IMPROVING SLEEP QUALITY MONITORING WITH IOT AND MACHINE LEARNING

Problem Statement

Current sleep monitoring systems are invasive or expensive, limiting widespread use and accessibility. there is a significant need for accessible and precise monitoring of sleep quality. Current solutions often fail to comprehensively capture critical sleep-related data such as body movement, heart rate, blood oxygen levels, and snoring patterns in real-time. Furthermore, existing systems may not seamlessly integrate various sensors with advanced data analysis platforms or might be prohibitively expensive, complex, and not user-friendly.

Solution

The proposed solution involves integrating an accelerometer, pulse oximeter, and microphone with an ESP32 microcontroller, leveraging Wi-Fi and Bluetooth for real-time data transmission to the AWS cloud. Machine learning algorithms, including a random forest model and recurrent neural network, analyze the data for comprehensive sleep quality assessment. The system ensures affordability, user-friendliness, and precise monitoring of body movement, heart rate, blood oxygen levels, and snoring patterns. By combining the Internet of Things (IoT) and machine learning, the innovative sleep monitoring system offers an accessible and accurate alternative, fostering improved sleep quality assessment in both home and hospital environments.

Tech Stack

Hardware

Software

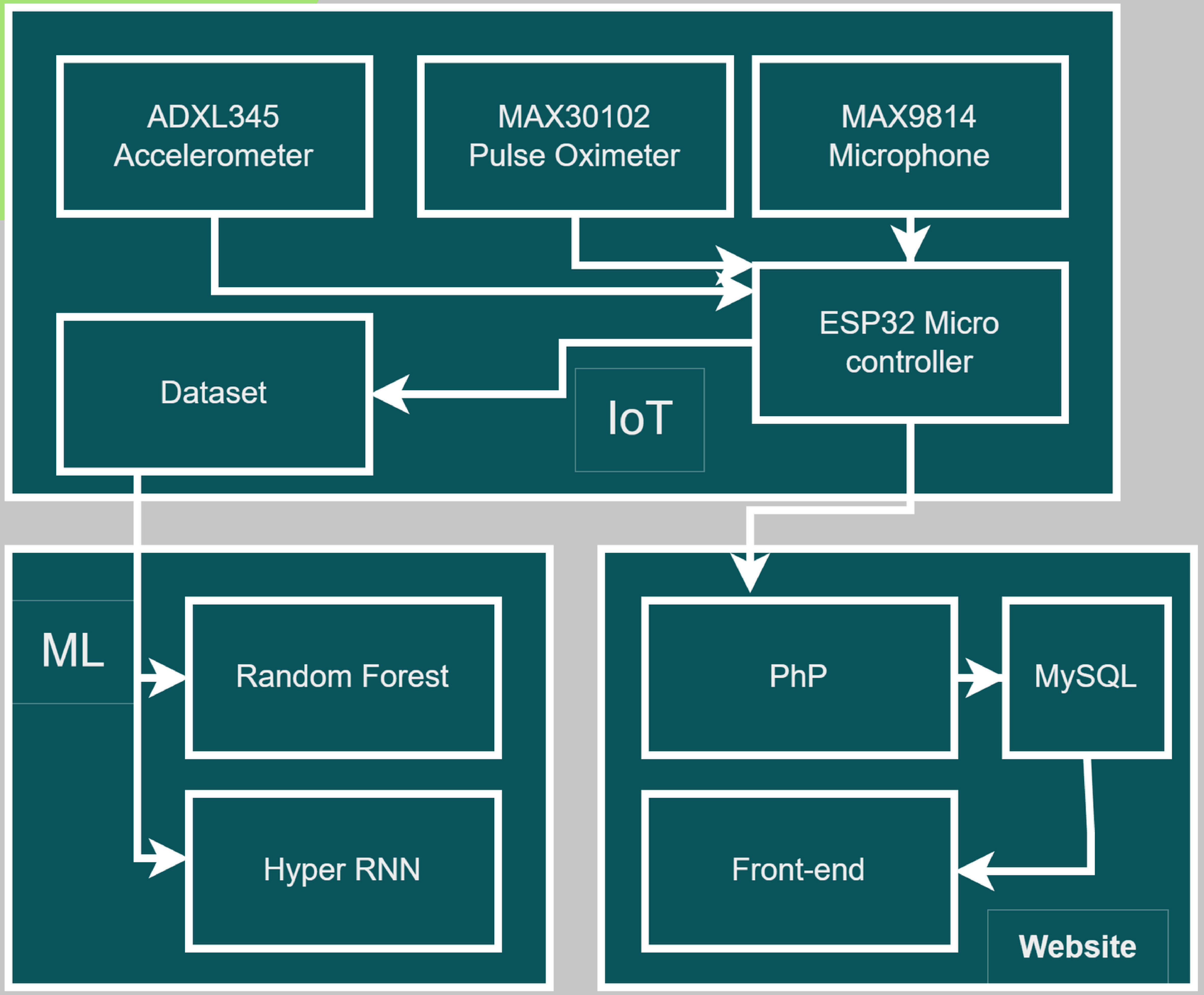
Working Principle

Modules:

IoT

ML

Website



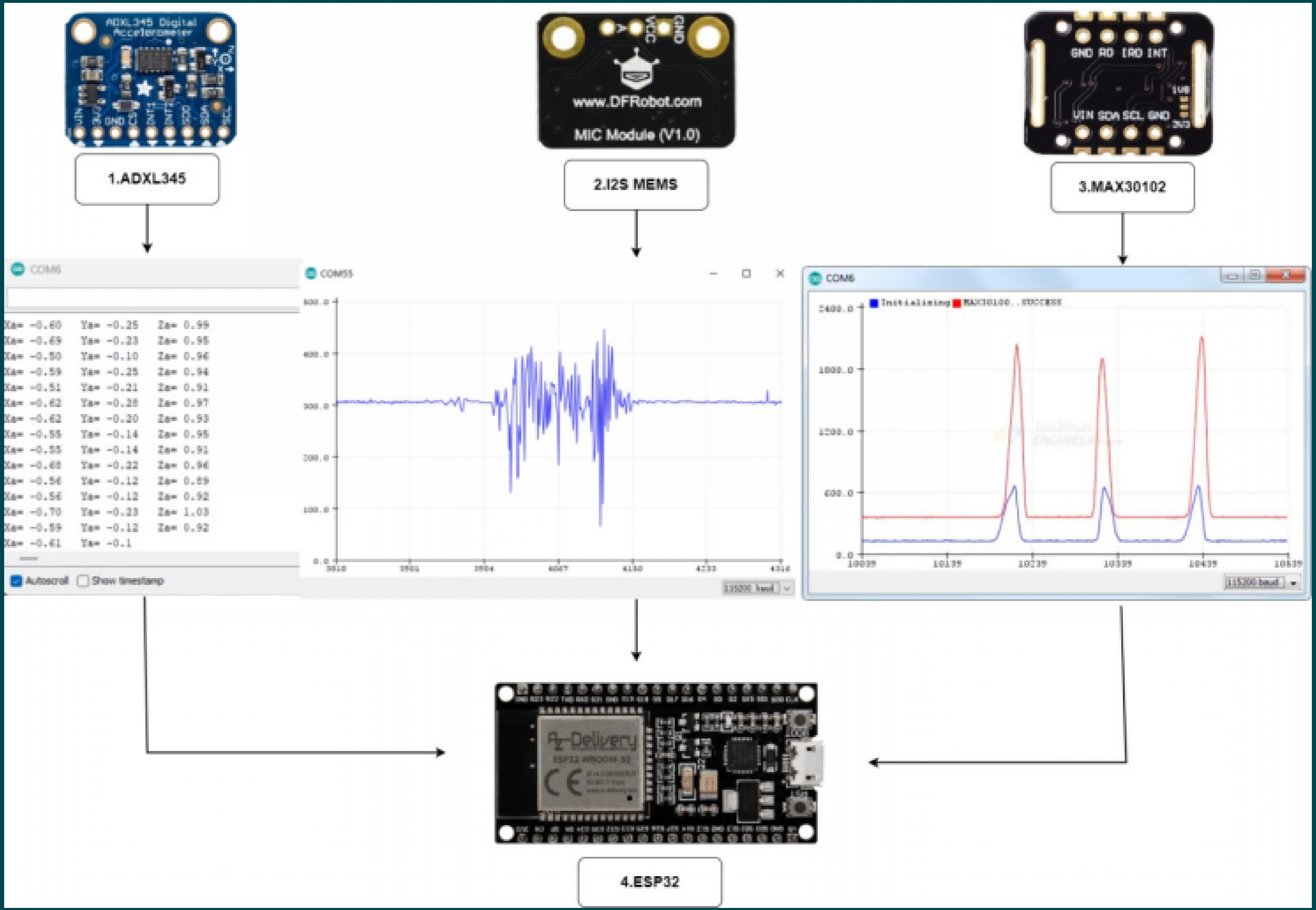
Hardware Architecture

Sensors:

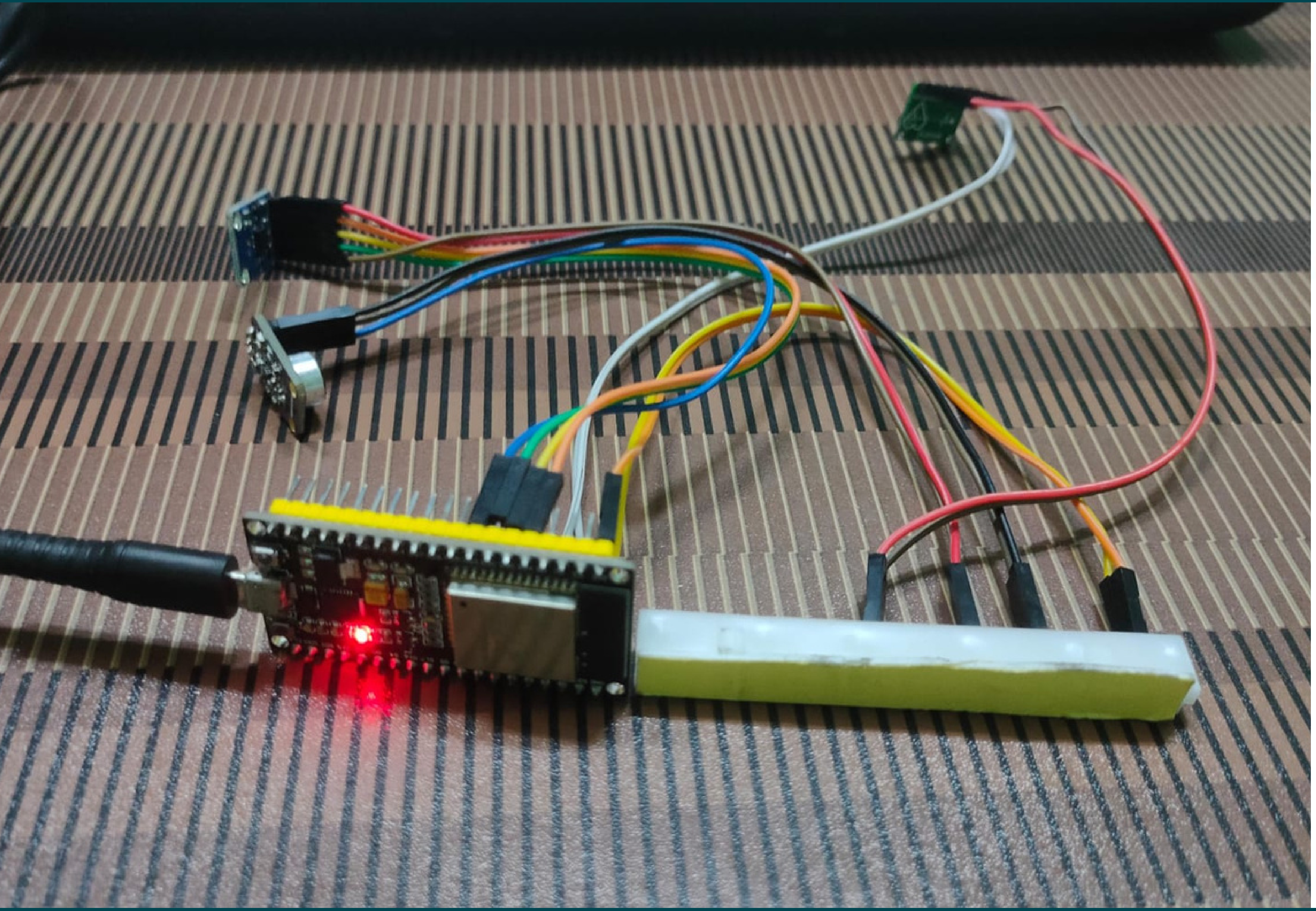
ADXL345-Accelerometer
12S MEMS - Mic
MAX30102 - Pulse Oxi

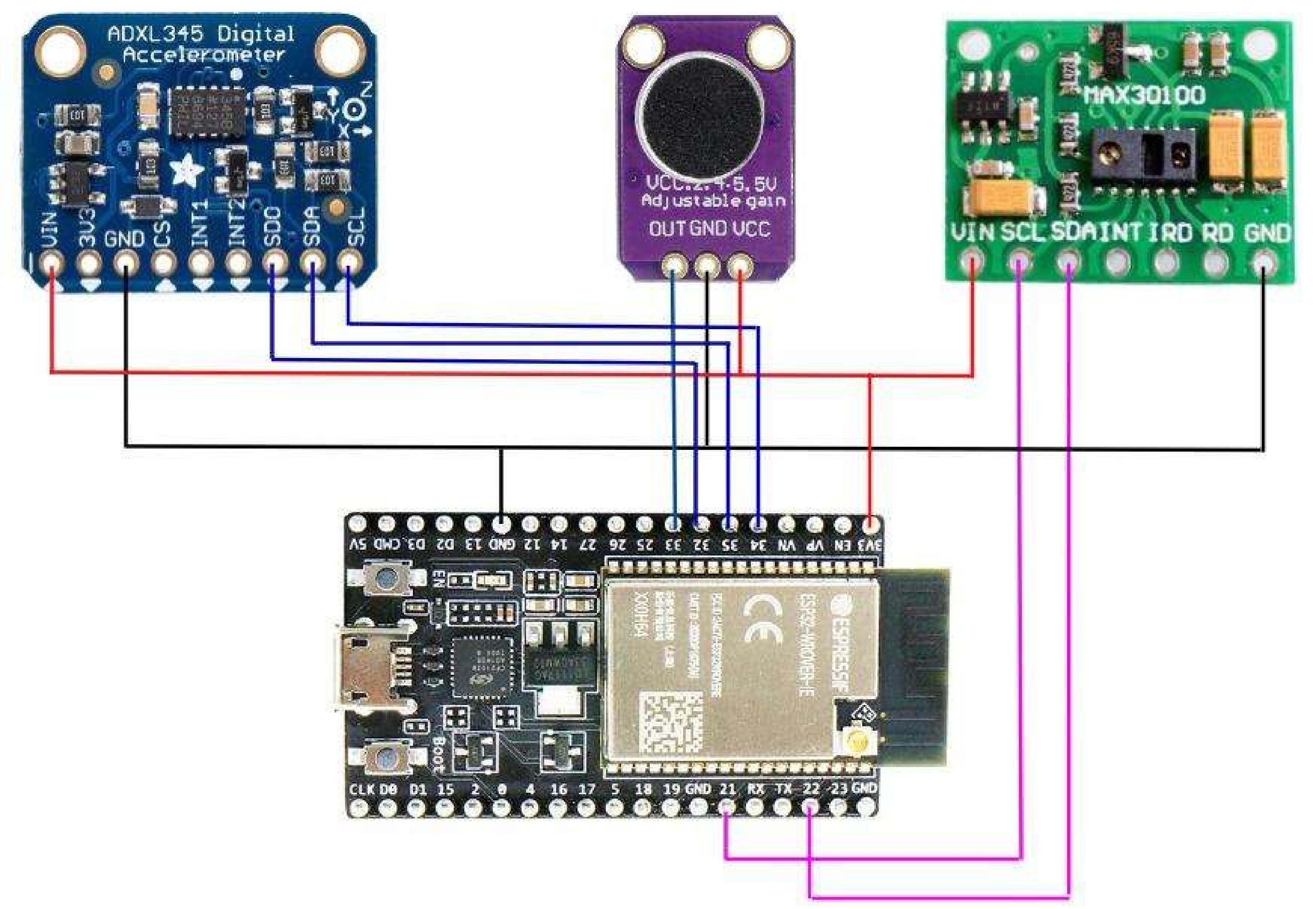
Micro Controller:

ESP32



Circuit Diagram





Dataset/COM :

```
"SpO2,HeartBeat,Noise,BodyMotion"
"94,68,1834,51.02"
"90,67,1831,363.01"
"92,66,1842,22.29"
"90,65,1870,37.05"
"90,68,1844,121.43"
"90,68,1873,59.67"
"93,65,1864,11.18"
"93,68,1831,75.47"
"90,68,1873,129.00"
"94,68,1893,7.07"
"92,65,1905,21.21"
"95,66,1909,33.30"
"92,65,1907,7.35"
"90,65,1892,30.25"
"95,66,1915,37.07"
"90,66,1914,131.95"
"90,65,1921,2.45"
"92,67,1865,117.11"
"90,66,1890,6.08"
"95,68,1909,14.59"
"95,66,1857,25.26"
"92,65,1843,30.95"
"94,66,1895,97.48"
```

COM7

Send

```
-------------
Connecting..
Successfully connected to : Santhosh
-------------
SPO2,HeartRate,NoiseLevel,Body Motion
93,67,1831,8.12

---------------getdata.php
httpCode : 200
payload  : // PHP code to access the database.
{"id":"esp32_01","SpO2":93,"Heart_Beat":68,"Noise":1796,"Body_Motion":17.15,"ls_time":"00:
---------------

---------------updateDHT11data_and_recordtable.php
httpCode : 200
payload  : // PHP code to update and record DHT11 sensor data and LEDs state in table.
// PHP code to access the database.

---------------
90,66,1640,23.26
```

Autoscroll Show timestamp Newline 115200 baud Clear output

Parameters

Parameters/Algorithm	Random Forest	Hyper RNN
Estimators	50	40
Time Steps	5	4
RMSE	0.017	0.064
Variance	0.170	0.168
MSE	0.0002	0.004
F1 Score	0.999	0.996

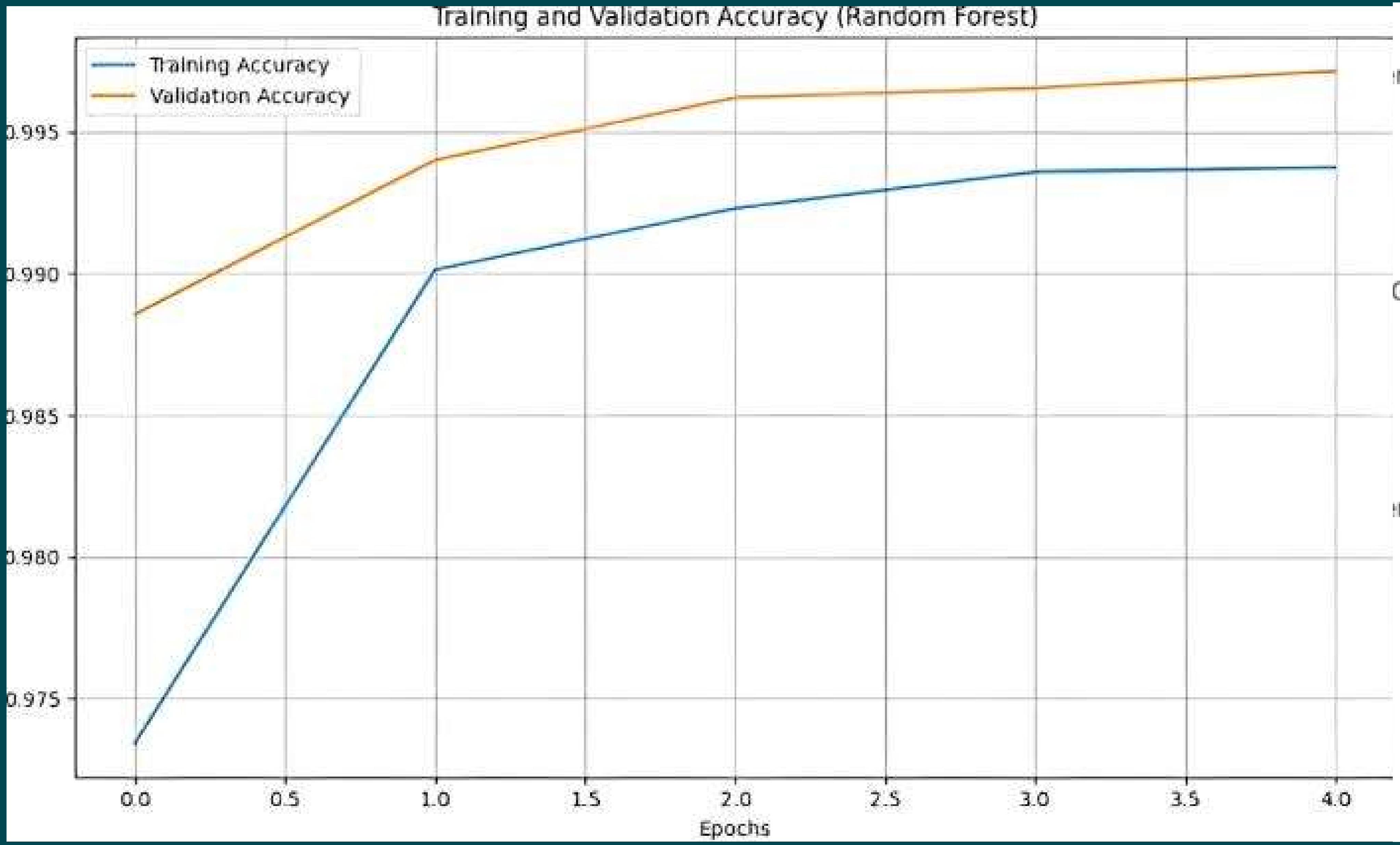
RNN / RF

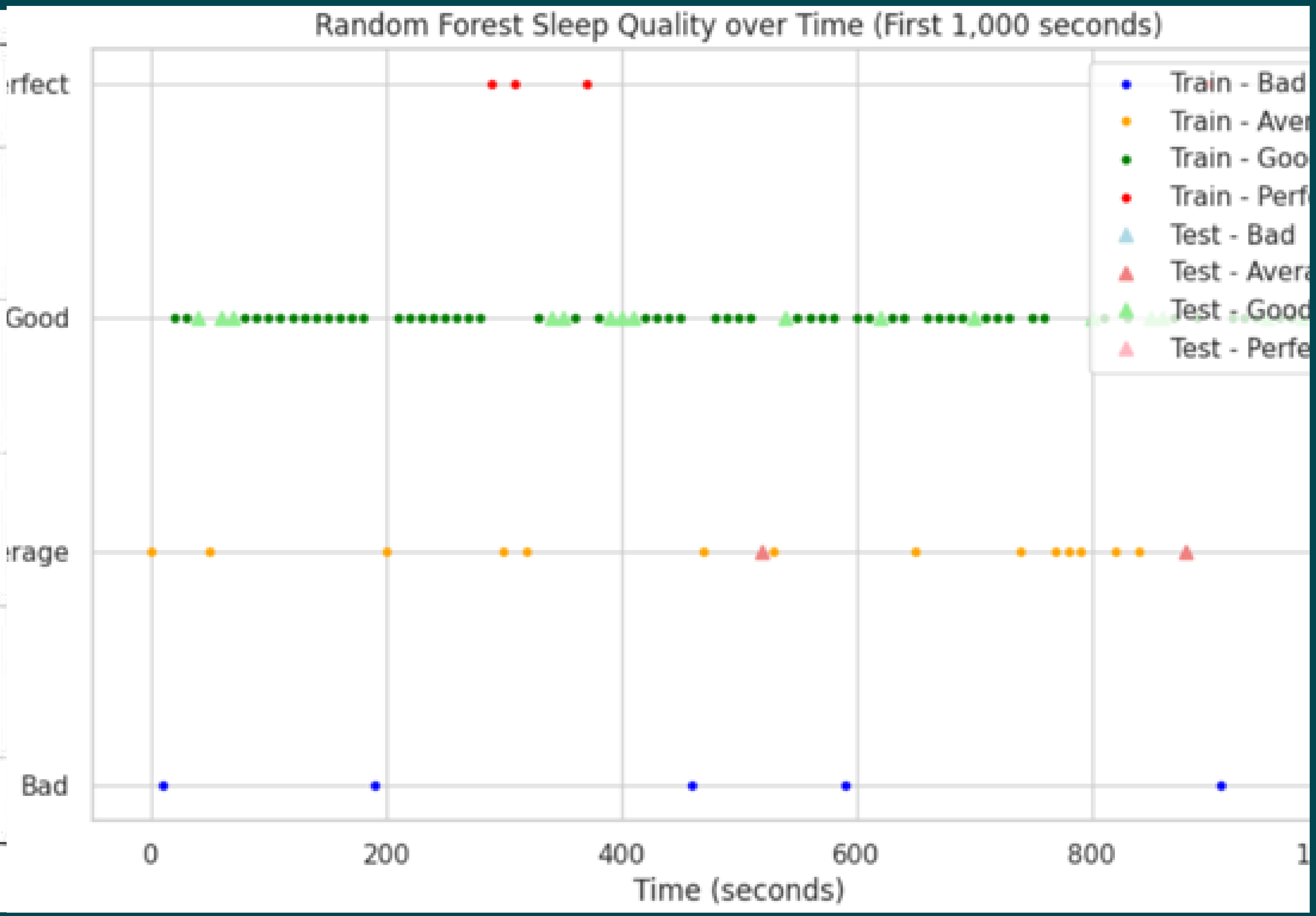
- The Random Forest graph illustrates an accuracy plateau at 86%, while the RNN graph displays a superior 95.7% accuracy.
- RNN demonstrates superior performance in processing sequential physiological data for nuanced sleep pattern analysis.

Optimal Values

Heat Beat	**65 - 67**
Noise	1700 - 1900
Body Movement	150 - 250
SpO2 %	90 - 96

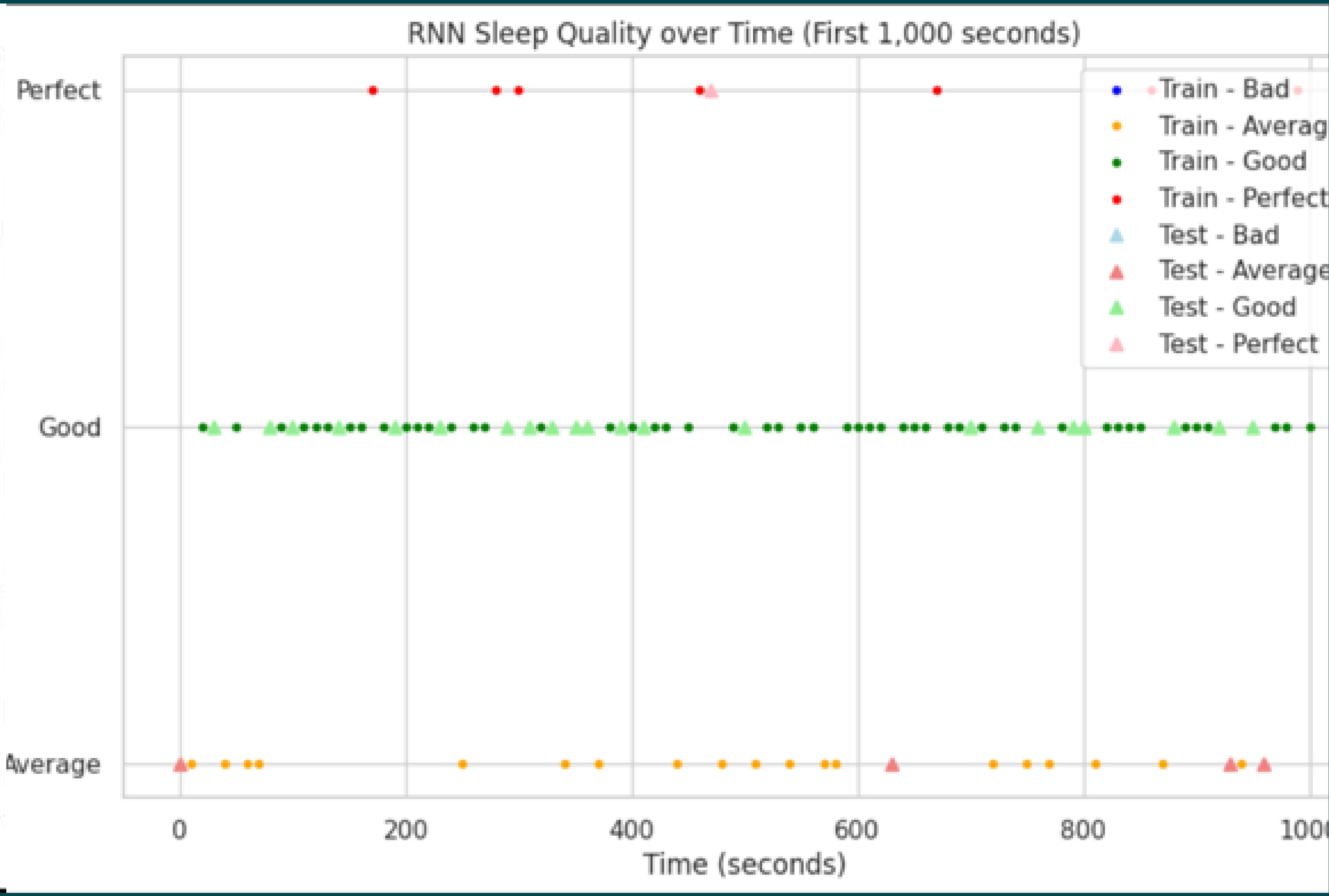
Random Forest





Hyper RNN

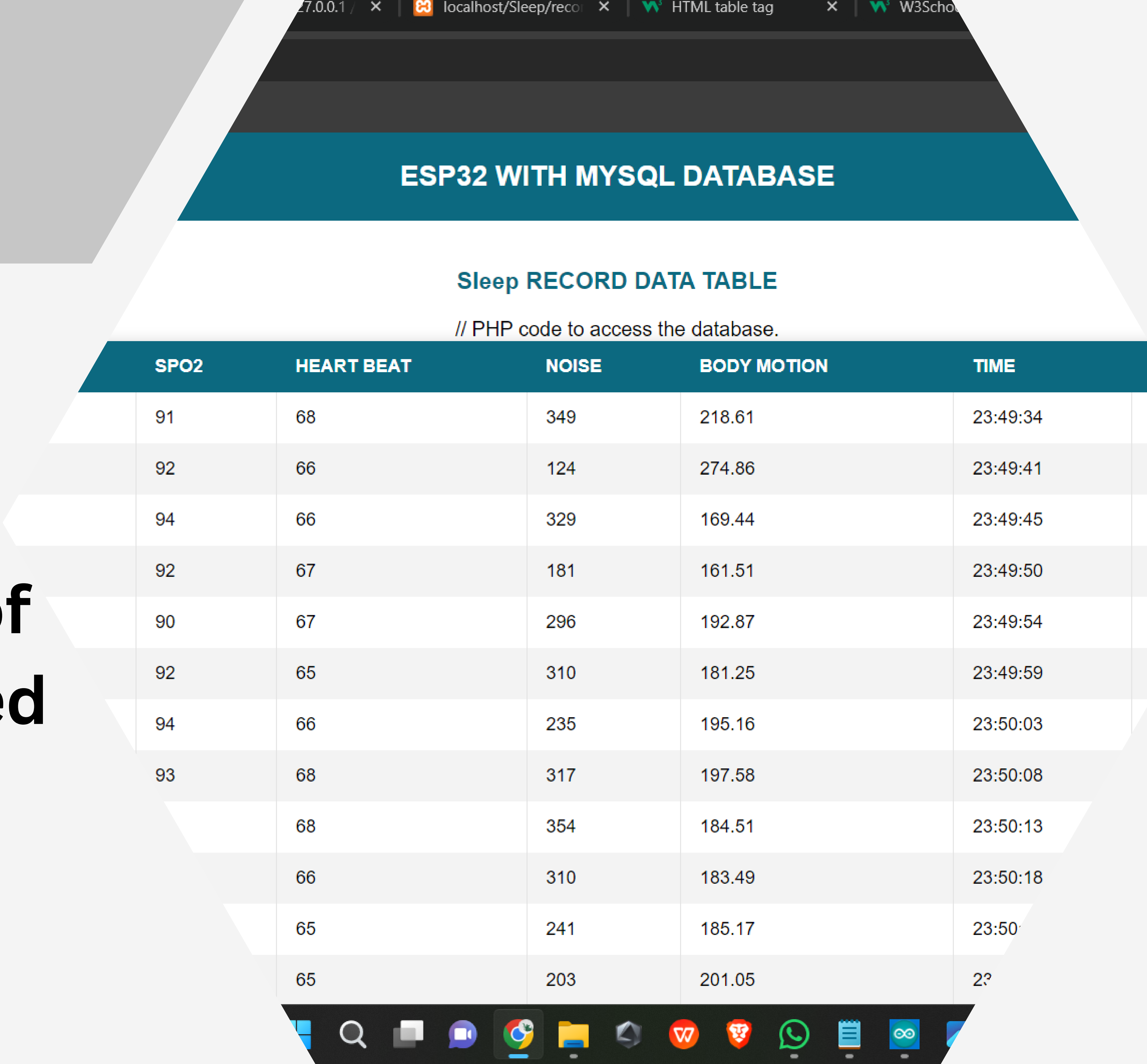

Training and Validation Accuracy (RNN)
Training Accuracy
Validation Accuracy
Accuracy
Epochs


RNN Sleep Quality over Time (First 1,000 seconds)
Perfect
Good
Average
Train - Bad
Train - Averag
Train - Good
Train - Perfect
Test - Bad
Test - Average
Test - Good
Test - Perfect
0
200
400
600
800
Time (seconds)

Website

Dynamically updates real-time sleep data.

View all the insights of our sleep-personalized recommendations to improve their sleep pattern.



ESP32 WITH MYSQL DATABASE

Sleep RECORD DATA TABLE

// PHP code to access the database.

SPO2	HEART BEAT	NOISE	BODY MOTION	TIME
91	68	349	218.61	23:49:34
92	66	124	274.86	23:49:41
94	66	329	169.44	23:49:45
92	67	181	161.51	23:49:50
90	67	296	192.87	23:49:54
92	65	310	181.25	23:49:59
94	66	235	195.16	23:50:03
93	68	317	197.58	23:50:08
	68	354	184.51	23:50:13
	66	310	183.49	23:50:18
	65	241	185.17	23:50
	65	203	201.05	2

Future Enhancement

- Sensor Upgrades and Integration
- Algorithm Refinement and Optimization
- Expansion of Monitoring Parameters
- Integration with Wearable Devices
- Low-latency wireless transfer
- Dynamic Insight graphs of sleep

Author	Topic	Content	Advantage	Disadvantage
W. H. M. Saad, C. W. Khoo, S. I. Ab Rahman, M. M. Ibrahim, and N. H. M. Saad	Development of sleep monitoring system for observing the effect of the room ambient toward the quality of sleep,	Development of a sleep monitoring system. Study on room ambient's impact on sleep quality.	Provides insight into room ambient effects on sleep quality. Offers a potential solution for personalized sleep monitoring.	Limited scope on other factors impacting sleep. Requires further validation for broader applicability.
S. Coussens, M. Baumert, M. Kohler et al.	Movement distribution: new measure of sleep fragmentation in children with upper airway obstruction	Introduces "movement distribution" as a novel measure of sleep fragmentation and provides insights into sleep patterns of children with upper airway obstruction.	Introduces "movement distribution" as a novel measure of sleep fragmentation	Limited to children with upper airway obstruction, may not generalize to other populations.
E. K. Choe, S. Consolvo, N. F. Watson, and J. A. Kientz	Opportunities for computing technologies to support healthy sleep behaviors	Presents opportunities for integrating technology into sleep health interventions.	Explores computing technologies' potential in promoting healthy sleep behaviors.	Focuses on potential rather than empirical evidence of effectiveness.

Author	Topic	Content	Advantage	Disadvantage
H. Sattar, I. S. Bajwa, and U. Shafi, “An IoT-based intelligent wound monitoring system	An IoT-based intelligent wound monitoring system,	An IoT-based intelligent wound monitoring system developed by H. Sattar, I. S. Bajwa, and U. Shafi.	Enables remote and real-time monitoring of wounds, enhancing patient care.	Requires reliable internet connectivity and potential security risks associated with IoT devices.
M. Kay, E. K. Choe, J. Shepherd et al	Lullaby: a capture & access system for understanding the sleep environment	Research by M. Kay, E. K. Choe, J. Shepherd, and colleagues.	Addresses the impact of technology on human behavior and social interactions.	May oversimplify complex sociotechnical issues and lack interdisciplinary perspectives.
B. Sarwar, I. S. Bajwa, N. Jamil, S. Ramzan, and N. Sarwar	An intelligent fire warning application using IoT and an Adaptive neuro-fuzzy inference system	Paper authored by B. Sarwar, I. S. Bajwa, N. Jamil, S. Ramzan, and N. Sarwar.	Presents collaborative research potentially covering diverse perspectives.	complexity, computational demands, potential real-time performance issues, increased processing burden.

Author	Topic	Content	Advantage	Disadvantage
T. Hao, G. Xing, and G. Zhou,	iSleep: unobtrusive sleep quality monitoring using smartphones,	ubiSleep, ubiquitous, sensor system, sleep monitoring, network, comprehensive.	Innovative approach utilizing smartphones for sleep quality monitoring.	Privacy concerns and potential inaccuracies in smartphone-based sleep monitoring.
Khizra Saleem, Imran Sarwar Bajwa , 1 Nadeem Sarwar, Waheed Anwar, and Amna Ashraf	Healthcare: Design of Smart and Cost-Effective Sleep Quality Monitoring System	"Real-time ball detection and tracking with embedded systems for sports analysis and robotics."	Smart and cost-effective IoT system for monitoring sleep quality in healthcare.	Potential challenges in ensuring accuracy and data security in IoT-based healthcare monitoring.
A. H. Sodhro, A. S. Malokani, G. H. Sodhro, M. Muzammal, and L. Zongwei	An adaptive QoS computation for medical data processing in intelligent healthcare applications	advanced algorithms, accurate tracking, trajectory prediction, sports analysis, robotics applications.	Adaptive Quality of Service (QoS) computation enhances efficiency of medical data processing in intelligent healthcare applications.	Potential complexity and implementation challenges in adapting QoS for varied healthcare data types.

Author	Topic	Content	Advantage	Disadvantage
A. Alkhayyat, A. A. Thabit, F. A. Al-Mayali, and Q. H. Abbasi	WBSN in IoT health-based application: toward delay and energy consumption minimization	ubiSleep, ubiquitous, sensor system, sleep monitoring, network, comprehensive.	Focus on minimizing delay and energy consumption in Wireless Body Sensor Networks (WBSN) for IoT health applications.	Potential trade-offs between minimizing delay, energy consumption, and maintaining data accuracy in WBSN for healthcare.
Khizra Saleem, Imran Sarwar Bajwa , 1 Nadeem Sarwar, Waheed Anwar, and Amna Ashraf	Healthcare: Design of Smart and Cost-Effective Sleep Quality Monitoring System	"Real-time ball detection and tracking with embedded systems for sports analysis and robotics."	Exploration of inter-WBAN cooperation to reduce outage probability in IoT health systems using energy harvesting.	Complexity and coordination challenges may arise in implementing inter-WBAN cooperation for energy efficiency.
A. A. Thabit, M. S. Mahmoud, A. Alkhayyat, and Q. H. Abbasi	“Energy harvesting Internet of Things health-based paradigm: towards outage probability reduction through inter – wireless body area network cooperation	advanced algorithms, accurate tracking, trajectory prediction, sports analysis, robotics applications.	Focus on improving energy efficiency through body-to-body cooperation in the Internet of Medical Things (IoMT).	Challenges in implementing and managing body-to-body cooperation in IoMT, including privacy and synchronization issues.

Paper Publication

The paper is completed and communicated.

Thank you

Santhoshraj Y
santyraj25@gmail.com

Varun N
varunnaresh06@gmail.com