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Remote ECG signal monitoring and classification based on Arduino with AD8232 sensor

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Abstract

Real time monitoring with IOT is developed in the industry of health care , this can enable the doctors and specialist to diagnosis the patient status in quick, smart and efficient methods. Although, there is a lot of research and studies are designed methods for observing the ECG signal remotely, there are no proposed methods for classifying these signals with monitoring, and therefore , to design complete health care system, classification techniques should be used to classify the extracted signal. In this paper , We have proposed ECG monitoring and classification system. The proposed system is extracted ECG signal based on AD8232 sensor with the ardunino nodeMcu, analog to digital converter and its communication is used to convert the signal to more precision , then the extracted signal is transmitted to cloud to be used at anywhere by using cloud, the signal is pre-processed to remove the noise and QRS complex is detected to determine the other characteristics of the signal such as heart rate, also to determine one cycle of ECG signal, later the signal is classified by using proposed convolution neural network model to detect the signal status. The extracted ECG signal is transmitted in real time to cloud (Ubidots cloud is used) through ESP8266 over to the cloud using WiFi based on MQTT publishing method. The experimental results are performed on different signals and the different stage of de-noising and QRS detection are applied and different pooling layers are used in the proposed CNN model. The results show that the proposed classification model is achieved accuracy (94.94%) with (94.56%), (94.56%) and (5.06) for sensitivity, specificity and error rate (ERR) respectively.

Keywords: IOT, ECG, CNN, and Cloud.

1. Introduction

Internet of things (IOT) is principle of being able to manage, analysis and control specific object at anywhere by using internet, different devices of network are connected by means of different physical media, which is accomplished by sensors, that receives the signal from real averment in the world, then this data is transmitted by utilizing the internet to specific cloud to be used by specialist for monitoring, controlling and make decisions based on different algorithms and methods.

IOT can be used widely in medical application. For older people, who are suffered from cardio disease , real time monitoring can provide the doctor with very important information about heart activity, the most significant means of heart activity status is electrocardiogram (ECG)signal, The typical ECG signal is shown in figure (1), it is constructed from P-wave, which represents the upper champers activity of the heart, QRS represents the most important champers of the signal and it is used for analysis the status of the heart, also it is used to determine the other characteristics of the signal, the other part is T wave , which is show the activity of lower champers, So any problem in the heart can be reflected on the waveform of these part especially QRS complex, which is detected by shorten, widening or lengthening QRS complex.[1,2,3,4]

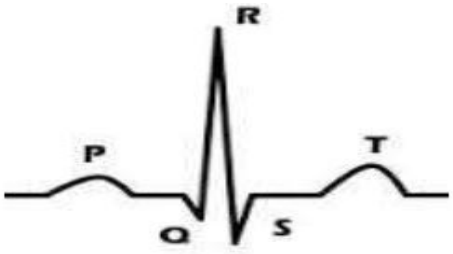


Figure (1) ECG waveform.

In this paper , We have proposed ECG monitoring and classification system, at first, ECG signal is extracted based on AD8232 with the arduino , then de-noising processing is used to remove the noise from the signal based on enhancement . Latter , QRS complex detection is used to detect peak of the signal, finally CNN model is designed to be used for ECG classification. The sensed data will be transmitted to Web server , from this web server, anyone can monitor status of patient at anywhere of the world, later data are downloaded to be used as input

to classification system. We are used Nodemcu esp8266 microcontroller, which is used MQTT connection in Webserver(Ubidots cloud), then the data is transmitted according to the programmed Wi-Fi and specified allocated IP address [5,6].

2. Literature Survey

In the literature review, there are different study and research are proposed using different methods to implement the ideas of ECG signal monitoring , some of which are depend on raspberry pi and the other are used arduino for extracting the ECG signal from human body then sending it to the specified cloud, or to use it directly by sending it to central computer.

Warish D. P. are used Raspberry Pi 3 with ECG sensor , temperature sensor to monitor state of patients in real time manner . This method is used by specialist to detect health problem, also they are used Deep Neural Networks (DNN) to analysis and process the collected information of patient [7] . Jasti Sowmya S. et al. proposed monitoring the patient continuously based on using sensors such as of temperature sensor , pulse rate and ECG sensor . The sensors are read data in real time , and according to the this values of sensor , the system will alert patient and patient's relative by SMS to the android mobile if up normal value is sensed otherwise the reading is repeated [8]. Surekha. N. et. al. are proposed health monitor system by using different sensors such as , blood pressure sensor , temperature sensor, ECG signal , then the data are collected and monitored using microcontroller device, according to the proposed system anyone anywhere in world can monitor status of patient's health based on connection to internet [9] . Rohit Kumar D. et. al are used different sensors for sensing real time patient status based on ECG sensors, blood pressure sensor, etc. . The proposed method includes processing of data , which is used to send extracted data to specified staff by using Internet of things (IOT) [10] . K. Seena Naik et al. are introduced a new monitoring method by using different sensors such as ECG sensor and heartbeat sensor, which are connected with Raspberry Pi microcontroller , the sensors are gathered data in real time and used 3G to display collected data on LCD devices and also it is displayed on doctor's device [11]. Ayaskanta M. et al. are proposed smart health monitoring system, which is implemented based on AD8232 heart sensor to monitor heart rate by send the sensed data is transmitted in stream of data to cloud by using wireless module , then this data t will be displayed on web server [12].

Although, there is a lot of research and studies has designed methods for observing the ECG signal remotely, there are no proposed methods for classifying these signals with monitoring, and therefore , to design complete health care system, classification techniques should be used classify the extracted signal, in this paper. We have proposed ECG monitoring and classification system, at first, ECG signal is extracted based on AD8232 with the Arduino , then de-noising processing is used to remove the noise from the signal based on enhancement . Latter, QRS complex detection is used to detect peak of the signal finally CNN model is designed to be used for ECG classification.

3. Proposed System Methodology

The proposed system is shown in figure (2), it is constructed from four main parts, the first part is signal extraction, which is performed by AD8232 sensor ,it is used to collect the ECG signal from human body and send it by ardunio (NodeMcu8266) .The second part, which represents signal enhancement and de-noising is used to enhance the signal from the noise ,while the third part represents the QRS complex detection, that can be used to determine some characteristics of the signal such as heart rate (HR) , while the last stage of the system is classification of the signal, which is performed by anew CNN model, which is designed based different pooling layers using wavelet transform , Gaussian based wavelet transform pooling layers and half Gaussian pooling methods [13-15] are used in CNN classification network, in addition to Max. pooling and average pooling methods [16,17].

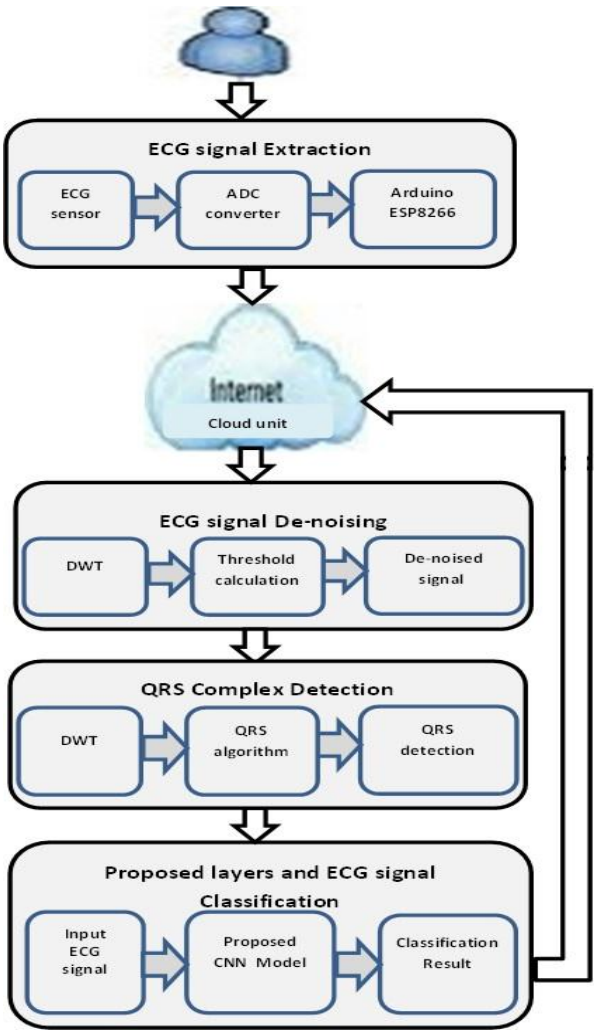


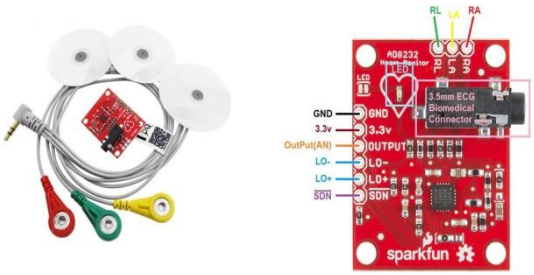
Figure (2) proposed ECG classification system.

3.1. ECG Signal Extraction

A remote monitoring and controlling of healthcare system by means of using sensors devices can be implemented in a global network by using arduino with sensors and other interfaces devices . The sensor devices collect , gathers and share the required information with each other to be used for analysis , monitor and control data with high accuracy. The proposed system is constructed from the following components.

i. ECG sensor (AD8232)

This device is integrated signal conditioning for ECG and other bio-potential applications of measurement. It is used to extract bio-potential signals in the presence of noisy conditions which can be amplified and filtered to reduce some noise such as those created by electrode placement or motion. This design can allow for an power analog-to-digital converter (ADC) or an embedded microcontroller to extract output signal easily. The AD8232 is used a two pole high pass filter to eliminate the noise that is produced from motion artifacts. This filter can be coupled with architecture of instrumentation of amplifier to achieve high gain with high pass in a single stage. AD8232 have a fast restore function that can reduce duration of long settling tails of high pass filters. After an signal change that rails the amplifier (such as a leads off condition), AD8232 adjusts to a higher filter cutoff automatically. This advantage can recover AD8232 quickly, and take valid measurements soon after connecting electrodes to the subject. Performance for the A grade models is Rated temperature range from zero °C to 70°C and working with temperature range from -40°C to 85°C, the description of this device is shown in figure (3) [18-20].

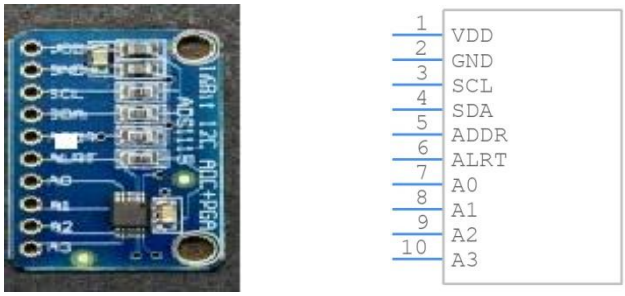


-A- -B-

Figure (3) AD8232 ECG sensor device. A- components . B-pin diagram .

ii. Analog to Digital conversion ADC (ADS1115)

The ADS1115 device is 4-channel 16-bit with low cost analog to digital converter. It can be used to take four channel input and converts them to 16 bit digital value. The serial peripheral interface (SPI) is used as bus to perform synchronous serial communication between this device and arduino. [11] , its clock is generated by arduino, the rate of transmitted data of this ADC/ ADS1115 is from rates up to 860 samples per second. This rate for samples are decides based on sampling rate ,which is software programmed by choosing sampling duration. This device is single supply operated and the range of voltage between 2.0 to 5.5V. The supply of arduino is 3.3V, hence it can be used to power the ADS1115 ADC which is also used for AD8232, also it is work specified from –40°C to 125C. Figure (4) shows the detail description of ADS1115 ADC.



-A-. -B-

Figure (4) ADS1115 ADC, A-integrated circuit. B- block diagram of pin.

iii. Arduino ESP8266

The Arduino ESP8266 is an open-source microcontroller that can be used in different application .This board is equipped with digital and analog input/output (I/O) pins , that can be interfaced with various other boards (shields) or circuits. The programming is performed based on Arduino IDE software. The most important advantage of this microcontroller is that it have the WiFi and Bluetooth , which can be used in most application of IOT, the diagram of this microcontroller is shown in figure (5).

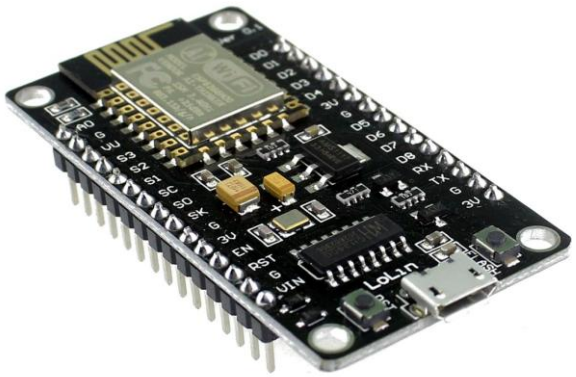


Figure (5) pin diagram of ardunio nodemcu.

3.2. ECG signal De-noising

Because that ECG signal contains different types of noises such electrode motion (EM) , baseline wander (BW), and muscle artifact (MA). Baseline is low frequency can be arises from breathing, skeletal muscle activity generate muscle artifact, while the change in the electrode skin impedance will cause electrode motion noise [21]. Unfortunately, these noise can reduce the accuracy of diagnosis, so the raw signal should be de-noised to reduce the effect of the noise, which can be satisfied by using wavelet transform and applying threshold as shown in figure (6), where the wavelet transform is applied to isolate the frequency band, then high frequency components of the signal is applied to threshold to reduce the noise which is contended as high frequency [22].

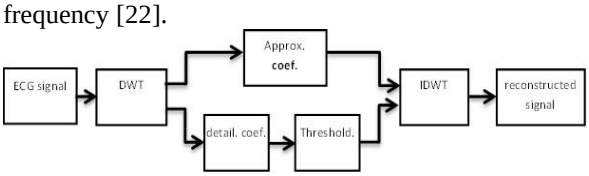


Figure (6) ECG de-noising system.

3.3. QRS complex Detection

QRS complex part of the ECG signal represents most important characteristics of ECG signal, which is used to diagnosis problem of the heart, so it is necessary to detect this peak to detect these features. In this paper, We are used the detected QRS to determine one cycle from the ECG signal to be used as input to classification stage . The original signal is applied to DWT, then approximation coefficients of the transform will be used to determine the basic features to detect peak of the signal as shown in figure (7) [4].

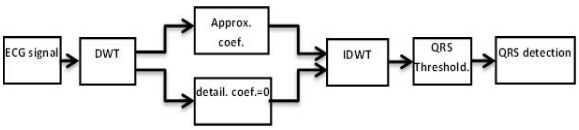


Figure (7) ECG de-noising system.

3.4. ECG Classification

We have design a new one dimension CNN model (1-D CNN) which is constructed from different layers as shown in figure (8). The input is csv data ECG signal , this input is passed through sequential layers of convolution, rectified linear unit layer (ReLu), pooling, add, fully and dense layers with the sequence that is shown in figure(8), which describes the details of the proposed model. Different pooling layers are used in the proposed model, these layers are used to extract the best features of the convolution output through the convolution neural network , these layers can overcome the disadvantages of the standard pooling method (Max. pooling and average pooling method).

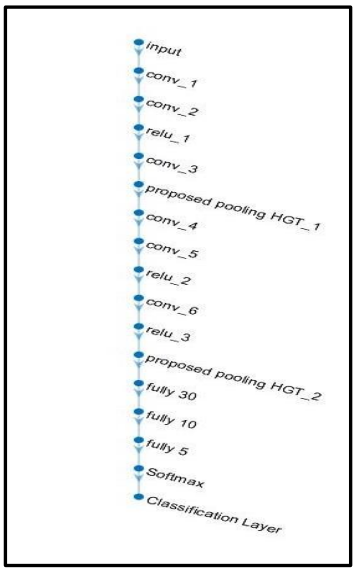


Figure (8) proposed 1-D CNN model

4. Experimental Results and Discussion

The system is implemented and the hardware component of the work is programmed by using arduino IDE, while the pre-processing and classification software are performed by using mat lab 2020a with Cori 7,2.4GH CPU. The proposed classification model is trained and tested using MIT-BIH ECG dataset [23,24]and the result are displayed .The ECG sensor is extracted the real signal from the body as shown in figure (9), which shows the real plotted signal in arduino IDE terminal , then the signal is published to the cloud (Ubidots cloud) as shown in figure (10), which represents screen shoot to procedure of transmitting the data to the cloud, then the data will be available on the server website and anyone can log in and obtain the required information.

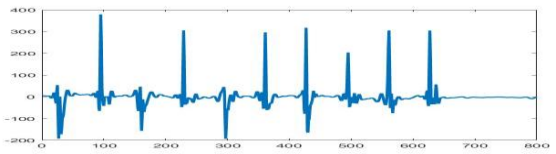


Figure (9) extracted signal using AD8232 sensor.

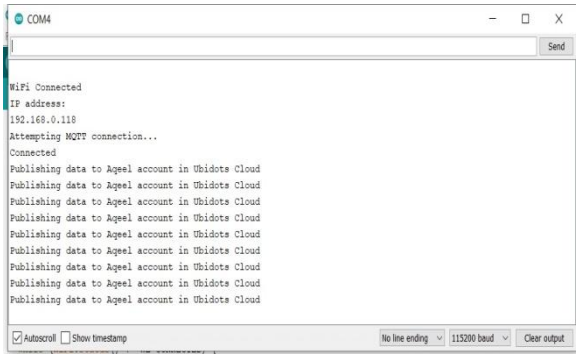
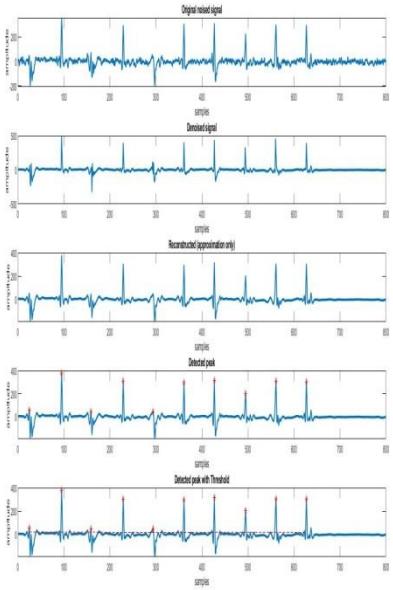
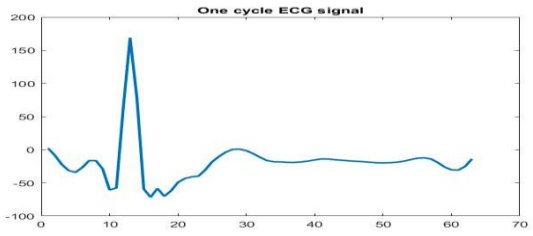


Figure (10) screen shoot for real time publishing of ECG data to Ubidots cloud.

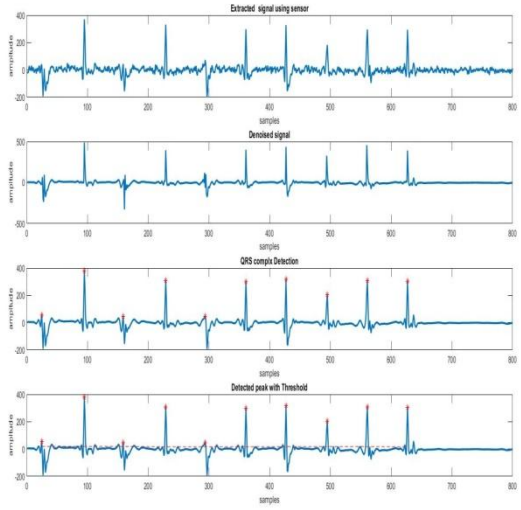
The result of de-noising and QRS complex detection for the extracted signal1 are shown in figure (11),which shows the de-noising stage to reduce the noise , also QRS complex is detected , it is clear the difference between the raw the signal, which have redundant in high frequency due to movement of electrode of the sensor, also the ECG cycle can be determine as shown in figure (12), then the waveform of one cycle for ECG is determined depending on HR based on QRS detection as shown in figure (11). The result for signal 2 is shown in figure (13) and figure (14) respectively.



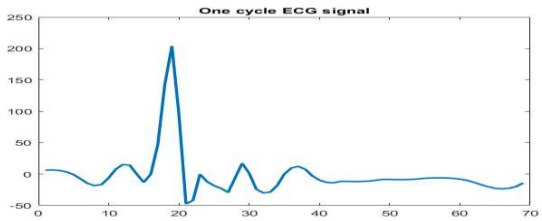
Figure(11) Extracted signal , de-noised signal and QRS complex detection for signal 1.



Figure(12) One Cycle ECG signal for extracted signal 1.



Figure(13) extracted signal , de-noised signal and QRS complex detection. For signal 2



Figure(14) One Cycle ECG signal for extracted signal 2.

The raw ECG signal should be processed to be suitable input to the classifier, these steps are shown in figure (15) . Figure (16) shows the original raw signal, that is extracted using proposed ECG extraction model . The original signal is fragmented into isolated cycles as shown in figure (17) to be classified later by the CNN model. The fragmentation is performed based on determining the QRS peak with respect to the number of sample for each cycle to isolate each cycle from the other .As shown in these figure , the sampling rate is less than 184 sample (the sample rate of the classification model for one ECG cycle), this signal should be up sampled to be input to the classification model. The resolution (up sampling) is shown in figure (18), this up sampling is accomplished by using averaging method to increase the sampling of the signal. Pre-processing is the final stage of preparation of the signal to be input to the classifier. As we mention previously , the sampling rate should be 184 sample , so the signal should have this number of sample, also the signal should be normalized , because the signal is measured in µv, so it must be converted to mv, all this preprocessing is shown in figure (19).

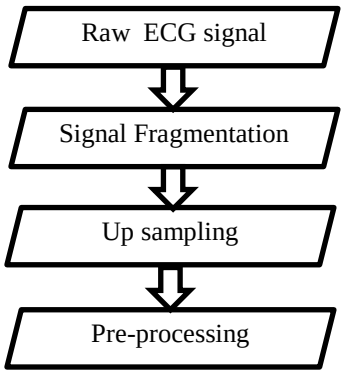


Figure (15) ECG cycle extraction steps.

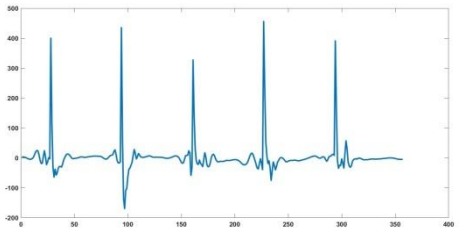


Figure (16) original signal .

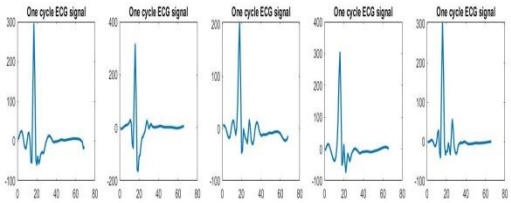


Figure (17) fragment of original signal .

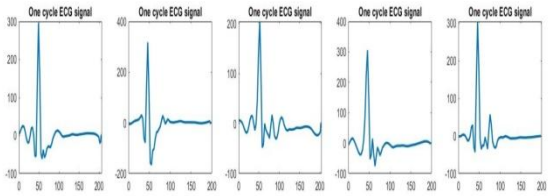


Figure (18) fragment after resolution (up sampling) .

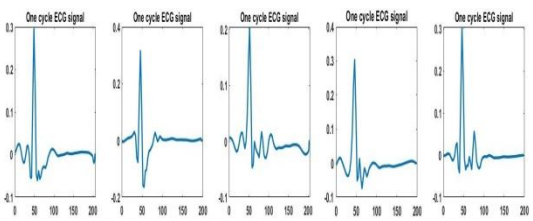


Figure (19) Normalized signal .

In the proposed classification CNN model, We are used different pooling layer to extract the features of convolution layers in the proposed CNN model and the results in terms of accuracy are described in Table (1), which shows that HGT method is achieved best result (94.94%) verses (93.97%) for GWT pooling methods [13,14] , (94.58) for (wt+ max)method, while the other performance metrics are shown in Table (2).The best results are satisfied with (HGT)method [24], also it is achieved(94.56%), (94.56%) and (5.06) for sensitivity specificity and error rate (ERR) respectively.

Table (1) Results of classification stage for different pooling layers.

Method	Max [Ref. 16]	Average [Ref. 17]	Wt+max	Wt+average	GWT	HGT
Accuracy (%)	**93.27**	**94.01**	٩٤,٥٨	٩٤,٣٨	٩٣,٩٧	٩٤,٩٤

Table (2) Performance measures for classification stage for different pooling layers

Method	Wt+max	Wt+average	GWT	HGT
Accuracy (%)	٩٣,٢٧	**٩٤,٢٧**	٩٣,٩٧	٩٤,٩٤
Sensitivity(SN%)	٩٣,٢٣	٩٤,٢١	٩٤,٢١	٩٤,٥٦
False positive Rate FPR(%)	٦,٦٧	**٥,٧٣**	٥,٧٩	٤,٤٤
Specificity (%)	٩٤,٢٤	٩٤,٥٦	٩٤,٥٦	٩٤,٥٦
ERR(%)	٦,٦٣	٥,٦٣	٦,٠٣	٥,٠٦

5. Conclusions

Internet of thing can be used in medical field to monitor, control and classify the status of patient remotely, so different research and methodology are developed to introduced a new application in health area. In this paper, We have proposed anew ECG monitoring , controlling and classification system based on deep learning convolution neural network (CNN), because ECG signal is very significant measure to diagnosis the problem of human heart, which can be used to diagnosis the cardio disease . The proposed ECG signal is extracted the ECG signal based on AD8232 sensor with ADS1115 analog to digital converter, which is connected to arduino NodMcu , and its communication and implementation are programmed by using arduino IDE terminal ,because the extracted signal have some types of noise, de-noising and enhancement algorithms are applied to improve the quality of the signal based on wavelet transform with adaptive threshold. Then QRS complex detection is performed to determine one cycle of ECG to be used as input to classification stage , then classification is performed by using the proposed CNN model, which is used convolution layer with different pooling layer to extract the features of the convolution . The extracted ECG signal is transmitted in real time to cloud (We have used Ubidots cloud) through ESP8266 over to the cloud using WiFi based on MQTT publishing method. The experimental results are performed on different signals and the different stage of de-noising and QRS detection are applied with good results and different pooling layers are used in the

proposed CNN model. The results show that best results for classification is satisfied with HGT pooling method , which is achieved accuracy (94.94%) verses (93.97%) for GWT method, also it is achieved (94.56%), (94.56%) and (5.06) for sensitivity specificity and error rate (ERR) respectively.

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