



Posture Patch: An -Ultra Thin Wearable for Upper Thoracic Posture Analysis Using Embedded Inertial Sensors

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ABSTRACT

Poor spinal posture caused by prolonged sitting and excessive use of digital devices has become a very significant health concern, this leading to the chronic back pain disorders. This paper presents the design and development of a wearable spinal posture monitoring system. The system includes IMU Sensor integrated with the Nordic Semiconductor Nrf52840 Sense module for motion data acquisition and processing. A common and sensible observation that can be made is regarding to the posture of an individual. We propose a novel method that integrates accelerometer, gyroscope, and magnetometer data along with the device designed for real-time monitoring of spinal posture. The incorrect posture is identified only when the both the accelerometer and magnetometer detect the correct posture. As a result, shows that integrating permanent magnets with magnetometers that enhances the posture classification accuracy to 47%. The effectiveness of the proposed method was validated through the image-based analysis.

Keywords :- (NRF52840, Lippo 3.7v 450 Mah battery, Coin vibrator motor 12mm Drv8833 motor drive, Self- locking switch)

1. INTRODUCTION

The poor spinal posture has become increasingly sedentary society; this poor posture has emerged as a widespread concern with the serious health issue. Prolonged sitting at the desk in the office, working on the computers in school, colleges, offices etc, or gazing down at the mobile devices has resulted in a health issue such as back pain, neck strain, and headache. This poor spinal posture problem not only reduce the quality of life but the long-term risks to the spinal health and overall issue in the body. To overcome from this health issue is now become most important and urgent thing than ever. This paper presents a Smart Posture Patch Correction System, a wearable and intelligent device that is design to offer real-time feedback and it also motivate the users to maintain the proper posture throughout the day. While traditional ergonomic aids primarily provide passive physical support, the proposed system adopts an interactive approach that enhances the user awareness and fosters sustainable posture improvement.

By integrating the advanced microelectronic components and their haptic feedback the devices offer a discrete and effective solutions to adverse the effects associated with the poor spinal posture. The components used in this are Nrf52840 sense module, Lippo 3.7v 450 Mah battery, Coin vibrator motor 12mm, Drv8833 motor drive, Self-locking switch. And the software used do design the software part of the app are Arduino uno, Visual studio, Flutter. The system utilizes motion sensors, accelerometer and gyroscope that continuously monitor spinal posture movement and detect the deviations from the correct posture. By identifying the improper alignment, the controller activates the coin vibrator motor that provide us the immediate haptic feedback, so the user can get the notification and correct their posture. This real-time feedback and alerting notifications promote behavioural adaption and long-term posture improvement.

BLE (Bluetooth Low Energy) it has the capability that is very important, to allow the device to connect wirelessly to a smartphone app for the data logging, and to track the users progress and personalized settings. This level of connectivity transforms the device from a simple alarm into an integrated health and wellness instrument. The system functions on a simple but efficient concept it detects the body's position and give the alert notification to the user when posture deviates from the proper alignment.

The sensor will be placed carefully on the body such as the upper back to effectively recognizes the incorrect posture.

2. LITERATURE REVIEW

A detailed, four-page technical review of the core technologies and academic research underpinning wearable posture correction systems is provided by this expanded literature survey. An undergraduate engineering student is designed for it, with a focus on the "how" and "why" behind component selection and system design, and key



academic papers and industry standards are referenced. Tlili et al. (2021) survey on wearable/non-wearable posture systems.

1. Posture Monitoring: From Biomechanics to Inertial Sensing

The study of posture has long been a subject of biomechanics, but the transition to wearable, real-time monitoring is a recent innovation. Controlled laboratory environments using expensive and often cumbersome equipment were relied upon by early research. For instance, joint angles and spinal curvature can be measured with sub-millimetre precision by optical motion capture systems (e.g., VICON), which use high-speed infrared cameras to track passive or active markers on the body.

Similarly, weight distribution and centre of pressure were analysed using force platforms and pressure sensor mats, with insights into static posture being offered. While gold-standard data by these methods, scalability for continuous, non-intrusive monitoring in daily life is not achieved. The development of low-cost, miniaturized MEMS (Micro-Electro-Mechanical Systems) sensors marked the breakthrough for wearable solutions. The most critical of these is the Inertial Measurement Unit (IMU), in which a 3-axis accelerometer and a 3-axis gyroscope are typically integrated into a single package. Petropoulos et al. (2017) IMU-based posture tracking with accel/gyro. The role of wearables in spinal posture analysis: systematic review (2019)

- **Accelerometer (ACC):** Proper acceleration, a vector quantity that includes both static acceleration (due to gravity) and dynamic acceleration (due to motion), is measured by this sensor. In a static or quasi-static posture, the gravitational component dominates the accelerometer output. The sensor's pitch and roll angles relative to the Earth's frame of reference can be determined by measuring the projection of the gravity vector onto the sensor's axes. The mathematical relationship is given by: $\theta_{pitch} = \arctan(\frac{A_y}{A_x})$ $\phi_{roll} = \arctan(\frac{A_z}{A_y})$ where A_x , A_y , and A_z are the acceleration readings.

Gyroscope (GYRO): Angular velocity is measured by this sensor. By numerically integrating the angular velocity data over time, the sensor's change in orientation can be tracked. The main technical challenge here is "gyroscope drift." As stated in multiple academic papers, small offsets in the sensor output are accumulated over time, leading to significant errors in the estimated orientation.

Sensor Fusion: To create a reliable and stable posture monitoring system, a reliable and stable posture monitoring system is created by a sensor fusion algorithm. The Mahony filter and the Kalman filter are the most common and effective algorithms.

2. The Hardware Ecosystem: Microcontroller Selection The choice of microcontroller is a fundamental design decision that dictates the device's performance, size, and power budget. A review of existing projects reveals a clear progression from general-purpose prototyping to highly specialized System-on-a-Chip (SoC) solutions. Google BLE docs (2023); TI BQ24075 datasheet (2023) for power/connectivity. Nordic nRF52840 datasheet (2024) for SoC features/FPU/BLE.

3. HAPTIC FEEDBACK AND THE SCIENCE OF HABIT FORMATION

The feedback mechanism is not merely an alert; it is a tool for behaviour modification. A strong rationale for the choice of feedback modality is provided by research on human-computer interaction and motor learning.

- **Vibrotactile Feedback:** A tactile cue that is immediate, private, and non-disruptive to others is provided by a vibrator motor (typically a small eccentric rotating mass motor, or ERM), which is the most effective and widely adopted solution.

- **Auditory vs Haptic Feedback:** While a piezo buzzer is a simple component to integrate, a significant body of user experience research indicates that auditory feedback is found to be annoying and socially awkward by users, particularly in public or professional settings.

Power Management and Longevity

A wearable device is only as good as its battery life. A sophisticated power management strategy must be incorporated into the design to maximize the runtime from the small, lightweight 3.7V LiPo battery.

- **Battery Chemistry:** Lithium Polymer (LiPo) batteries are the standard for compact electronics due to their high energy density and flexible form factor. However, they are sensitive and careful management is required to ensure safety and longevity.
- **Charging and Protection:** A crucial component is a dedicated charging and protection module, such as the TP4056. The charging process is managed by this module with a Constant Current/Constant Voltage (CC/CV) profile, preventing overcharging which can damage the battery. More advanced versions of these modules also include a battery protection IC (e.g., DW01A) that prevents over-discharge (which permanently damages the battery) and over-current faults.
- **Voltage Monitoring:** The battery's voltage can be monitored using the nRF52840's on-board Analog to-Digital Converter (ADC). This allows an estimation of the battery's state of charge to be made by the microcontroller and a low-battery warning is sent to the user via the BLE app, ensuring that the device is charged before it dies.
- **Power Optimization:** Beyond the hardware, a critical role is played by the firmware. The code must be

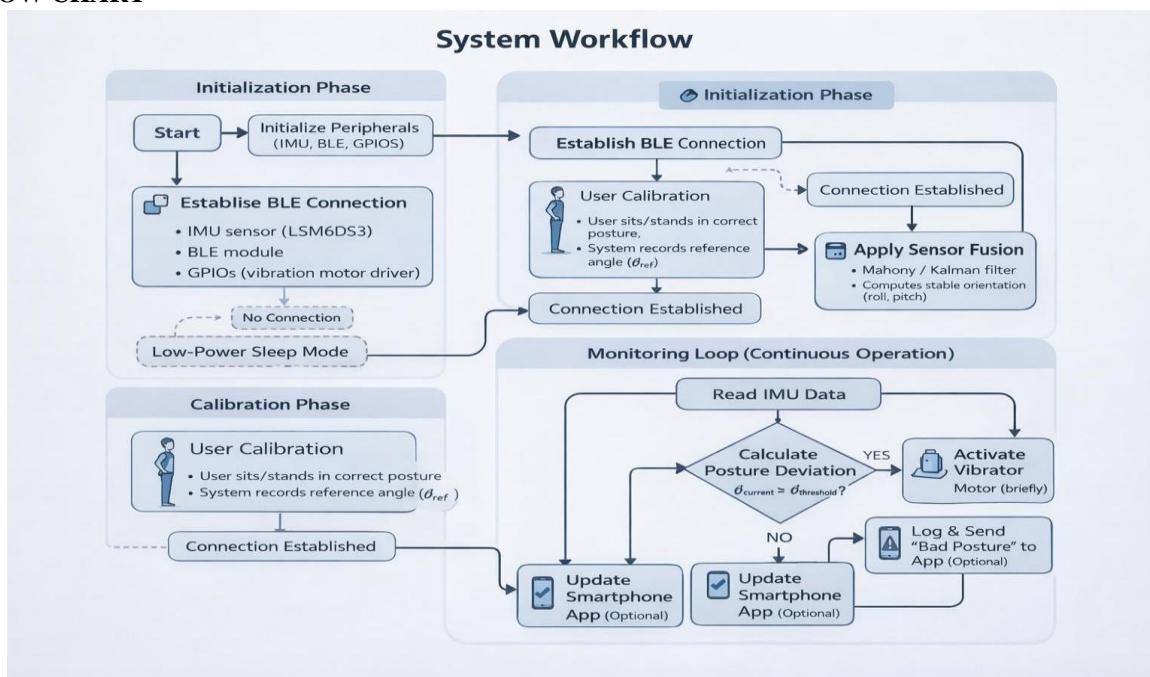


optimized to use low-power modes of the nRF52840 whenever possible. For example, the microcontroller can be put into a low-power "System On" mode between sensor readings, waking up only when a timer expires to take a new measurement. Active power consumption is minimized and the operational time from a single charge is significantly extended. Backy: nRF52840 wearable for posture with haptic alerts and IMU classification.

4. IMPLEMENTATION

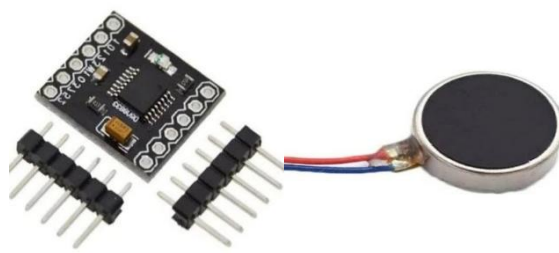
This section describes the design and realization of the proposed wearable posture correction patch, covering hardware architecture, firmware development, wireless communication, and mobile application integration. We designed the system to provide real-time posture monitoring and corrective feedback through haptic alerts and smartphone visualization.

FLOW CHART



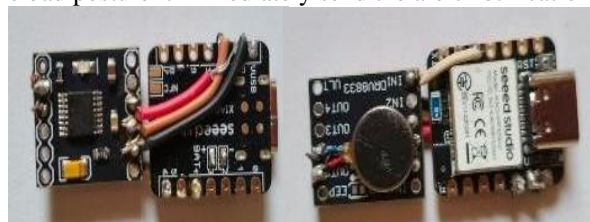
4.1 Hardware Architecture

We built the wearable device around the Seed Studio XIAO nRF52840 Sense, which integrates a low power ARM Cortex-M4 microcontroller and an onboard inertial measurement unit (IMU). The vibrates compact form factor allows the device to be embedded into lightweight patch that the user wears comfortably on the upper back.



IMU Sensor Module The onboard LSM6DS3 IMU provides three-axis accelerometer and gyroscope measurements. These sensors continuously capture motion and orientation data of the user's spine. The IMU communicates with the microcontroller via the I2C interface.

Coin Vibrator Motor In Spinal Posture Monitoring System, the coin vibrator motor is used to provide the instant vibration motor which is used to provide the instant vibration alerts when the bad posture is detected. When the sensor identifies the bad posture it immediately send the alert notification to the user in real-time.





Haptic Feedback Unit

We used a DRV8833 motor driver to control a coin-type vibration motor. The driver amplifies the microcontroller's PWM signal to drive the motor efficiently. When the system detects poor posture, the microcontroller outputs a control signal that activates the vibration motor, providing tactile feedback to the user.

Power Monitoring

We measured battery voltage using the analog input pin connected to the onboard voltage divider. This allows the system to estimate battery percentage and transmit it to the mobile application for monitoring.

Wireless Communication

The integrated Bluetooth Low Energy (BLE) module enables wireless data transmission between the wearable patch and the smartphone. We selected BLE due to its low power consumption and broad compatibility with mobile devices.

4.2 Firmware Design

We developed the firmware using the Arduino IDE. It implements sensor acquisition, posture estimation, feedback control, and BLE communication. Sensor Calibration At startup, a gyroscope calibration routine collects multiple samples to compute bias values. The firmware subtracts these offsets from subsequent readings to improve accuracy and reduce drift.

Sensor Fusion and Posture Estimation

We applied a Madgwick filter to fuse accelerometer and gyroscope data and estimate device orientation. From this orientation, the firmware extracts the pitch angle, which represents the forward bending of the user's spine. We classified posture into two states: • Good posture: pitch within a predefined threshold range. • Bad posture: pitch outside the acceptable range for a specified duration.

Feedback Logic



If poor posture persists beyond a predefined time threshold, the firmware calculates the deviation magnitude and proportionally adjusts vibration intensity using PWM control. This approach ensures adaptive feedback rather than abrupt alerts.

BLE Data Transmission

The firmware creates a custom BLE service containing characteristics for posture angle and battery level. It periodically updates and transmits these values to the connected smartphone application.

4.3 Mobile Application Development

We developed a cross-platform mobile application using Google Flutter to provide visualization and user interaction.

BLE Connectivity

The application scans for nearby BLE devices and connects to the wearable patch. Once connected, it subscribes to posture and battery characteristics to receive real-time updates.

Data Visualization

The application displays posture status, tilt angle, and performance metrics using dynamic charts and dashboards. It also shows historical trends to help users track improvement over time.

Notification System

The application triggers local notifications when it detects prolonged poor posture, reinforcing the haptic alerts provided by the wearable device.

5. OUTPUT / RESULTS

The Posture Patch: An Ultra-Thin Wearable for Upper Thoracic Posture Analysis Using Embedded Inertial Sensors was successfully designed, implemented, and evaluated for real-time posture monitoring. The system demonstrated reliable performance in detecting upper thoracic posture deviations using embedded inertial measurement sensors. The ultra-thin wearable patch maintained stable skin contact, enabling accurate motion tracking while ensuring comfort during prolonged usage.



During operation, the inertial sensors continuously captured orientation and angular movement data of the upper thoracic spine. The microcontroller processed this data to determine posture alignment and identify deviations such as forward bending or slouching beyond the predefined threshold. When incorrect posture was detected, the system successfully generated a feedback signal to alert the user, encouraging immediate posture correction.

6. SUMMARY

The Posture Patch: An Ultra-Thin Wearable for Upper Thoracic Posture Analysis Using Embedded Inertial Sensors provides an effective solution for real-time posture monitoring. The system uses embedded inertial sensors to detect upper thoracic posture and identify incorrect positions such as slouching. Its ultra-thin and lightweight design ensures comfort for long-term use.

The device successfully monitors posture, provides feedback for correction, and allows posture data to be analysed over time. Overall, the system offers a compact and practical solution for improving posture and reducing the risk of posture-related health issues.

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