Application of Motion Sensors in Hand Writing Conversion

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Abstract --- Converting your ideas from scribbled down notes to a useful soft copy is a strenuous and time consuming task. A pen that employs its motion to transfer the writing into an editable word document is a key to this problem. The paper proposes the use of the dynamics of writing process as a solution to the problem. The device has accelerometer and gyroscope sensors fused together for recording the motion of the pen, and 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, as described in the paper. Once the motion is recorded, a specially designed algorithm defined briefly in this paper is used to reconstruct the word. The research does not accommodate special characters and foreign languages. We propose the use of our research as the base for future work where special characters and foreign languages can be accommodated for.

Keywords— online handwriting recognition; motion detection; dynamic character recognition; error correction.

I. INTRODUCTION

With the dawn of the 21st century computers have been elevated from their status of a machine to an individual in our lives. Their miniaturization, touch screen interface, easy access, versatility of application has made them an essentiality of modern life. With development in Human Computer interface (HCI) and high speed computations they have been successful in solving complex mathematical models for real time scenarios [1]. This advent in computer technology has made our lives high speed, sophisticated, effortless and more advanced. In this new life style dawned by technology every second counts and people like to do as little effort as possible while doing maximum work done.

Motion detection is a broad term that facilitates the simplification of many small time consumption processes of daily life. The motion sensors usually are the accelerometer, gyroscopes and magnetometers to measure the linear and rotational motions. MPU 6050 is an efficient motion sensor that has an accelerometer and gyroscope fused on a single chip. This paper introduces the methods involved for fine tuning of this sensor and further using this sensor to convert the handwriting to an editable document.

Philosopher, thinkers, students, teachers and writer are well aware of the pain of converting scribbled ideas obtained through brainstorming into a digitalized copy for further processing and use in the modern world. The user had to go through the strenuous exercise of typing the whole document which is not only a waste of time but also hard work. An easy solution to this is hand writing recognition technology (HWR) [2], which can be both offline and online based.

The previous work in this field was initiated with the ideals of implementing optical character recognition (OCR) for the detection and identification of handwriting. Later with the advent in technology the real time conversion based tablets using surface computing came in existence. Both the technologies used probabilistic algorithms. The frequently used algorithms in previous works and their reconstruction rates are, Hidden Markov Model (HMM) has94.29% [3], the probabilistic neural networks (PNN) achieved the reconstruction rate of 98% [4] , multiple multilayer perceptron (MLP) classifier yielded a rate of 97.35%[5], the structure-adaptive self-organizing map (SOM) classifier were able to achieve a rate of 96.05%[5] and the genetic algorithms reconstructed the words at an accuracy of 98.44%. [6]

The design of the pen is such that it is independent of the feature specific surface that reduces the cost and the hauling size. The strokes of the pen are recorded with the use of pressure switch controlling the switching of the motion sensor. The pen can be used in numerous ways due to its wide range applications. It can eliminate the hassle of typing as it substitutes the keyboard. Writing with this pen saves the effort and time consumed after brainstorming to convert the handwritten essays to a printable format. The pen can be employed as a forensic analysis device to perform online signature verification.

II. OFFLINE HANDWRITING RECOGNITION

Offline recognition [7] [8]is based on Optical Character Recognition (OCR)[9] of the scanned copy of the written document. The major drawback with this is that it is not a real time solution [10], [11]. A writer will first have to write a document, scan it, carry OCR on it and then get an editable document. However, an even better solution is to carry out HWR in real time in this way the writer gets a soft copy while he writes down his ideas.

III. ONLINE HANDWRITING RECOGNITION

For the online recognition technique we use surface computers and dynamic character recognition (DCR). In this paper, we will study the use of the DCR technique for hand writing recognition. It is chosen over OCR because of its real time manipulation, time saving approach, easy mobility and higher recognition rates.

The DCR makes use of the motion sensors[12], which record the orientation and acceleration of the pen gestures. These gestures are then utilized to form a data base that contains the motion of input hand written characters. In this paper, a probabilistic algorithm is designed which is based on the methodology of neural networks and genetic algorithm design. The hand written input fed by the user will be inserted into the algorithm which takes it through different steps and finally gives the output by comparing it with the data base.

IV. HARDWARE

The hardware is basically composed of the motion detection module which is able to record the motion of the pen while the user writes. The IC chosen during the research process was the MPU 650 IC which is based in the MEMS (Micro Electro Mechanical systems) technology.[13] The IC has a gyroscope and accelerometer sensor fusion in it; they respectively record the movement of the pen using orientation and acceleration readings. The microcontroller is used fo communication with the MPU6050 device.

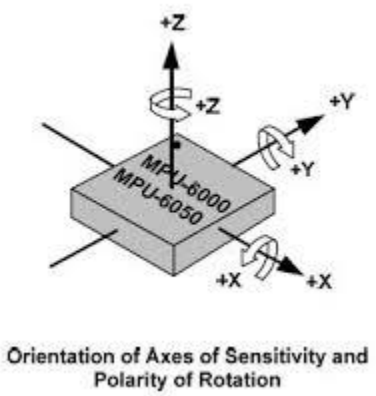

Figure 1 Demonstration of the axis of motion detector[1]

The device is configured to yield the desired ranges of accelerometer in ‘g’ and gyroscope reading range in ‘dps’. The readings are read from the registers of the MPU 6050 using serial communication. The serial bus provides the power to the motion sensor. The hard ware also comprises of a pressure switch that helps the user avoid the recording of air gesture movements. When the user is about to write he can use the pressure switch to turn on the recording and again turn it off by using the same switch to eliminate the error data. The sampling time for which the device is configured, is selected such that the reconstruction of the alphabet is precise and accurate. Too large sampling time will result in inaccuracy in analysis. Too small sampling time would create a large data set whose manipulation is difficult. A block diagram representing the pen components is shown in Figure 2.

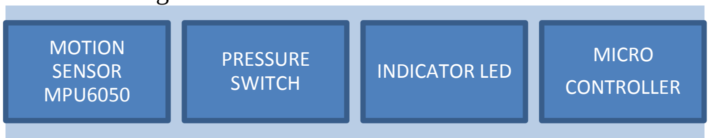

Figure 2 Block diagram of the pen

V. MOTION SENSOR

The motion detection sensor is the GY-521 breakout board that has an accelerometer and gyroscope sensor fusion unit MPU-6050. The MPU-6050 caters for the x-axis, y-axis, and z-axis movements as shown in Figure 1. The accelerometer on this IC is used to record the acceleration and the tilt angle of the pen. The gyroscope is accounted for recording the orientation of the user input. [14] The data gathered in the raw form is converted to acceleration and rotational motion using the formulae to convert it to analog readings in m/s^2 and rad/sec respectively. This data is in the form of motion waveforms which are processed by error corrections and further algorithm is applied on it.

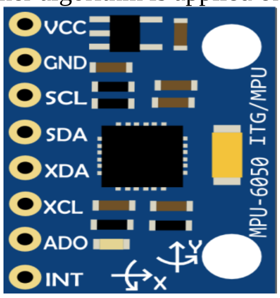

Figure 3 Motion detection unit of the pen[2]

The IC shown in figure 2 has many inbuilt functions; A/D converter in it helps to record the data in the digital form. The axes mainly in use are the Cartesian x-axis and z-axis as the writer inputs the data in this plane. The y-axis is used to record the up and down movement of the pen resulting from its user’s motion. The orientation, acceleration and tilt angle obtained from the motion detection unit of the pen device produce enough useful information that helps to trace the intermediate plot of the data that is used for further processes of matching and conversion. The motion sensor has an inbuilt temperature sensor that yields the temperature of the surrounding of the components. This temperature sensor is used to monitor the working temperature of the sensor.

VI. ERROR CORRECTION

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[1] Data Sheet of MPU 6050, page 21

[2] http://fritzing.org/projects/mpu-6050-board-gy-521-acelerometro-y-giroscopio

Since the motion detection unit is providing the base of the research work i.e. the data set. The acceleration and the orientation are used for further processes of this research that is why it is necessary to calibrate the motion sensor finely to reduce the input noise and for precise output conversion.[13], [15] The Motion detection sensor is calibrated using the self test registers. The well calibrated sensor produces the effective perfect results and help to achieve a greater reconstruction rate as output. The equation for displacement from acceleration is [16]

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

A.Self Test

The wire.read() command of Arduino language is used to read the data from the self test registers. This data is converted to useful self test measures of the MPU 6050 as provided in its register map data sheet. The self test data yields the factory trim and that in turns provides us with the self test results in percentage. When this percentage is under specified limits the device is working properly.

B.Sensor Configuration

The wire.write() command of Arduino language is used to write a data value to the configuration registers of the device to configure it to yield proper data output within the specified scale ranges. Also the sample rate is set using the register configurations.

C. Raw Data

The data from the motion sensor in its very raw form is digitalized. To further use this data we manipulate this data in the microcontroller itself using the correction factors specified in the data sheet. The correction factors of the data sheet provide data from accelerometer and gyroscope in 'g' and 'dps' respectively. This data is further converted to ms^{-2} and rad/sec for manipulation using the conversion factors. The acceleration about the x axis vs the acceleration about the y axis can be seen in the plot given below. We see that the data obtained is very noisy and we implement filters on the raw data. The data obtained in the raw form from MPU 6050 is seen in Figure 4.

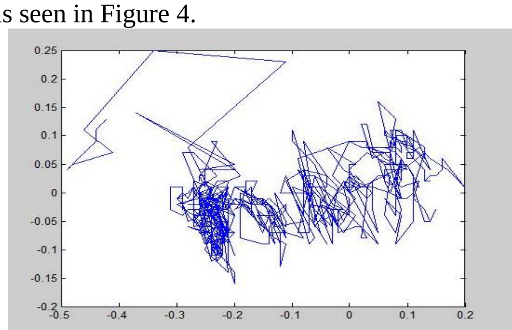

Figure 4 Raw data from the MPU 6050

D. Filters

The raw data is filtered out to obtain a noise less data. The filters that can be used are the Kalman and the complementary filters. The complementary filters use the combination of low pass and the high pass filter. This combination takes in both the accelerometer and gyroscope data to yield a single value at a point. In this paper we are using the Kalman filter to eliminate the noise.

The Kalman filter is implemented on each of the axis of the accelerometer and gyroscope data. It uses a set of equations to predict and update the values about an axis to remove the noise effect. [17]

The predict equations are;

$$x_{n|n-1} = x_{n-1|n-1} \qquad (2)$$

$$p_{n|n-1} = p_{n-1|n-1} + q_n \qquad (3)$$

And the update equations are;

$$K_n = \frac{p_{n|n-1}}{p_{n|n-1}+r} \qquad (4)$$

$$x_{n|n} = x_{n|n-1} + K_n(y_n - x_{n|n-1}) \qquad (5)$$

$$p_{n|n} = (1 + K_n)p_{n|n-1} \qquad (6)$$

Where;

x= estimated state

y= measured state

First, we have used the Kalman filter on the acceleration data as shown in the figure 5. The line Y1 indicates the raw data that shows the distortion and the line X1|1 is the filtered data.

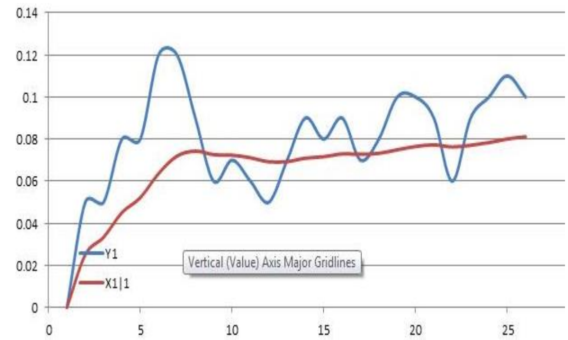

Figure 5 Raw vs Filtered data

This filtered data is then integrated by using the equation (1) to get displacement as the output. The x in (1) denotes the displacement and n in equation (1) denotes the point at which it is measured. This displacement across the x axis and y axis when plotted the x and y axis for a given input character 'u' yield Figure 6.This displacement data is then again passed from the Kalman filter to get a smooth curve. That curve is further used for manipulations.

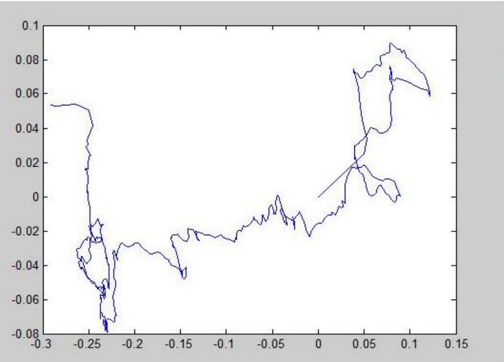

Figure 6 Displacement across the x-axis and y-axis calculated using the filtered accelerometer data

VII. ALGORITHM

The algorithm of reconstruction is divided into various steps as described below.

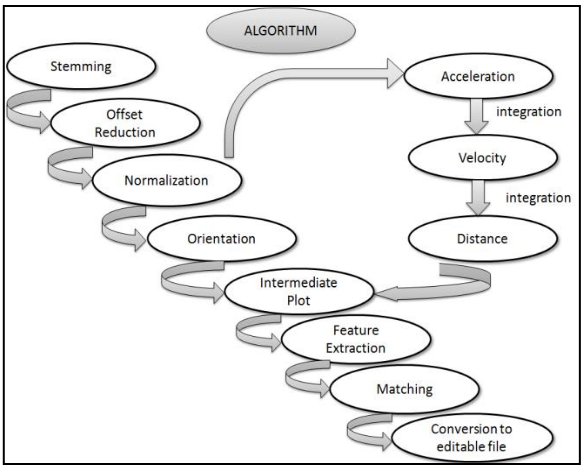

Figure 7 Algorithm Flow Chart

The algorithm is designed to convert the data received by the IMU sensor into a recognizable letter on a computer screen. First the data is passed through some initial signal processing of stemming, normalization and off set reduction.[18]This processed data is transferred into a kalman filter to reduce the error reading and noise. The values for r and q are specified according to our requirement in the kalman filter. This data will then be fed into the conversion algorithm that converts the acceleration reading received from the MPU-6050 into distance reading by double integration. The distance reading and x and y axis are plotted against each other to form an intermediate plot.[19] This plot is then passed through feature extraction algorithm; the features [20]of this plot are then compared to the data base using an online recognition algorithm with a good conversion rate.[21]

VIII. RESULTS

In our paper we have studied motion detection IC MPU-6050 in detail, the data received is used to draw an intermediate curve which is redefined and made smoother by noise reduction using the Kalman filter. The result obtained can further be used to generate a character in an editable file according the algorithm proposed by in Figure7. The raw data after processing is smoothing out is shown in Figure 8.

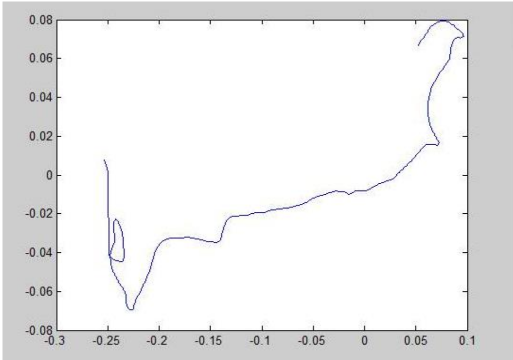

Figure 8 The Reconstructed Alphabet 'U'

IX. CONCLUSION

In this paper we have extensively studied the use of motion sensors. One of its applications that we have researched on is the dynamic character recognition for the reconstruction of hand writing into an editable document. We have used a motion detection IC the MPU 6050 for the recording of acceleration and orientation readings. These readings are refined by a number of error corrections explained in the paper. The filtered data can be further manipulated to reconstruct the letters by implementing our probabilistic algorithm. Our research takes into account the dynamics of the writing process and provides a less expensive, more accurate and real time alternative to Optical Character Recognition.

X. FUTURE WORK

The future aspect of the research includes the increase the efficiency of reconstruction rate by the optimization of the data base. It also consists of the introduction and training of symbols, slanting characters and letters of other languages to the algorithm and the variation in the writing speed, time and style of the writer can be catered for. The limitations of this research can be catered for in the future work by including the numeric, special characters, and forign languages. We propose the use of genetic algorithm in combination with our designed algorithm for the progression of future work.

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