HANDWRITING ANALYSIS USING IMU FOR SMALL HANDWRITING SIZE

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I hereby declare that this report title "*Handwriting Analysis Using IMU For Small Handwriting Size*" is the results of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature: …….

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Date : JUNE 01, 2017

"I hereby declare that I have read through this report entitle "Handwriting Analysis Using IMU For Small Handwriting size" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronic Engineering"

Signature : …….

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Date : JUNE 01, 2017

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ABSTRACT

Handwritten character recognition is one of the example of constant development of computer tools leads to a requirement of easier interfaces between man and the computer. Handwritten character recognition is one of the computer's ability where it can receive and interpret the handwritten input data from source as the document and also can transform it to machine readable and editable format. In this project the system was implemented using MATLAB software tools. There are several steps involved in this system including feature generation, feature selection and extraction and data classification. In signal preprocessing, there are some procedures involved which are calibration, filtering and normalization. During the preprocessing phase, the errors are filtered. During the feature generation phase, some formulas involved to process the acceleration include mean and root mean square (RMS). The purpose of feature selection and extraction is to increase the accuracy of the classification. Artificial Neural Network is recommended as the classifier for handwritten digit and hand gesture recognition in this project. Neural Network can make classification decision accurately and has advantage in high speed of learning. After completing the feature generation phase, the data classification process will take place and the extracted handwriting character will be classified. By applying the equation of mean, alphabet 'i' shows the highest accuracy which is 96.71% followed by alphabet 'u' that has accuracy of 90.71%. Alphabets 'a', 'e' and 'o' have almost same accuracy which are 82.81%, 83.72% and 85.13%. The accuracy depends on the acceleration and the hand gesture of the writing. After implementing the neural network, the overall performance of the digital pen achieved is 57%.

ABSTRAK

Pengenalpastian aksara/watak tulisan tangan adalah salah satu contoh pembangunan yang berterusan peralatan komputer yang membawa kepada keperluan antara manusia dan komputer. Pengenalpastian aksara tulisan tangan adalah salah satu keupayaan komputer di mana ia boleh menerima dan mentafsir data tulisan tangan dari pelbagai sumber sebagai dokumen dan juga boleh mengubah tulisan tangan kepada format yang boleh dibaca dan di sunting. Dalam projek ini, sistem dilaksanakan menggunakan perisian MATLAB. Terdapat beberapa langkah yang terlibat dalam sistem ini termasuklah pemilihan ciri dan pengektrakan ciri serta klasifikasi data. Dalam fasa pra-pemprosesan isyarat, terdapat beberapa langkah terlibat seperti penentukuran, penapisan aksara dan pemulihan aksara. Semasa fasa pra pemprosesan, kesilapan akan ditapis. Semasa fasa generasi ciri, beberapa formula terlibat dalam proses pecutan termasuk min dan punca min kuasa dua (RMS). Tujuan pemilihan ciri dan pengekstrakan adalah untuk meningkatkan ketepatan klasifikasi. Rangkaian neural amat disyorkan sebagai pengelasan tulisan tangan dan pengiktirafan tulisan tangan dalam projek ini. Rangkaian neural boleh membuat klasifikasi keputusan yang tepat. Selepas menamatkan fasa generasi ciri, proses pengelasan data akan berlaku dan watak tulisan tangan yang diekstrak akan diklasifikasikan. Dengan mengguanakan persamaan min dan sisihan piawai, ‘i’ menunjukkan ketepatan tertinggi iaitu 96.71% diikuti dengan ‘u’ yang mempunyai ketepatan sebanyak 90.71%. ‘a', ‘e’ dan ‘o’ mempunyai ketepatan yang hamper sama iaitu 82.81%, 83.72% dan 85.13%. Ketepatan ini bergantung kepada halaju dan pergerakan tangan ketika menulis. Selepas menggunakan rangkaian neural, prestasi keseluruhan pen digital yang dicapai ialah 57%.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

IMU	-	Inertial Measurement Unit
MEMS	-	Micro Electro Mechanical System
LDA	-	Linear Discriminant Analysis
PNN	-	Probabilistic Neural Network
ANN	-	Artificial Neural Network
KBSC	-	Kernel-Based Class Separability
DTW	-	Dynamic Time Warping
DNN	-	Deep Neural Network
HMMs	-	Hidden Markov Models
PCA	-	Principal Component Analysis
FLD	-	Fisher's Linear Discriminant
ROC	-	Receiver Operating Characteristics
GUI	-	Graphical User Interface
STD	-	Standard Deviation
RMS	-	Root Mean Square

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Motivation

Knowledge discovery in database is an interactive and iterative process involve several steps such as selection, pre-processing, data classification and data analysis. Knowledge in data is very important as the knowledge will help to identify and interpret data which can be used later in future. For the example, knowledge discovery in database can be apply in interpreting the population data, classify the type of disease (medicine) and many more.

In March 2015, Minister of Lands, Housing and Urban Development of Uganda said, Uganda's urban population will increase from six million in 2013 to over 20 million in 2040. However, government having a problem in analyse the population data as majority of the population is concentrated on rural and urban areas only. So in this case, knowledge in discovery is important as this method can identify and interpret data of the population based on their area of living.

Besides, as reported by Health and Care Magazine, nearly 3000 cases per year involving brain tumors among the children. Among all the cases, nearly half of them are considered fatal. According to Director of brain research at Children's Memorial Hospital in Chicago (Health & Care, 20120, they have intention to create a database of gene of the patients in other to give them a better treatment. Therefore, they use knowledge discovery in database to classify the type of tumors.

In November 2002, former President of United States of America, President Bill Clinton spoke at Democratic Leadership Council [3], mentioned that after the event of 11 September 2001, the Federal Bureau of Investigation (FBI) has received a great amount of data considering five terrorist related to the incident. As stated from the data, one of the terrorist possessed 30 credit cards with some combined balances and stay in the country for

almost 2 years. Moreover, President Bill Clinton concluded that further investigations are needed to gain some information for the data.

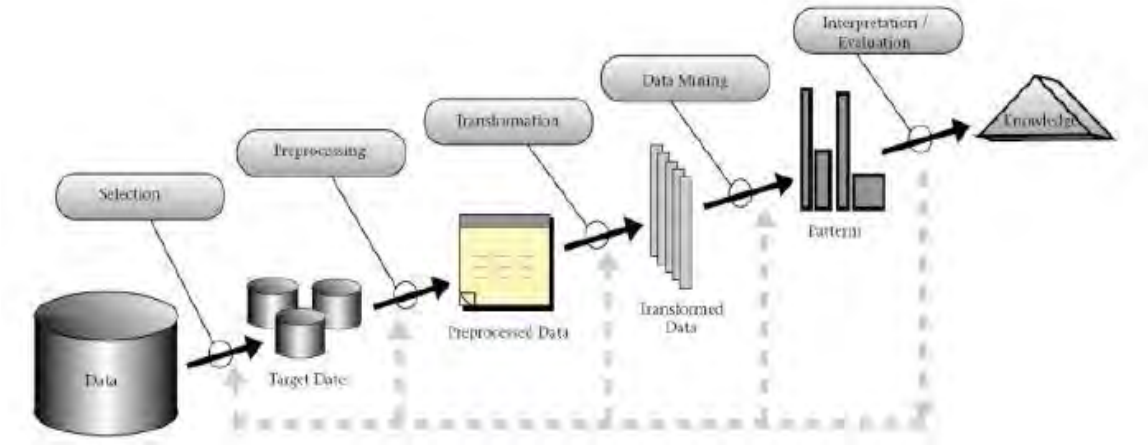

Figure 1.1: Steps in Knowledge Discovering of Database [22]

Handwriting analysis using IMU for small handwriting size will be focus in this project. Handwriting analysis is related to the knowledge discovery in database as the procedure in completing this project is quite similar with knowledge discovery in database. This project is aimed at developing a digital pen which will be helpful in recognizing small characters.

1.2 Problem Statement

Every aspect for the experiments such as sensor used, orientation of the hand gesture and acceleration that measured by accelerometer sensor have to be considered. The selection of the sensor is very important as it will be used to recognize desired command by hand motion to control the device. The mean and variance equation should be use in signal pre-processing as they are important features for handwriting recognition. These features are needed to simplify the raw data as many data are involved and the data have different range of value. Previous researchers have problem in selecting the most suitable method that need to be used to analyse the performance of digital pen for small handwriting. The acceleration of the hand gesture or hand motion also should be considered in conducting this project as this digital pen will be tested by some different users. The sensor will be placed on the digital pen in other to determine the orientation of hand gesture/motion of the users. We faced small problems in this task as some users are left-handed and some are right-handed. So, the users hand gesture orientation will be different.

1.3 Objective

The objectives of this project are:

1. To develop an experimental digital pen using IMU sensor which can recognize desired command by hand motion to control the device.
2. To extract important features from the sensor for the handwriting recognition.
3. To analyse the performance of the digital pen in term of small handwriting recognition.

1.4 Scope

In order to achieve the objectives above, some scopes have to be considered:

1. The device can be used to write digits or words on the paper in any orientation of hand gesture.
2. The analysis of this project would focus on five selected alphabets only based on the user's small handwriting to specify the performances of the device. The used of IMU sensor that consist of accelerometer and gyroscope would detect the trajectory and algorithm of the user's hand gesture.
3. The analysis of this project would focus on handwriting on flat surface only (paper) that has been specified into small size (5mm X 5mm).

CHAPTER 2

LITERATURE RIVIEW

In this chapter, another review will take part in order to complete the task given based on the previous research projects that are related to this project would be discussed. The perfect way to have a good explanation about this project is by exploring the facts related to this project in the internet, some reference books, a few of literature review on journal or patent about this project. Apart from that, this information will become additional sources to the project and can lead to successful project.

2.1 Project Background

A digital pen is a battery-operated writing device that allows the users to digitally capture a handwritten note or drawing by recognizing the hand gesture. Some of the digital pens come with handwriting recognition software that allows the users to import their handwritten notes into typed text. These pens do not require a docking station but instead send the captured notes directly to the user's PC or cell phone. In addition, the digital pen printing solution improves workflow, saving user's money, increasing data accuracy and security and making the operation more efficient than ever before [12]. Nowadays, digital pens come out in two different recognition features which is for 2D output and 3D output. Compared to conventional keyboard and touch-screen input methods, hand-writing character recognition in three-dimensional (3D) space using inertial sensors is an emerging technique. By using an inertial sensor-based device, users can freely write characters in 3D space [5].

2.2 Previous Research on Digital Pen for Handwriting Recognition

Wang et. al. [1] presents a handwritten character recognition system based on acceleration. The digital pen consists of an accelerometer sensor, a microcontroller and an RF wireless transmission module for sensing and collecting accelerations of handwriting and gesture trajectories. The character recognition system using a 3-dimentional (3D) accelerometer [1,3] includes the procedures of acceleration acquisition, signal processing, feature generation, feature selection and feature extraction. In signal processing, the accelerations are calibrated to remove the drift errors. The errors are then filtered via moving average filter and high-pass filter before entering the normalization process. Users can use the pen to write digits or characters and the accelerations of hand motions or hand orientation measured by the accelerometer which is wirelessly transmitted to a computer for online trajectory recognition.

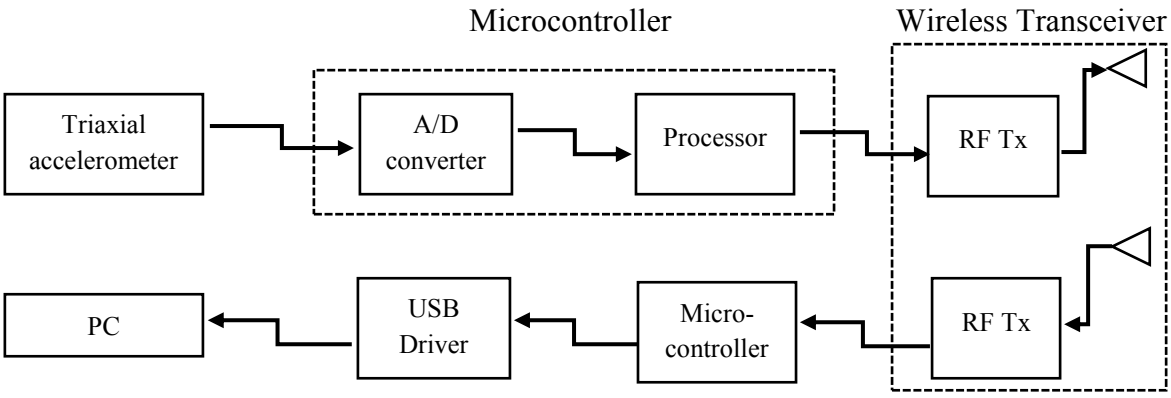

Figure 2.1: Schematic diagram of the digital pen module [1]

Meenaakumari et. al [2] presents an MEMS accelerometer sensor based on gesture recognition and its applications. The hardware module consists of a triaxial mems accelerometer, microcontroller and zigbee wireless transmission module for sensing and collecting accelerations of handwriting and hand gesture trajectories. The accelerometer is connected wirelessly to a personal computer for trajectory recognition. The character recognition procedures consist of information assortment collections and signal preprocessing for reconstructing the trajectories to remove the cumulative errors caused by drift of sensors. The author state that, by changing the position of MEMS, the users are able to show the alphabetical characters and numerical within the PC [2].

Motion sensor [1,3, 5,6,7] is a device which the accelerometer and gyroscope fused on a single chip together. Mirza et. al. [3] proposed a pen that employs its motion to transfer the writing into an editable word document by record the motion of the pen and applying a microcontroller for serial communication. The raw data from the motion sensors is converted to a processed useful data by implementing a number of error corrections. Once the motion is recorded, a specially designed algorithm defined briefly used to reconstruct the word. The well calibrated sensor produces the perfect results and help to achieve a greater reconstruction rate as output. The equation for displacement from acceleration as shown below [3]

$$X_{n+1} - X_n = \left[\frac{1}{2}a_{n+1} + \frac{3}{2}a_n + 2\sum_{j=1}^{n-1} a_j\right]\frac{t^2}{2} \qquad (1)$$

Deselaers et. al. [4] presents a trajectory of the phone's corner that is touching the writing or drawing surfaces. Gyropen is a method that give the same experiences to user as writing using a pen [4]. The angular trajectory is used in this reconstruction which removes the necessity for accurate absolute 3D position estimation, a task that can be difficult using low-cost accelerometer. The Gyropen is connected to a handwriting recognition system and perform two proof-of-concept experiments to demonstrate that the reconstruction accuracy of Gyropen is accurate enough to text entry.

Shashidhar et. al [5] presents a wireless-inertial-measurement-unit (WIMU) based hand motion analysis technique for handwriting recognition in three-dimensional (3D) space. The proposed handwriting recognition system is not bounded by any limitations or constraint; users have the freedom and flexibility to write characters in free space. It uses hand motion analysis to segment hand motion data from WIMU device that incorporates magnetic, angular rate, and gravity sensors (MARG) and a sensor fusion algorithm to automatically distinguish segments that represent handwriting from non-handwriting data in continuous hand motion data. Dynamic time warping (DTW) [5] recognition algorithm is used to recognize handwriting in real time. The users can freely write in air using an intuitive WIMU as an input and hand motion analysis device to recognize the handwriting in 3D space.

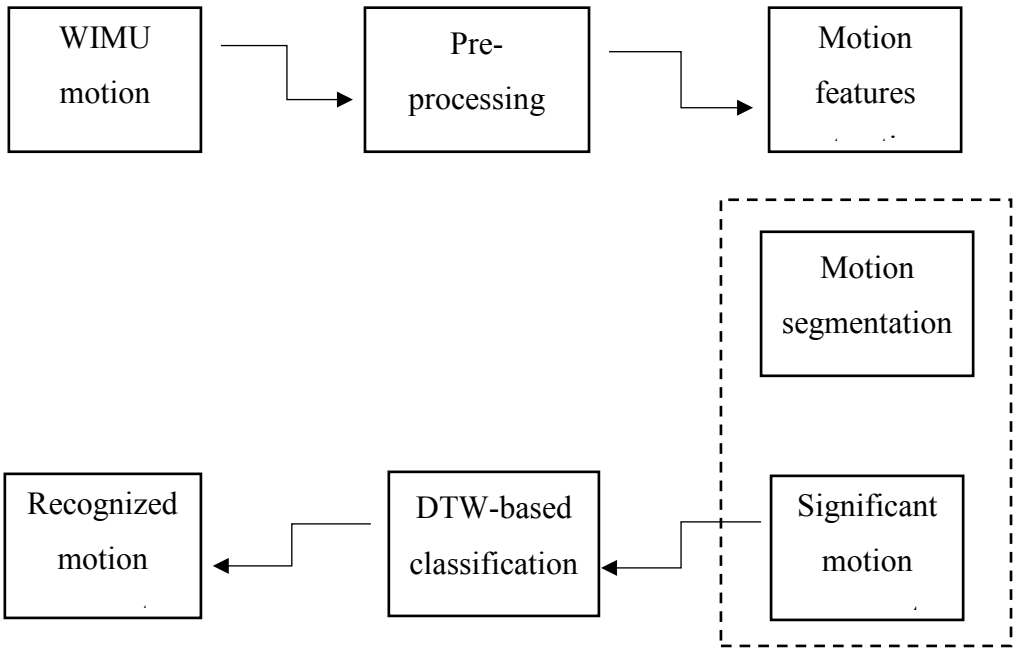

Figure 2.2: Handwriting segmentation and classification [5]

Li et. al [6] proposed a novel interactive method for recognizing handwritten words using the inertial sensor data available on smart watches. The goal is to allow the user to write with a finger and used the smart watch sensor signals to infer what user has written. Past work has exploited the similarity of handwriting recognition to speech recognition in order to deploy HMM based methods. In contrast to speech recognition, however in this scenario, the user can see individual letters that recognized on a sequential basis, and provide feedback or corrections after each letter. The researchers exploit these key difference to improve the input mechanism over a classical source-channel model. For a small increase in the amount of time required to input a word, they improve recognition accuracy from 59.6% to 91.4% with an implicit feedback mechanism and to 100% with an explicit feedback mechanism.

The digital pen [1,7] is a pen type portable device having inertial sensor example triaxial accelerometer for general motion sensing, that facilitates the users to interact with computer, Zigbee module used for wireless communication. Leena et. al. [7] presents an effective trajectory recognition algorithm that can efficiently select most significant features from the time and frequency domains of acceleration signals collected from inertial sensor and project the feature space into a smaller feature dimension for motion recognition with high recognition accuracy.

Georgi.M et. al. [8] evaluate the performance of a wearable gesture recognition system that captures arm, hand and finger motions by measuring movements and muscle activity at the forearm. The analyse the signals of an IMU worn at the wrist and the EMG of muscles in the forearm to infer hand and finger movements. A set of 12 gestures was defined based on their similarity to actual physical manipulations and to gestures known from the interaction with mobile devices. They recorded performances of the gestures set by five subjects in multiple sessions. Hidden Markov Models (HMMs) [8] is used as the classifiers. They achieve a recognition rate of 97.8% in session-independent and 74.3% in person-independent recognition.

The nature of handwritten characters, conversion of handwritten data into electronic data [9] usually black and white image file and neural network approach to make machine capable of recognizing hand written characters. Perwej et. al [9] developed a machine recognition of hand written character using neural network. In preprocessing phase, each character deals with technique for enhancing contrast, removing noise and isolating regions whose texture indicate a likelihood of character information. The picture classifier Principal component analysis (PCA) is used as a tool in exploratory data analysis and for making predictive models.

Milner.Ben [10] has developed a conventional tablet-based handwriting recognition which used a pair of accelerometers sensor as the device to measure the movement of the pen. The accelerometer package is produced by Analog Devices [20] with the accelerometer placed at the side of the pen. Sampling frequency of around 60Hz [10] is applied by the author as the sampling frequency must high enough to ensure the rapid acceleration can be accurately measured. Because of handwriting recognition and speech recognition have close similarity, it was decided to model the handwriting using Hidden Markov Models (HMM) as HMM is the technique that have been success in the speech recognition task.

Choi et. al. [11] presents a pen-style hardware for the recognition of handwritten characters. The hardware has a 3-dimentional acceleration sensor, an amplifier, a microcontroller with AD converter and communication port but does not need any touching screen. The algorithm procedures include the signal preprocessing, feature extraction and classifier. Both Hidden Markov Models (HMM) and Dynamic Time Warping (DTW) are used as the recognition classifier in this project [11]. The hardware and software for the experiment with 10 Arabic numerals show high recognition rates where 100% for the writer-dependent and 90.8% for writer-independent cases. This recognition rates clearly

demonstrates that the usefulness of the acceleration-based handwritten character recognition system can work even without touching screen or pad.

End point detection is proposed for motion direction by acceleration [12]. Instead of the conventional methods based energy feature normalization in automatic speech recognition and threshold-based algorithms, supervised learning in pattern recognition is proposed in this task to discriminate a motion state and a non-motion state. The selected acceleration values based on correlation coefficient are used to form the feature vectors and then transformed 2D or 3D feature vectors into variants vectors with Principle component analysis and Fisher's Linear Discriminant (FLD). Apart from the various feature vectors, artificial neural network has been designed to analyse the feasibility of the proposed algorithm.

Dhivya et. al. [13] presents a pen like input device for computer using inertial sensor (MEMS). The device consists of triaxial accelerometer, an atmega8 microcontroller and a zigbee wireless transmission module. Based on inertial sensor this device can be used as a normal pen and the characters written by using this pen will be displayed in monitor. The accelerometer used in this device is function as the detector to measure the acceleration of the hand movement and recognize the hand gestures. The digital pen device can be used to write the hand digits or alphabets by the users. The signals from the accelerometer will be transmitted to the monitor with the help of Zigbee. The signals will be processed in the pc and the results will be displayed in monitor. Hence there is no need for keyboard typing which is quite difficult than normally writing by using a pen in a notebook.

Sanchez et. al. [14] proposed a system of on-line character analysis and recognition using fuzzy neural networks (FasArt). Two methods for segmenting handwritten components into strokes are proposed, with better experimental results for the method based on the biological models of handwriting in term of consistency. A systematic experimental study of different schemes is also described based on Shannon entropy and clustering maps. Lastly, the steps towards the construction of an allograph lexicon are shown that the generation of fuzzy-rules by FasArt architecture.

Priyanka.M et. al. [15] presents an electronic handwriting character recognition (E-HWCR) device. On-line handwriting character recognition using accelerometer is the basic proto-type for all the latest technologies. With the advancement of electronics, the different technologies used in computer vision helps to organize a hand written character more effectively and yields a reliable input [21]. In this project, the recognition process is done by using a micro-electromechanical device (MEMS) accelerometer and microcontroller within

built ADC. The characters are stored using processor and it is interfaced to the computer for recognizing the data with any Integrated Development Interface (IDE) person's hand such as bio-metric technique works on accelerometers in built.

Pen with inbuilt inertial sensors are new input instruments which may be used as an alternative to keyboard [13]. Jahidabegum.K et. al. [16] developed a digital pen device for character recognition system for text entry using inertial sensor. Motion trajectory recognition is very challenging in this project because the different users have different speeds and style or orientations to write the character or make gesture. Character recognition accuracy depends on the features selection and classification technics. Accuracy is evaluated using two classification technic which are Simple PNN classifier and KNN classifier where KNN classifier gave better recognition accuracy rate than Simple PNN.