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**A Digital Pen Based On Accelerometer for Handwritten Digit**

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**Abstract**

In this paper we proposed an Accelerometer based on Micro Electro Mechanical Systems. The (MEMS) which is used in Digital pen for handwritten Digit and Gesture recognition. The (MEMS) is composed of an accelerometer, microcontroller and wireless module RF. user can hold this pen and write digit in air at normal speed. During drawing or writing movements the inertial sensor signal generated for the movements are transmitted to a computer via the wireless module. After measurement of this acceleration signal we can recognize it by using trajectory recognition algorithm. In this trajectory recognition algorithm we are using the acceleration acquisition, signal preprocessing, feature generation and Probabilistic Neural Network (PNN). The algorithm is capable of translating time-series acceleration signal into important feature vector. The trajectory recognition algorithm first extract the time-and frequency-domain features from the acceleration signals and, then, further apply two important feature i.e. Zero Crossing and Range Feature. Finally with the help of probabilistic neural network (PNN) we can recognize the digit. In this paper Our results have successfully validated the effectiveness of the trajectory recognition algorithm for handwritten digit using the proposed digital pen.

**Keywords:** Accelerometer, gesture ,handwritten recognition, probabilistic neural network(PNN), linear discriminant analysis (LDA),RF wireless module, Microcontroller..

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**Introduction**

The “Electronic Whiteboard” and “Digital Pen” are new instruments in the office automation industry that may someday completely replace the computer keyboard, which is still the preferred alphanumeric human-to-computer input device. These new devices aim to capture human handwriting or drawing motions in real-time and store motion strokes for digit recognition or information retrieval at a later time. For sensing this accelerations of the humans and capture the motion trajectory information has been proposed the inertial sensors in this portable device So, the advantage of inertial sensors for general motion sensing is that they can be operated without any external reference and limitation in working conditions. However, motion Trajectory recognition is relatively complicated because different users have different speeds and styles to generate various motion trajectories. Thus, many researchers have tried to narrow down the problem domain for increasing the accuracy of handwriting recognition systems

In 1964, the first graphics tablet was launched, the RAND Table, also known as the Grafacon (Graphic Converter). It makes use of electromagnetic resonance to digitize pen motion. In the next 40 years of development, many different well-developed

methodologies to digitize handwriting have been proposed. Targeting business and academic institutions, ultrasonic, infrared and optical sensing are currently the most popular technologies for detecting the position of a digital pen on a large area electronic whiteboard. Luidia Inc.and Sanford LP have separately proposed systems, eBeam and mimicr respectively, that can modify a conventional whiteboard by placing a receiver in its corner. The receiver uses infrared and ultrasound technologies to translate pen movement into positions which are recorded on a computer. However, the price of the overall system is very expensive, and the active area is limited.

Recently, some researchers have focused on reducing the error of handwriting trajectory reconstruction by manipulating acceleration signals and angular velocities of inertial sensors. However, the reconstructed trajectories suffer from various intrinsic errors of inertial sensors. Hence, many researchers have focused to improve effective algorithms for error compensation of inertial sensors to improve the accuracy of recognition. Yang *et al.* [2] proposed a pentype input device to track trajectories in 3-D space by using accelerometers and gyroscopes. An efficient

acceleration error compensation algorithm based on zero velocity compensation was developed to reduce acceleration errors for acquiring accurate output reconstructed trajectory. but It increases additional cost for motion trajectory recognition systems as well as the algorithm of the trajectory recognition is also becomes complicated. Lim *et al.*[3] proposed computed correlation coefficients of the absolute value of acceleration and the absolute value of the first and second derivatives of acceleration to form feature vectors. then they applied principal component analysis(PCA) and (FLD) Fisher linear discriminant to reduce the dimension of the feature vector. With the reduced feature, a time-lagged feedforward network was trained to recognize 2-D handwritten gesture and best performance with an overall accuracy of 95%. In this project we have proposed an accelerometer based digital pen for handwritten digit & gesture recognition.

In this pen type portable device consist of a triaxial accelerometer, RF wireless module and Microcontroller. The acceleration signals measured by this transmitter are transmitted to the computer by using wireless module. After measurement of this acceleration signals we can recognize it by using trajectory recognition algorithm. In the recognition algorithm basically we are using acceleration acquisition, signal preprocessing, feature generation. In the feature generation we can added two feature i.e Range feature and zero crossing. The signal preprocessing procedure consists of calibration, a moving average filter, a high-pass filter, and normalization. In the feature generation it includes Zero Crossing i.e. how many time signal has been crossing zero line and Range Feature i.e. starting point minus ending point.

In general By using the feature generation methods we can increase the accuracy of classification and reduce the computational burden and finally this reduced features are given to the as the inputs of classifiers. In this paper, we proposed a probabilistic neural network (PNN) as the classifier for handwritten digit and hand gesture recognition.

The main aim of this paper to develop the portable digital pen with a trajectory recognition algorithm, i.e. with the digital pen, users can deliver diverse commands by hand motions to control electronics devices anywhere without space limitations, and an effective trajectory recognition algorithm, i.e., the proposed algorithm can efficiently select significant features from the time and frequency domains of

acceleration signals and project the feature space into a smaller feature dimension for motion recognition with high recognition accuracy.

In this paper we worked on only two Axis i.e. X,Y and third Axis Y is not used because all this paper based on 2D. now in this paper we will see the details of hardware components of the digital pen in detail, respectively. The trajectory recognition consisting of acceleration acquisition, signal preprocessing, feature selection, and PNN. Then we will see the simulation results of the digit and gesture recognition. Finally conclusion given in the last section.

**System overview**

This is the block diagram of system which is the digital pen. We will develop a pen-type portable device and a trajectory recognition algorithm. The pen-type portable device consists of a triaxial accelerometer, a microcontroller, and an RF wireless transmission module. The acceleration signals measured from the triaxial accelerometer are transmitted to a computer by using the wireless module. Users can use this digital pen to write digits and make hand gestures at normal speed. The measured acceleration signals of these motions can be recognized from the trajectory recognition algorithm. in This paper accelerometer sensitivity is set from -3g to +3g. And it could be changeable for higher range.

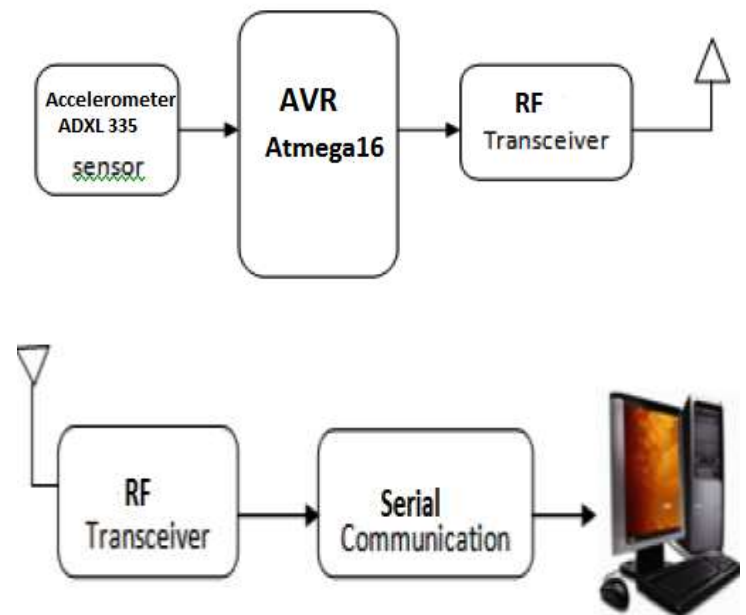


Fig. 1. Block diagram of Transmitter and Receiver

III. HARDWARE PART OF DIGITAL PEN

In the hardware part, it includes the AVR microcontroller, RF wireless module, MEMS Accelerometer, Power supply, LCD display.

#### A. AVR Microcontroller with ADC

The ATmega16 is high performance, low-power CMOS 8-bit microcontroller based on advanced RISC Architecture. By executing powerful instructions in a single clock cycle, the ATmega16 achieves throughputs approaching 1 MIPS per MHz allowing the system designed to optimize power consumption versus processing speed. Presence of the microcontroller within the ADC has been chosen because two factor could corrupt the acceleration signal i.e., crosstalk between three channel lines and the external electromagnetic noise. To minimize such corruption or noise it is better to convert the analog signal to the digital signal as early as possible. Therefore, microcontroller with ADC has been selected. The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle.

#### B. Chip Specifications

In this ADC it should be noted that ADC supplies 10 bit, but lower 2 bits have been discarded due to considerable noise. Therefore, only the higher level 8 bits have been actually used.

Because of to maximize the portability, the low power consumption has been considered as the main characteristic on the chosen chips.

#### C. MEMS Accelerometer

In this project used the MEMS –ACCELEROMETER -MXA 2300 The MEMS IC device is a complete acceleration measurement system fabricated on a monolithic CMOS IC process. The device operation is based on heat transfer by natural convection and operates like other accelerometers having a proof mass except it is a gas in the MEMSIC sensor. A single heat source, centered in the silicon chip is suspended across a cavity. Equally spaced Aluminum/poly-silicon thermopiles (groups of thermocouples) are located equidistantly on all four sides of the heat source (dual axis). Under zero acceleration, a temperature gradient is symmetrical about the heat source, so that the temperature is the same at all four thermopiles, causing them to output the same voltage. Acceleration in any direction will disturb the temperature profile,

due to free convection heat transfer, causing it to be asymmetrical.

#### D. RF Wireless Module

RF module is integrated with a highly configurable baseband modem. The modem supports various modulation format and has a configurable data rate up to 500k Baud. RF communication works by creating electromagnetic waves at a source and being able to work up those electromagnetic waves at a particular destination. Higher frequencies result in shorter wavelengths. The wavelength for a 900 MHz device is longer than that of a 2.4 GHz device. In general, signals with longer wavelengths travel a greater distance and penetrate through, and around objects better than signals with shorter wavelengths. Transmit power refers to the amount of RF power that comes out of the antenna port of the radio. Transmit power is usually measured in Watts, milliwatts or dBm. Receiver sensitivity refers to the minimum level signal the radio can demodulate. It is convenient to use an example with sound waves; Transmit power is how loud someone is yelling and receive sensitivity would be how soft a voice someone can hear. Transmit power and receive sensitivity together constitute what is known as “link budget”. The link budget is the total amount of signal attenuation you can have between the transmitter and receiver and still have communication occur. Data rates are usually dictated by the system - how much data must be transferred and how often does the transfer need to take place. Lower data rates, allow the radio module to have better receive sensitivity and thus more range. In the XStream modules the 9600 baud module has 3dB more sensitivity than the 19200 baud module. This means about 30% more distance in line-of-sight conditions. Higher data rates allow the communication to take place in less time, potentially using less power to transmit.

#### E. Power supply

Our project requires +5V for microcontroller and sensors and 3.3V for AVR and RF transceiver module. +5 volt power supply is based on the commercial 7805 voltage regulator IC. This IC contains all the circuitry needed to accept any input voltage from 6 to 16 volts and produce a steady +5 volt output, accurate to within 5% (0.25 volt). It also contains current-limiting circuitry and thermal overload protection, so that the IC won't be damaged in case of excessive load current; it will reduce its output voltage instead.

## IV. TRAJECTORY RECOGNITION ALGORITHM

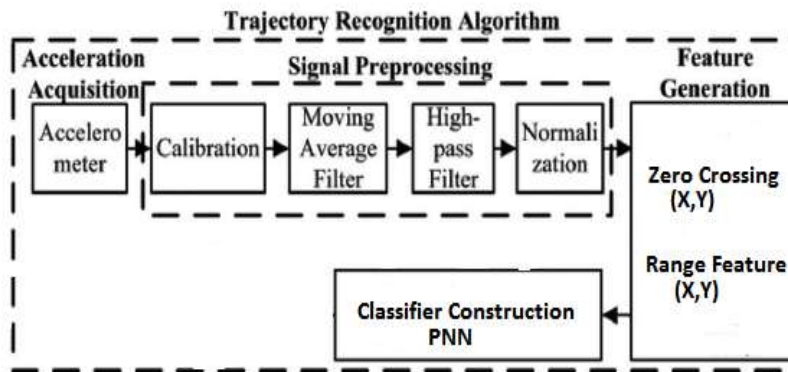


Fig.2. Block diagram of the trajectory recognition algorithm

This is the block diagram of the trajectory recognition algorithm. In this block diagram it includes the acceleration acquisition, signal preprocessing, feature generation, feature selection, and feature extraction. By using this algorithm we can measure the acceleration signals of hand motions measured by triaxial accelerometer. we will discuss the detail block by block procedure of the trajectory recognition algorithm.

1) Acceleration Acquisition

In this the acceleration signals of the hand motions are measured by a triaxial accelerometer. After measurement of this signal given to the microcontroller. In this Acceleration Acquisition signal preprocessing can be evaluate and consist of calibration, a moving average filter ,a high-pass filter, and normalization. In this moving average filter to reduce high-frequency noise and the filter is expressed as below

$$y[t] = \frac{1}{N} \sum_{i=1}^{N-1} x[t + i] \tag{1}$$

Where x[t] is the input signal ,y[t] is the output signal and N is the number of point in the average filter. In this we set N=4

The acceleration signals of hand motions are generated by the accelerometer and collected by the microcontroller. In the signal preprocessing calibration is used to remove the drift errors. Then we use high-pass filter to remove the gravitational acceleration from the filtered acceleration to obtain accelerations caused by hand movement. In general, the size of samples of each movement between fast and slow writers is

different. Therefore, after filtering the data, we first segment each movement signal properly to extract the motion interval. Then, we normalize each segmented motion interval into equal sizes via interpolation. Once the preprocessing procedure is completed, the features can be extracted from the preprocessed acceleration signals and applied to feature generation.

2) Feature Selection

In this paper we have selected two important feature for handwritten digit i.e. Zero Crossing and Range Feature and they are explicated as follow.

i) Zero Crossing: In this Zero Crossing we calculate the number of zero-crossing within a signal.by this mean the number of times a value changes from + to – and vice versa. When we will receive the digital value from AVR Controller that multiply the value by the value next to it i.e.(i \* i+1). then taking the sign value sign (val) determine if the positive or negative.

$$ZC(V) = \sum_{i=1}^{n-1} | \text{sgn}(V_i * V_{i+1}) | \tag{2}$$

Now, the logic behind this equation is that when we pass the value (V) which is coming from X and Y axis in above equation that time we get the absolute value of the summation of the signum from calculating (V<sub>i</sub> \* V<sub>i+1</sub>) .. The signum(V<sub>i</sub> \* V<sub>i+1</sub>) should produce -1, 1, ..., values.

When we write the digit or make hand gesture that time the X and Y Axis value has been changed.

ii) Range Feature: the calculation of range is very straight forward. all we need to do is find the difference between the largest data value in our set and the smallest data value. In the range feature we

calculate initial value minus final value means we have to calculate the Digits starting point value minus ending point value.

$$\text{Range} = \text{Initial Value} - \text{Final Value.}$$

3) PNN ( Probablistic Neural Network) Classifier

In our study, we assume that an additional button can be used to allow users to indicate the starting point and ending point of motion. That is, the limitation of the proposed trajectory recognition algorithm is that it can only recognize a letter or a number finished with a single stroke. We are currently developing algorithms for letters or words with multistrokes which involve more challenging problems. In the next section, we

will focus on the experiment of motion with single stroke and all this project also depend upon single stroke and show the result on PC with the help of PNN. After feature generation, these reduced features will be fed into the PNN classifier to recognize different hand movements. But in this paper we are applying PNN for Digit 2 5,6 And 3,8 because all this digit has same Zero Crossing but range is also different. then all remaining digits no need to apply PNN. The PNN is very useful to converge to a Bayesian classifier, and thus, it has a great potential for making classification decisions accurately and providing reliability measures for each classification. In this PNN there are training and testing procedure has been developed.

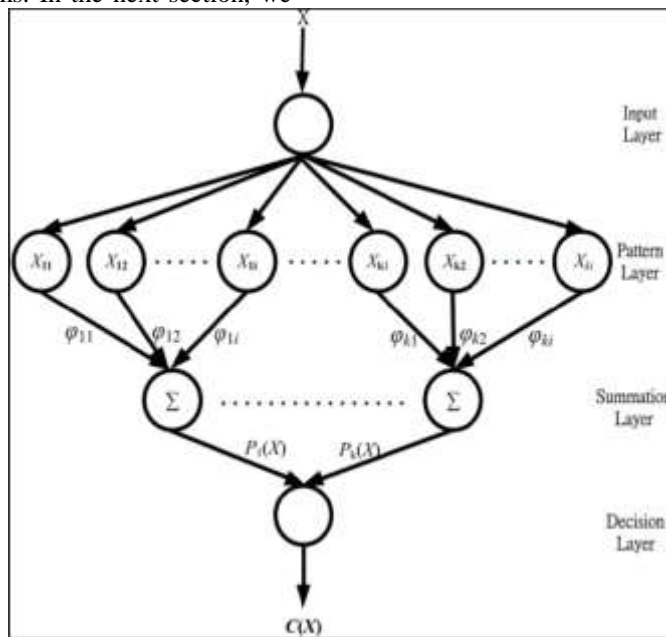


Fig.3. Topology of a PNN classifier

In the training procedure of the PNN only need to adjust the weights and biases of the network architecture. Therefore, the most important advantage of using the PNN is its high speed of learning and it can be more accurate than multilayer perceptron networks. PNN require more memory space to store the model and approach bayes optimal classification Basically, the PNN consists of an input layer, a pattern layer, a summation layer, and a decision layer as shown in Fig.3 The function of the each layer of the PNN is given as follows.

**Layer 1:** The first layer is the input layer, and this layer performs no computation. The node of this layer given to the input features  $\mathbf{x}$  to the neurons of the second layer

$$\mathbf{x} = [x_1, x_2, \dots, x_p]^T \quad (3)$$

$p$  is the number of the extracted features.

**Layer 2:** The second layer is the pattern layer, and the number of neurons in this layer is equal to  $NL$ . Once a pattern vector  $\mathbf{x}$  from the input layer arrives, the output of the node of the pattern layer as shown in fig.3.

$$\varphi_{ki}(x) = \frac{1}{(2\pi)^{d/2} \sigma^d} \exp\left(-\frac{(x - x_{ki})^T (x - x_{ki})}{2\sigma^2}\right)$$

where  $X_{ki}$  is the neuron vector,  $\sigma$  is a smoothing parameter,  $d$  is the dimension of the pattern vector  $x$ , and  $\varphi_{ki}$  is the output of the pattern layer.

**Layer 3:** The third layer is the summation layer. The work of this layer is inputs are summed in this layer to produce the output as the vector of probabilities. Each node in the summation layer represents the active status of one class.

$$p_k(x) = \frac{1}{2\pi^{d/2}\sigma^d} \frac{1}{N_i} \exp\left(-\frac{(x-x_{ki})^T(x-x_{ki})}{2\sigma^2}\right)$$

**Layer 4:** The fourth layer is the decision layer. If the a priori probabilities and the losses of misclassification for each class are all the same, the pattern  $x$  can be classified according to the Bayes' strategy in the decision layer based on the output of all nodes in the summation layer.

$$c(x) = \arg \max \{p_k(x)\}, \quad k = 1, 2, \dots, m$$

In this paper, the output of the PNN is represented as the label of the desired outcome defined by users. For example, in our handwritten digit recognition, the labels "1," "2," "3," "4," "5," "6," "7," "8," "9," and "10" are used to represent handwriting digits 1, 2, . . . , 9, and 0, respectively.

**Overview of the trajectory recognition algorithm**

We will discuss the trajectory recognition algorithm in the following steps.

**Step I:** Capture the acceleration signals from the pen type accelerometer module.

**Step II:** After this filter out the high-frequency noise of the accelerations by the moving average filter and then remove the gravity from the filtered accelerations by a high pass filter. In the last, we normalize each segmented motion interval into equal sizes via interpolation technique.

**Step III:** Generate the time- and frequency-domain features

from the preprocessed acceleration of each axis including, range Feature x,y, zero crossing x,y third axis is not used.

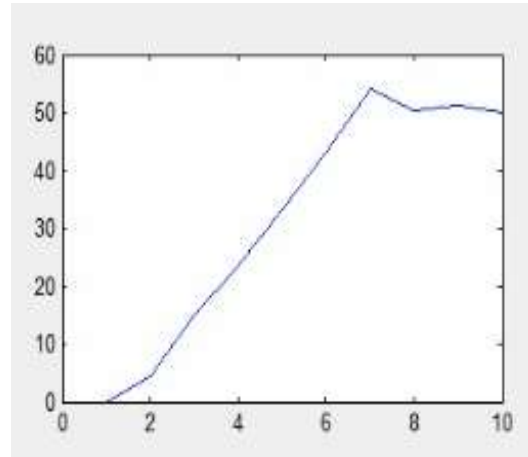
**Step IV:** Finally Identify the Digit with the help of PNN Classifier.

**Experimental result**

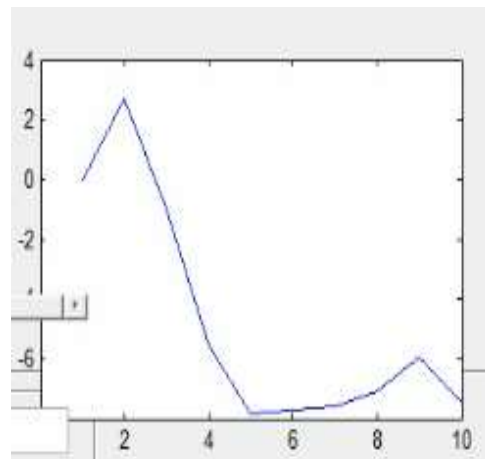
In this section, the effectiveness of trajectory recognition algorithm is validated by the following two experiments:

1) handwritten digit recognition and 2) gesture recognition. The proposed trajectory recognition algorithm consists of the following procedures: acceleration acquisition, signal preprocessing, feature generation, and Probablistic Neural Network) PNN. All below shown graphs are calculated on practical based not on therotical based. When we write a Digit or make gesture that time graph will be shown in different manner means X and Y value can be shown variable manner. and accuracy can be maintained. in

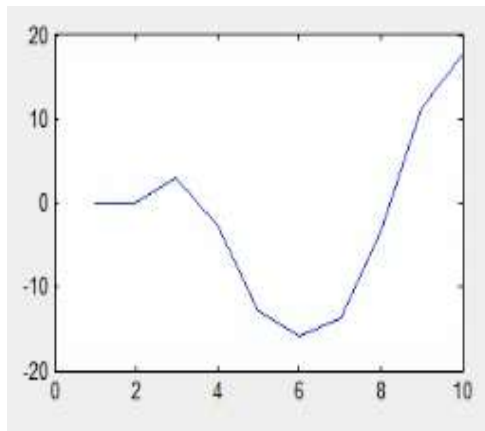
this we used different combination of feature selection and trained by feature from different feature engineering methods and finally employed PNN to recognize handwritten digits and hand gesture.



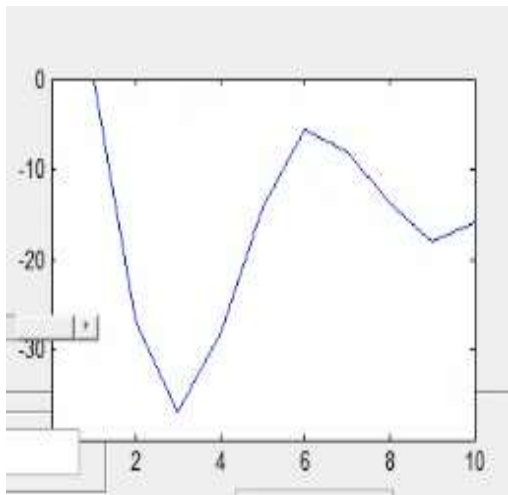
(Graph for the X-direction rotation)



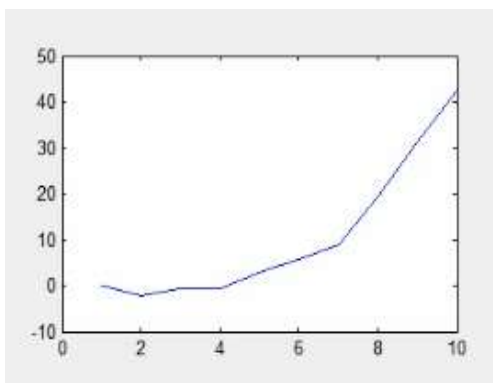
(Graph for the Y-direction rotation  
 (For digit 1))



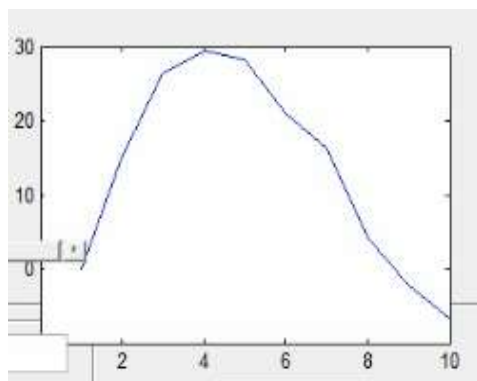
(Graph for the X-direction rotation)



(Graph for the Y- direction rotation)  
 (For Digit 4)



(Graph for the X- direction rotation)



(Graph for the Y- direction rotation)  
 (For digit 7)

In the experimental result, it denotes the graph for the X and Y direction for Digit 1,4 7. when we write on the board by using this digital pen then this pen moves in the X and Y direction then it denotes the

graph X and Y direction rotation and according to that graph it displays the value of X and Y on the PC.

1	2	3	4	5	6	7	8	9	0

Fig.4. Pictorial digit trajectories

### Conclusion

In this paper MEMS accelerometer instrument picks up the acceleration generated during handwriting which is transmitted on PC with the help of pen tip. However, as random noise degrades the acceleration readings, a positional drift results when double integration of acceleration is applied. We used the trajectory recognition algorithm framework that can construct effective classifiers for acceleration-based handwriting and gesture recognition. The trajectory recognition algorithm consists of acceleration acquisition, signal preprocessing, feature generation and (PNN). With the reduced features, a PNN can be quickly trained as an effective classifier. All above results are shown in 2D .The overall handwritten digit recognition rate was 98%, and the all above result are calculated on practical. From above result the different user has to be written digit in different manner that time graph is also changed means different graphs plot shown on PC.

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For a MEMS motion sensor based digital writing instrument