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An Accelerometer Based Hand Gesture Recognition Digital Pen

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Abstract— This paper represents an accelerometer based hand gesture recognition digital pen for hand written digit trajectory recognition applications. The digital pen consist of a microcontroller, a triaxial accelerometer and a wireless transmission RF module for sensing collecting acceleration of handwriting trajectories. The proposed recognition of trajectory algorithm composes of the steps of acceleration acquisition, signal pre-processing, feature generation, feature selection, and feature extraction. Users can use the digital pen to write digits. The accelerations of hand motion calculated by MEMS accelerometer are wirelessly transmitted to a computer for online trajectory recognition. The trajectory algorithm identifies the most important feature by a Probabilistic Neural Network (PNN) classifier algorithm for reducing the dimension of features.

Keywords— MEMS Accelerometer, Microcontroller, Hand gesture recognition algorithm, Trajectory Algorithm

I. INTRODUCTION

Handwriting Recognition is mostly used for authentication and security purpose. There are two types of recognition that is offline recognition and online recognition. The constructed system is an online hand writing digit recognition written in air. The digit recognition is done by an MEMS accelerometer. This MEMS accelerometer gives response for every slight deflection or movement in the system. A significant advantage of MEMS accelerometer for general motion sensing is that they can be operated without any external reference and limitation in working conditions. However, digit recognition is relatively complicated because different users have different speeds and styles to generate various motion trajectories. Hence, many researchers have tried to increasing the accuracy of handwriting recognition systems. Recently, some researchers have working on reducing the error of handwriting trajectory reconstruction by using MEMS acceleration signals and angular velocities of inertial sensors. However, the reconstructed trajectory algorithms suffer from various intrinsic errors of inertial sensors. Thus, many researchers have focused on developing effective algorithms to reduce error of inertial sensors & to improve the recognition accuracy. An efficient acceleration error compensation trajectory algorithm based on zero velocity compensation was developed to reduce acceleration errors for acquiring accurate reconstructed trajectory. The features of the pre-processed acceleration signals of each axis include ZCD and Range. Before classifying the motion trajectories, we perform the procedures of feature selection and extraction methods. The PNN classifier is used for better accuracy.

II. LITERATURE SURVEY

Meenaakumari *et. al.* [1] presents an MEMS accelerometer which is based on digit recognition trajectory algorithm and it is applications. The hardware unit consists of a microcontroller, a triaxial MEMS accelerometer, and zigbee wireless transmission module for sensing and collecting accelerations of handwriting and hand gesture trajectories. Users will use this hardware module to write down digits, alphabets in digital manner by making hand gestures. The trajectory algorithm composed of information collection, signal pre-processing for reconstructing the trajectories to satisfy the cumulative errors caused by drift of sensors. So, by changing the position of MEMS (micro electro mechanical systems) she will be able to show the alphabetical characters and digits on the computer. The drawback of system is that it can display the character or numbers in seven segment display format.

Renuka *et al.* [2] proposed the online character recognition system in which the character is processed while it was under creation. To capture the motions online, the general motion sensor, MEMS accelerometer which can be operated without any external reference and restriction in working conditions is used. Trajectory recognition is relatively complex because different users have different speed, pressure and strokes to generate a variety of motions. Many researchers have tried to narrow down the troubles for increasing the accuracy of handwriting recognition systems. By manipulating the acceleration signals and angular velocities of inertial sensors, some researchers have reduced the error of handwriting trajectory reconstruction. On the other side, these trajectory reconstructions go through from different inherent errors due to the usage of inertial sensors.

Jeen-shing *et. al.* [3] developed a pen-type portable device and recognition of trajectory algorithm. The pen-type portable device consists of a microcontroller, a triaxial accelerometer and an RF wireless transmission module. The acceleration signals deliberate from the triaxial accelerometer are transmitted to a pc via the wireless module. Users can make use of this digital pen to write digits and make hand gestures at normal speed. This paper has presented a trajectory recognition algorithm structure that can construct efficient classifiers for acceleration-based handwriting and gesture recognition.

The proposed trajectory recognition algorithm consists of acceleration acquisition, signal pre-processing, feature generation, feature selection, and feature extraction. With the reduced features, a Probabilistic Neural Network (PNN) can be quickly trained as an effective classifier.

III. HARDWARE DESIGN OF DIGITAL PEN

The pen device consists of a triaxial MEMS accelerometer, microcontroller with a 10-b A/D converter, and a wireless transceiver that is RF module. The triaxial MEMS accelerometer measures the acceleration signals generated by a user's hand motions. The microcontroller collects the analog acceleration signals and converts these signals to digital ones by using A/D converter. The wireless transceiver that is RF module transmits the acceleration signals wirelessly to a personal computer (PC). The output of any axis (x, y, and z) is analog voltage which is directly proportional to the acceleration in that axis. Acceleration values can be positive, negative or zero so, the output voltage has a zero bias output. The output given at this point means zero acceleration in that particular axis. So, the zero point voltage is greater than output voltage, it indicates the negative acceleration. The microcontroller integrates a high-performance 10-bit Analog to digital converter and 8-b microcontroller unit (MCU) on a signal chip. The output signals of the accelerometer are sampled at 100 Hz by the 10-bit Analog to digital converter. Then, all the data sensed by MEMS accelerometer are transmitted to personal computer (PC) wirelessly by an RF transceiver, at 2.4-GHz transmission band with 1-Mbps transmission rate. The overall power consumption of the hand gesture digital pen circuit is 30mA at 3.7 V.

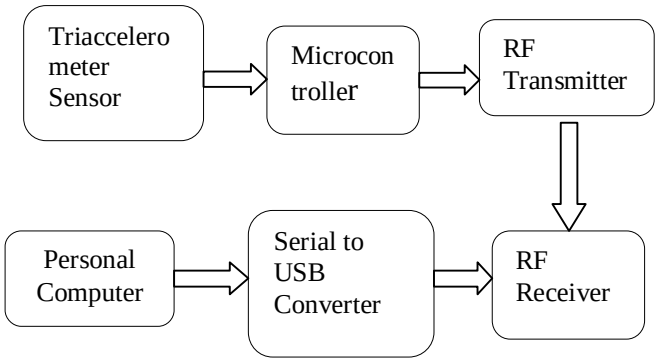

Figure1: Steps of Hardware Design of Digital Pen

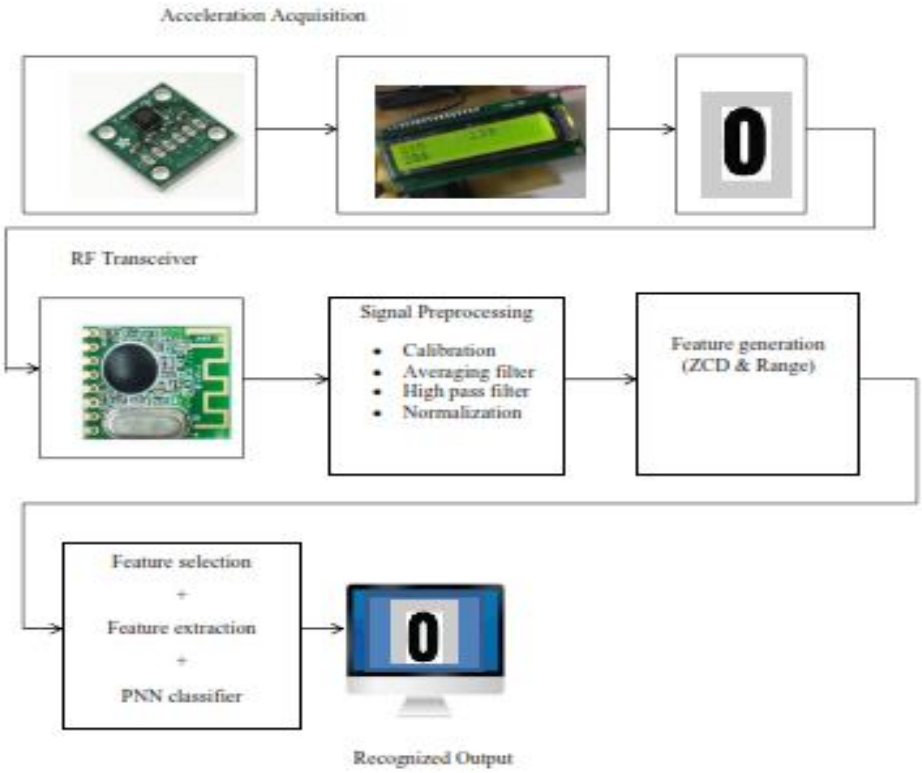

Figure 2: Block diagram of Transmitter and Receiver

The MEMS sensors are available in various types such as Piezoelectric, Capacitive, Magneto-resistive, Piezoresistive, Heat Transfer, etc. Here in this project we are using capacitive sensor that is ADXL335.The ADXL335 is a thin, small, low power, complete 3 axis accelerometer. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from shock, motion, or vibration. The ADXL335 sensor (accelerometer) is available in small package. ADXL335 operates on supply of 1.8 V to 3.6 V.

IV. TRAJECTORY RECOGNITION ALGORITHM

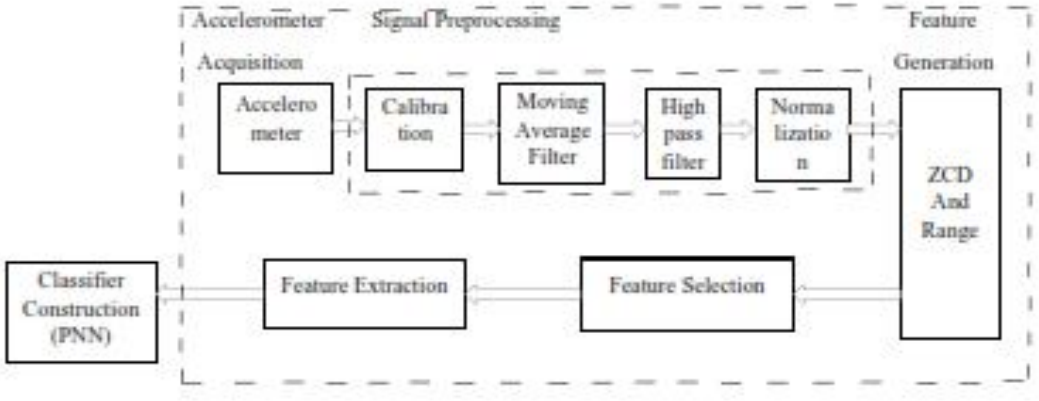

Figure3: Block Diagram of Trajectory recognition algorithm

The acceleration signals of the hand motions are measured by a triaxial MEMS accelerometer and then pre-processed by filtering and normalization. The features are extracted from the pre-processed data to represent the characteristics of different hand motion signals. To reduce the computational load and increase the recognition accuracy of the classifier, we Utilize PNN to reduce the dimension of the selected features. Here introduce the detailed procedure of the proposed trajectory recognition algorithm as follows.

1. Signal Pre-processing:

The raw acceleration signals of hand motions are generated by the MEMS accelerometer and collected by the microcontroller. Due to human nature, our hand always trembles slightly while moving, which causes certain amount of noise because of different motions according to different person. The pre-processing signal consists of calibration, a moving average filter, a high-pass filter, and normalization. First, the accelerations are calibrated to remove drift errors and offsets from the raw motion signals. The second step of the signal preprocessing is to use a moving average filter to reduce the high-frequency noise of the calibrated accelerations and signal becomes more smoothly.

2. Feature Generation:

The characteristics of different hand motion signals can be obtained by extracting features from the pre-processed *x*-, *y*-, and *z*-axis signals, and instead of extracting features from the triaxial acceleration signals, including mean, STD, VAR, IQR correlation between axes, MAD, RMS. Here, we extract two dominating features such as Zero crossing (ZCD) and Range.

3. Feature Selection:

Feature selection comprises a selection criterion of signals and a search strategy. In this zero crossing (ZCD) and range feature is selected for further computation.

Digit	ZCD for x	ZCD for y
0	1	2
1	1	0
2	1	3
3	1	4
4	2	1
5	1	3
6	1	3
7	1	1
8	1	4
9	2	2

Table1: Zero crossing Detector table Digit

From above table we can see that zero crossing ZCD for digit 2, 5, 6 & 3, 8 are same for that we have to use classifier to recognize the digit correctly. Use Probabilistic Neural Network (PNN) classifier because of its higher recognition rate.

4. Feature Extraction:

For pattern recognition problems, LDA is an effective feature extraction method (or dimensionality reduction method) which uses a linear transformation to transform the original feature sets into a lower dimensional feature space. The purpose of LDA (feature extraction method) is to divide the data distribution in different classes and minimize the data distribution of the same class in a new space.

5. Classifier Construction:

PNN Classifier:-

The Probabilistic Neural Network (PNN) was first proposed by Specht. With enough training data, the PNN (Probabilistic Neural Network) is guaranteed to converge to a Bayesian classifier, and thus, it has a great potential for making classification decisions accurately and providing probability and reliability measures for each classification. Therefore, the most important advantage of using the PNN (Probabilistic Neural Network) is its high speed of learning. Typically, the PNN(Probabilistic Neural Network) consists of an Associate input layer, a pattern layer, a summation layer, and a decision layer as shown in Fig. 4. The Operation of the neurons in each layer of the PNN is defined as follows.

1) **Layer 1**: The first layer is the input layer and this layer performs no computation. The neurons of this layer convey input features of **x** to the neurons of the second layer.

2) **Layer 2**: The second layer is the pattern layer and the number of neurons in pattern layer is equal to *NL*.

3) **Layer 3**: The third layer is the summation layer. The contributions for each class of inputs are summed in summation layer to produce the output as the vector of probabilities. Where *Ni* is the total number of samples in the k^{th} neuron.

4) **Layer 4**: The fourth layer is the decision layer.

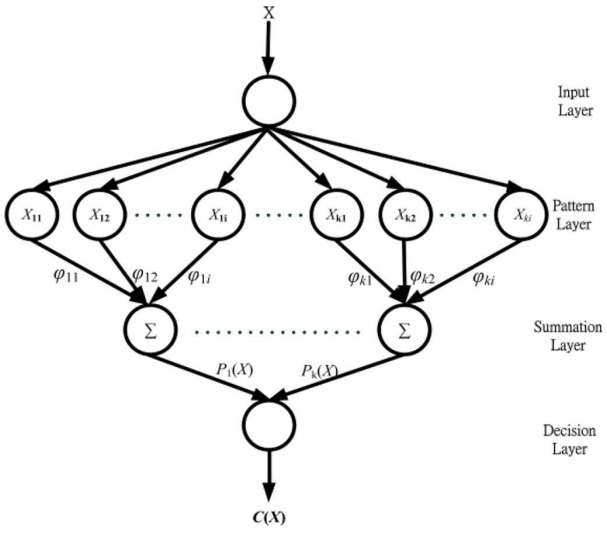

Figure4: PNN Classifier

V. ALGORITHM FOR PROPOSED SYSTEM

The entire system process is explained below in detail by step by step process.

Step 1: The motion of ADXL335 accelerometer in any direction is send to microcontroller in form of raw signal in (1x80 vector) through wire connection.

Step 2: These values then pass through the process of calibration in signal preprocessing.

Step 3: Then the values are processed through moving averaging filter to make (1x20 vector) average values in signal preprocessing.

Step 4: The high pass filter processes this data in signal preprocessing.

Step 5: The data then pass through process of Normalization.

Step 6: After this features extraction is done (zero crossing (ZCD) &Range)

Step 7: Here we use serial to USB communication for fast response.

Step 8: Using Matlab software PC (personal computer) displays the motion in terms of character or digit or hand gesture.

VI. PERFORMANCE ANALYSIS AND RESULT

The Digit which we want to recognize can be drawing in air using gesture analysis as follow.

1	2	3	4	5	6	7	8	9	0
									

Table1: Pictorial Digit Trajectories

Simulation Result:

The following diagram shows the simulation result for digit 1 & digit 0. To show simulated result in matlab we constructed a graphical user interface window which show the recognize digit as well as the graph of the X axis & Y axis.

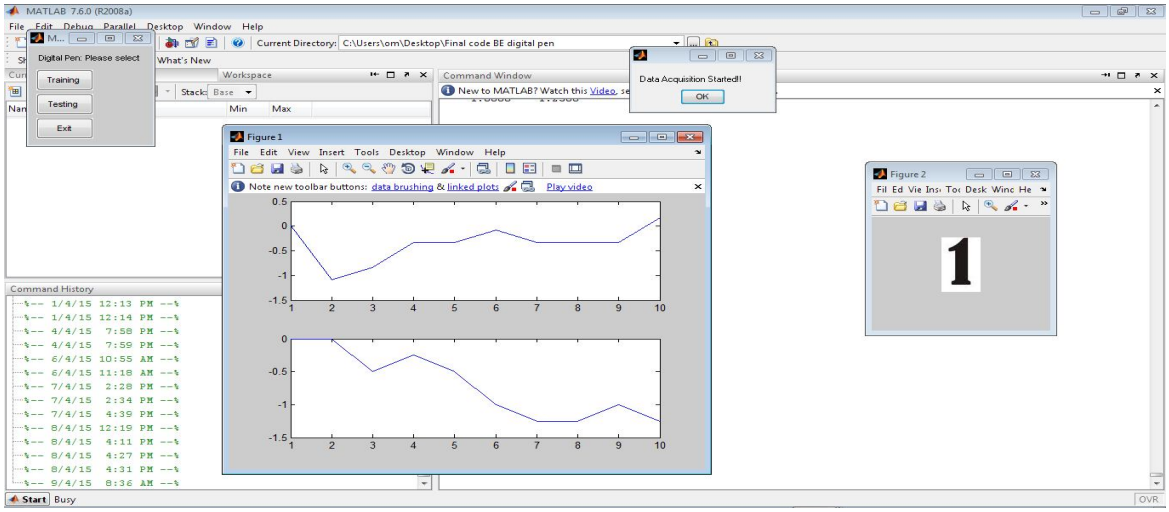

Figure 5: Digit 1 Recognize On GUI

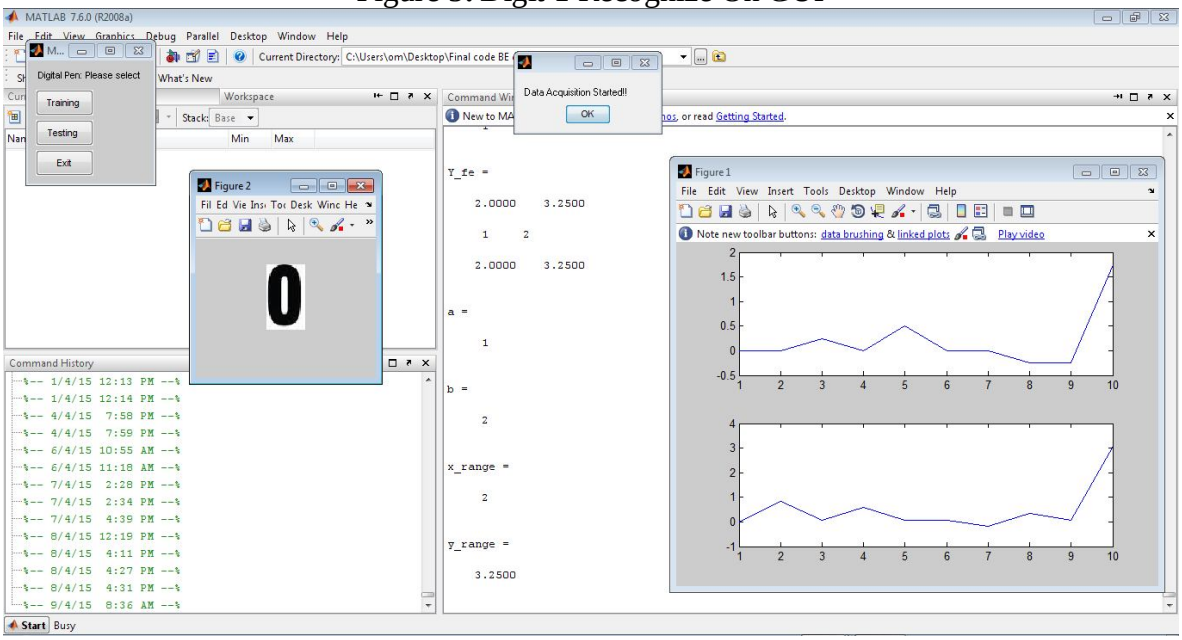

Figure 6: Digit 0 Recognize On GUI

VII. FUTURE SCOPE

The development of the portable device like pen is used to generate desired commands by hand motions to control electronic devices without space limitations. The acceleration made by the hand motion is measured by the MEMS accelerometers are wirelessly transmitted to the computer. The Digital pen can be used for multi stroke handwriting by making some modifications in algorithm. With the multistroke handwriting user can write the full sentence with normal speed. In this system the pen section can be interface with microcontroller wirelessly or microcontroller can be installed inside pen section by using system on chip technology to fabricate a microchip. Blank line before and one blank line after. Use a period (".") after the heading number, not a colon.

VIII. CONCLUSION

This paper has presented a systematic trajectory recognition Algorithm framework that can construct effective classifiers for acceleration-based handwriting and gesture recognition. The proposed trajectory recognition algorithm consists of acceleration acquisition, signal preprocessing, feature generation, feature selection, and feature extraction. With the reduced features, a Probabilistic Neural Network (PNN) can be quickly trained as an effective classifier.

IX. REFERENCES

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[3] Jeen-Shing Wang, Member, IEEE, and Fang-Chen Chuang, "An Accelerometer-Based Digital Pen with a Trajectory Recognition Algorithm for Handwritten Digit and Gesture Recognition," IEEE Trans. On Industrial Electronics., vol. 59, no.7, July. 2012.

