EXERCISE ACCURACY DETECTION USING SMART WEARABLES

THAPAR INSTITUTE
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(Deemed to be University)

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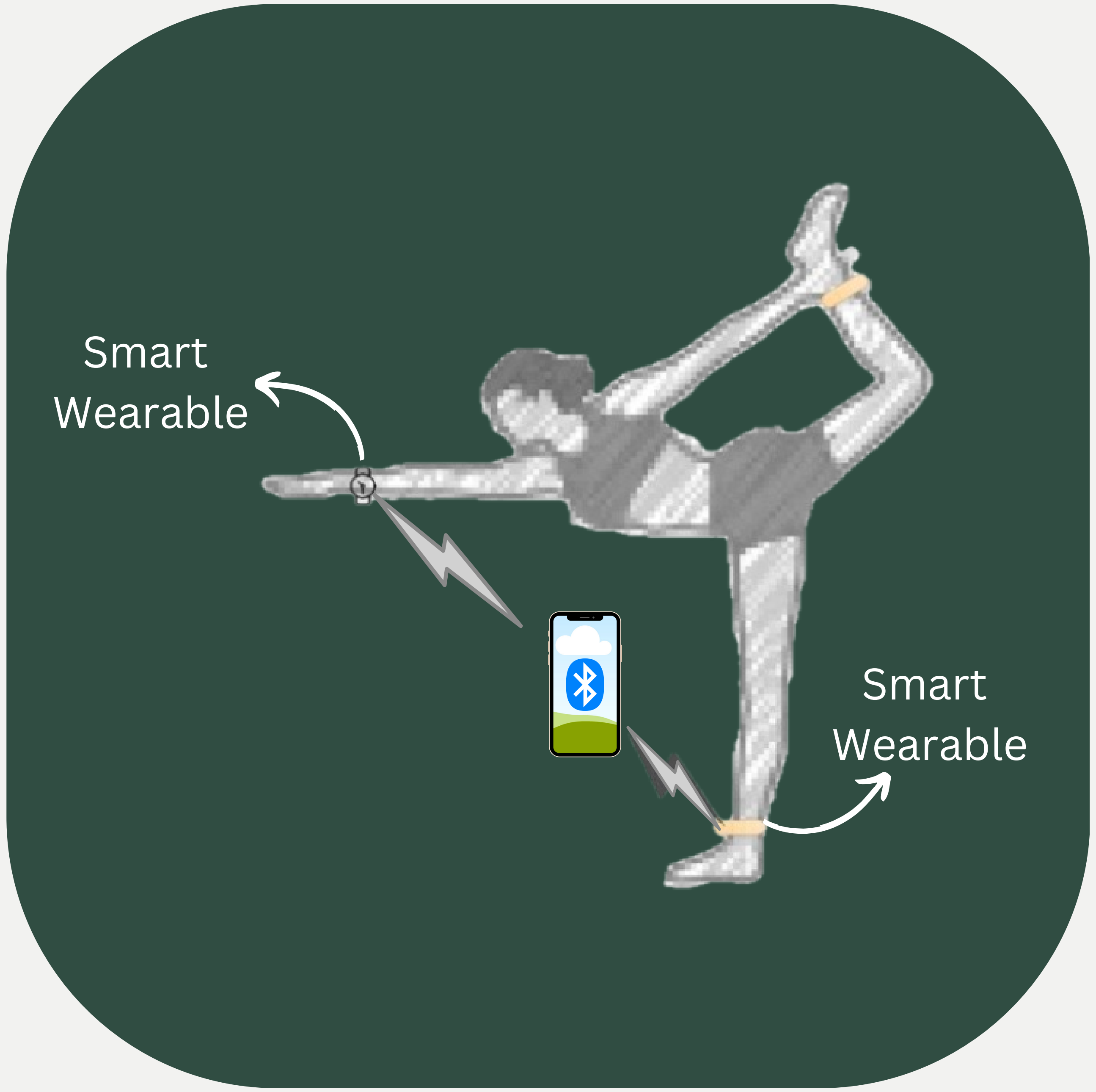
PROJECT OVERVIEW & ANALYSIS

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 and work with libraries such as Adafruit Sensor Library and protocols like I2C(wire), SPI, and BLE for communication.
3. To implement the **Madgwick Filter data fusion algorithm** that combines data from accelerometers, gyroscopes, and other IMU sensors to estimate the orientation (i.e., pitch, roll, and yaw) of a device in three-dimensional space.
4. Using buffering and queuing mechanisms on the backend server 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 RESTful APIs** for communicating with wearable devices.
8. To **Design UI using React.js** and implement database schemas to store exercise data, user profiles, and fitness goals.

ASSUMPTIONS AND CONSTRAINTS

Assumptions:

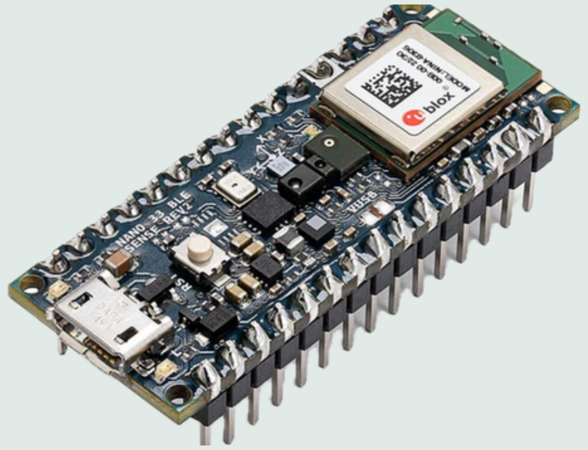
1. Consistent wearable usage.
2. Data precision and reliability.
3. Active user engagement.
4. Effective communication support.

Constraints:

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

PROJECT REQUIREMENTS

Hardware Components



Arduino Nano 33 BLE Sense Rev2

BMI 270 6-Axis, low power Inertial Measurement Unit

1250 mAh 3.7V single cell Rechargeable LiPo Battery

Light weight enclosure with strap

Tech Stack

SciPy

python™

NumPy

pandas

TensorFlow

Firebase

Frameworks

React JS

kafka

BLE

APACHE STORM™

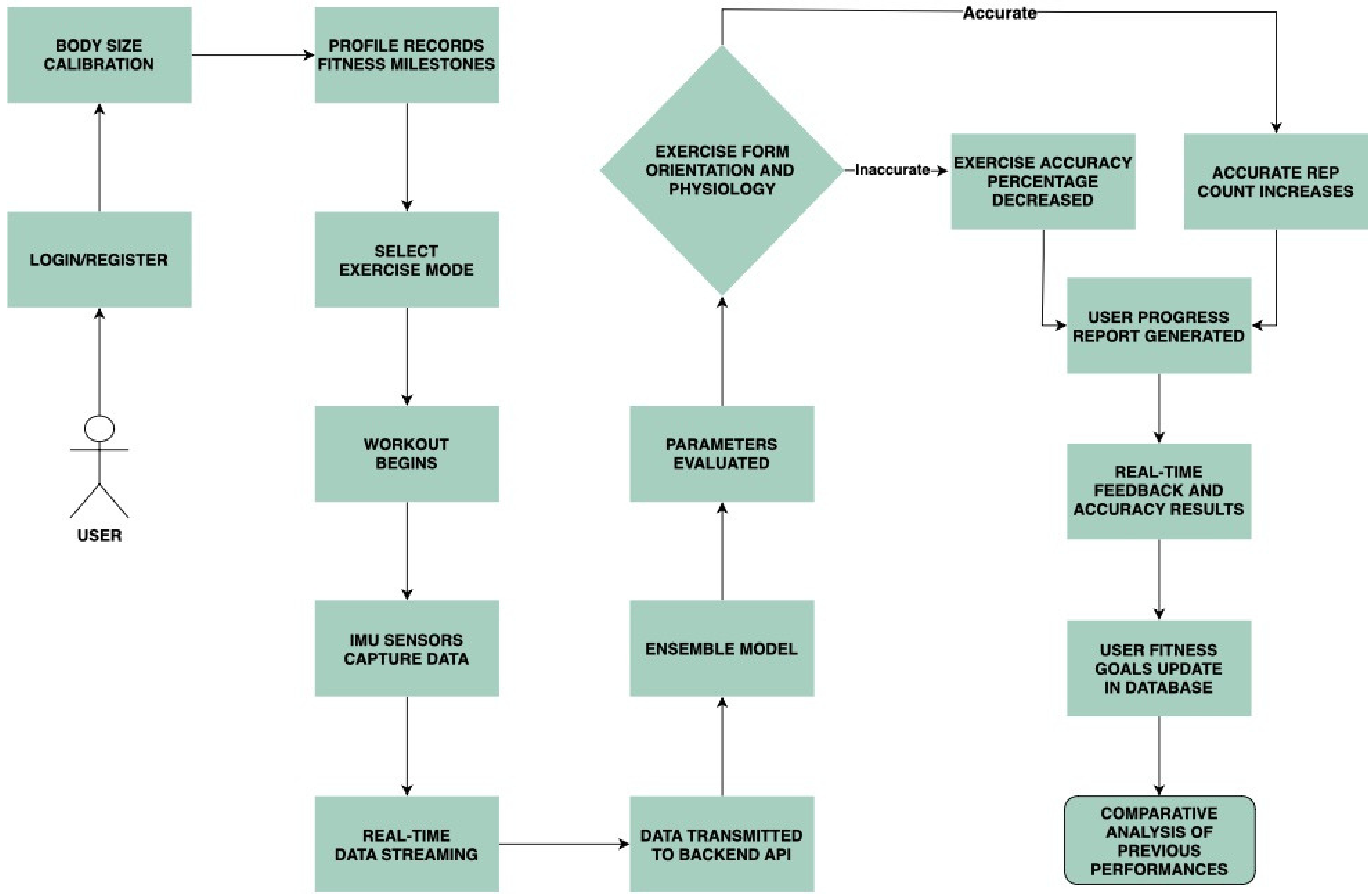
ARDUINO

node JS

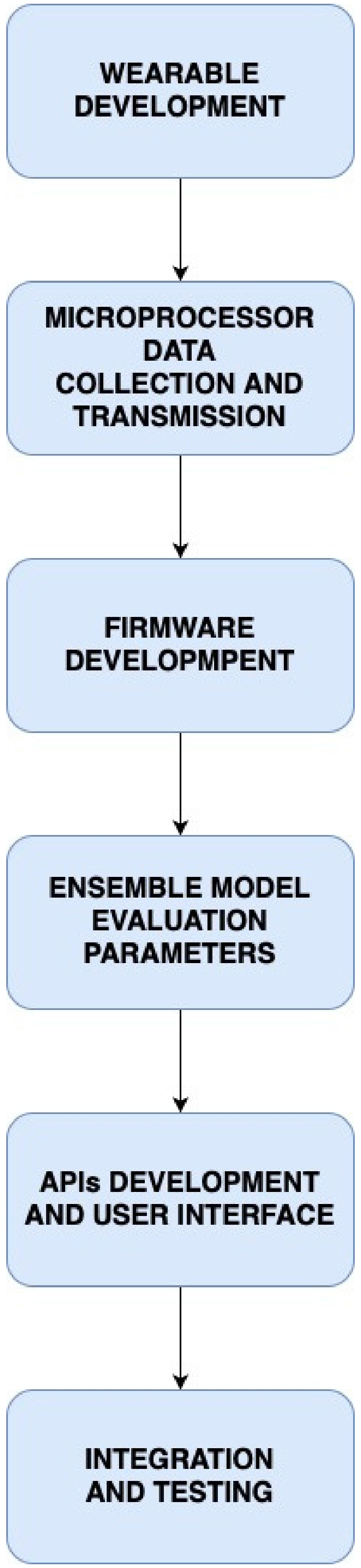
PROJECT OUTCOMES

1. Assessed exercise position accuracy using inertial sensors embedded within smart wearable devices to capture precise movement data during exercises.
2. Integrated the ensemble model with a higher accuracy that evaluated the data generated to analyze and correct movement patterns without human guidance.
3. Employed timestamp-based synchronization algorithms that provided real-time feedback to guide novices towards safer exercise techniques.
4. By providing comprehensive progress tracking features, this IoT-based solution enables users to monitor and compare their fitness goals and celebrate milestones effectively.
5. Contributed to the dynamic ecosystem of ongoing exploration and advancement in the intersection of wearable technology and fitness assessment.

METHODOLOGY FLOWCHART



METHODOLOGY



Acquire IMU sensors such as accelerometers and gyroscopes, and integrate it with the Arduino microprocessor to construct the wearable.

Employing Madgwick Filter to combine the data from the sensors and relay it the backend API via BLE. Using Apache kafka for package streaming to minimalize data loss.

Developing the logic on Arduino IDE for linking the data captured by the two wearables. Using Time syncronization algorithms and NTP for improved batch processing.

RNNs, SVM, LSTM, and Random Forest, we develop an ensemble model that evaluates parameters including jerk (accelerometer data), angular velocity (gyroscope data), Euler angles (roll, pitch, yaw), displacement, timestamps, user metadata (such as height and weight), and other quality metrics.

Using Node.js for backend development paired with Firebase for real-time database. Implementing RESTful APIs or WebSocket endpoints for communication with wearable devices.

Conduct rigorous testing to validate data synchronization, accuracy of exercise form assessment, helping the user to achieve their fitness goals and overall system reliability.

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	Deploying the backend framework for real-time processing from the wearable data
2.	Adityaraj Bisarti	Developing and testing ML models, construction of the wearable
3.	Nikhilesh Dhiman	Designing and integrating the firmware of wearable, construction of the wearable
4.	Ishita Arora	Developing the logic for data processing from the wearable and wireless communication
5.	Gursewak Singh	User Dashboard development using React.js and other web framworks

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THANK YOU