Group 5: SMART PILLOW

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Abstract

Report abstract goes into this. Abstract should not be more than 200 words long.

1 Introduction

Sleep is a period of rest during which we relax our body and let our body regulate various bodily functions. Sleep is essential to us as it affects our mental and physical state and functioning. Sleep touches every aspect of the health of our body and is truly essential for our well-being. Sleep is vital for the proper development of their mind and body.

However, in today's chaotic world, it has become challenging to have a decent sleep schedule, and we have lately been neglecting our sleep hence, affecting our mental and physical well-being. Mental disorders like depression, stress, anxiety, etc., result from lack of proper sleep. People suffer from constant headaches and mental disorders, yet they refuse to change their sleep schedule. Recent studies show that a large proportion of adolescents lack proper sleep, and thus, we see them suffering from chronic mental disorders nowadays.

According to data from Apollo Hospitals, there have more than a million people suffering from such disorder called **Sleep Apnea** in India alone. The patient has trouble in breathing accompanied with heavy snoring while sleeping and in some cases can choke a person in their own sleep. Detection of this is not an easy task, this is where our product comes in and monitors the persons sleep and detects any anomaly throughout the night.

This report goes through our complete Iot device, describing the full idea, as well as the implementation of each component in details under methodology along with the shortcomings as well as the future scope of our device. We also present the final product and its working.

2 Related Work

We have analysed the approaches taken by various other researchers and cited compare to our approach. We shall the most relevant papers of all the research paper that we read. Further we will compare these appraoches to our own and show how we differ from them.

- [1]The first research paper that we went through was the 'Sensor Pillow System.' As respiration, pulse, temperature, and blood pressure are the main physiological parameters that affect sleep hence the pillow system monitors respiration patterns and body movement with the aim of developing a less burdened and less constrained system easy to use for someone with no technical knowledge. The pillow contains a pressure bed distributed along the surface to monitor the respiration parameter.

- [2]The second research paper talks about a real-time adjustable pillow that monitors the sleep apnea of the user. The pillow checks for sleep apnea using a pulse oximeter and adjust the height and shape of the pillow accordingly in order to control the apnea. They use five bladders in the pillow to allow pillow reshaping. The bladders are located near the neck, side of head and a base bladder to support other bladders.
- [3]The third paper was a 'Smart Comfort Pillow,' which is appropriate for infants to comfort them using vibrations and monitor their movements. This pillow can help comfort infants when their parents are away and help them sleep by inducing heartbeat vibrations and measuring their PPG signals, and actively monitoring their movements.
- [4]The following research paper talks about a smart pillow system using temperature and humidity sensors to monitor the surrounding conditions while also observing the sleeping pattern of the user to deduce the ample environmental parameter for better sleep quality of that user.
- One of the research papers that we went through talks about a pillow system using speakers to induce sleep in people suffering from insomnia and also has a massager embedded, which functions when the inbuilt alarm of the pillow goes off. This pillow uses a piezoelectric sensor to sense pressure and will only work when it detects any pressure on the pillow.
- One of the research papers is about a smart pillow system built using IoT based system which helps monitor the stressfulness of users by observing sleep habits. Since the physiological parameters such as respiration, blood pressure, and temperature and non-physiological parameters such as sleeping hours and sleep positions vary a lot during different stages of sleep hence, this system helps monitor the various parameters for the person and also detects their stress levels.

The papers studied so far had the following flaws:

- most of the pillow devices only gathered and presented the data instead of actuating it.
- some of the implementations could be considered a breach of privacy.
- usage may not be easy for people with no technical knowledge.
- Some devices are not plug and play and hence are harder to use.

To avoid these drawbacks, we shall incorporate the following:

- A washable pillowcase
- Built-in speakers for multi-utility sounds with custom music.
- Easily readable and presentable form of processed data.
- Encryption of data while communication.
- Smoothly controlled pillow shape for utmost comfort.

3 Proposed Idea

Guidelines: In this section, you formally introduce your project idea and describe the work done in the project.
We have tried to create a smart pillow so as to make sleep monitoring accessible to people. They wouldn't have to wait in order to visit the sleep monitoring rooms. This smart pillow helps monitor the room temperature using temperature sensors and can detect snoring using sensors.

Our idea of smart pillow includes sleep monitoring with respect to various physiological factors and along with this we use the ECG signal from the patient to check for sleep apnea events throughout the night, we also include a sound emitter for vibration induced sleep (VIS). We shall also include reshaping abilities to alliviate medical disorders related to sleep.

We use a cloth [5] which has embedded ecg sensors which are used to monitor the patient. This sensor will send the raw data to the pillow. Along with this we shall have a built in mic in the pillow which will record sound and store it on the pillow.

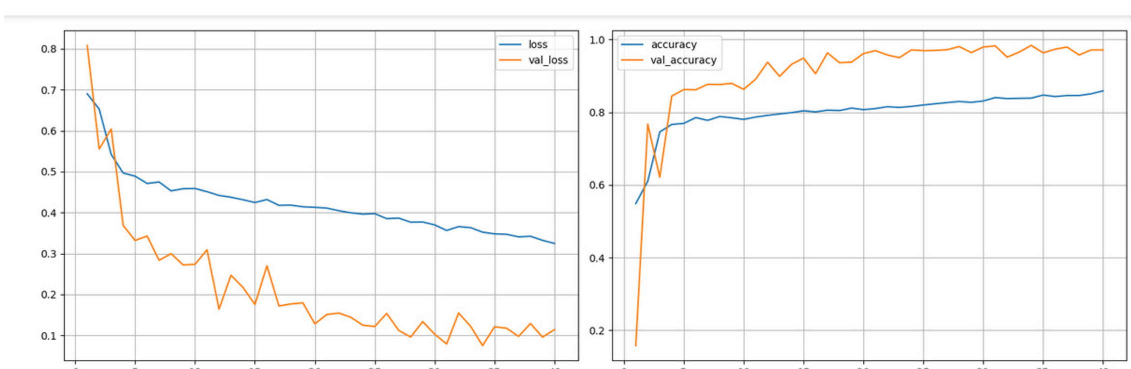
The pillow will use http requests to transmit the data to the main server where we process the data to feed into the ML models to check for snoring and sleep apnea events, which are displayed onto a webapp which has a live ecg displayer so that the person can monitor their own ecg at the comfort of their home.

4 Methodology

4.1 ML model to detect Sleep Apnea

We were to detect sleep apnea in a person during a certain time based on the persons ECG readings, their age and sex. The data used for this was available online. There were 35 patients whose ECG was recorded throughout the duration of sleep (6-10 hours). Each of these ECG files also had an annotations file that corresponded to whether or not a person had sleep apnea.
The raw ECG data was preprocessed to give us two different forms of data that we could use to make a prediction model. This preprocessing consisted of digitising the data that was initially in forms of continuous waveform, normalising this about the moving median and then converting it to another waveform using the interpolate function. Along with this, the age and sex of the person is also stored in this new data file.
The model consists of 2 LSTM layers for the input, followed by a dense layer, concatenation of the LSTM and dense layers, again followed by 2 dense layers and finally the activation layer. The activation function used is sigmoid, it gives us values between 0 and 1 which signify the probability of the person suffering from sleep apnea. The loss function used is binary cross-entropy.

```
 Layer (type)                Output Shape         Param #     Connected to
==================================================================================================
 input_5 (InputLayer)        [(None, 240, 2)]     0           []

 lstm_6 (LSTM)               (None, 240, 256)     265216      ['input_5[0][0]']

 lstm_7 (LSTM)               (None, 240, 256)     525312      ['lstm_6[0][0]']

 input_6 (InputLayer)        [(None, 2)]          0           []

 lstm_8 (LSTM)               (None, 256)          525312      ['lstm_7[0][0]']

 dense_6 (Dense)             (None, 32)           96          ['input_6[0][0]']

 concatenate_2 (Concatenate)  (None, 288)         0           ['lstm_8[0][0]',
                                                               'dense_6[0][0]']

 dense_7 (Dense)             (None, 8)            2312        ['concatenate_2[0][0]']

 dense_8 (Dense)             (None, 1)            9           ['dense_7[0][0]']

 activation_2 (Activation)   (None, 1)            0           ['dense_8[0][0]']

==================================================================================================
Total params: 1,318,257
Trainable params: 1,318,257
Non-trainable params: 0
```



4.2 DL model to detect Snoring

This model uses a simple deep learning model to classify the snoring sounds from the non snoring ones This model requires Python and the following Python libraries installed:

- NumPy
- Pandas
- matplotlib
- scikit-learn
- seaborn

The dataset contains two folders - one for snoring and the other for non-snoring. Folder 1 contains snoring sounds. It has total 500 sounds. Each sound is 1 second in duration. Among the 500 snoring samples, 363 samples consist of snoring sounds of children, adult men and adult women without any background sound. The remaining 137 samples consist of snoring sounds having a background of non-snoring sounds.
Folder 0 contains non-snoring sounds. It has total 500 sounds. Each sound is 1 second in duration.
The 500 non-snoring samples consist of background sounds that might be available near the snorer. Ten categories of non-snoring sounds are collected, and each category has 50 samples. The ten categories are baby crying, the clock ticking, the door opened and closed, total silence and the minor sound of the vibration motor of the gadget, toilet flashing, siren of emergency vehicle, rain and thunderstorm, streetcar sounds, people talking, and background television news.

Model

- Model has 5 layers
- Out of the the we have used 2 convolution layers and 2 dense layers.
- We have used the sigmoid layer as the activation layer for the final layer since this is a binary classification problem.
- Model was train based on the Adam optimizer.

Results
After training the model for 1 epochs

- Accuracy - 1.0000
- loss - 0.0025
- val_recall - 1.0000

4.3 Server and Client

The server runs on the system ip(dynamic) on the port 8000. We have used the python module *http.server* to setup this server. There is an optional QR code generated for the ip address for the server since the link will change depending on the system it is running on.
We import the ML models into the server from the files *Prediction.py* and *snore.py* We extract the output from these models and store the user perceivable output in a json which is used to display data on the web browser.
We have 2 local files for the server which store the sensor reading, one for the pressure readings and another for the ECG readings. These files are updated by the *PUT* requests discussed later. The ECG reading shall be used for the sleep apnea detection whereas the pressure values are used to calculate the period of deepest sleep of the patient.

We now describe how we handle various HTTP requests using the server

Get

We see the path the request points to and write back the contents of the file and send the response for the request. For the ECG reading we send the data as an array of values but for the user data we send the data as a json so these are handled separately.

PUT

We see the path the request points to and update the file with the given data. For the ECG readings we keep a buffer array of capacity 5 times the incoming data, we remove the first $\frac{1}{5}$ reading and append the recieved data which would later be sent to the frontend.

Now on the client side, we have 2 dummy sensors (ECG,pressure) running which keep generating dummy values (random for presure, cyclic hardcoded for ECG) onto the dedicated files for the readings. The job of the *pillow* is to check when these files change, which we check by the last modified tag of the files and send a *PUT* request to change these file data on the server side.

4.4 Display API

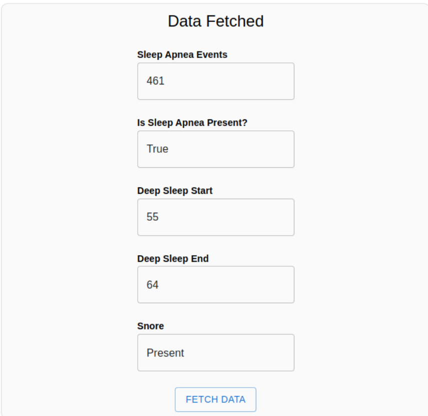
We make GET request to the server at each interval of 2 seconds to fetch the real-time ECG readings and display them on the Web App on a line chart. We can also fetch the last passed data by sending the request to API and fetching Sleep Apnea Presence, Sleep Apnea events, Snoring presence, Deep Sleep start and Deep Sleep End and further we display these values in the corresponding fields. The chart shows 100 units time span of ECG data and gets updated every 2 sec wuth 20 units of new data and discards the previous 20 units from showing on the chart.

5 Results

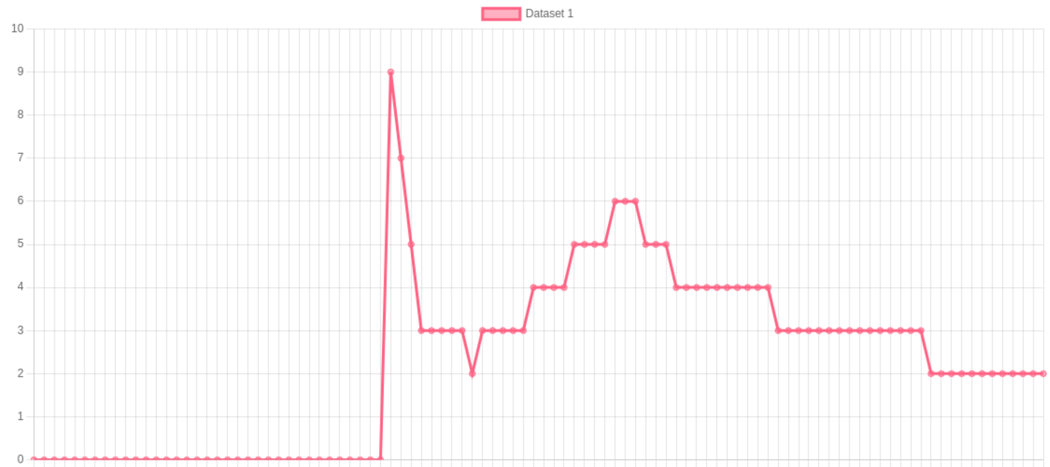
The codes used in this project can be found in this github repository **Smart-Pillow**

We have a runnable server which is used by the pillow to send the raw sensor generated values.

We get the Sleep Apnea events and its presenc, the deep sleep duration and the snoring presence in the data fields on fetching data.



We further receive real time digitised ECG readings and display it on the chart by periodically sending GET requests to the server.



6 Discussion and Future Work

6.1 Future Scope

Since each project has a scope for improvement, hence over the process of building this project, we came through a lot of scenarios and determined how our project could improve in the near-future.

- Adding more secure protocols and authorization like JWT Tokens with HSA256 hashing.
- Observe the temperature and humidity and connect the IoT board to the thermostat in the room to actuate and regulate the temperature of the room pertaining to which the user has the deepest sleep.
- Add pillow shape transform depending upon the pressure value by the pressure sensor. More pressure on the pillow would signify a deeper and more relaxed sleep hence, we could actuate the pillow shape.
- Determine the time periods when the user had the deepest sleep after playing the music and can continue to play or stop the music depending upon that.
- Make a mobile friendly web-app with interactive graph and realtime updates.

7 Conclusion

The aim of the project was to monitor the sleep of the user over the night and determine the favourable conditions over the whole observation time. The smart-pillow monitors the sleep and then helps in inducing sleep using white-noise playing in certain intervals during the sleep.

We were able to efficiently monitor the sleep of the user and detect the sleep apnea and deep sleep duration by observing the snore and other activities. Having worked on this project, we determined several shortcomings and aim to improve our project over the future.

8 Individual Contributions

Sr No.	Name	Contribution
1	Ankur Kumar	Set up the simulation using dummy sensors on a HTTP server. Merging the ML models, Deep sleep finder to the server. Setting up the communication between server and sensors. Report writing.(26.8)
2	Yukkta Seelam	Researched numerous ML models for sleep apnea, understood the best features & model parameters, Implemented the Ml model to high accuracy. Report writing.(24%)
3	Batta Soumith	Researched numerous ML models for snore detection, understood the best features & model parameters, Implemented the Ml model to high accuracy. Report writing.(23%)
4	Manas	Used the files from the server to render data in user percievable format, used frontend techniques to enable a live data chart for ECG reading. Report Writing.(26%)
5	Ajeet Kumar	Present in group discussions(0.2%)

Table 1: Contribution of members

References

[1] T. Harada, A. Sakata, T. Mori, and T. Sato, "Sensor pillow system: monitoring respiration and body movement in sleep," in *Proceedings. 2000 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2000) (Cat. No.00CH37113)*, vol. 1, pp. 351–356 vol.1, 2000.

[2] S. Li and C. Chiu, "A smart pillow for health sensing system based on temperature and humidity sensors," *Sensors*, vol. 18, no. 11, 2018.

[3] S. H. Yang, S. Park, T. Yang, I. Jin, W. Kim, C. Liu, S.-W. Kim, and J. Eune, "Introducing smart pillow using actuator mechanism, pressure sensors, and deep learning-based asr," in *Proceedings of the 9th Augmented Human International Conference*, AH '18, (New York, NY, USA), Association for Computing Machinery, 2018.

[4] A. Veiga, L. García, L. Parra, J. Lloret, and V. Augele, "An iot-based smart pillow for sleep quality monitoring in aal environments," *2018 Third International Conference on Fog and Mobile Edge Computing (FMEC)*, pp. 175–180, 2018.

[5] A. A. Arquilla K, Webb AK, "Textile electrocardiogram (ecg) electrodes for wearable health monitoring," in *Sensors (Basel)*, 2020.