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Detection of Apnea Event with ANN Using Acceleration Data

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Abstract – In this study, the accelerations caused by the diaphragm movements during respiration were monitored with a 3-axis accelerometer and the measured accelerations were recorded on an SD card. A measurement system for this purpose was developed. The moments in which diaphragm movements stopped were detected by using Matlab. An ANN has been designed to simulate measured real data. A total of 5886 real data were applied to ANN. In the training of ANN, 3943 randomly selected from these data (66.6% of the total data) were used. The remaining 1943 data (33.33% of the total data) was also used for the test. Thereby estimating the apnea event was provided by the designed ANN. The results were plotted and proved to be quite similar to each other.As a result, apnea events have been successfully detected.

Keywords – Apnea event, accelerometer, ANN, microprocessor.

I. Introduction

The apnea syndrome characterizing by abnormal breath pause during sleep are a common sleep disorder. In 2012, it is reported by Xie and Minn [1] that, it affects 2% of middle-aged women and 4% of middle-aged men, approximately. An apnea is defined as the decreasing of magnitude of respiration movement to less than 5% of normal value in breathing cases for certain amount of time by Várady et al. [2]. In other words, stopping the air flow for at least 10 sec during breathing is defined as Sleep Apnea. There are 3 types of sleep apnea;

Obstructive sleep apnea (OSA): This type of apnea is identified by the existence of thoracic effort to continue breathing when the air flow completely stops and this is more frequent pattern [3].

Central sleep apnea (CSA): This type of apnea is identified by a complete cutoff of both airflow and respiratory movements during, at least, 10 sec [3].

Mixed sleep apnea (MSA): Pattern of this apnea type is a combination of the previous two types, defined by a central respiratory pause followed, in a relatively short time interval, by an obstructive ventilator effort [4].

II. Materials and Method

The data recording system includes Arduino Mega microcontroller, 4x24 character LCD display, ADXL345 acceleration sensor, SD memory etc. All of the power is supplied with a 12V battery source. In the system, the acceleration movements in the diaphragm region during the breathing were observed with a 3-axis accelerometer (ADXL345) and were recorded on a SD memory card in real time. If there was no movement of any axis for 10 seconds or more, the condition was determined as "apnea event" (according to reference that American Academy of Sleep Medicine-AASM [5]). Acceleration values of XYZ axes measured by the developed device were applied to ANN model with 3 input 1 output. Accelerometer data were selected as input (X_i, Y_i, Z_i), and the apnea event was considered output (A_j). As the ANN algorithm, feed- forward neural networks named standard back propagation training algorithm was preferred. In the designed ANN, three layers were formed, 18 neurons in the hidden layer, two neurons at the entrance and 2 neurons at the exit layer. Values of 5-10-18-20-25 were selected for the number of neurons in the hidden layer and a mesh with 18 hidden neurons giving the most suitable result was selected. A total of 5886 data were applied to ANN. In the training of ANN, 3943 randomly selected from these data (66.6% of the total data) were used. The remaining 1943 data (33.33% of the total data) was also used for the test. Thereby estimating the apnea event was provided by the designed ANN. The results were plotted and proved to be quite similar to each other.

A. Acceleration Sensor

Accelerometer sensors measure proper acceleration with respect to the earth gravity. It is not the coordinate acceleration which is change of speed in space, but it is rather the acceleration that gives the orientation according to the weight provided by the gravity with quantity.

3 axis (XYZ) MEMS accelerometers are used to sense orientation, vibration, coordinate acceleration and shock by measuring magnitude and direction of the proper acceleration [6].

The ADXL345 is also a MEMS based triplex -axis accelerometer with digital output. It is manufactured by Analog Devices Inc. It features a selectable ±2-g, ±4-g, ±8-g or ±16-g measurement range (selected the ±2g setup in this study); resolution of up to 13 bits; fixed 4-mg/ least significant bit (LSB) sensitivity; a tiny 3-mm × 5-mm × 1-mm package; ultralow power consumption (25µA to 130µA); standard 2-wire Inter-Integrated Circuit (I^2C) and Serial Peripheral Interface (SPI) serial digital interfacing; and 32-level first in first out (FIFO) storage[7]. MEMS accelerometers that are used from military areas to health

care industry have been explained in [8-9]. Hence, this combination of features makes the ADXL345 an appropriate accelerometer to observing the movements of diaphragm for our study. Figure 1 shows mechanism illustration of the MEMS accelerometer used in the experiments.

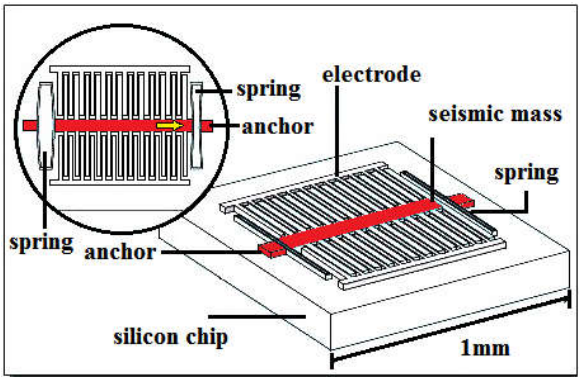

Fig. 1 ADXL345 accelerometer mechanism illustration [6].

B. Measurement Device

At the measurement circuit, an acceleration sensor which has the ability to define position by using 3-axis cartesian coordinate systems is used to measurement of accelerations on the diaphragm. The accelerations data measured by the sensor were recorded on the SD card (32gb). Figure 2 shows a block diagram of the designed and realized system.

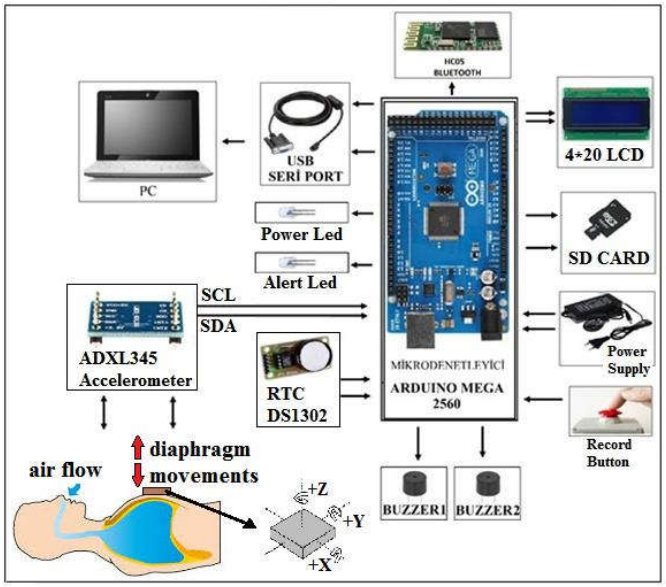

Fig. 2 The block diagram of designed and realized system.

Sampling frequency of designed and realized system is 20Hz. Each 32-bits of float received data are composed of x, y and z data. Thereby, the amounts of data transferred are 20 x 3 x 32 = 1920 bits / sec and it is suitable for a wireless transmission.

The circuit of the system was composed of Arduino Mega (preferred because of the need for the number of peripheral ports) microcontroller (licensed with Creative Commons Attribution Share-Alike 2.5), 4x20 character LCD display, accelerometer sensor, SD memory component, RTC (real time clock, produced by the Dallas company,) and a button (for recording). The required power for the entire circuit has been obtained from a circuit containing a 12V battery. Arduino board is being programmed with the Arduino Software (IDE). V.1.6.4 software was used to program the Arduino microcontroller. The accelerometer was extended via a cable (usb type of cable) during the tests.

The apnea detection through accelerations resulting from diaphragm movements and measuring device are explained in detail at reference [10].

C. Modelling with ANN

ANN is an important optimization method that has become popular in recent times and is preferred to many areas [11,12]. In modelling with ANN, V7.12.0.635 (R2011a) Matlab software version which has Neural Network Toolbox and GUI interface is used. Acceleration values of the XYZ axes measured by the developed device are applied to the ANN system that has 3 inputs 1output constructed that shown in Figure 3, and the Apne event is estimated at the output.

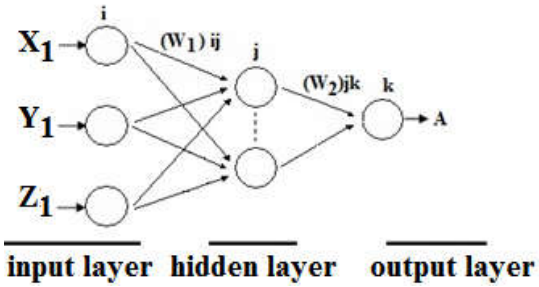

Fig. 3 ANN structure.

As the ANN algorithm, feed- forward neural networks named standard back propagation training algorithm was preferred. In the designed ANN, three layers were formed that 18 neurons in the hidden layer, the two neurons at the input and 2 neurons at output layer. For the number of neurons in the hidden layer, 5-10-18-20-25 values were tried and the network with 18 hidden neurons giving the most suitable result was selected. The log-sig activation function was selected as the activation function. The mathematical expression of this function was given in Equation 1.

$$F(x) = \frac{1}{1+e^{-x}} \tag{1}$$

Up to 1 den of 5000 tests were done to find the number of iterations. As a result of these experiments, the most appropriate number of iterations for ANN was taken as 1500.

III. Results

Thanks to the designed system, accelerations occurring on the diaphragm were measured with an accelerometer. With three input and output ANN was designed to detect the apnea event from measured accelerations. The measured 5886 acceleration data was applied to the designed ANN and the apnea events were detected successfully

The presence of the apnea event is considered as '1' and the case of not apnea as '0'. The results obtained from ANN and the experimental data were compared with each other in Figure 4.

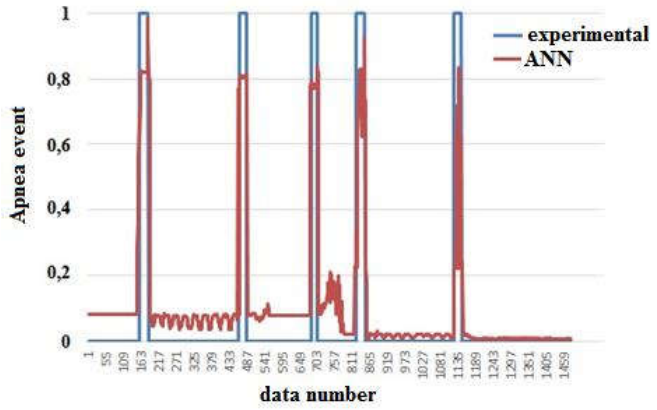

Fig. 4 Comparison of measured data with ANN data and apnea detection.

As shown in Figure 4, the results of the ANN test results and experimental test data are very close. The apnea event can be easily understood by looking at both results.

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