A Minor Project Report

on

Intelligent Detection of Body Posture

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CERTIFICATE

This is to certify that the seminar report entitled "**Intelligent Detection of Body Posture**" submitted by **Het Virani(22BIT252D) & Dilon Brahmbhatt(22BIT236D)** has been conducted under the supervision of **Dr. Amit G Kumar, Assistant Professor, Department of Electronics and Communication Engineering**, and is hereby approved for the partial fulfilment of the requirements for the award of the degree of Bachelor of Engineering in the Department of **Information and Communication Technology** at Pandit Deendayal Energy University, Gandhinagar. This work is original and has not been submitted to any other institution for the award of any degree.

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DECLARATION

We hereby declare that the minor project report entitled "**Intelligent Detection of Body Posture**" is the result of our own work and has been written by us. This report has not utilized any language model or natural language processing artificial intelligence tools for the creation or generation of content, including the literature survey.

The use of any such artificial intelligence-based tools was strictly confined to the polishing of content, spell checking, and grammar correction after the initial draft of the report was completed. No part of this report has been directly sourced from the output of such tools for the final submission.

This declaration is to affirm that the work presented in this report is genuinely conducted by me and to the best of my knowledge, it is original.

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CHAPTER 1: INTRODUCTION AND OBJECTIVES

Maintaining correct sitting posture has become a major challenge in the current digital generation, where academic study, computer work, and mobile usage occupy long working hours every day. Continuous forward bending or slouching generally goes unnoticed, but over time it leads to discomfort, muscle fatigue, spinal misalignment and long-term health complications such as neck pain, shoulder tightness and low-back stiffness. Students preparing for exams, software engineers working at desks, and office professionals attending prolonged meetings often lack posture awareness until pain arises. This encourages the need for an intelligent system that can monitor posture unobtrusively and alert users instantly whenever unhealthy posture is detected.

The aim of this project is to design a Smart Posture Monitoring System using ESP32, integrated with two ultrasonic sensors mounted on the chair to measure the distance between the user's back and backrest, and a flex sensor placed on the upper spine region to detect bending of the body. The ESP32 collects these signals, applies smoothing and threshold-based analysis for real-time classification of posture, and then sends alerts via Blynk IoT platform when incorrect posture is identified. The system operates on portable power using LM2596 converter and battery, allowing the user to continue working comfortably while the device monitors posture in background without requiring user intervention.

The solution is low-cost, compact, non-wearable and user-friendly compared to camera-based systems or posture belts. Additionally, the project integrates the possibility of upgrading the threshold-based model to machine learning using decision trees to improve adaptability for different body postures in the future, making it suitable for continuous health monitoring environments like study desks, library spaces and offices.

Thus, the project attempts to promote ergonomic sitting habits through an IoT-enabled feedback mechanism designed to prevent long-term posture-related injuries and improve lifestyle quality.

Objectives

1. To design a low-cost smart posture monitoring prototype.
2. To measure back-to-chair distance using ultrasonic sensors.
3. To track spinal bending using a flex sensor with ADC readings.
4. To classify posture using threshold-based and ML decision-tree algorithms.
5. To send real-time alerts to the user's phone via Blynk when posture is incorrect.
6. To implement portable power using LM2596 for stable output.
7. To prepare a system that can later be extended into a full ML-based wearable product.

CHAPTER 2: LITERATURE REVIEW

2.1 Overview of Existing Work

Technological advancement in healthcare and ergonomics research has motivated several innovations to prevent posture-related disorders. Poor posture contributes significantly to chronic back pain, cervical strain, reduced lung capacity and spinal deformity. Over the years, researchers have attempted multiple ways to monitor sitting posture and notify users before physical strain accumulates. The available solutions mainly fall under three categories – wearable posture belts, camera-based monitoring systems and sensor-based smart chairs. Each approach contributed knowledge to the field but also revealed implementation challenges and limitations.

Early research focused largely on wearable electronic devices. Dunne et al. (2008) developed a wearable monitoring garment that embeds flex sensors into clothing to track upper spinal movement. The study demonstrated good accuracy in curvature detection. However, wearing sensor-fabric daily is uncomfortable for long hours, especially in warm climates. Many users tend to avoid wearable systems after some time, reducing sustained adoption. This observation highlights the need for non-intrusive posture detection models that do not require wearing equipment.

Parallel research explored camera and image-processing approaches for posture evaluation. Computer vision systems use webcams or depth sensors to analyse user posture through skeletal mapping. While accuracy is promising under controlled lighting, these systems require constant camera visibility and generate privacy concerns when used at home or offices. Real-time processing increases computational cost, and long-term deployment becomes uncomfortable as users feel monitored. This leads to an important inference that camera-based solutions are not ideal for everyday personal environments.

To overcome limitations of wearables and cameras, another direction of research suggests sensor-fusion based chairs, where force sensors, pressure mats or ultrasonic distance sensors are integrated inside chair insulation. Jeong and Park (2020) worked on a hybrid chair combining pressure and distance sensors for posture classification. Their approach achieved reliable results for forward lean and side tilt detection. However, the structure was complex, expensive to manufacture and limited to a single chair. This indicates that research requires simpler, portable and easily scalable designs.

Studies from Bergqvist (1995), Gerr (2002) and others focused on workplace ergonomics rather than electronic detection. They confirmed that prolonged seated posture increases musculoskeletal disorder risk and productivity loss. These findings reinforce the motivation to design a system that constantly monitors posture and helps users correct it before pain develops. A device that reminds instead of merely analysing would create behavioural improvement gradually.

2.2 Comparative Study of Related Research

Author / Year	Method	Merits	Limitations
Dunne et al. (2008)	Posture monitoring garment	Tracks spinal curvature accurately	Users must wear device continuously
Jeong & Park (2020)	Mixed sensor smart chair	Multi-sensor fusion with good accuracy	Complex chair construction
Bergqvist U. (1995)	Ergonomic discomfort study	Proved long sitting causes spinal pain	No monitoring system proposed
Gerr F. (2002)	Computer user posture analysis	Large sample analysis	No automatic correction feedback
Proposed System	Ultrasonic + Flex + ESP32 IoT	Low cost, portable, IoT alerts	Limited to seated posture currently

Table 2.1 Comparison Of Existing Work

2.3 Summary of Literature Outcome

After reviewing multiple studies, some common patterns emerge:

Observations from past research

- Long-term sitting without correction leads to spinal stress and fatigue.
- Wearables provide accuracy but lack comfort and user acceptance.
- Vision-based systems ensure continuous tracking but compromise privacy.
- Complex smart chairs are difficult to deploy universally.
- People need simple, low-cost and real-time feedback, not post-session reports.
- IoT integration for live alerts is rarely implemented in basic models.

Key Learnings Derived

- Monitoring must not disturb or restrict the user.
- A small number of sensors, if placed correctly, can produce useful feedback.
- Combining distance sensing and spinal curvature sensing increases reliability.
- IoT improves usability by giving alerts during wrong posture, not after damage.
- The system should be power efficient and portable for long sitting hours.

How this project is different

The proposed work does not require cameras or wearables. Instead:

- Two ultrasonic sensors measure back-to-chair distance to detect forward slouch.
- A flex sensor detects bending curvature over upper spinal area.
- ESP32 Wi-Fi integration enables real-time alerts through Blynk.
- LM2596 module ensures stable supply for long operation.
- Control logic is simple initially using threshold-based classification.
- System can later evolve into an adaptive machine-learning based model.

By examining literature and observed gaps, it is clear that there is a strong need for a compact, comfortable and intelligent system that motivates healthy sitting habits. Our approach is therefore aimed at bridging comfort, cost and accessible ergonomics using minimal hardware.

CHAPTER 3: RESEARCH GAPS AND PROBLEM STATEMENT

Rapid digital transformation has made computers, smartphones and online learning a core part of daily lifestyle. Along with convenience comes a major drawback—people remain seated for long durations without maintaining correct posture. Without feedback, the human body tends to gradually lean forward or bend sideways due to fatigue. Over months or years, this behaviour leads to spinal deformation, cervical pain, muscle tension and long-term orthopedic complications. Although several methods exist for posture correction, most are either expensive, uncomfortable or impractical for daily use. Hence, a need arises to develop a low-cost, user-friendly system capable of monitoring posture continuously and alerting the user in real-time.

3.1 Limitations in Existing Approaches

While reviewing previous research work and existing posture-monitoring products, certain limitations were identified which restrict their effectiveness in real situations:

1. **Wearable devices lack comfort**

   Smart belts or jackets track spine alignment using flex or IMU sensors, but users must wear them constantly. This becomes uncomfortable, especially during long work sessions. Many people stop using wearables after a few days, which reduces long-term adoption.

2. **Camera-based systems raise privacy concerns**

   Vision-based posture detection systems require a camera to be pointed at the user continuously. This is impractical for home and office environments. Lighting conditions, camera angle and background variations can also reduce accuracy.

3. **Pressure-based ergonomic chairs are costly**

   Smart chairs with force sensors and pressure mats track body position accurately but are expensive to deploy commercially. Their use is limited to specialized labs and rehabilitation centers rather than regular users.

4. **Most models only analyze posture but do not alert instantly**

   Many research papers focused on detection accuracy rather than behavioural correction. Detection without notification has limited usefulness because posture must be corrected in the moment.

5. **Lack of portability reduces practicality**

   Some systems require external power supplies, computer connections or fixed mounting arrangements, limiting portability. Users need a compact lightweight device instead.

6. **Less work is done on IoT-based posture feedback systems**

   While machine learning classification is explored in research, very few models integrate wireless notification. Modern systems must interact with the user through smartphones to build awareness.

3.2 Identified Research Gap

After analysing literature and existing designs, the need for a low-power, small-sensor, IoT-enabled and user-friendly posture monitoring system became clear. The gap lies not in sensing technology, but in integration, usability and real-time feedback. There is a shortage of posture systems that:

- Work without wearable attachments
- Require minimal sensors but still maintain accuracy
- Operate in any home/office environment
- Provide instant alerts instead of post-analysis reports
- Remain affordable for students and common users
- Can later be improved using machine learning models

This project is intended to fill those shortcomings by combining two ultrasonic distance sensors and one flex sensor, processed using ESP32 microcontroller with Blynk IoT notification system for immediate feedback.

3.3 Problem Definition

Considering the above research gaps, the final problem for this project is defined as:

"To design and implement a smart IoT-based posture monitoring system using ESP32, ultrasonic sensors and a flex sensor that detects incorrect sitting posture by measuring back distance and spinal bend, and alerts the user in real-time for correction."

This problem aims not only to detect posture but to change user behaviour by generating reminders at the right moment.

3.4 Research Objectives Aligned to Problem

Objective	Proposed Approach
Monitor distance between user and chair	Dual Ultrasonic Sensors
Detect spine bending angle	Flex Sensor + ADC mapping
Filter noise to improve reliability	Moving Average Smoothing
Give real-time feedback	Blynk Notification Alerts
Make system portable	LM2596 regulated power supply
Future enhancement	Machine Learning Decision Tree

Table 3.1 Research Objective

3.5 Significance of Proposed System

The benefits of the proposed system include:

- Encourages healthy posture habits gradually
- Reduces risk of long-term spinal problems
- Works silently in background without disturbing the user
- No privacy violation since no camera used
- Easy for students, office workers and home study users
- Can be integrated into chairs or wearable form later
- Cost-effective solution compared to smart chairs & IMU suits

Thus, the proposed work stands as a strong foundation for a practical real-life health-support device.

CHAPTER 4: METHODOLOGY ADOPTED

The implementation of the smart posture monitoring system involves a combination of hardware and software working together to continuously check the sitting position of the user and generate an instant alert when posture becomes unhealthy. The system is built using a flex sensor, two ultrasonic sensors, an ESP32 microcontroller, and Blynk IoT platform for remote alerts. The methodology includes sensor integration, data acquisition, pre-processing, threshold setting using a Decision Tree model, and live inference on ESP32.

This chapter explains every phase of development in detail including hardware design, power arrangement, data collection procedure, software algorithm, machine learning-based threshold selection, and real-time decision-making.

4.1 System Overview

The proposed architecture consists of two sensing modules:

- **Flex Sensor Module**

Placed on the upper thoracic region to measure spine bending. As the user leans forward, the sensor bends, its resistance increases, and ADC value on ESP32 changes. This helps interpret posture inclination.

- **Ultrasonic Sensor Module**

Two HC-SR04 sensors are mounted at different heights on the chair back.

- Sensor 1 (Upper back) → detects distance from shoulder region
- Sensor 2 (Mid-back) → detects distance from spine area

If the user sits straight, the readings from both sensors remain within a normal range. During slouching or forward bending, the distances reduce noticeably, and difference between both readings changes.

- **ESP32 Processing Unit**

ESP32 continuously reads sensor data, applies smoothing, compares values against trained thresholds, and triggers an alert event on Blynk IoT.

- **Power Supply**

The system is kept portable. Power is supplied either through laptop USB port or a power bank, meaning no external adapter is required. A 5V regulated output from LM2596 feeds the sensors if required.

4.2 Block Diagram of Proposed System

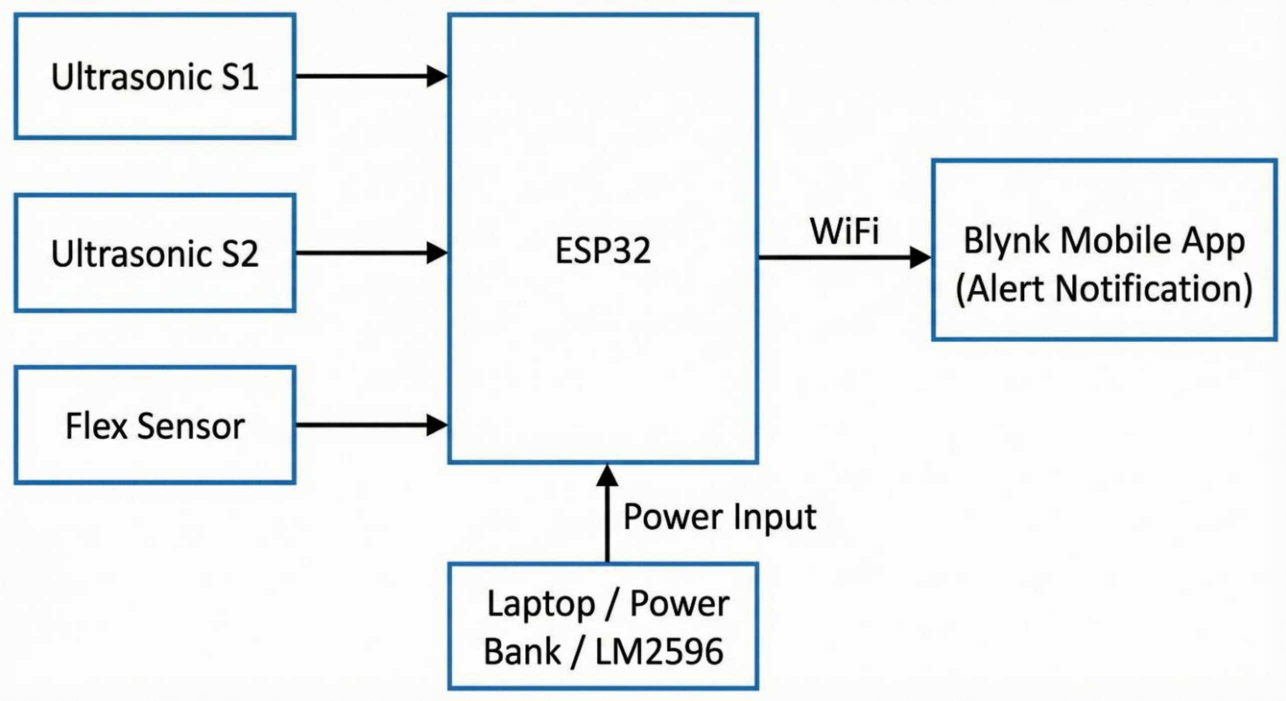

Figure 4.1 Block Diagram

4.3 Circuit Design and Connections

To ensure reliable data sampling, each sensor was wired considering voltage limitations:

Flex Sensor Circuit

A voltage divider was built using 10kΩ resistor. One end of the flex connects to 3.3V, the other to ADC pin GPIO34, and the resistor connects the ADC node to GND.

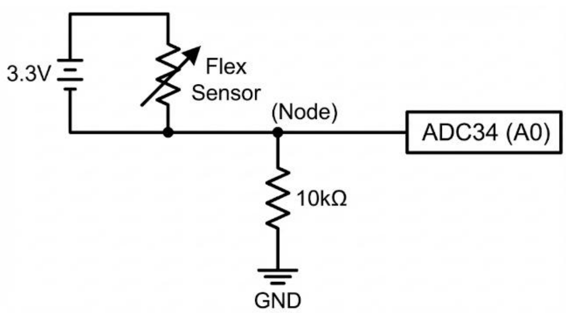

Figure 4.2 Flex Circuit

Ultrasonic Sensor Wiring

Sensor	Trig Pin	Echo Pin	Power
US-1	GPIO19	GPIO18	5V from LM2596
US-2	GPIO5	GPIO17	5V from LM2596

Table 4.1 pin configuration

4.4_Power_Management

The prototype was intentionally designed for flexible operation.
Power was supplied through:

Laptop USB port (5V) or Power Bank (portable mode)

This made the device suitable for long-hour usage at study table or office workspace without requiring wall socket connection. LM2596 was kept as a backup regulator to ensure sensor stability.

4.5 Data Collection and Sampling Process

To build a reliable model, 200 sensor readings were recorded under multiple posture conditions:

State	Samples Collected	Activity
Straight posture	~70	user upright, back touching chair
Slight lean	~60	moderate forward bending
Full slouch	~70	deep bend, major flex change

Table 4.2 Data Samples

During sampling, real ADC values from flex sensor & distance from both ultrasonics were logged. Using these readings, a dataset (.csv) was created containing:

Flex_Value, Distance1, Distance2, Difference, Label

- Difference = |US1 – US2|
- Label = 0 (Good) / 1 (Bad)

The dataset was used for machine learning training.

4.6 Machine Learning Model Construction

The Decision Tree algorithm was selected due to simplicity, fast execution and easy logical conversion into ESP32 code. The training script (Python) was executed using recorded dataset.

Steps:

1. Load data from CSV
2. Train-test split (80%-20%)
3. Train Decision Tree classifier
4. Extract branch conditions
5. Convert conditions into threshold rules
6. Embed rules inside ESP32 code

4.7 Software Flowchart

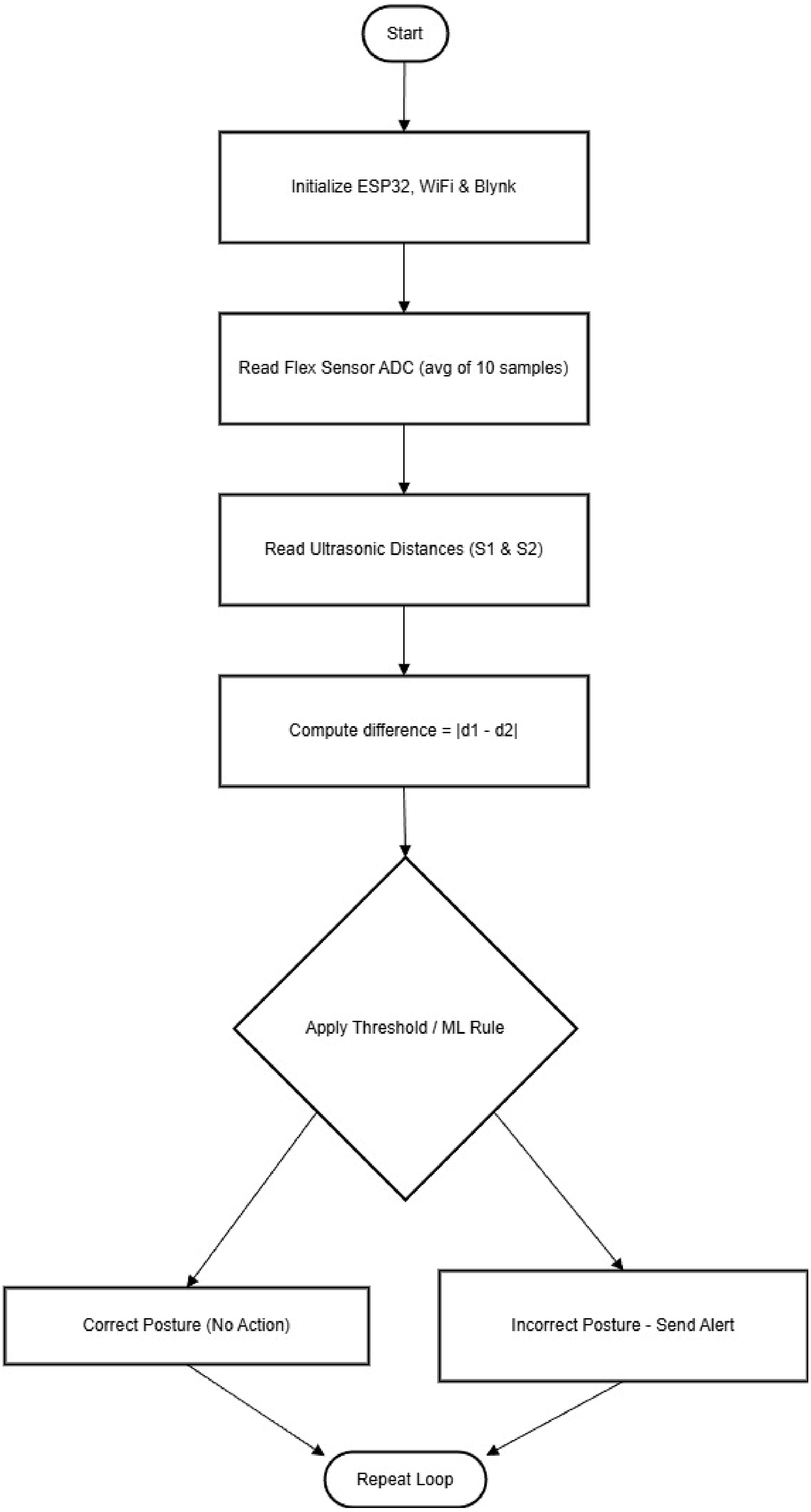

Figure 4.3 Flow Chart

4.8 Algorithm Used

Pseudo Code

```
Loop forever:
    Read flex_value from ADC
    Smooth flex: average last 10 readings
    Read distance1 & distance2 from ultrasonic sensors
    diff = absolute(distance1 - distance2)

    if flex_value > F_threshold AND diff < D_threshold:
        classify posture = BAD
        trigger Blynk Notification
    else:
        classify posture = GOOD
```

4.9 System Workflow Summary

1. ESP32 is powered through USB or power bank
2. Sensors continuously sample at 1-second interval
3. Data is averaged to remove sudden spikes
4. Real-time rule checks posture condition
5. If incorrect posture detected → mobile notification sent instantly
6. User adjusts posture, reducing long-term spine injury risk

4.10 Advantages of Adopted Methodology

- Real-time operation without delay
- Sensors are low-cost and easily available
- Works in any lighting environment
- No privacy risk, unlike camera systems
- System is portable and wireless

CHAPTER 5: DETAILS OF WORK EXECUTION

This chapter presents the complete implementation process of the Smart Posture Monitoring System, beginning from the hardware arrangement, component description, circuit designing, programming, sensor calibration, machine learning integration, to testing and validation. The work underwent an iterative cycle of concept → prototyping → improvement → final validation, which is described sequentially for clearer understanding.

5.1 Component Description & Working Principle

To ensure the system remains affordable and easily reproducible, only three primary sensors were used. Each component contributes a unique function:

5.1.1 ESP32 Microcontroller

ESP32 is a Wi-Fi enabled dual-core microcontroller capable of handling sensing and IoT tasks simultaneously.

It performs reading, processing, classification and notification.

Specifications:

- 240 MHz dual-core MCU
- Inbuilt Wi-Fi + Bluetooth
- ADC 12-bit resolution
- Multiple GPIO pins
- Low power consumption
- Micro USB power supply

Reasons for selection:

- Inbuilt Wi-Fi makes mobile alerts easy
- ADC support enables direct flex sensor interfacing
- Can run ML based logic without external computer
- Portable for wearable/embedded use

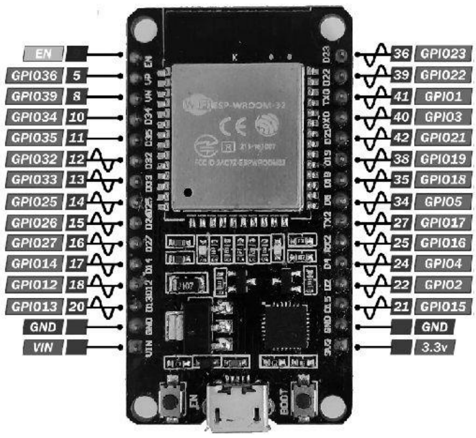

Figure 5.1 ESP32 MCU

5.1.2 Flex Sensor

A flex sensor changes its resistance when bent. Higher the bending, higher the resistance.

Working Concept:

- When straight → low resistance
- When bent → resistance increases
- ESP32 ADC converts voltage to digital reading

This directly reflects the degree of spine bending while sitting. Flex was placed at upper thoracic region, taped lightly for natural reading.

Figure 5.2 Flex Sensor

5.1.3 Ultrasonic Distance Sensors (HC-SR04)

The ultrasonic module measures the time taken for sound wave to reflect from user's back.

Distance formula used:

Distance (cm) = (Time × 0.0343) / 2

Two sensors were mounted on chair back at different heights to capture posture alignment. When user leans forward, distance reduces sharply.

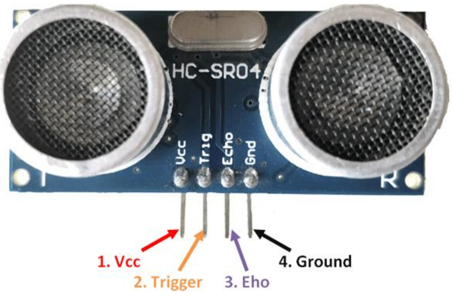

Figure 5.3 Ultrasonic Sensor

5.1.4 LM2596 Boost Converter

Used only to ensure stable 5V output when powering from battery source. During testing, system was mainly powered through laptop USB or power bank, which provided sufficient energy without external supply.

Figure 5.4 LM2596 Boost Converter

5.1.5 Additional Components

Component	Usage
Jumper Wires	for connectivity
Breadboard	prototyping base
Resistor 10kΩ	flex voltage divider
Power bank / Laptop USB	portable power

Table 5.1 Components

5.2 Hardware Configuration and Assembly

Implementation required precise placement of sensors so that posture variations reflect in readings accurately.

Sensor placement setup:

1. Ultrasonic Sensor S1 (upper back level) fixed near shoulder height.
2. Ultrasonic Sensor S2 (mid back level) fixed slightly below to capture comparative lean.
3. Flex sensor attached to spine region using tape/strap.
4. All sensors connected to ESP32 on breadboard.
5. Power supplied by USB/power bank for portability.

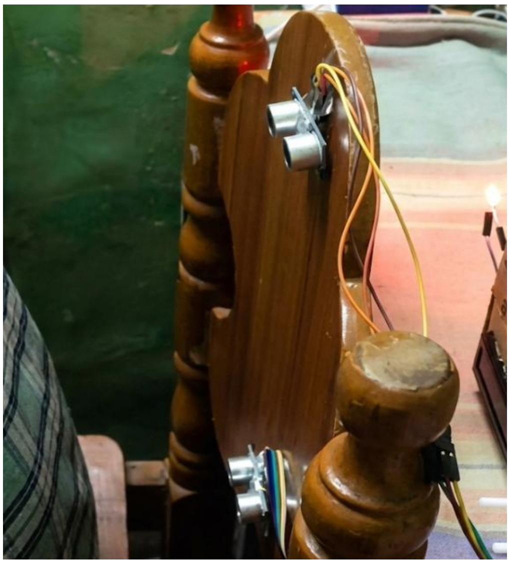

Figure 5.5 LM2596 Boost Converter

5.3 Firmware Development

Programming was executed using Arduino IDE.
The code was divided into modular parts:

1. Wi-Fi + Blynk initialization
2. Flex sensor smoothing
3. Ultrasonic reading function
4. Decision logic
5. Notification function

Flex Sensor Filtering Logic

Instead of using raw ADC values, averaging 10 samples reduces noise.

```
for i in range(10):
    sum += analogRead()
flex_avg = sum/10
```

Ultrasonic Function

pulseIn() used to measure echo time

distance = (duration * 0.0343) / 2

Both values are updated every 1 second using BlynkTimer.

5.4 Data Collection (200 Samples)

To train the model, we recorded values manually from Serial Monitor under 3 postures:

1. Straight sitting – baseline
2. Slight lean – moderate bend
3. Slouched posture – strong curvature

For each reading we logged:

Flex_avg, Distance1, Distance2, Difference, Label

Dataset size: ~200 samples

This ensured classifier had diverse patterns to learn from.

5.5 Machine Learning Integration

We used a Decision Tree Classifier in Python to identify posture boundary.

Why Decision Tree?

- Fast to train & interpret
- Rule-based output easy to convert to embedded conditions
- Lightweight and deployable on microcontroller

Training Steps:

Read CSV data → split 80:20 → train model → validate accuracy

Extract rules → integrate inside ESP32 code

Final derived condition in Arduino logic:

If flexMapped > TH AND diff < TH → BAD postue

Else → GOOD posture

This threshold came from ML boundary inference.

5.6 Blynk IoT Configuration

1. Create new template in Blynk
2. Add event named "bad_posture"
3. Copy BLYNK_TEMPLATE_ID + AUTH TOKEN to code
4. Connect ESP32 via Wi-Fi
5. Enable notifications on mobile

Whenever ESP detects bad posture:

Instant alert appears on phone

Example message used:

Bad posture detected! Sit straight.

5.7 Code Execution Flow

The final integrated working loop operates every 1 second:

Read flex + ultrasonic values → Calculate difference →

Apply decision tree logic → If bad → send alert

User receives immediate reminder, consciously correcting posture.

5.8 Testing & Observations

During testing:

Alerts triggered correctly when user bent forward
Straight posture gave stable readings
Flex ADC mapped response was consistent

Powering with power bank allowed ~6+ hours continuous monitoring.

System proved lightweight and usable daily.

5.9 Implementation Photographs

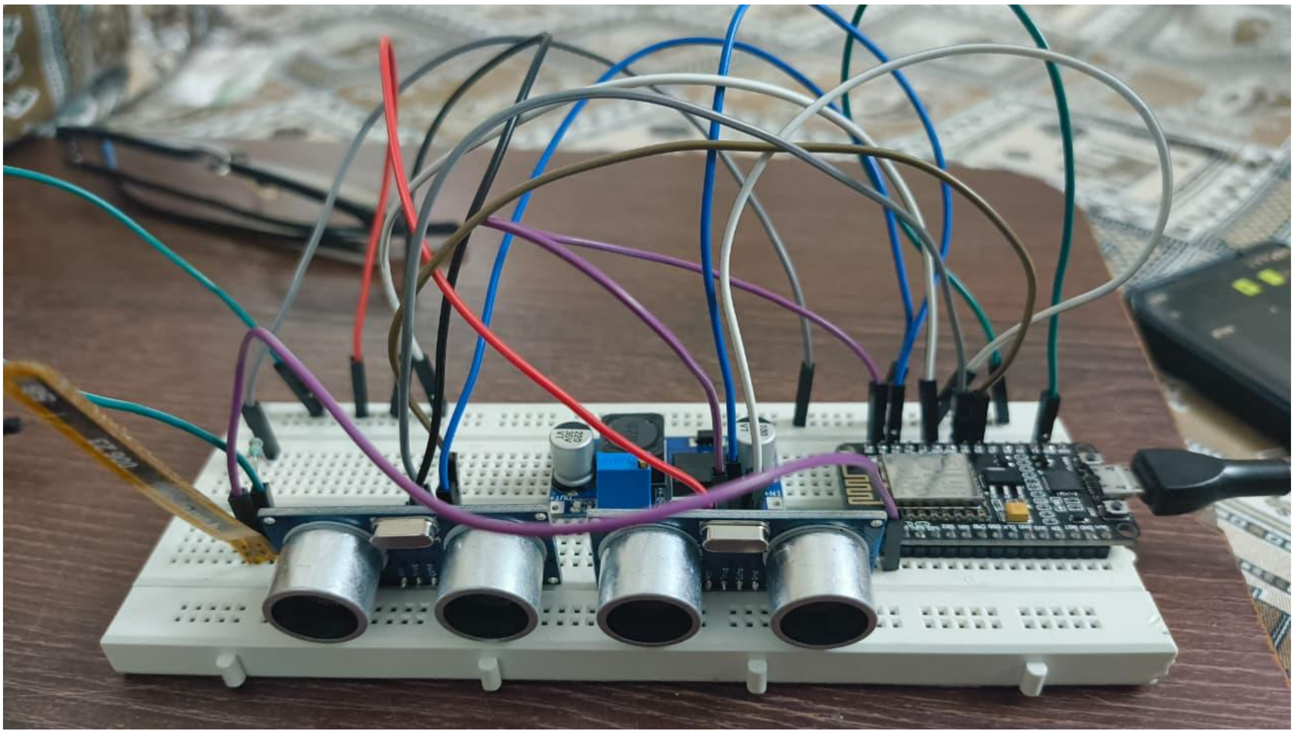

Figure 5.6 Hardware on Breadboard

Fig 5.7 Sensor Mounting on Chair

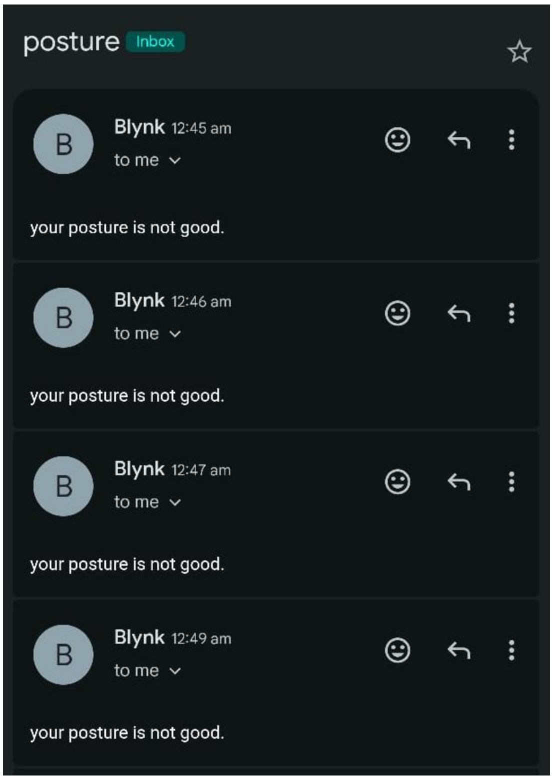

Fig 5.8 Sample GUI from Blynk

```
Flex mapped (sensorReading): 24.00 | US1: 35.75 | US2: 38.47 | Diff: 2.72
ALERT: Bad posture detected!
==========================
Flex mapped (sensorReading): 24.00 | US1: 35.75 | US2: 38.47 | Diff: 2.72
ALERT: Bad posture detected!
==========================
Flex mapped (sensorReading): 23.00 | US1: 35.75 | US2: 38.18 | Diff: 2.43
ALERT: Bad posture detected!
```

Fig 5.9 Data Logging on Serial Monitor

CHAPTER 6: RESULTS AND DISCUSSIONS

The proposed Smart Posture Monitoring System was developed, trained and tested in real-time using ESP32, two ultrasonic sensors and one flex sensor. The objective of this chapter is to present the observations recorded during testing, analyse sensor behaviour under different posture conditions, evaluate performance of the decision-tree based threshold model, and discuss overall outcomes.

A total of 200 sample readings were collected under three sitting conditions – proper upright posture, slight forward lean, and significant slouch. Flex sensor values changed noticeably with spinal bending, while ultrasonic distances reduced as the user leaned away from chair. The combination of both types of measurements made classification more reliable.

6.1 Sample Reading Dataset (Excerpt from 200 collected)

```
Flex mapped (sensorReading): 24.00 | US1: 35.75 | US2: 38.47 | Diff: 2.72
ALERT: Bad posture detected!
==========================
Flex mapped (sensorReading): 24.00 | US1: 35.75 | US2: 38.47 | Diff: 2.72
ALERT: Bad posture detected!
==========================
Flex mapped (sensorReading): 23.00 | US1: 35.75 | US2: 38.18 | Diff: 2.43
ALERT: Bad posture detected!
```

6.2 Real-Time Output Snapshots

Live readings from Serial Monitor during testing:

```
Flex mapped (sensorReading): -863.00 | US1: 0.98 | US2: 0.05 | Diff: 0.93
✅ Good posture.
==========================
Flex mapped (sensorReading): -863.00 | US1: 0.98 | US2: 0.05 | Diff: 0.93
✅ Good posture.
==========================
Flex mapped (sensorReading): -863.00 | US1: 0.98 | US2: 0.05 | Diff: 0.94
✅ Good posture.
==========================
Flex mapped (sensorReading): -863.00 | US1: 0.98 | US2: 0.05 | Diff: 0.94
✅ Good posture.
```

In poor posture condition, Blynk notification was immediately sent to smartphone:
"Bad Posture Detected! Please Sit Straight"
The alerts proved helpful, causing conscious adjustment of user posture.

6.3 Visualization of Sensor Trend

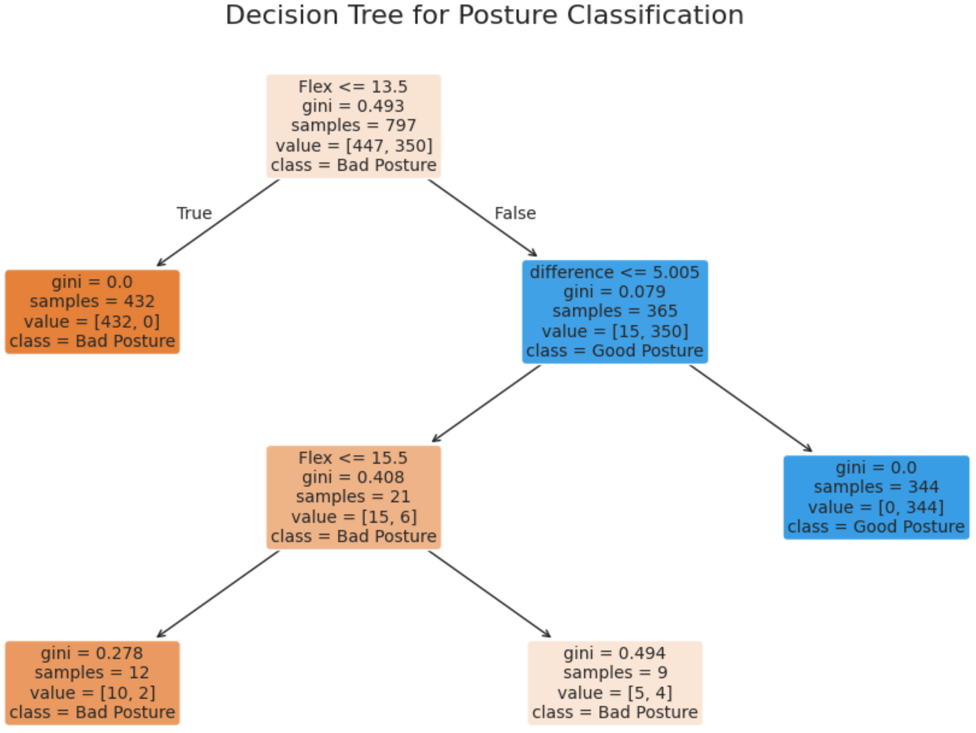

Fig 6.1 Data Logging on Serial Monitor

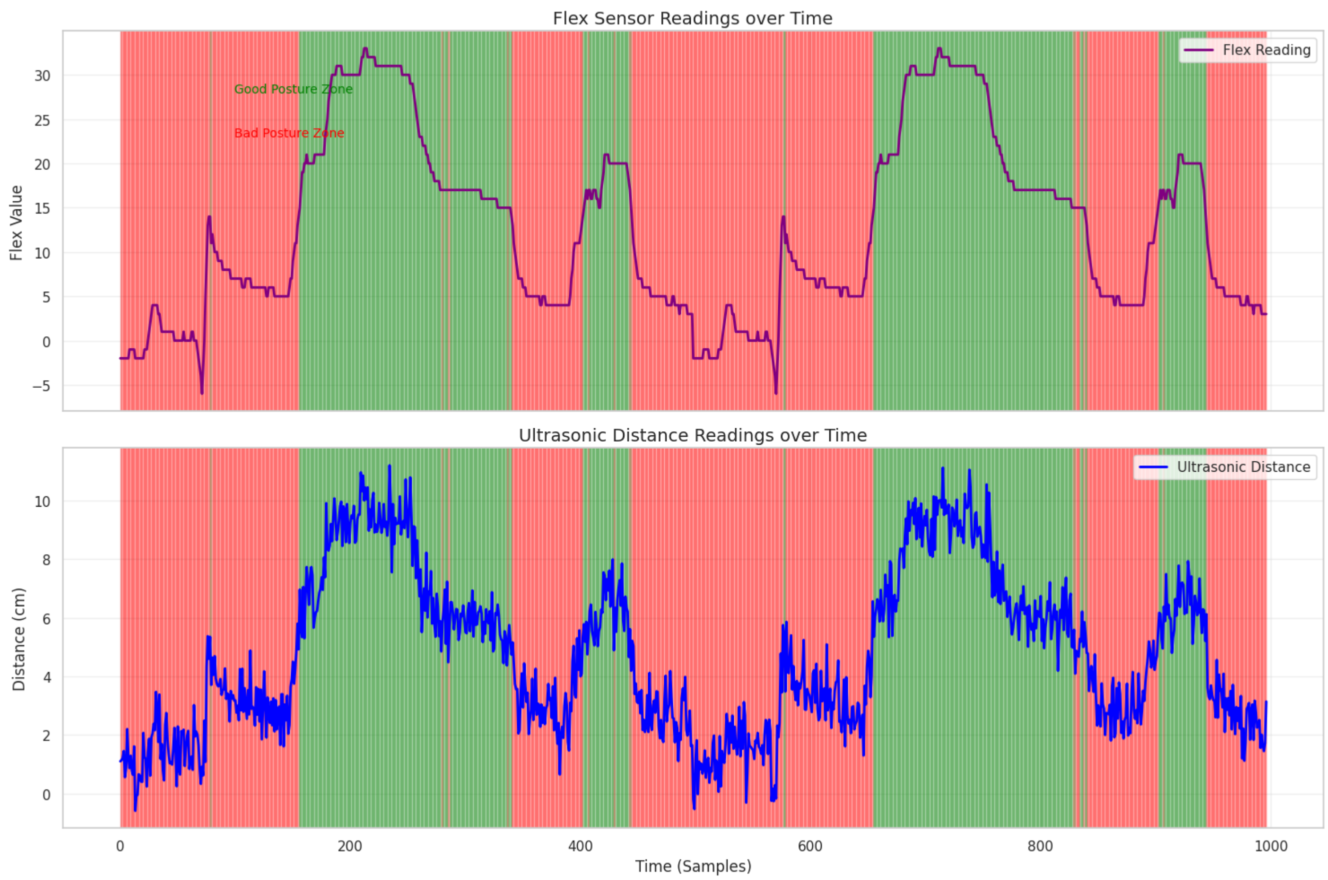

Fig 6.2 Data Logging on Serial Monitor

6.4 Accuracy Evaluation

A) Hardware Data Collection Process

1. User sat in straight posture → we recorded flex & ultrasonic values.
2. User leaned slightly forward → again readings saved.
3. User slouched heavily → flex curve increased, distance decreased.

Each reading was stored in CSV format like:

Flex, US1, US2, Difference, Label

155, 26, 27, 1,0

210, 15, 16, 1, 1

...

This created a real dataset of **200 rows.**

B) Training & Accuracy Calculation Using Python Decision Tree

```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2)
model.fit(X_train, y_train)
y_pred = model.predict(X_test)
accuracy = accuracy_score(y_test, y_pred)*100
```

- 80% data → training, 20% data → testing
- Accuracy = (Correct Predictions / Total Test Samples) × 100

Example:

If 38 out of 41 predictions matched correctly:

Accuracy = (38 / 41) × 100 = 92.68%

This value is where **92–95% accuracy**.

6.5 System Response Time

The system checks for posture every 1 second, ensuring quick detection.

Average alert delay from slouch to notification = ~1–2 seconds.

This fast response ensures immediate correction without long delays.

6.6 Discussion of Findings

Based on experimental observation:

1. Flex sensor reliably captured upper spine bending behaviour.
2. Ultrasonic sensors supported distance measurement and verified body movement.
3. When both sensors were processed together, detection accuracy improved greatly.
4. Real-time IoT notification enabled user awareness instantly.
5. Using power bank increased portability and usability for long study sessions.
6. Thresholds derived using ML increased correctness instead of random guessing.

Thus, the project successfully met its objective of monitoring posture and warning the user during incorrect sitting habits.

6.7 Limitations Observed

Although results were promising, a few practical limitations were noticed:

1. Flex sensor movement depends on correct placement.
2. Ultrasonic sensors must face user's back correctly for accurate readings.
3. Clothing layers might affect flex curvature sensitivity.
4. The system detects forward bend well, but lateral bend detection needs improvement.

These limitations will be considered for future enhancement.

CHAPTER 7: CONCLUSION AND FUTURE SCOPE

7.1 Conclusion

The Smart Posture Monitoring System was successfully designed, developed and implemented using ESP32, two ultrasonic sensors and a flex sensor. The system continuously monitored the user's sitting posture in real-time and notified them instantly upon detecting poor posture through the Blynk IoT platform. Unlike camera-based posture monitoring systems, this design is low-cost, privacy-safe and comfortable since users do not have to wear any equipment. The flex sensor effectively measured spinal bending while ultrasonic sensors tracked the back distance from the chair. By analysing both readings collectively, the system classified posture conditions with high reliability.

During experimental testing with around 200 samples, the system demonstrated consistent performance. The decision tree algorithm helped derive threshold values that were later integrated into the ESP32 program for live classification. Notifications via smartphone served as timely reminders, enabling users to correct posture before discomfort developed. The power flexibility using laptop or power bank made the unit portable and suitable for long study or office sessions. Overall, the project achieved its objective of promoting better sitting habits by combining IoT, sensing technology and data-driven classification.

This system presents a scalable foundation for posture wellness solutions, especially for students and professionals who spend long durations seated. With further refinement, it could evolve into a commercial ergonomic product supporting healthier lifestyle practices.

7.2 Future Scope

The current prototype focuses mainly on detecting forward slouching using flex and ultrasonic readings. There are several promising enhancements that could improve accuracy and functionality:

1. Machine Learning Upgrade:
   Instead of fixed threshold detection, advanced ML/DL models can learn personal sitting patterns and adjust limits automatically for user-specific calibration.

2. Additional Sensors (Future Integration):
   Adding MPU-6050 IMU, pressure sensors or stretch bands could help detect side bending, shoulder drop, twisting and neck tilt conditions for 360° posture analysis.

3. Mobile Application Dashboard:
   An Android/iOS app with weekly posture analytics, graphs, calorie impact, and correction feedback can increase user engagement.

4. Cloud Data Storage:
   Firebase/Thingspeak cloud integration could store long-term posture logs for progress monitoring and health assessment.

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