy as it looks. Different information needs to be analysing beforehand, and selected classification method must be design. Classification regularly used to identify and classify a group of objects into a similar category. Classification has been used widely and become the most popular solution for solving recognition problem. Binary classification and multiclass classification are the example of two classification problems that emphasized by researcher. Binary classification is simple classification problem involves separating an object into two classes. Contrasts to binary classification, multiclass classification involves an object assigning into one of several classes (Har-Peled, Roth, Zimak, 2003). Majority of classification method required measurable properties that describe the object. Measurable properties or well-known with the term feature are measurable properties of object obtained by means of feature extraction method using signal processing technique.

2.2 Data Glove

Data glove is a glove-like device worn at human hand with intent on capture physical data such as the bending of finger. Data Glove is not only limited for grasping analysis, virtual reality interaction and robotic hand interface but also it depends on the creativity of user to apply data glove device in real-life. Research on data glove has started long ago, with the advancement of science and technology, numerous type of sensor has been adopted for enhancing the novelty of the data glove and reducing the construction cost. Flexible optical bending sensor, IR camera, LED, flexible bending sensor, magnetic tracking device, and inertial sensors are among popular sensor technology used to track finger movement. Up till present, various type data glove has been design for specific task such as data glove for finger bending, data glove for force distribution, and high-end data glove capable to provide haptic feedback (Bouzit, Burdea, Popescu, Boian, 2002; Ben-Tzvi, Ma, 2014; Winter, Bouzit,2006; Kyung-Won, Dongseok, Changmook, Yongkwon, Sungchul, Mignon,2006).

Swee, Ariff, Salleh, Siew, Leong (2007) develop a completed system that can translated Malaysia Sign Language (BIM) aim toward assisting deaf person to communicate with public efficiently. Their data glove is equipped with accelerometer for capturing hand movement and flexible bending sensor to acquire the data. Using signal processing technique and Hidden Markov Model (HMM) a pattern recognition method, the data glove succeeds on recognize 25 BIM word and transform the result into speech output. Chan-young, Ju-hwan, Inhyuk (2009), developed a wireless data glove for unrestricted upper-extremity rehabilitation system. They construct data glove using flexible bending sensors to measure finger flexures. Their data glove capable to controlling the motion of 3D graphic in real time. The purpose of the data glove is for interfacing with rehabilitation robot for the upper-extremity paralysis. Saggio, Bocchetti, Pinto, Orengo, (2010) develop HITEG-Glove by implementing flexible bend sensor to capture physical finger data. They use Blender software and successfully controls 3D virtual hand model. Kim et. al, (2012) develop a freehand 3D interaction wrist worn gloveless sensor known as Digits. Digits were designed to be less instrumentation contrast to regular data glove and equipped with IR camera, IR laser line generator, IR diffuse illuminator and inertial-measurement unit (IMU) to track hand movements. Their data glove able to sense full 3D user hand position and has been demonstrated for capability of mobile phones interaction, eyes-free interaction, and gaming interaction.

Although the research of developing new data glove still ongoing, there are few other data gloves develops by company and already available in market. CyberGlove System LLC., (2010) are company that market their data glove product. CyberGlove company has established their first data glove product in 1990 and till at this moment continues to produce new data glove and software to assist data glove function and application. Data glove manufactured by CyberGlove Company is Cyber Glove II, CyberGlove III, and CyberGrasp. Virtual Realities Ltd., (2013) are one of corporation well-known with leading distributor of 3D peripheral products, input/output devices, bundled software and integrated systems to the educational, industrial, entertainment, and military markets. They expended its manufacturing with developing several type data gloves aims for educational, entertainment and industrial proposes. The examples of the manufacture data glove are Peregrine, 5 DT Data Glove 5 Ultra, 5DT Data Glove 14, DG5 Glove 3.0, 5DT Data Glove MRI, VMG 30, IGS Glove and ShapeHand. Several other noteworthy data glove research is Sayre glove, MIT LED glove, Digital

Data Entry Glove, 5DT Glove, Dexterous Hand Master, Power Glove, CyberGlove, and Space Glove (Sturman, Zeltzer, 1994).

Data Glove that was used on this research is GloveMAP. GloveMAP is a form of wired glove construct via flexible bend sensor aimed to acquire finger flexion data (Adnan, 2012a). Through excellent GloveMAP data manipulation, a promising outcome can be achieved as instance waveform produce by GloveMAP is displayed into virtual reality (Adnan et. al, 2012b) as an alternative by means of regular Graphical User Interface (GUI) (Refaat, Ahmed, 2004). Furthermore, through GloveMAP, PCA-based finger movement and grasping classification development (Adnan, Khairunizam, Shahriman, Juliana, Aziz,2013) has been conducted successfully.

Currently, GloveMAP produced an output in voltage. Although, voltage output is reasonable for the researcher, voltage output is hard to grasp by general public without signal analysis background. For this reason, an experiment to convert voltage output from GloveMAP into angle output that can be easily understood by public are designed. Via motion capture environment, data acquisition of angle information from finger flexures is captured in order to get the relationship between the voltage and angle. Conversion of voltage output into angle has several advantages especially its capability to increase the public understanding about signal output from GloveMAP. Conversion to angle also capable to reducing the cost of renting motion capture system (BeyondMotion, 2009), simplify the future work of the GloveMAP research as the output can be understood straight forwardly, and also can be use on education and rehabilitation especially when patient needed to repeat grasping or gesture movement for certain degree of angle without assist by medical doctor. Complete summarize of data glove previous work are as shown in Table 2.1.

Table 2.1: Summarize of data glove research.

Author	Title	Data Glove	Sensor Type
Swee et. al, (2007)	Wireless data gloves Malay sign language recognition system	Hand Glove	Flexible bending sensor
Chan-young et. al, (2009)	Development of wireless data glove for unrestricted upper-extremity rehabilitation	wireless data glove	Flexible bending sensor
Saggio et. al, (2010).	Wireless data glove system developed for HMI	HITEG-Glove	Flexible bending sensor
CyberGlove Systems, (2010)	Data Glove	CyberGlove III, Cyber Glove II, and CyberGrasp	Flexible bend sensor, abduction sensor
Kim et. al, (2012)	Digits: Freehand 3D Interactions Anywhere Using a Wrist Worn Gloveless Sensor	Digits data glove	Camera-based sensor
Virtual Realities Ltd., (2013)	Data Glove	Peregrine, 5 DT Data Glove 5 Ultra, 5DT Data Glove 14, DG5 Glove 3.0, 5DT Data Glove MRI, VMG 30, IGS Glove and ShapeHand	Optical bending sensor, Flexible bending sensor and etc.

2.3 Motion Capture System (MOCAP)

Motion capture system (MOCAP) is a software that presented an alternative approach in angle analysis whereby the software already equipped with calculation to acquire both magnitude and components for position, angle, velocity and acceleration (Qualisys, 2013). Generally, this system has capability to record the movements of human, and then using the recorded data to animating graphics. MOCAP widely use in commercial such as video game and movie, biomedics, biomechanics, education and artistic. Notable usage of MOCAP is in the study of skeletal parameter by Kirk, O'Brien, Forsyth, (2005). They manipulate MOCAP and Data Glove on robust tracking of human hand postures for robot teaching. While on 2006, Young-Il, Kyoung-Hwan, Jihong (2006), display a promising research in low cost motion capture system for PC-based immersive Virtual Environment (PIVE) system.

2.4 Grasping Analysis

Apart from vision, human also capable to recognize objects by grasping. Grasping in HCI is not merely an act of gripping object physically with hands, but combination of kinematic model of human hand, grasping posture and orientation (Cobos, Ferre, Sánchez-Urán, Ortego, Aracil, 2001). Numerous research concerning about grasping for HCI and HMI has been exploring for centuries. The taxonomy which generally mean a manner of classifying a thing has been developed by various researchers in order to standardized set of grasping characteristic. Napier, Feix, Kamakura and Cutkosky are among researcher that proposed the grasping taxonomy for reference. Napier, (1956) have classified human grasping into power grasp and