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Abstract. With the growing social pressure, most people are facing health problems and most of these are causing because of frequent heart attacks. It is very important to design an effective system that can diagnose the forthcoming happening of heart attacks or atrial fibrillations. As IoT (Internet of Things) is the most emerging and prominent technology in the modern era, a combination of the personal computer and IoT has become very efficient technology. The combined system provides various features to the user such as in emergencies to detect heart disease possibility through symptoms, sending messages to doctors according to the stage of the possibility of disease, and helps in fixing it. In case of an emergency, the system sends an emergency report to the desired doctor. In this paper, we propose an IoT based heart disease detection system using a Recurrent Neural Network (RNN). In our approach, we use Long Short Term Memory (LSTM) algorithm. The proposed system can perform the diagnosis of heart disease using RNN. The developed system helps the physician to prescribe patients without being present physically. The estimation of the result claims that the proposed system can detect heart disease efficiently.

Keywords: Recurrent Neural Network (RNN) · Long Short Term Memory (LSTM) · Internet of Things (IoT) · Atrial Fibrillation

1 Introduction

In the modern era, despite having technology in every person's reach, without the proper use of those technologies to monitor his/her health status, health problems are increasing day by day at a high pace. The death rate is also increasing. The most agitating problem now is heart failure.

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Heart failure, also known as Atrial Fibrillation (AF), is defined by the dysfunction of the heart's electrical system or irregular beating of a heart. Nowadays, leading a more modern life, we are being much unconscious about our health status. As heart attack may happen without any previous symptoms, it may lead to death very often. The day-by-day death rate is increasing so rapidly in this case. So it is the urge to be aware of health status so any happening may be avoided.

Therefore, a system is being proposed by designing a system that includes a wireless sensor to receive information with the respective human body heartbeat rate. Information will be transmitted on an IoT platform that is accessible by the user via the Internet. Using a continuous record of the body, those parameters are used to detect the heart-failure more efficiently. Moreover, an automatic alert generation feature is also added for emergencies.

The system architecture takes the raw signal into the input layer. After that, the hidden layer or recurrent layer using RNN and LSTM distinguishes the signal whether it is normal sinus rhythm or atrial fibrillation. Normal Sinus Rhythm (NSR) is the normal or actual sinus node impulse of heartbeat such as 72 per minute mostly ranging within 60 to 100 per minute. Atrial Fibrillation (AF), associated with an increased risk of stroke and heart failure, is a type of supraventricular tachycardia. When there is an abnormal impulse of heartbeat seen then it is assumed as a symptom of atrial fibrillation. Following this process, the possibility of heart failure can be detected through comparison.

Internet of Things defined by IoT is the more modern technology that has a vast field. Combining LSTM with IoT has become more fruitful technology. The combined system provides various features to the user such as determining heart disease possibility through symptoms, sending messages to doctors according to the stage of the possibility of disease, and helping in fixing it. In case of an emergency, the system sends an emergency report to the desired doctor.

2 Related Work

There are many methods to monitor the heart condition. As monitoring heart condition system is getting more popularity due to the easy accessibility, time-saving mechanism, and result accuracy, clinical experts are becoming dependent on these methods more than before. Therefore, it is crucial to find a robust method that can detect the problems and monitor the heart condition more accurately. Researchers have conducted a variety of researches on heart diseases adopting different approaches. Most common of them include IoT based approach for fetching data related to heart diseases from the human body [1–3] and the application of data mining and machine learning algorithms for analyzing such data and prediction of diseases [4–6]. In recent years, various deep learning algorithms are also showing promising accuracy in heart disease prediction results [7–10].

To remove the noises associated with the collected data through IoT devices, a novel approach is proposed [11] that makes use of the Sequential Recursive (SR) algorithm, Discrete Wavelet Transform (DWT) algorithm, and Fishers Linear Discriminant (FLD) algorithm for noise removal purpose. The filtered data collected this way is then matched with the existing heart disease dataset of MIT-BIH to diagnosis the problems in the heart. Though this way of diagnosis is evaluated using real-time data of different people, it still lacks in meeting some major problems related to the system like discovering and adjustment of the error in the retrieved data from sensors, the frequent updates of the knowledge-base in online, and the security issues.

To predict and diagnose heart diseases, another IoT based process is proposed in [12] with the help of cloud storage. Here, at first, data related to heart diseases are collected from the human body which is to be stored in cloud storage. The system also holds an existing dataset on heart diseases collected from the UCI (University of California, Irvine) repository and the patient's historical data from the previous experiments. Thus it tries to find out the diseases applying several machine learning algorithms on the available data. The system found that among the four classifiers used for testing, J48 outperforms others constituting about 91.50% accuracy in F1-score.

To provide instant and efficient information of heart diseases, a system is introduced in [13] that consists of Data Collection module, Data Prediction module, and User Interface module. The purpose of Data Collection module is collecting analog data by sensors from human body and converting, sampling, and grouping that data in digital format for further processing. In Data Prediction module, naive bayes algorithm is applied to the featured data extracted by the wavelet transform algorithm during data collection phase. Thus the system finally predicts whether a person has any of the three categories of heart diseases (Tachycardia, Bradycardia, Ventricular Tachycardia) with an accuracy of 95.67%.

To enhance the performance of the prediction result of the heart diseases, Khan [14] applied Modified Deep Convolutional Neural Network (MDCNN) for classifying sensor data as normal or abnormal. He also made a comparative analysis between MDCNN and other conventional classifying algorithms that revealed the feasibility of MDCNN over other algorithms he used.

To ensure the security of data in networking associated with IoT enabled artificial intelligent systems, a smart framework is proposed for the hospital atmosphere in [15]. However, the system was tested in small-scale and real-time operability is yet to be addressed.

3 System Architecture and Design

3.1 Architecture of the System Framework

The system architecture of the heart failure detection framework in Fig. 1 comprises four modules: input module, training module, testing module, and output module. Here the input module is responsible for fetching data from sensors. The training module processes data and saves weight and bias for further checking. The testing module predicts results through comparison and the output module provides the result of whether Atrial Fibrillation or Normal Sinus Rhythm.

Input Module. The first module is the input module. This module is used for fetching real-time data from sensors using Arduino. Fetched data is then passed to a personal computer for further analysis.

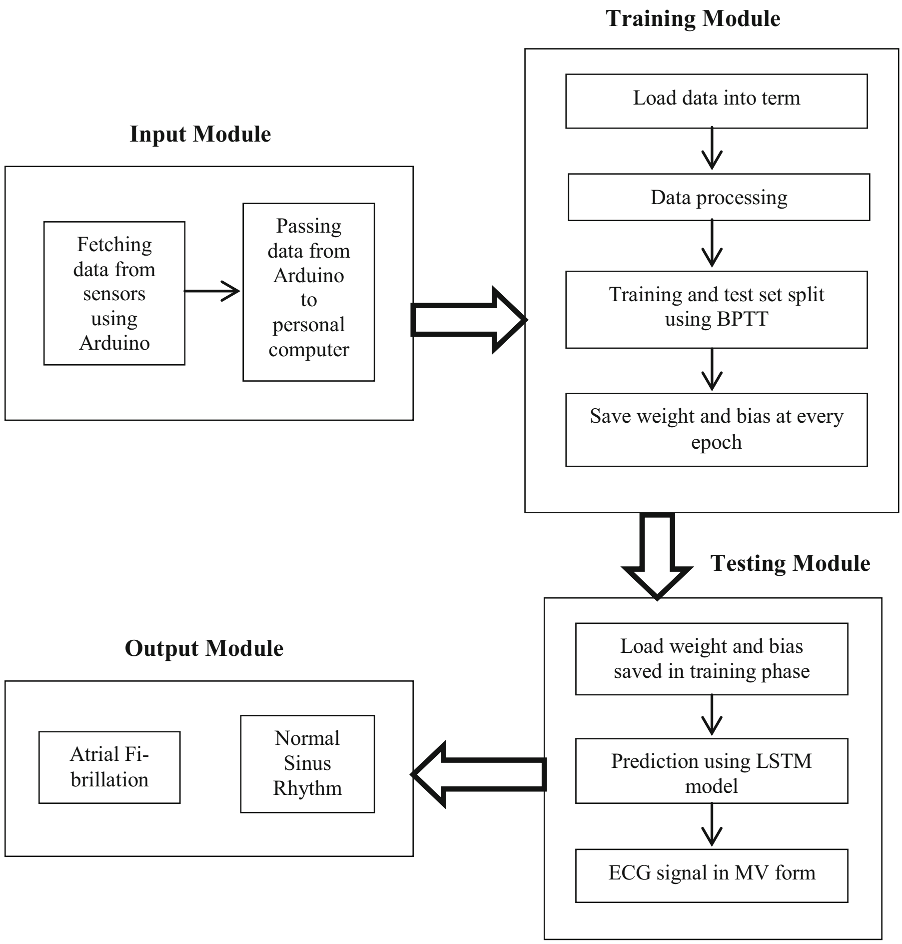

Fig. 1. The architecture of the proposed framework

Training Module. The second module is the training module. In this module after loading into data, term data is processed and split for training using Backpropagation through time (BPTT) algorithm. In each epoch weight and bias is generated. Weight and bias of each epoch are saved for further analysis. For training LSTM network sigmoid activation function, binary cross-entropy for loss calculation and Adam optimizer are used. In the training process, the Euclidian distance between two consecutive samples is calculated. Propagating through this process, the error is calculated and weight and bias are updated.

Testing Module. In the third module, the testing module test prediction is given. Here trained weight and bias of the model are loaded. AD8 single LED data is used as test data. Test data is taken using Arduino. Data was taken for 1 min. 15000 data alike are given as input. The predicted result is got based on this input.

Output Module. The fourth or final module is the output module. In this module comparison between testing dataset and training dataset is done. The final predicted result is given based on this comparison. The result prediction algorithm is used for assuming the final result. The final result may either be Atrial Fibrillation or Normal Sinus Rhythm.

3.2 Tasks of the System Framework

We divided the work of our framework into three different subtasks. These subtasks are discussed below.

Training LSTM Model. After taking the data set, training LSTM is started. Firstly dataset is split and knowing the ground truth x_train and y_train is set where x-train takes a large number of samples and the last column defines y_train. In x_train there are diverse samples whereas y_train contains only 0 or 1.

After adding weight and bias to both x_train and y_train the training process starts. We used sigmoid function as activation function containing the equation$1/(1 + e^{(-x)})$. Error is also measured using this activation function. The weight and bias of maximum accuracy are saved for further calculation. Training through BPTT, we got accuracy with 100%. The algorithm and an example of the LSTM training model are shown in Fig. 2 and Fig. 3 respectively.

Algorithm: Training LSTM Model
Input: Atrial fibrillation training syt.csv
1**. Begin**
2.**Set x**_train
3. **Set**y_train
4. **Add** (weight, x_train)
5. **Add** (bias, x_train)
6. **Add** (weight, y_train)
7.**Add**(bias, y_train)
8.**Sigmoid**(x_train)
9.**Sigmoid**(y_train)
10.Evaluate (x_train, y_train)
11.**If** error>0:
12.reduce(weight, bias)
13. **If** error<0
14. increase (weight, bias)
15. Measureaccuracy
16.**If** accuracy == max
17. save (weight, bias)
18. **End**

Fig. 2. Algorithm of training LSTM model

Testing the LSTM Model. Testing LSTM is also done after the dataset is taken. Using weight and bias to x_train, y_train, x_test, y_test test process continues. Testing provides both model accuracy and log loss. Defining Euclidian distance between samples, the error is corrected. The building of the test model completes building the LSTM

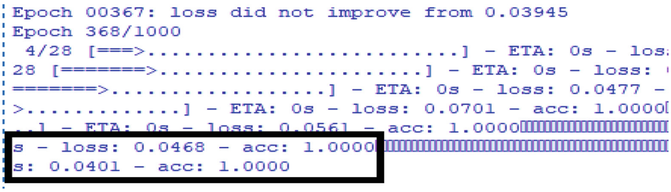

Fig. 3. Training example of LSTM network

model. The test accuracy of the model was 96%. The algorithm and an example of the LSTM testing model are shown in Fig. 4 and Fig. 5 respectively.

Algorithm: Testing LSTM Model
Input: ‘Atrial fibrillation training syt.csv
1**. Begin**
2**. Set x**_train
3. **Set** y_train
4. **Add** (weight,x_train)
5. **Add** (bias,x_train)
6. **Add** (weight,y_train)
7. **Add** (bias,y_train)
8. **Sigmoid** (x_train)
9. **Sigmoid** (y_train)
10. Evaluate (x_train,x_test,y_train,y_test)
11. Measure model accuracy
12. Measure log loss
13. **Return**(model accuracy, log loss)

Fig. 4. Algorithm of testing LSTM model

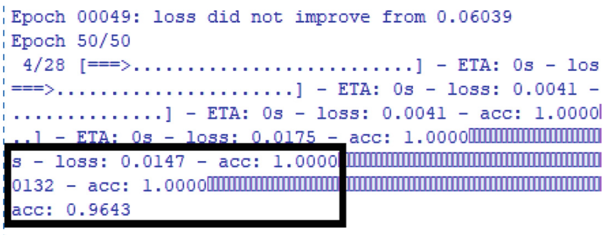

Fig. 5. Testing example of LSTM network

Prediction of Result. From the testing process, model weight and bias are taken. After fetching the raw signal, it is normalized so that the entire sample corresponds between 0 and 1. Then the raw signal is split and evaluated for prediction.

Predicted result corresponding to y_test provides whether it is Atrial Fibrillation or Normal Sinus Rhythm using 0 and 1 respectively. The algorithm for result prediction is shown in Fig. 6.

Algorithm: Result Prediction
1. **Load** (weight, bias)
2. Fetch raw signal
3. Normalize (row signal)
4. Split (raw.signal,x_test,y_test)
5. Evaluate
(x_train,x_test,y_train,y_test)
6. Predict (y_test)
7. **Return** (prediction)

Fig. 6. Algorithm for result prediction

4 Implementation and Experiments

4.1 Experimental Setup

In Fig. 7 we showed the sensor connectivity. We used a single LED ECG connector to connect it with the human subject. Three electrodes: blue, red, and black wire connected to two arms and belly of a human subject. Here red and blue electrodes mainly receive electric signals and the black electrode cancels noises. To implement our system, we used python 3.6 on a personal computer, ECG sensor, Arduino, and biomedical patch.

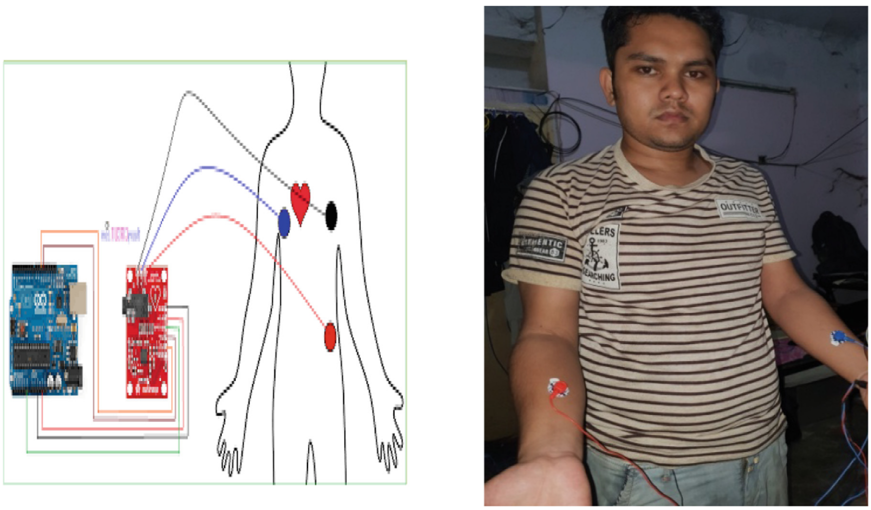

Fig. 7. Sensor connectivity

4.2 Data Collection from Sensor

Using the Py-serial library, we recorded the signal. The total number of signals recorded was 15000. The result was saved to a CSV file. We used Arduino to pass the collected data to the computer (in Fig. 8).

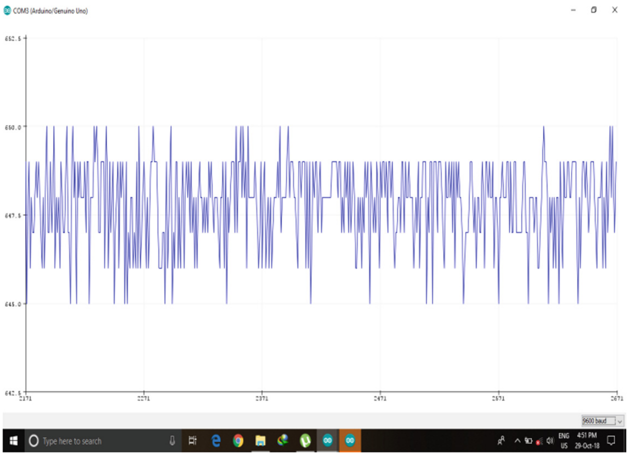

Fig. 8. Data collection using Arduino

4.3 Acquired Data Preprocessing

After recording to CSV file, the file is further analyzed and being normalized in the range 0 to 1. History of LSTM weight and bias was saved after training. This is used for prediction. Weights of LSTM and data from Arduino is used as input in LSTM.py. We used the MIT-BIH data set.

4.4 LSTM Model Training with Back Propagation Through Time and Result Calculation

We calculated several predictions. For each epoch number, a prediction was generated where backpropagation through time LSTM model propagation was used. From these annotations, the predicted result was given as either 0 or 1. 0 is for normal sinus rhythm and 1 is for atrial fibrillation. The requirements for training our system are shown in Table 1.

Table 1. The requirements for training

Hidden layer	32
Input dimension	1499
Activation function	Sigmoid
Loss calculation	Binary cross entropy
Optimizer	Adam optimizer
Accuracy check	Matrix

5 Experimental Evaluation

We evaluated the extent to which this work is successful in achieving the objectives that are defined at the beginning. In this, we have shown some real-life experimental results from our proposed system. Here, to verify the system we have talked to several patients, doctors and fulfill their requirements through our system. Later we evaluated the system.

5.1 Experimental Data

We experimented with the residence of Liver Society, Muradpur, Chattogram. We experimented this over 20 people. The result found in this experiment is given in Table 2.

Table 2. Experiment with people

Number of people	Response
19	Normal Sinus Rhythm
1	Atrial fibrillation

5.2 Result and Analysis

Here we have examined if the proposed framework is providing correct results or not. These activities can be performed based on different features for different patients. We queried whether the system was effective and responding timely in case of an emergency as our interest was helping in an emergency. We got satisfactory results by interacting with mass people.

Query with mass people provided us a better outcome. We requested them to give honest reviews about the system and got satisfactory results. In all cases, the proposed framework gained higher scores (shown in Table 3). This indicates that the framework is quite successful to remind the 25 or 30 up people to check out one of the very common diseases-heart attacks. As our key interest was to help in an emergency so that they can perform at the appropriate time, we have become able to fulfill our objectives. The bar chart in Fig. 9 illustrates it more vividly.

Table 3. List of questions after implementing the application

Question	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Q1: Do you think the system is effective?	0	0	0	7	13
Q2: Do you think the system is responding timely and correctly?	0	0	0	9	11
Q3: Do you think that the use of the emergency button will help in case of an emergency?	0	0	1	5	14
Q4: Do you think detect diseases button will helpful for 45 up ages people who will commonly face heart attack.	0	0	2	4	14
Q5: Do you think search doctor button will helpful for patients?	0	0	1	5	14

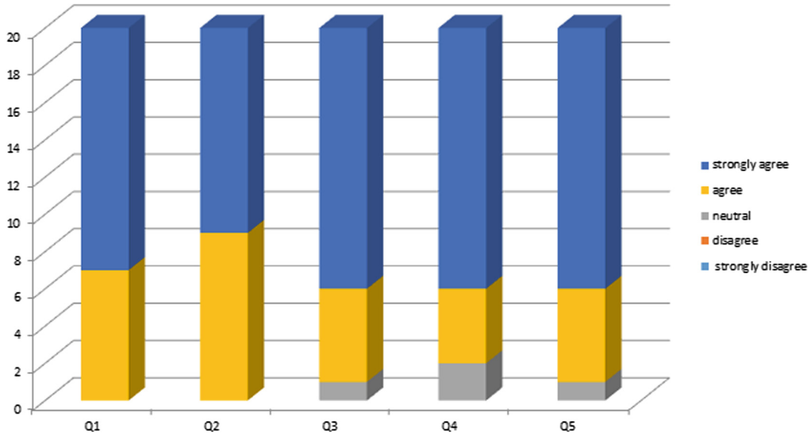

Fig. 9. User opinion after implementing the system

6 Conclusion

The combination of a personal computer and IoT has become an innovative technology in the healthcare system. In this work, a recurrent neural network model is proposed that automatically detects heart failure or atrial fibrillation from ECG signals. Here, at first, Arduino collects data from the (Heartbeat) sensor and saves in a personal computer which is then transferred wirelessly to an IoT platform using Personal Computer. Then features from ECG recording are extracted and used as the input for the recurrent neural networks (RNN) composed of recurrent layers. The recurrent neural network we considered as our base is the Long Short-Term Memory (LSTM) and for normalization Sigmoid function is used. Disease diagnosis operation using the neural network is performed based on comparison with the trained dataset. The system may help the physician to prescribe a patient without being present physically, thus developing the medical services and effective diagnosis which is based on IoT.

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