EXERCISE ACCURACY DETECTION USING SMART WEARABLES

CPG Number 235

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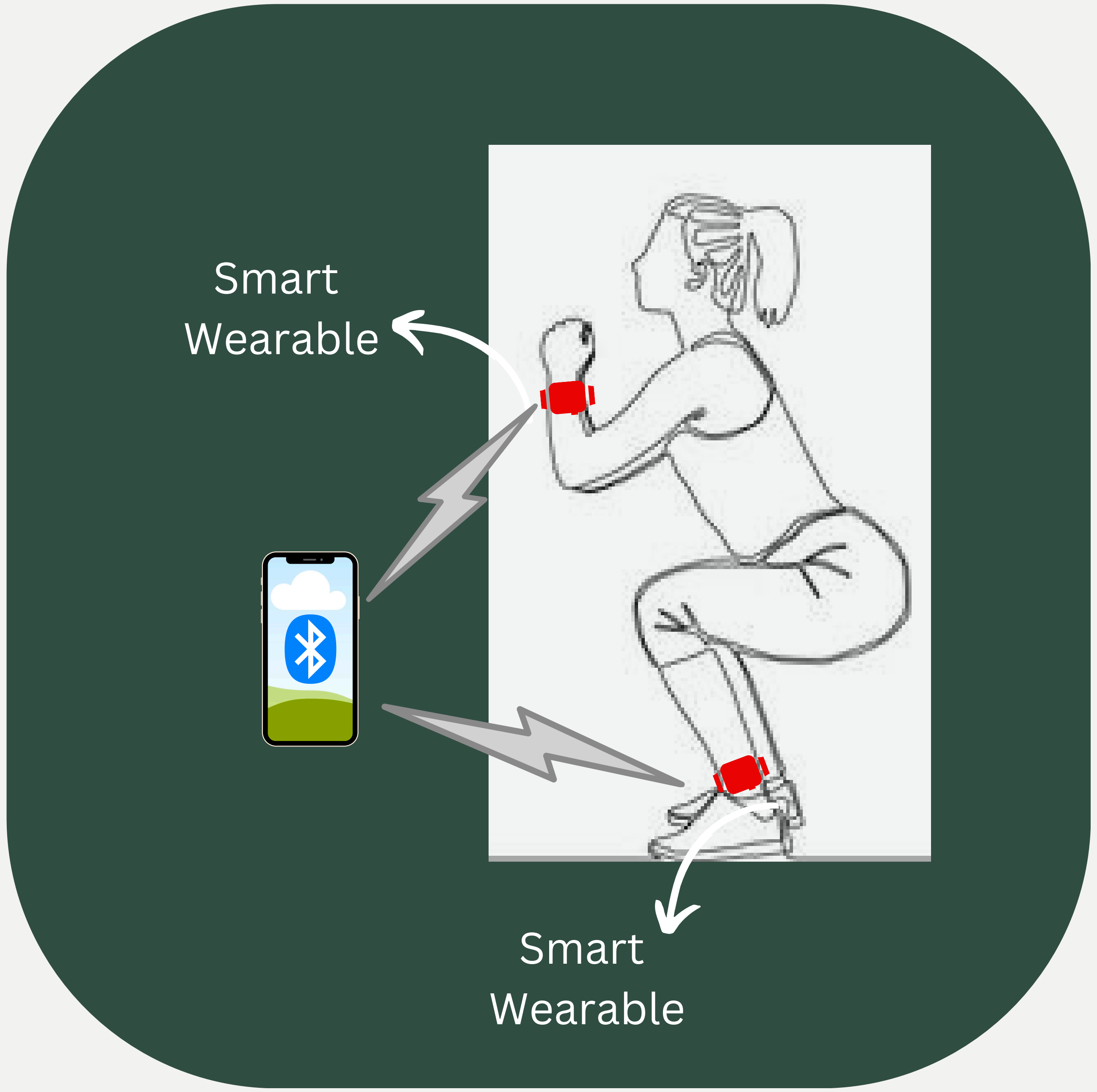
PROJECT OVERVIEW & ANALYSIS

1. Develop a reliable solution using smart wearables to assess exercise positions.
2. Collect data from two wearables (wrist and ankle) to track and evaluate user performance against fitness goals.
3. Enhance the effectiveness and safety of workouts with consistent user progress reports.
4. Address challenges like data synchronization and algorithm creation.
5. Contribute to advancements in wearable technology.
6. Drive innovation in the field of digital health and wellness.



RELATED WORK

[1] Wearable Fitness Trackers and Smart Watches: Companies like Fitbit, Garmin, Withings Pulse and Apple have developed wearable fitness trackers equipped with sensors to monitor users' activity levels, heart rate, and exercise performance that help track progress toward fitness goals.

[2] Exercise Form Analysis Apps: There are mobile applications available that analyze exercise forms using smartphone sensors. These apps use the phone's built-in accelerometer and gyroscope to detect movement patterns and provide feedback on exercise form and technique.

[3] Medical Rehabilitation Applications: In the field of medical rehabilitation, wearable sensors are used to monitor patients' movements during physical therapy exercises. These systems provide clinicians with objective data on patients' progress and adherence to prescribed exercise regimens.

[4] Virtual Reality (VR) and Augmented Reality (AR): Providing real-time feedback on form and techniques by creating virtual environments.

[5][6][7] Research Studies: Numerous research studies have explored the use of wearable sensors and motion tracking technologies for assessing exercise performance and form.

PROBLEM STATEMENT AND OBJECTIVES

Problem statement: Exercise accuracy assessment and monitoring via smart wearables.

Objectives:

1.To study smart wearable devices with advanced **IMU-based systems**.

2.To develop an **IoT-based model** using Arduino Nano and work with libraries such as Adafruit Sensor Library and BLE for communication.

3.To combine the data from the IMU sensors - accelerometer and gyroscope and estimate the orientation (i.e., pitch, roll, and yaw) of the device in three-dimensional space.

4.Using buffering and queuing mechanisms on the application backend to handle out-of-order data arrivals and reconstruct data streams by implementing protocols like **Network Time Protocol (NTP)** and **Timestamp-based Synchronization.**

5.To select the **Machine Learning models** based on their superior evaluation metrics such as accuracy, F1-score, precision, drawing insights from previous research papers.

6.To use **cross-validation techniques** to tune the hyperparameters for optimizing the model performance for models such as **RNNs, SVM and Random Forest**.

7.To develop **Kotlin based functionalities** for communicating with wearable devices.

8.To Design **UI using Android Studio** and implement database schemas to store exercise data, user profiles, and fitness goals.

ASSUMPTIONS AND CONSTRAINTS

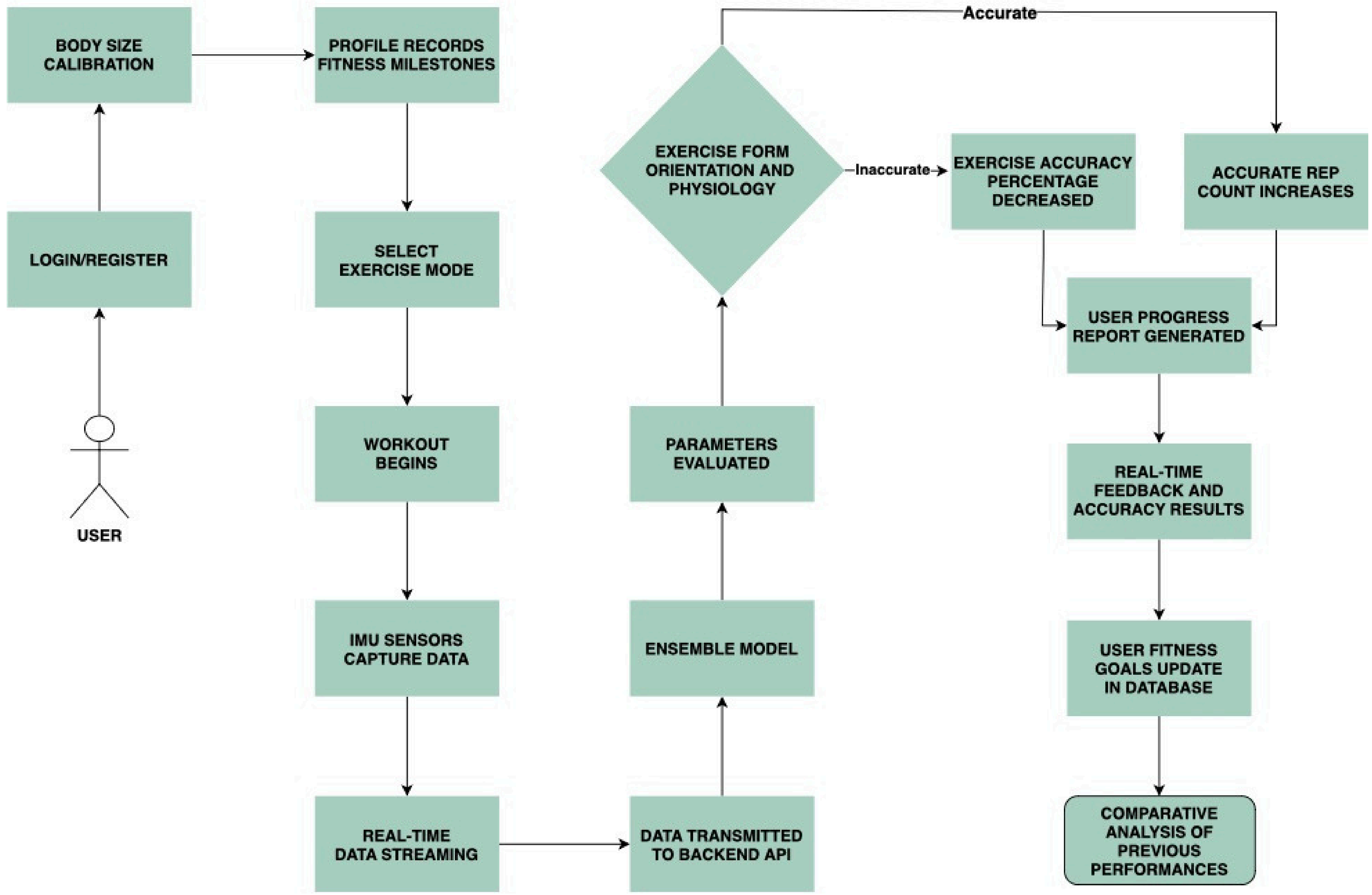
Assumptions:

1. Consistent wearable usage.
2. Data precision and reliability.
3. Active user engagement.
4. Effective communication support.

Constraints:

1. Compatibility with user devices.
2. Environmental impact on performance.
3. Limited training and testing data availability.

METHODOLOGY FLOWCHART



METHODOLOGY

WEARABLE DEVELOPMENT

- Wearable construction for Ankle and Wrist
- Arduino Nano with BLE
- Embedded IMU sensors
- Consists of Accelerome-ter and gyroscope
- Tracks movements and orientation

SENSOR DATA COLLECTION & TRANSMISSION

- Capture movement and position of wearables
- Utilise IMU sensors to collect orientation data
- Transmit to the app. backend via BLE communica-tion protocol.

FIRMWARE DEVELOPMENT

- Develop the logic on Arduino IDE
- Synchronise data from the two wearables
- Convert data into CSV format.
- Apply segmentati-on Algo.
- NTP for improved batch processing.

ENSEMBLE MODEL ANALYSIS

- Evaluate parameters
- Jerk, Angular velocity, Euler Angle.
- Built using RNNs, SVM, and Random Forest.
- Hyperpara-meter tuning via Cross Validation
- Improving output parameters

APP DEVELOPMENT

- Utilize Android SDK for app development
- Kotlin for programmi-ng
- Design the user interface of the app using Material Design Component

INTEGRATION AND TESTING

- Integrate data with the app
- Evaluate Ensemble Model on testing data
- Use BluetoothGatt and test the accuracy
- Exercise form assessment and accuracy improvement

ALGORITHMS

SUPPORT VECTOR MACHINE

- Less prone to overfitting
- Offers versatility by using different kernel functions

RANDOM FOREST

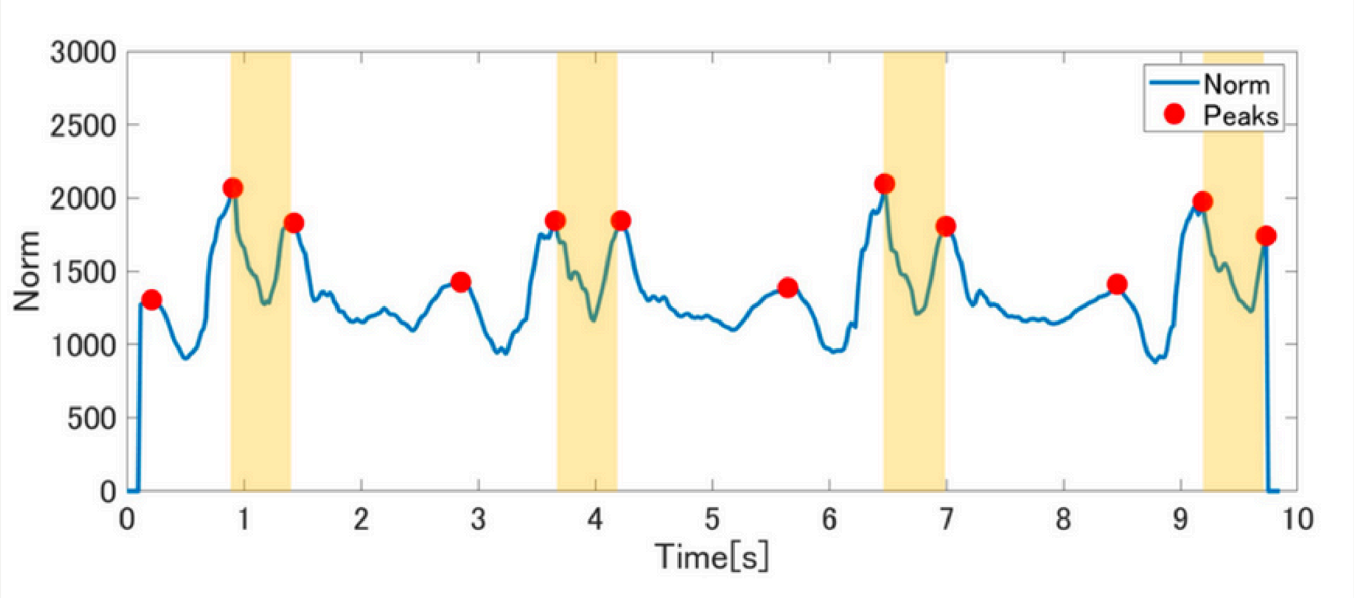
- Improves accuracy and generalization
- Provide insights into feature importance

RECURRENT NEURAL NETWORKS

- Well-suited for sequential data
- Recognizes complex patterns in exercise movements.

SEGMENTATION ALGORITHM

- Acceleration signal is segmented by extracting the data between the period of two consecutive peaks.
- We define a “segment of exercise” as the raw acceleration data between the time interval of two consecutive peaks.
- There will be a sliding window that is exercise specific. This results in perfect precision and high recall.

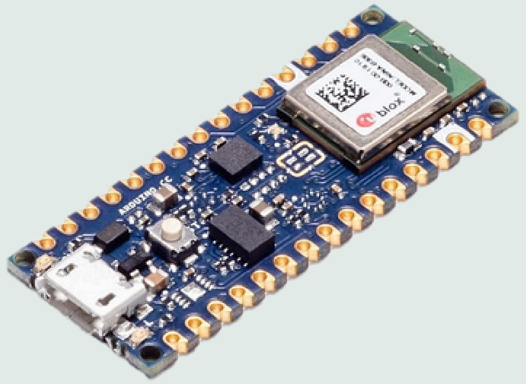


DATASET

- Create individual datasets for each exercise and wearable, each containing data from IMU sensors.
- Using segmentation Algorithm, there will be specific intervals for data capturing.
- There will be 6 attributes (accelerometer and gyroscope):
  - Acc_x
  - Acc_y
  - Acc_z
  - Gyro_x
  - Gyro_y
  - Gyro_z
- For example, in the case of squats (10 reps X 5 intervals):
  - Readings from one individual from one wearable: [50,6]
  - Readings from 50 live samples:
    1. [2500,6] - Wrist
    2. [2500,6] - Ankle
- For 5 exercises, total dataset: 5X2 = 10
- Each dataset will be served for Ensemble Model Training to calculate desired output parameters.

PROJECT REQUIREMENTS

Hardware Components



Arduino Nano 33 BLE sense Rev2

BMI 270 9-Axis, low power Inertial Measurement Unit

1250 mAh 3.7V single cell Rechargeable LiPo Battery

Light weight enclosure with strap

Tech Stack

SciPy

python™

Kotlin

pandas

TensorFlow

K Keras

Frameworks and IDE

BLE

kafka

SQLite

ARDUINO

android studio

PROJECT OUTCOMES

1. Exercise position **accuracy** is assessed using inertial sensors in the smart wearable.
2. The ensemble model evaluates and analyzes the data generated to correct the exercise positions **without human guidance**.
3. Implemented **timestamp-based synchronization** algorithms.
4. Users can track their progress using the **progress-tracking feature.**
5. Contributed to the **advancing field** of wearable technology and fitness assessment.

OUTPUT PARAMETERS

1. **Accuracy:** Proportion of correctly classified exercise positions. This is crucial for the overall system effectiveness of our project.
2. **Precision:** Proportion of correctly classified exercise positions among all positions classified as a particular exercise. It helps minimize false positives for reliable user feedback in our project.
3. **Recall:** Proportion of correctly classified exercise positions among all actual positions of a particular exercise. This minimizes the risk of missing critical movements during workouts in our project.
4. **F1 Score:** Balances precision and recall, providing a comprehensive assessment of system performance in our project.
5. **Error Rate:** Counts misclassifications, helping us improve system performance.

TASK FEATURES

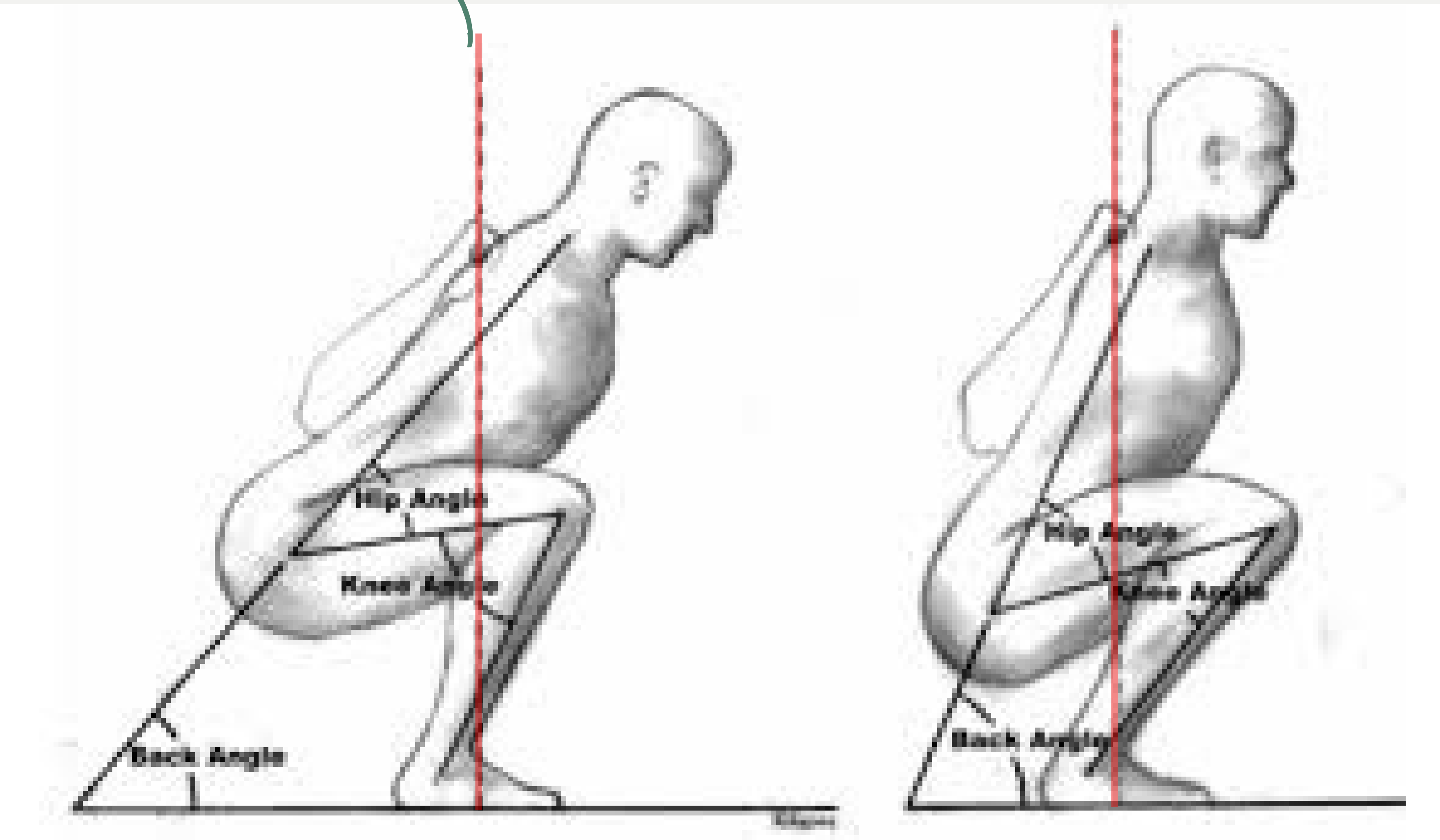
There are total 6-Axis in the IMU sensor that records these parameters - Jerk (Relative X,Y,Z) and Angular Velocity (Relative θx, θy, θz) during each exercise performed by the user. These parameters are used to calculate the following features:

List of calculated features per axis

Feature	Count
Amplitude	6
Median	6
Mean	6
Maximum	6
Minimum	6
Peak-to-Peak	6
Variance	6
St. Dev.	6
Root Mean Square (RMS)	6
Skewness	6
Derivative Mean	6
Derivative St. Dev.	6
Derivative Variance	6
Derivative RMS	6
Axis Correlations	15

Table 1

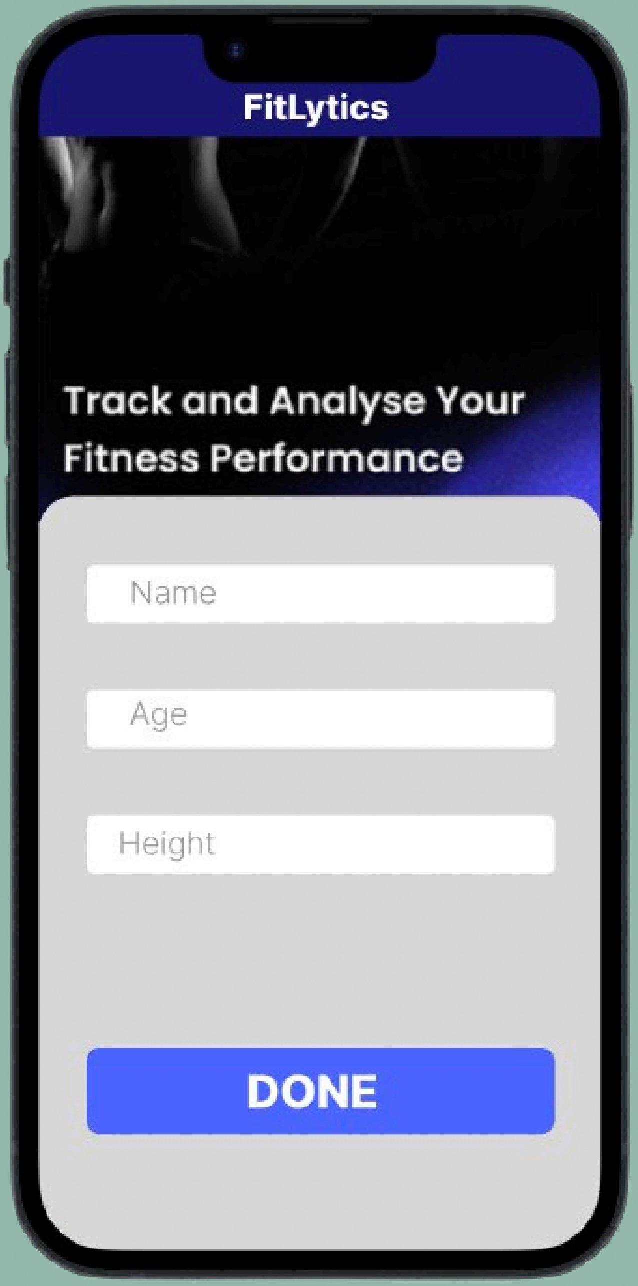
Dominant Y-axis



Correct position **Incorrect position**

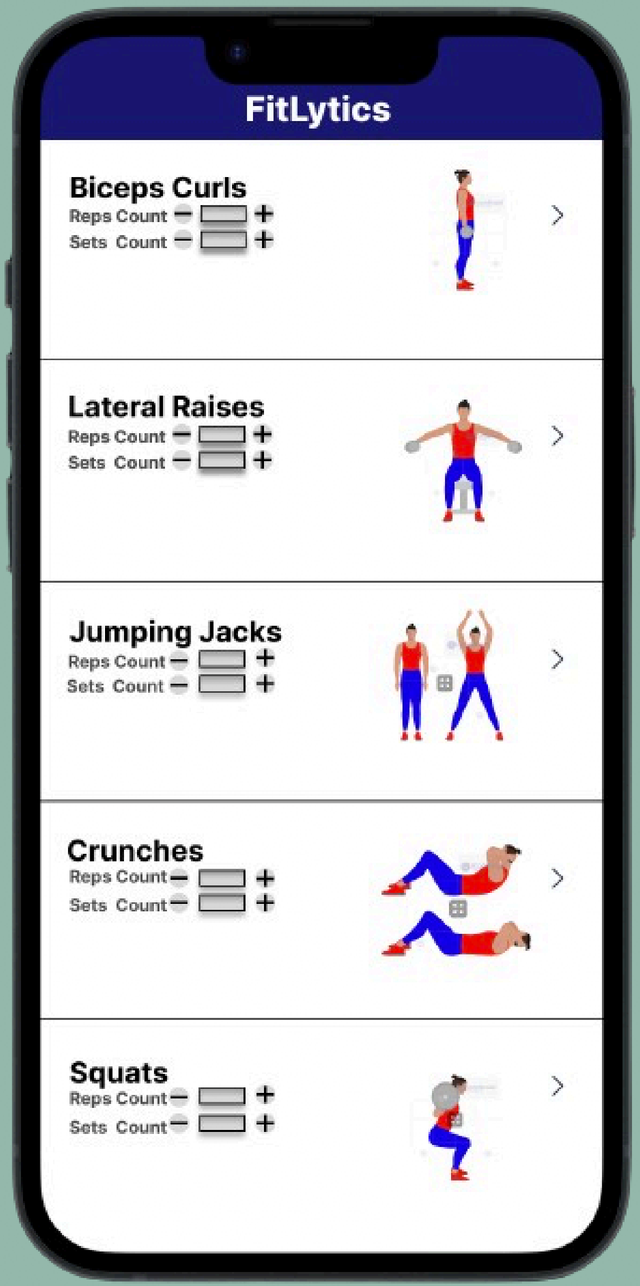
Image source: https://www.movementstrengthandconditioning.com/blog/low-bar-or-high-bar-squat

USER INTERFACE



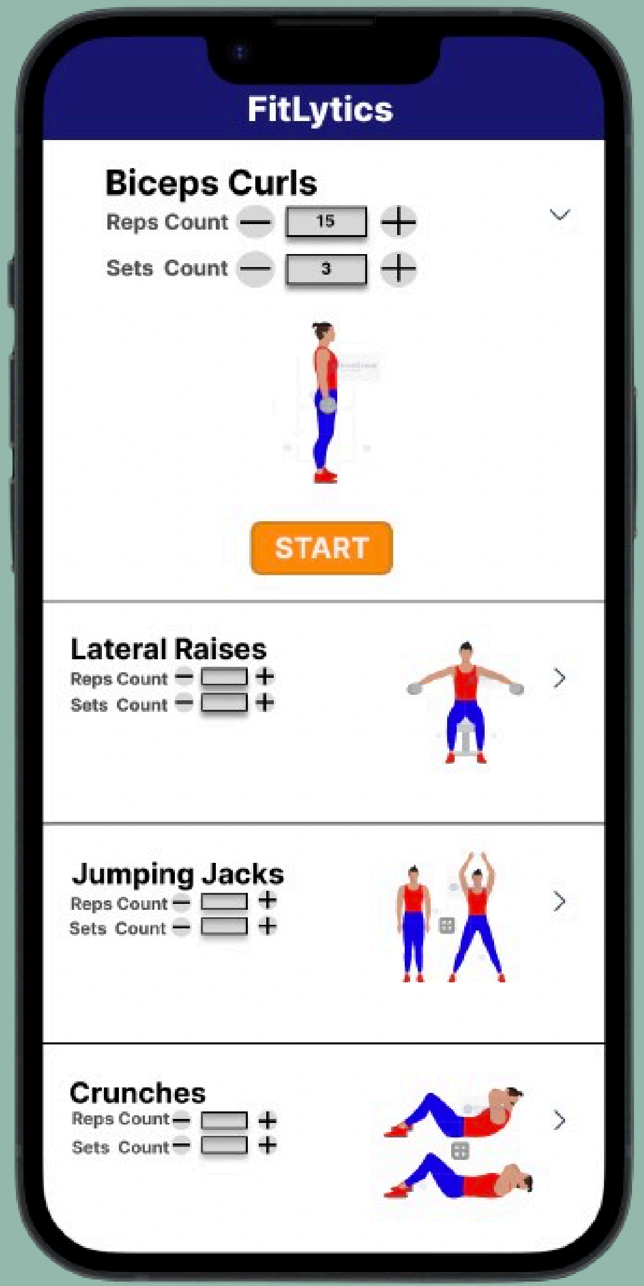
Step 1

Enter Credentials which includes user metadata such as height



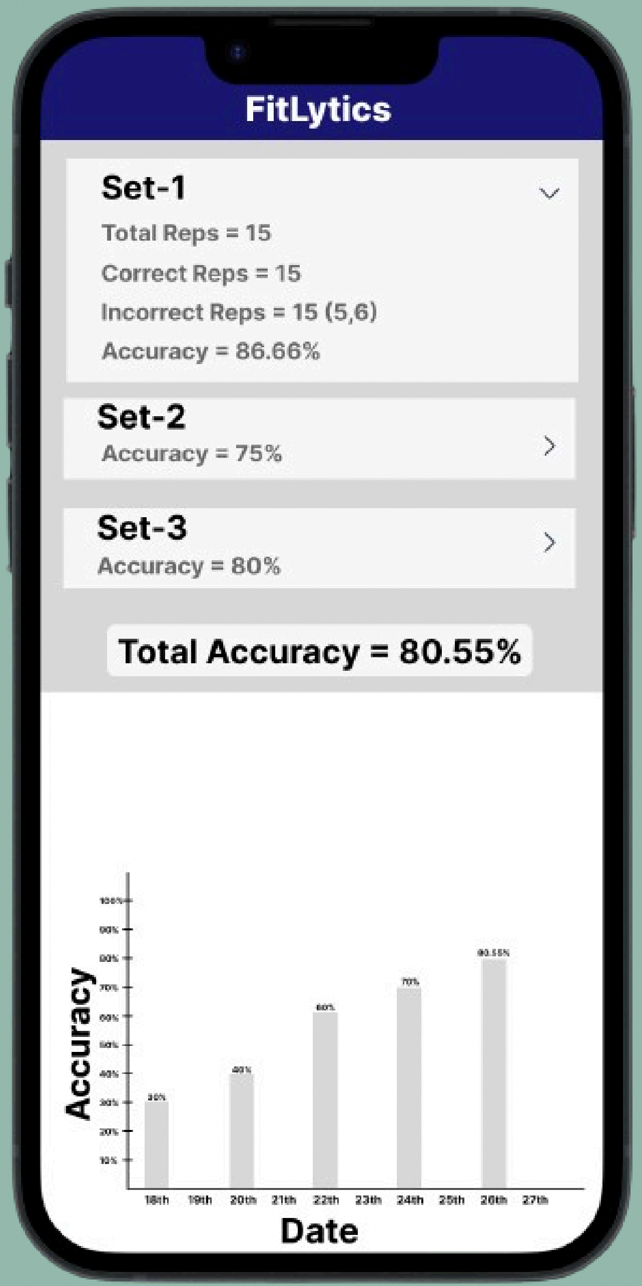
Step 2

Select Exercise with an attached animation of it from the given list



Step 3

After Selecting the exercise, choose the count of sets and reps and click START



Step 4

User can analyse the generated progress report after the completion of exercise

WORKPLAN

S.No	Activity	Month	February			March			April			May			June			July			August			September			October			November			December		
		Slot No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1	Identification, formulation & Planning of project	Plan																																	
		Actual																																	
2	Technical specifications and hardware selection	Plan																																	
		Actual																																	
3	Wearable development	Plan																																	
		Actual																																	
4	Wearable's firmware development	Plan																																	
		Actual																																	
5	Data collection and dataset development	Plan																																	
		Actual																																	
6	Data Model Development	Plan																																	
		Actual																																	
7	Data model integration and testing	Plan																																	
		Actual																																	
8	User Application Development	Plan																																	
		Actual																																	
9	Results Evaluation	Plan																																	
		Actual																																	
10	Final Report	Plan																																	
		Actual																																	

CONTRIBUTION OF INDIVIDUAL TEAM MEMBERS

Sr. No.	Team Member	Contribution
1.	Prakriti	Construction of the wearable, User Interface (UI) design, and API integration
2.	Adityaraj Bisarti	Developing and testing the Ensemble model, construction of the wearable, and data processing
3.	Nikhilesh Dhiman	Integrating firmware for real-time processing from the wearable data, Developing the RESTful APIs for the backend server
4.	Ishita Arora	Evaluating the Ensemble model, establishing the firmware for communication between wearable and API
5.	Gursewak Singh	User Dashboard development using React.js and other web frameworks

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THANK YOU