Motion Quality Tracker

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Problem statement

Physical activity is widely encouraged as a key to a healthy lifestyle, but what is even more important than exercise itself, is to do it correctly. Inappropriate exercise technique is a widespread problem that affects people of all levels of fitness and all sports, as stated in this study. For beginners, it often leads to suboptimal results, while for more experienced individuals, it can contribute to joint strain, muscle imbalances, or even long-term injuries. In rehabilitation settings, patients may struggle to perform movements correctly due to lack of proper guidance.
In addition, learning a new exercise or sport often requires continuous supervision from a qualified expert. This dependence on another person not only increases the cost but also consumes valuable time for both the user and the trainer. As a result, it limits the potential for effective and independent training.

Solution overview

The proposed solution is a wearable system that provides real-time feedback on exercise performance, using motion analysis to detect and correct improper technique.
Each exercise has characteristic movement patterns that define whether it is performed correctly. For example, an incorrectly executed squat can lead to knee or lower back injuries. A properly performed squat typically includes a straight back, correct foot positioning, adequate depth, and balanced weight distribution. Since the human body moves during the squat, an IMU sensor placed on the pants at hip level can collect relevant motion data. This sensor provides measurements of acceleration and angular velocity, which can be analyzed to determine whether the movement matches the expected correct form.
Depending on the exercise, the device can be positioned elsewhere on the body, provided that the chosen location offers sufficient data for performance evaluation and does not obstruct users movement. The systems requires a few key building blocks.

- IMU sensor
- ESP32 microcontroller
- AI model
- Custom 3D printed enclosure

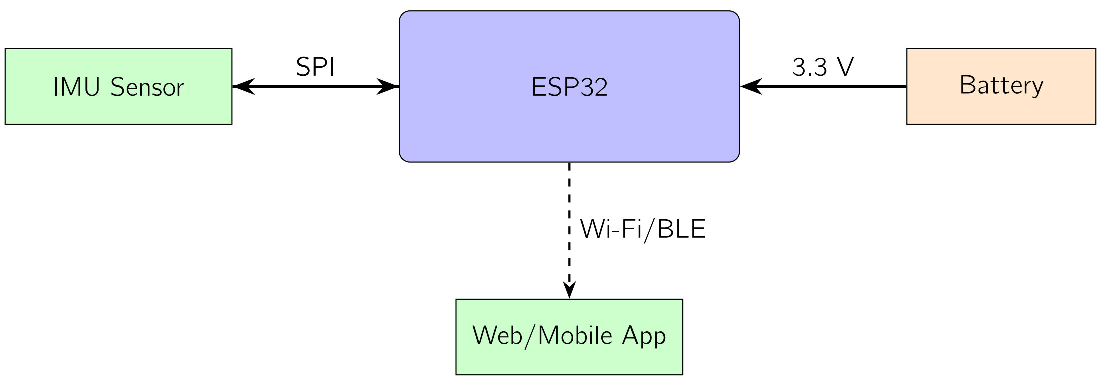

Figure 1: System architecture.

The **IMU sensor** combines MEMS accelerometer and gyroscope to collect motion data (acceleration and angular velocity), which is transferred to the microcontroller via SPI. The selected microcontroller is the **ESP32**, chosen for its wireless communication capabilities (Wi-Fi/Bluetooth). It enables integration with a mobile or web application that displays the exercise feedback. ESP32 is battery-powered to enable easy attachment to the body

and ensure unrestricted body movement. A **Li-ion battery** and the **BQ24295 charger** with built-in protection will be used. The device will be rechargeable via a USB-C charger, ensuring convenient and efficient charging.
The **AI model** will be trained using a manually collected dataset[1] of accelerometer and gyroscope signals, utilizing the LiteRT (TensorFlow Lite) framework. The EdgeImpulse platform will be used for data acquisition. The AI model will be deployed directly on the microcontroller, ensuring low latency and real-time classification with a target accuracy above 90 %. This approach follows the **Edge AI** paradigm, where inference is performed locally on the embedded device, eliminating the need for cloud connectivity and enabling on-device decision-making.
All hardware components will be integrated into a compact **3D-printed enclosure** suitable for body attachment.

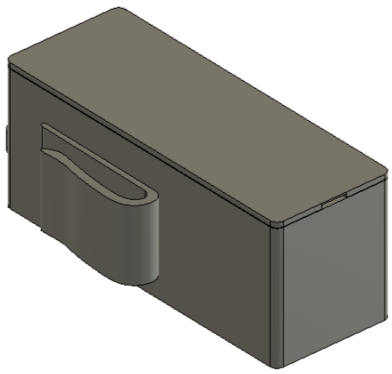

Figure 2: Proposed wearable enclosure for hardware components.

Software design

The software architecture is designed with a modular and layered approach to ensure clarity and scalability. At the lowest level, the Hardware Abstraction Layer (HAL) interfaces directly with the IMU sensor using the SPI protocol and manages power-related functions. A dedicated Data Acquisition module continuously gathers accelerometer and gyroscope signals for further analysis.
The core of the system lies in the AI Inference module, which runs a lightweight model optimized using LiteRT. This model classifies motion patterns in real time with minimal latency. Above this, a Communication module handles wireless data transmission over Wi-Fi or Bluetooth Low Energy (BLE), allowing the device to interface with a web or mobile application. All tasks are managed by a FreeRTOS.

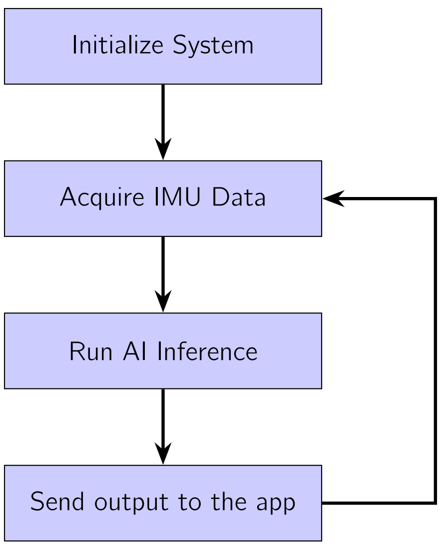

Figure 3: Flow diagram of the Motion Quality Tracker system.

[1] The training and validation data will be collected from various colleagues at the university.

List of hardware components and budget estimation

Component	Quantity	Price	Link to product
ESP32-DevKit V1	1	9,50 €	Mouser
Li-ion battery 900mAh, 3,7V	1	6,95 €	Soldered
Li-ion charger BQ24295	1	12,50 €	Soldered
IMU Sensor	1	17,10 €	Mouser
PLA Filament	1	22,99 €	BambuLab
Total price: 69,04 €			

Table 1: Components and budget overview.

Validation of the final product

Once the project is complete, it is essential to ensure that it functions correctly. For the Motion Quality Tracker device, this primarily involves evaluating the accuracy of the AI model running on the microcontroller. The accuracy will be tested by selecting a specific exercise, such as a squat, and gathering data from various individuals. Some of these individuals will perform the exercise correctly, while others will perform it incorrectly. The device's ability to correctly identify proper versus improper form will be tracked, and its accuracy will be calculated based on these results.

Additionally, the device can be used to validate a variety of movements beyond squats, such as a tennis racket swing or a soccer ball kick. By testing these different exercises, it will be possible to assess where the device performs most accurately and determine its most suitable applications.