**POSTURE ANALYSIS SYSTEM WITH ARTIFICIAL INTELLIGENCE-BASED IMAGE PROCESSING AND SENSOR INTEGRATION**

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**A Graduation Project Report**

**Electrical Electronics Engineering Department**

**JUNE 2025**

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**A Report Presented in Partial Fulfilment of the Requirements for the Degree Bachelor of Science in Electrical Electronics Engineering**

**ESKISEHIR OSMANGAZI UNIVERSITY**

**JUNE 2025**

# POSTURE ANALYSIS SYSTEM WITH ARTIFICIAL INTELLIGENCE-BASED IMAGE PROCESSING AND SENSOR INTEGRATION

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# ABSTRACT

Postural disorder refers to the deviation of the spine from its normal alignment due to improper posture or musculoskeletal abnormalities. Nowadays, especially due to modern lifestyle factors such as prolonged sitting, physical inactivity, and excessive use of technology, this problem has become increasingly prevalent. This research proposal aims to develop an innovative device and software system for the detection and correction of postural disorders. The main objective of the project is to analyze users' posture through photos taken from different angles and to determine the severity of postural deviations while providing informative feedback.

The system, supported by artificial intelligence-based image processing techniques, aims to improve users' posture habits by providing real-time feedback. The innovative aspect of the project lies in the combined use of multi-sensor integration and AI algorithms. Various sensors, such as accelerometers, gyroscopes, and flex sensors, will be employed to evaluate posture from multiple angles, alongside the captured images. This approach provides more accurate and reliable results compared to existing postural assessment systems. Additionally, when a postural disorder is detected, the device designed to be lightweight and comfortable will deliver instant feedback to help the user correct their posture.

The research methodology involves users wearing the device over a specific period while having their posture analyzed through AI-powered evaluation of images taken from different perspectives. The device continuously monitors posture in real time and combines this data to perform a comprehensive postural analysis. The project outputs are expected to provide significant benefits in terms of public health through academic and industrial collaboration. If successful, the project will have a meaningful socio-cultural impact, including improvements in education, healthcare, and public awareness.


**Keywords:** posture disorder, artificial intelligence, image processing, sensor integration.

# ÖZET

Duruş (postür) bozukluğu, hatalı duruş veya kas-iskelet yapısındaki bozulmalara bağlı olarak omurganın normal hizasından sapmasıdır. Günümüzde özellikle modern yaşam tarzının getirdiği uzun süre oturma, hareketsizlik ve teknoloji kullanımı bu problemi daha da yaygın hale getirmiştir. Bu araştırma önerisi, duruş bozukluklarının tespitine ve düzeltilmesine yönelik yenilikçi bir cihaz ve yazılım sisteminin geliştirilmesini amaçlamaktadır. Projenin temel hedefi, kullanıcıların postürlerini farklı açılardan çekilen fotoğraflar aracılığıyla analiz ederek, duruş bozukluklarının derecesini belirlemek ve bu bozukluklar hakkında bilgi sağlamaktır.

Yapay zekâ tabanlı görüntü işleme teknikleri ile desteklenen sistem, kullanıcılara gerçek zamanlı geri bildirim sunarak duruş alışkanlıklarını iyileştirmeyi hedefler. Projenin yenilikçi yönü, çoklu sensör entegrasyonu ve yapay zekâ algoritmalarının bir arada kullanılmasıdır. İvmeölçer, jiroskop, ve flex sensörler gibi çeşitli sensörler kullanılarak ve ayrıca çekilen fotoğraflarla duruşun çoklu açılardan değerlendirilmesi sağlanır. Bu sayede, mevcut duruş bozukluğu tespit sistemlerine kıyasla daha doğru ve güvenilir sonuçlar elde edilir. Ayrıca, kullanıcıların duruş bozuklukları tespit edildiğinde, hafif ve konforlu bir tasarıma sahip olan cihaz üzerinden anlık geri bildirim verilerek duruşlarının düzeltilmesine yardımcı olunur.

Araştırmanın yöntemi, kullanıcıların belirli bir süre boyunca cihazı kullanmaları ve farklı açılardan çekilen fotoğrafların yapay zekâ ile analiz edilmesi üzerine kuruludur. Cihaz, kullanıcıların postürlerini gerçek zamanlı olarak takip eder ve bu verileri bir araya getirerek duruş analizi yapar. Projenin çıktıları, akademik ve sanayi iş birlikleri ile toplum sağlığı açısından önemli faydalar sağlayabilir. Eğitim, sağlık alanında iyileştirmeler ve toplumsal bilinç artırma gibi yaygın etkilerle birlikte, projenin başarılı olması durumunda önemli bir sosyal-kültürel etkisi olacaktır.

**Anahtar Kelimeler:** duruş bozukluğu, yapay zekâ, görüntü işleme, sensör entegrasyonu.

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# LIST OF SYMBOLS AND ABBREVIATIONS

| **Symbol** | **Explanation** |
|---|---|
| π: | pi number. |

| **Abbreviation** | **Explanation** |
|---|---|
| EEE: | Electrical and Electronics Engineering. |
| I2C: | Inter-Integrated Circuit. |
| VCC: | Voltage Common Collector. |
| IDE: | Integrated development environment. |
| DC: | Direct Current |

## 1. INTRODUCTION

Posture refers to the alignment of the musculoskeletal system according to different movement and sitting positions. In particular, the arms, legs, and lower back are key areas that actively work to maintain proper musculoskeletal alignmen [1]. Postural disorders may arise due to factors such as standing with a curved spine, prolonged slouching while working at a desk, sleeping in incorrect positions, genetic predispositions, or developmental issues during the prenatal period [2]. These disorders, which affect specific parts of the body, tend to progress over time and cause pain. Such conditions significantly reduce the quality of life and may lead to more serious health problems. Figure 1 illustrates examples of commonly observed postural disorders.


*Figure 1: Normal and Incorrect Postures [3]*

**Lordosis** refers to the inward curvature of the cervical (neck) and lumbar (lower back) regions of the spine. It causes the cervical and lumbar vertebrae to curve forward, resulting in a prominent arch in these areas. A curvature of 30 to 40 degrees in the cervical spine and 40 to 60 degrees in the lumbar spine is considered normal. When the inward curve in the lumbar (lower back) or cervical (neck) regions becomes exaggerated, the lower back appears more hollow than usual, and the pelvis seems to tilt forward. Factors contributing to lordosis may include pregnancy, obesity, weak abdominal muscles, or prolonged standing [4].

**Kyphosis** is a condition in which the spine curves forward abnormally. While the thoracic (upper back) region typically has a natural outward curve (kyphotic) and the lumbar region has an inward curve (lordotic), kyphosis is diagnosed when the upper back's curvature exceeds 50–60 degrees or the lumbar curve flattens below 15 degrees. This condition causes the shoulders to slump forward and gives the back a rounded appearance. Long hours spent leaning over a desk, poor sitting posture, carrying heavy backpacks, or weak back muscles are common causes of kyphosis [5].

**Flat Back** is a postural disorder generally observed in tall and underweight individuals. In this condition, the head and neck lean slightly forward, the upper back is mildly curved outward, and the lower back appears flatter than normal [6].

**Sway Back** describes poor posture where the pelvis tilts forward, and the spine has an exaggerated curve. This makes the person appear to be leaning backward while standing [7].

**Scoliosis** is a postural disorder in which the spine curves laterally to the right or left by 10 degrees or more, resulting in an S or C shaped appearance on an X-ray. Mild scoliosis usually causes no major issues, but severe cases can affect breathing and mobility. The severity is measured in degrees. The top and bottom vertebrae of the curve are identified, and lines are drawn parallel to their endplates. Perpendicular lines are then drawn from these, and the angle between them, known as the Cobb Angle (as shown in Figure 2), indicates the degree of scoliosis [8].

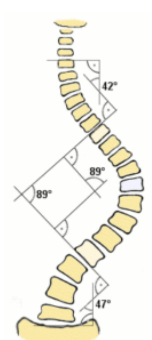



*Figure 2: Cobb Angle [8]*

Problems caused by postural disorders are rooted in the misalignment of muscles, bones, and joints, which leads to unnecessary strain on these structures. This results in tension in the muscles and stress on the joints, causing pain in areas such as the back, neck, shoulders, waist, and hips. Muscle tightness in the neck and upper back, which often accompanies postural disorders, can lead to nerve compression, resulting in chronic headaches, migraine attacks, and persistent tension in the neck throughout the day. Postural disorders like kyphosis can also seriously affect various bodily systems. They may lead to breathing difficulties, shortness of breath, fatigue, poor blood circulation, and issues such as varicose veins. Incorrect posture increases the body's energy consumption, which can cause fatigue, weakness, and a constant sense of tiredness during daily activities.

Postural disorders not only affect physical health but also have negative impacts on emotional and mental well-being. Poor posture may lead to a lack of self-confidence and negatively influence body language. In addition, chronic pain and discomfort may result in depression and mental fatigue. Although postural disorders may initially seem minor, they can develop into serious health issues ranging from muscle and joint pain to respiratory problems. Early intervention and the development of correct posture habits are critically important for preventing these conditions and maintaining overall health [9].

The accurate diagnosis of postural disorders is crucial for determining the most appropriate treatment method. Various approaches are used to identify these disorders, including digital, clinical, and manual methods. One of the most common and straightforward techniques is **observation and manual assessment**, where posture is evaluated by a physiotherapist, orthopedist, or posture specialist through visual inspection and physical examination. These experts assess the head and neck position, spinal curvature, and shoulder alignment to diagnose the specific type of postural disorder. While this method is fast and practical, it has a high margin of error.

In addition, specialized measurements and tests may be employed to diagnose postural issues. A person's posture, spinal curvature, and body weight distribution are meticulously assessed in these tests. Advanced tools and computer-assisted analyses can be used to obtain a more detailed understanding of the condition. Imaging techniques such as **X-ray**, **Magnetic Resonance Imaging (MRI)**, and **Computed Tomography (CT)** are commonly used by physicians to examine spinal structure in detail. These methods help determine the cause of the disorder and guide treatment planning. However, despite their detailed results, they can be costly and involve radiation exposure, posing potential risks to the human body.

Alternative methods such as **goniometry** and **photogrammetry** are also available. In goniometry, the angles of various joints are measured using a goniometer to identify the type of postural disorder based on angular values. However, this method may yield inconsistent results in certain measurements. In **photogrammetry**, photographs of the subject are taken and uploaded into computer software, which then calculates postural angles in Figure 3. Horizontal and/or vertical lines are drawn to indicate the angles between key points. Compared to other methods, photogrammetry is more cost-effective and reliable [10]. Therefore, the proposed project benefits from a method similar to photogrammetry.

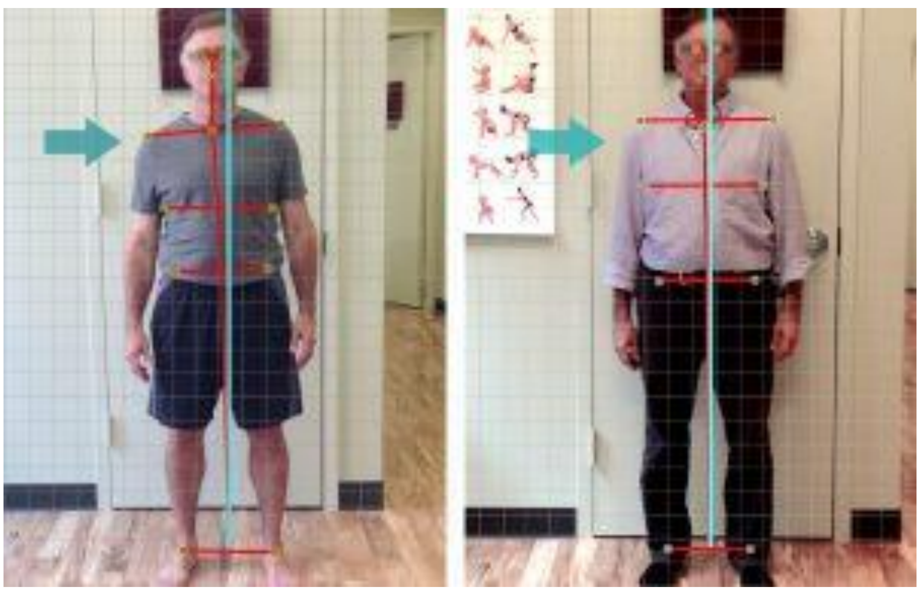


*Figure 3: Determining posture disorder using photogrammetry [11]*

The methods mentioned above are commonly used in clinical settings, hospitals, and similar environments. In addition to these, several projects have been developed to support the detection of postural disorders. For example:

A **wearable posture tracker** was designed as a posture correction strap incorporating a stretch sensor and an accelerometer in Figure 4. The accelerometer was attached at the xiphoid process position on the body to monitor changes in posture while the subjects were sitting in poor positions such as slouching, leaning backward, or being unbalanced to the left or right. This position is illustrated in the figure below. These postures were identified based on the tilt angle measured by the accelerometer. A stretch sensor was placed on the upper back of the subjects to detect shoulder rounding. The capacitance of the stretch sensor changed linearly depending on the shoulder movement [12].

However, this project had usability issues. It could cause discomfort during prolonged use, and while the user was walking, sitting, or bending, the device occasionally produced false alerts related to postural disorders.

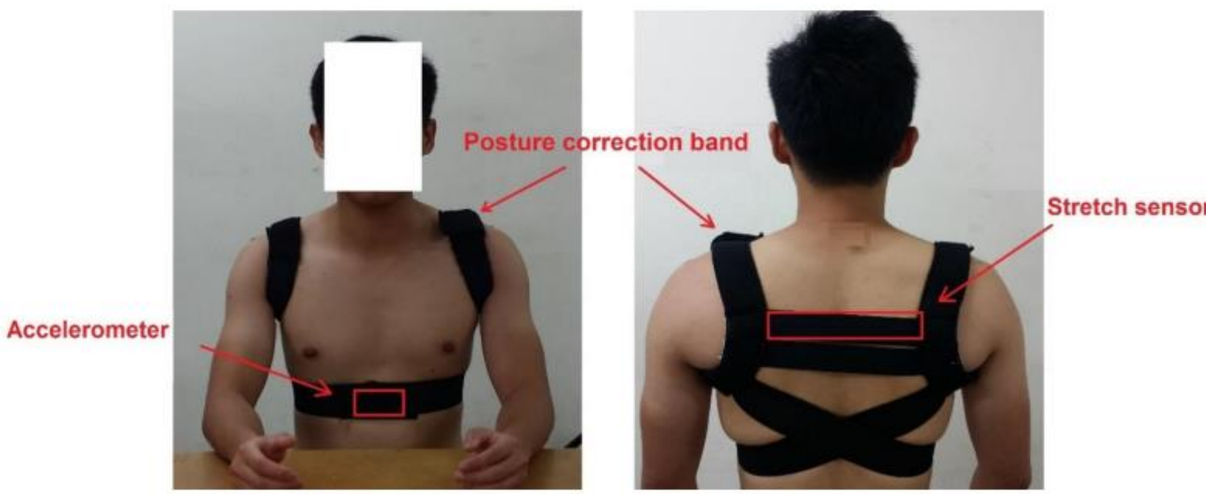
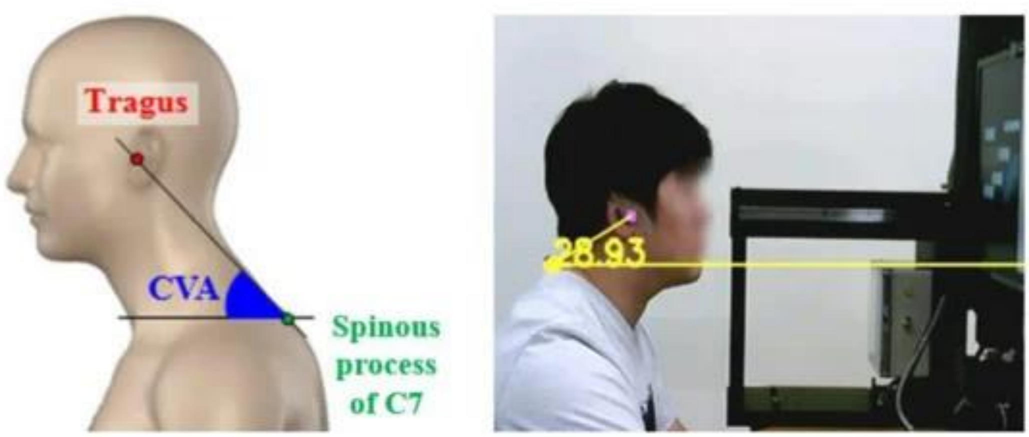



*Figure 4: Wearable posture tracker [12]*

The **PostureScreen Mobile** application can be used to evaluate a person's posture and alignment. It is especially preferred by fitness professionals and physiotherapists. The main purpose of the application is to detect users' postural disorders, provide corrective recommendations, and track their progress over time. By performing both 2D and 3D photo analysis, it delivers detailed results. These analysis results are presented to the patient in comprehensive reports, including information about body alignment and how to correct postural abnormalities [13]. Therefore, this project was developed not for the purpose of diagnosing a condition, but rather for assisting in its treatment.

In the study titled **“Comparison of Neck Posture and Fatigue According to Monitor Types (Adjustable and Fixed Monitors) Using Flexion Relaxation Phenomenon (FRP) and Craniovertebral Angle (CVA)”**, the effects of adjustable monitors on fatigue and neck posture were investigated. The study showed that the use of adjustable monitors resulted in less fatigue compared to fixed monitors. CVA analysis revealed that the frequency of **Forward Head Posture (FHP)**, which negatively affects neck alignment, was lower with adjustable monitors than with fixed ones.

Moreover, the posture-correcting effect of adjustable monitors was found to be more significant in the low FRR (Flexion Relaxation Ratio) group. As a result, it was concluded that adjustable monitors may lead to reduced neck fatigue and improved neck posture compared to fixed monitors in Figure 5 [14].




(a) (b)

*Figure 5: (a) Craniovertebral angle; (b) Open source computer vision [14]*

In the study **“Vertebra-Focused Landmark Detection for Scoliosis Assessment”**, Cobb angles are determined based on the positions of key landmarks in Figure 6. The X-ray images used in the study include 17 vertebrae from the thoracic and lumbar spine. Each vertebra contains four corner landmarks (top-left, top-right, bottom-left, and bottom-right), resulting in a total of 68 landmarks per image. The relative order of these landmarks is crucial for accurately locating the tilted vertebrae.

However, considering that the model cannot guarantee the predicted landmarks will remain in the correct positions—especially in the presence of false positives—directly extracting all 68 landmarks from the output feature map is not feasible. To address this issue, the landmarks are divided into several groups, and an output feature map with **17 × 4 = 68 channels** is generated. Nevertheless, this approach suffers from a class imbalance between positive and negative points, as each channel of the output feature map contains only one positive point. This imbalance negatively affects the model's overall performance [15].

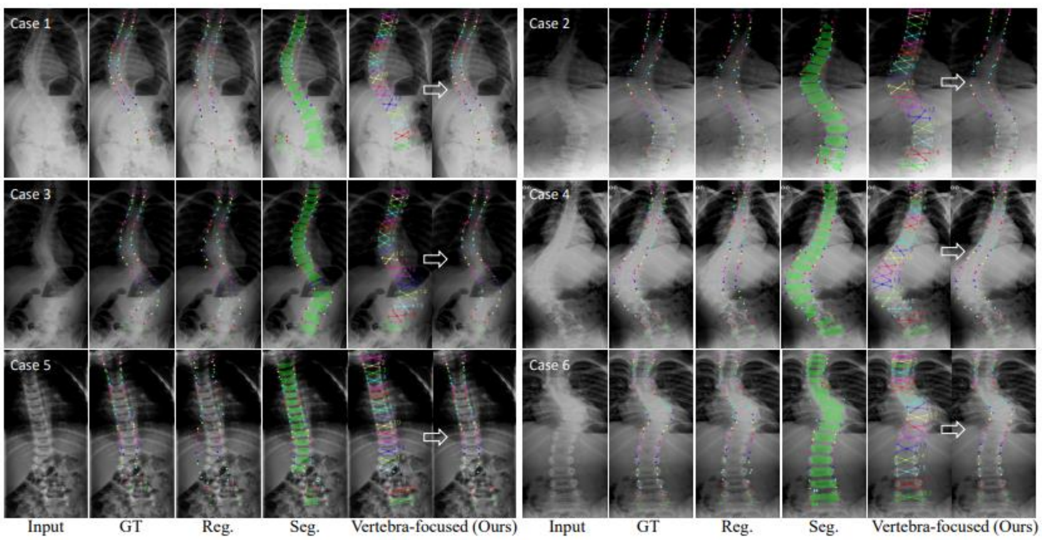



*Figure 6: Qualitative results of landmark detection [15]*

## 2. REQUIREMENTS SPECIFICATION

- **Physical Requirements**

  The total weight of the device must be under 600 grams

  The device should be lightweight enough not to be perceived by the user and should not cause any discomfort during use.

  The device worn by the user should be designed to ensure comfort and should not interfere with daily activities

- **Performance and Functionality Requirements**

  The system should ensure 100% accuracy in detecting a human figure whenever the user captures a photo.

  The system shall prompt the user to take photos from four specified angles (front, right side, left side, and back) and verify that each image contains at least 90% of the user's body.

  The analysis phase of the system must not exceed 1 minute.

  The sensors of the device must be properly calibrated.

- **Economic Requirements**

  The total cost of the project cannot exceed $250 per unit.

- **Environmental Requirements**

  There must be no other people in the background when the photo is taken.

  The wearable device must have a protective design to withstand environmental factors such as rain, humidity, and dust.

- **Health and Safety Requirements**

  The design of the wearable device should ensure that conductive wires do not come into direct contact with the skin to avoid discomfort or safety risks.

  The wearable device should not use high voltage. 3.3V DC voltage is safe for the human body.

- **Manufacturability and Maintainability Requirements**

  The system's components can be easily found on the market.

  In case of a system malfunction, the components should be easily replaceable.

## 3. STANDARDS

- **ISO/IEC 29182 – Sensor Network Reference Architecture (SNRA):**

The sensor network structure used in this project complies with the principles defined in this reference architecture for data collection and transmission.

- **IEEE 802.11 – Wireless Communication Standard:**
  The ESP32's wireless connectivity was established based on this standard, providing a stable and secure data transmission infrastructure.

- **ISO 9241-210 – Ergonomics of Human-System Interaction:**
  The user interaction design of the warning system (vibration, buzzer, etc.) was developed in accordance with user-centered design principles outlined in this standard.

- **ISO/IEC 60559 – Floating-Point Arithmetic:**
  The processing of MPU6050 sensor data, including angle calculations, adheres to this standard for consistent and precise floating-point operations.

- **IEEE 754 – Standard for Floating-Point Arithmetic:** The mathematical handling of sensor data and Euler angle computations is based on the precision and representation rules defined in this standard.

## 4. PATENTS

- A wearable device designed to identify risky or incorrect postures and prompt corrective actions., Patent No: US20050237209A1
- Detects user's sitting posture using pressure sensors embedded in furniture and gives visual feedback., Patent No: US20170020438A1
- A pressure-sensitive pad that triggers alerts when bad posture is detected due to weight shifts. Patent No: WO2001026506A2
- Involves multiple sensor modules placed on the body to measure orientation and provide corrective feedback. Patent No: US20150065919A1

# 5. THEORETICAL BACKGROUND

Ideal posture is defined as the proper alignment of the spine according to the anatomical plane of the body. However, due to various reasons (such as prolonged sitting, poor ergonomic habits, and muscle imbalances), this alignment can be disrupted. In such cases, body segments (head, neck, back, lower back) deviate from their optimal angles, leading to postural disorders. Fundamentally, a postural disorder can be described as the angular deviation of body parts with respect to specific axes. For instance, forward bending of the back (kyphosis), excessive inward curvature of the lower back (hyperlordosis), or lateral curvature of the spine (scoliosis) are all examples of such deviations.

In this project, the MPU6050 sensor is used to detect these angular deviations. The MPU6050 is an Inertial Measurement Unit (IMU) sensor that combines a 3-axis accelerometer and a 3-axis gyroscope. The accelerometer measures the orientation of the sensor relative to gravity (used to determine tilt angles), while the gyroscope measures angular velocity (used to track directional changes over time). The data from these two sources together enable continuous tracking of the body's position in space.

Using the sensor data, the posture of the body is represented in terms of Euler angles, which are three fundamental parameters used to describe the orientation of an object in 3D space:

- **Pitch**: forward or backward tilt (e.g., hunching of the back)
- **Roll**: sideways tilt (e.g., one shoulder lower than the other)
- **Yaw**: rotation around the vertical axis (usually less relevant for posture analysis)

In angle calculations, **accelerometer data** is typically used to estimate **pitch** and **roll** in real time, while **gyroscope data** tracks how these angles change over time. The angles are shown in Figure 7.

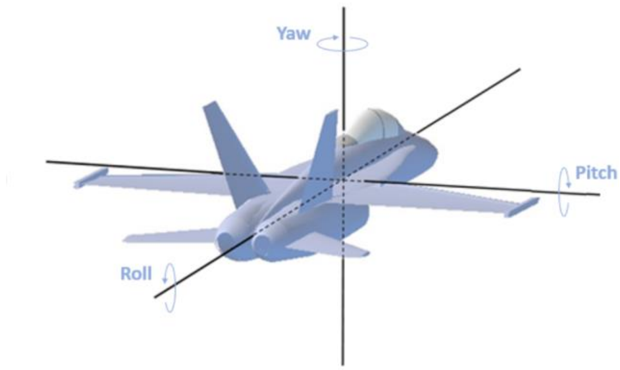



*Figure 7: Representation of Yaw, Pitch and Roll movements on an aircraft model [16]*

In practice, Euler angles obtained from MPU6050 sensors placed at various points on the body can be analyzed in real time to determine whether the user's posture is correct. For example, if the pitch angle in the back region consistently exceeds 20 degrees, it indicates that the person is remaining in a hunched position for an extended period (indicating poor posture). Through such angular analysis, posture disorders can be detected early and preventive feedback can be provided.

In conclusion, this project relies on angular data to detect postural disorders, and the **MPU6050 sensor** is used for the computation of these angles. Sensor data is analyzed and Euler angles are calculated to evaluate the user's posture. Eular angles are shown in Figure 8.

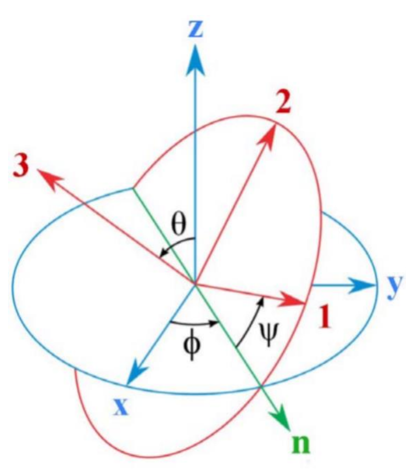



*Figure 8: Eular angles [17]*

$$\phi = arctan2(2(wx + yz), 1 - 2(x^2 + y^2)) \quad (1)$$

$$\theta = arcsin(2(wy - zx)) \quad (2)$$

$$\psi = arctan2(2(wz + xy), 1 - 2(y^2 + z^2)) \quad (3)$$

Sensor-based solutions alone may not be sufficient for accurately detecting posture disorders. Therefore, in this project, in addition to MPU6050 sensors, image processing techniques were also utilized. A mobile application was developed in which real-time posture analysis is performed using the device's camera, leveraging the **Pose Detection** feature of **Google ML Kit**.

Google ML Kit is a machine learning library that runs on both Android and iOS devices. It includes a built-in pose detection model capable of identifying key human body landmarks (such as the head, shoulders, elbows, hips, knees, etc.) and constructing a skeletal representation of the body. This enables the user's posture to be digitally modeled and allows the calculation of angles between joint points. Figure 9 shows the 33 points used for pose detection.

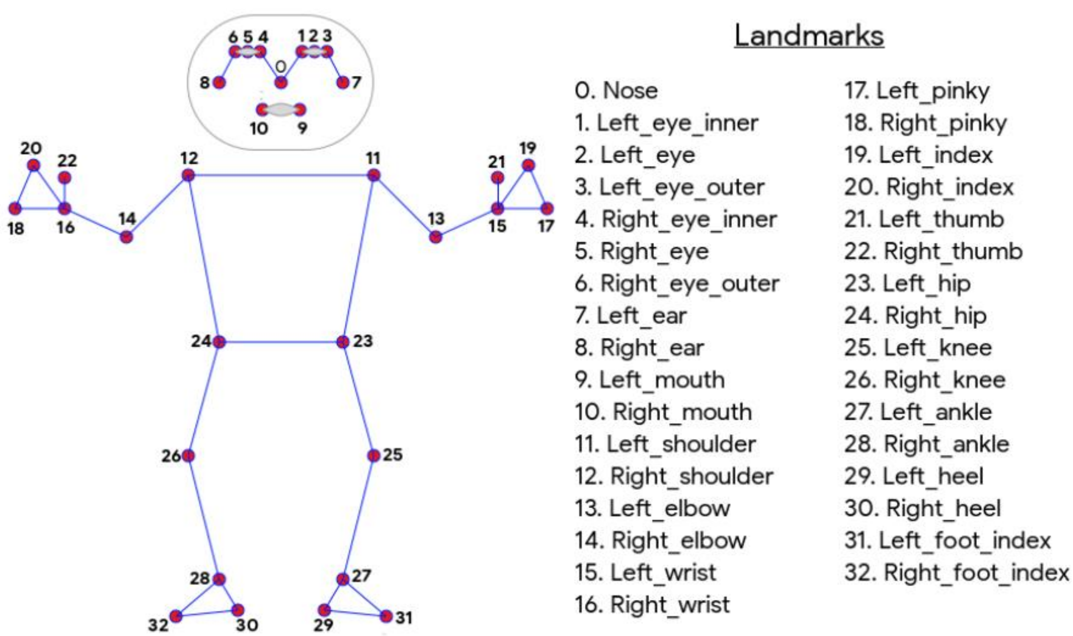



*Figure 9: 33 points used for posture analysis [18]*

Within the scope of the project, the data obtained from the camera feed was used to evaluate parameters such as:

- Forward or lateral tilt of the head,
- Shoulder alignment,
- Spinal straightness (postural uprightness),

and determine whether the user maintains an ideal posture. The pose data extracted from the image is compared against a predefined reference model to detect potential posture disorders.

One of the key advantages of this method is that it does not require any physical sensor connections; analysis can be performed solely with the mobile device's camera. Additionally, since Google ML Kit operates on-device, real-time and fast analysis can be carried out without the need for an internet connection. Pose Detection Example with Google ML Kit is shown in Figure 10.

*Figure 10: Pose Detection Example with Google ML Kit*

# 6. METHODOLOGY

In this project, an integrated system consisting of both hardware and software components has been developed to detect individuals' postural disorders and raise user awareness on the issue. The system is designed to perform posture analysis using sensor data collected from the user and provide feedback when certain threshold values are exceeded. Within the scope of the project, hardware components that enable real-time tracking of body movements work in coordination with a mobile application responsible for image processing and user interaction.

This methodology section will provide a detailed explanation of the development process, including the methods followed, the hardware and software components used, and the integration of these components.

## 6.1 System Hardware

The core control unit of the project is the ESP-WROOM-32 microcontroller board. Developed by Espressif Systems, this board is widely used in IoT-based projects due to its dual-core processor, high-frequency operation capability, a large number of I/O pins, and built-in Wi-Fi and Bluetooth modules.

One of the main reasons for selecting the ESP32 in this project is its ability to process sensor data quickly and reliably, while also supporting Wi-Fi communication with the mobile application. This eliminates the need for an additional wireless communication module (such as the HC-05), allowing both sensor control and data transfer to the mobile application to be handled by a single board. Additionally, its low power consumption makes it highly suitable for wearable and portable technology applications.

In addition to these features, the ESP32 offers support for multiple digital and analog pins, allowing several sensors and output components to be connected simultaneously. In this project, two MPU6050 sensors, one flex sensor, a vibration motor, and a buzzer are connected to the ESP32 via these pins. The sensors communicate over the I2C protocol and are connected to GPIO21 (SDA) and GPIO22 (SCL) of the ESP32. The flex sensor, being analog, is read through GPIO34, while the vibration motor and buzzer are controlled as digital output via GPIO23. Figure 11 below also shows the pin connections of the components to the ESP32 board schematically.

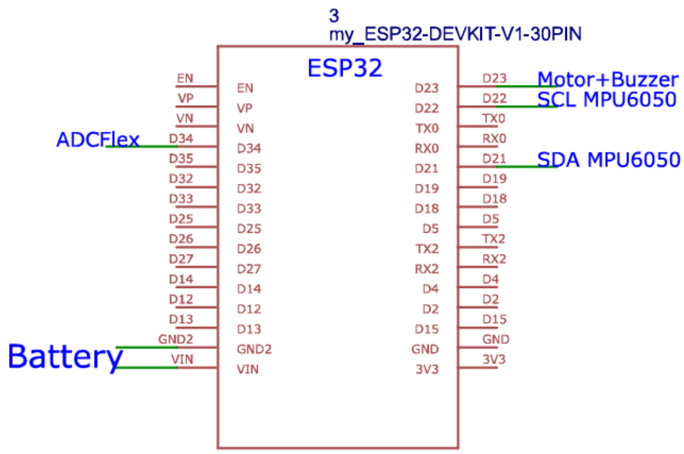



*Figure 11: ESP-WROOM-32 Pin Connection Diagram*

### 6.1.1 Angle Measurement with MPU6050 Sensors

The primary data source for detecting posture disorders is provided by MPU6050 accelerometer and gyroscope modules. The MPU6050 contains a 3-axis accelerometer and a 3-axis gyroscope, enabling it to perform six degrees of freedom motion tracking. Through these sensors, the positions of various body segments at different angles can be identified and changes in posture over time can be monitored.

Two MPU6050 sensors are used in this project. One is placed in the back region, and the other near the back region/right shoulder. This configuration allows for independent tracking of the upper body and head positions, resulting in more precise posture analysis.

Both sensors communicate with the ESP32 via the I2C protocol. Since each device on the I2C bus must have a unique address, the default address conflict is resolved by setting one sensor to the default address 0x68, and altering the second sensor's address to 0x69 by pulling its AD0 pin to 3.3V. This enables both sensors to operate simultaneously on the same I2C bus without interference. The connection diagram of the MPU6050 sensors is given in Figure 12.

Using acceleration and gyroscope data from the sensors, Euler angles are computed to assess potential posture issues such as forward leaning, lateral tilting, or spinal curvature. These are then analyzed based on predefined threshold values.

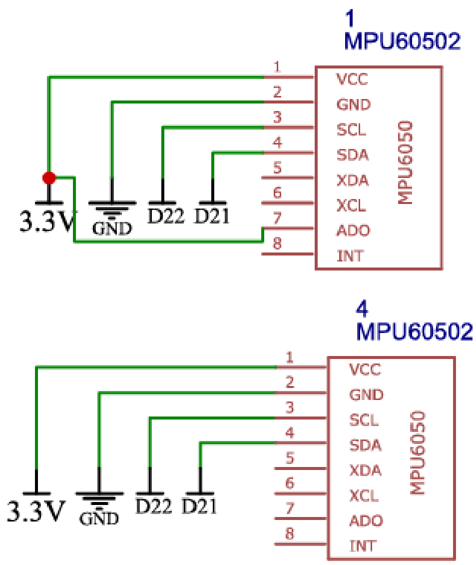



*Figure 12: The connection diagram of the MPU6050*

### 6.1.2 Posture Bending Detection with Flex Sensor

A flex sensor is also included in the system, placed specifically on the back to detect forward bending or hunching behavior. The flex sensor is an analog sensor that changes its resistance based on the degree of bending. These resistance values are read via the ESP32 to estimate the bending angle of the spine.

The data obtained from the flex sensor is analyzed together with the angular data from the MPU6050 sensors, enhancing the accuracy and reliability of the overall system. This multi-sensor approach helps reduce false positives/negatives and increases system robustness. The circuit diagram of the flex sensor is given in Figure 13.

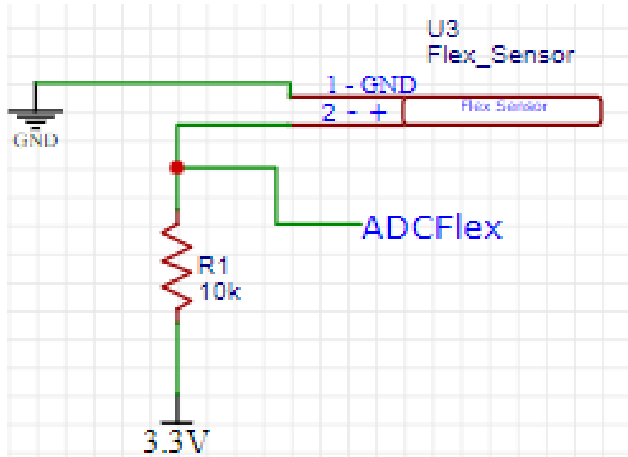



*Figure 13: The circuit diagram of the flex sensor*

### 6.1.3 Alert Mechanism: Vibration Motor and Buzzer

One of the most crucial features of the system is its ability to provide real-time feedback to the user. To achieve this, a vibration motor and a buzzer are used in Figure 14. These components deliver alerts through different modalities: the vibration motor provides tactile feedback, while the buzzer emits an audible alert. When the system detects that the body angle has exceeded a predefined threshold based on data received from the sensors a potential posture problem is identified. However, to avoid false alerts caused by temporary movements, the system checks whether this incorrect posture is maintained for at least 10 seconds. If the user continues to hold the incorrect posture beyond this duration, both the vibration motor is activated and the buzzer is triggered to notify the user. This feature ensures that the system provides effective feedback against both short-term and persistent posture irregularities.

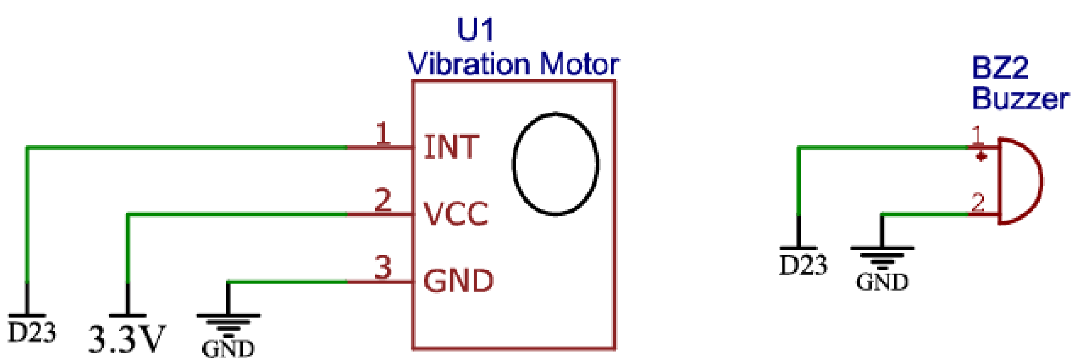



*Figure 14: Vibration motor and buzzer*

### 6.2 Software

In this project, it is aimed to design an application that everyone can easily use, unlike previous projects, by using artificial intelligence algorithms. With this application, it is aimed to detect posture disorders with the help of the Google ML Kit model of human body images taken from different angles.

Google MLKit is available for both Android and iOS platforms, MLKit provides pre-trained on-device models with low latency and without the need for an internet connection. They can easily incorporate custom models trained with TensorFlow Lite or AutoML Vision into the MLKit framework. With this structure, MLKit makes common AI functions that require speed and scale ready for use in mobile projects with minimal integration cost [19]. The ML kit points and sample usage are given in Figure 15.

*Figure 15: Detection of human joint positions using the ML kit model [20]*

### 6.2.1 Mobile Application

When the user starts the mobile application, 3 different buttons appear; the first of these is the section where we take photos and perform posture analysis, the second is the section where the analysis data is recorded, and the last button is the section where the daily feedback of the data received from the designed wearable device is given to the user, as seen in Figure 9. When the analysis button is pressed, the date of that day is entered and the user continues; then, when the take photo button is pressed in Figure 16, photos are taken from 4 different angles.

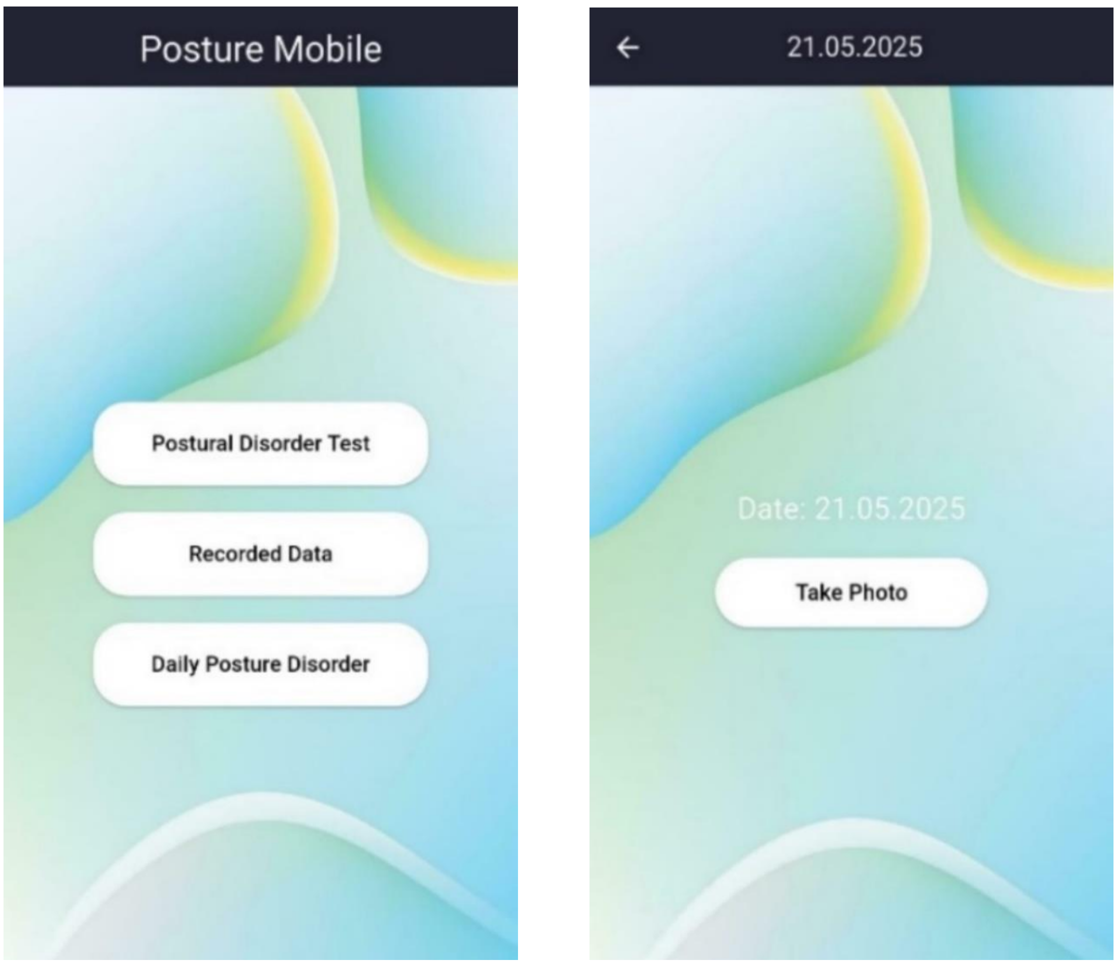



*Figure 16: Application home page - Analysis page*

First front, then from the right, left and back angles, as seen in Figure 11. When the text All photos was taken successfully appears on the screen, the continue button is clicked and 4 different buttons appear on the previous screen in Figure 17; these buttons are the saved photos button where the photos are recorded, the photo analysis button where the posture disorder analysis is performed from the photos, the device analysis button where the analysis is performed with the data received from the sensors, and finally, return to the home page button.

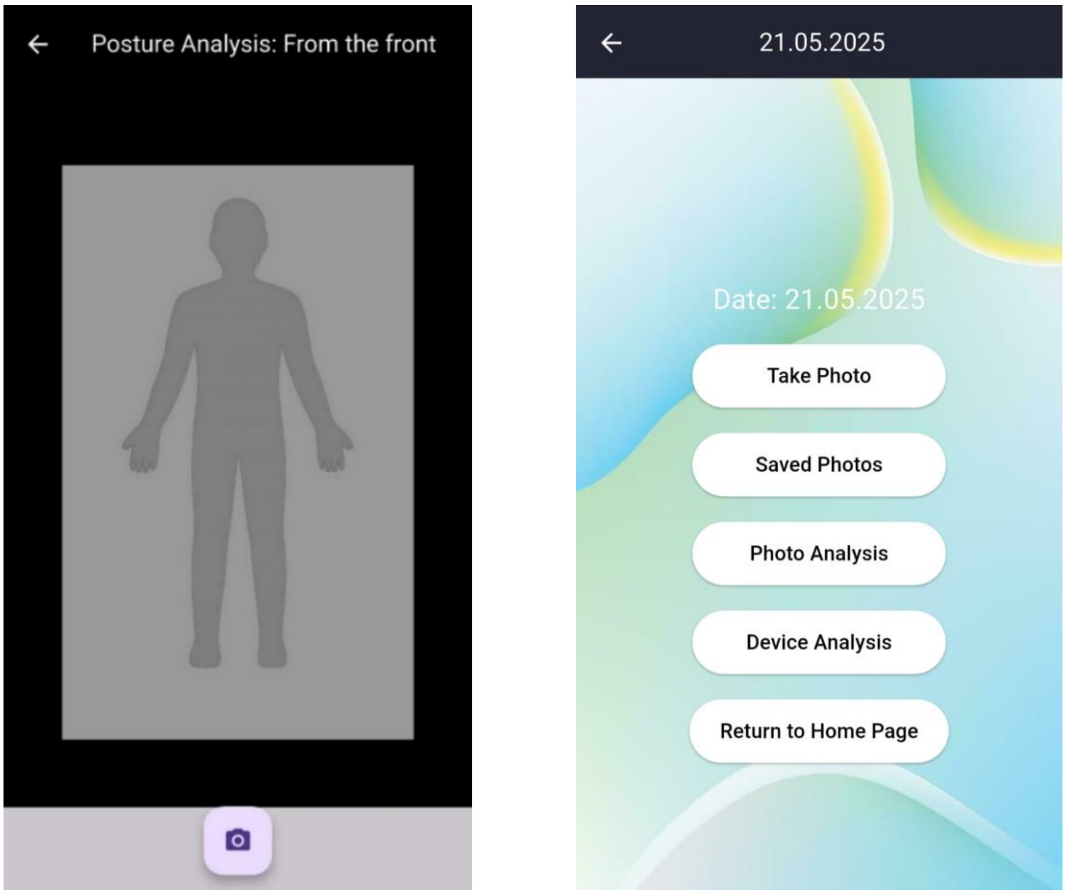



*Figure 17: Photo taking screen - Analysis result  screen*

When the photo analysis button is pressed, the Ml kit model draws the body turning points we determined in the photos taken and shows them in the photos. Various calculations are made using these points and a separate posture disorder analysis is performed for each photo and the analysis results are reflected on the screen under each photo as seen in Figure 18.

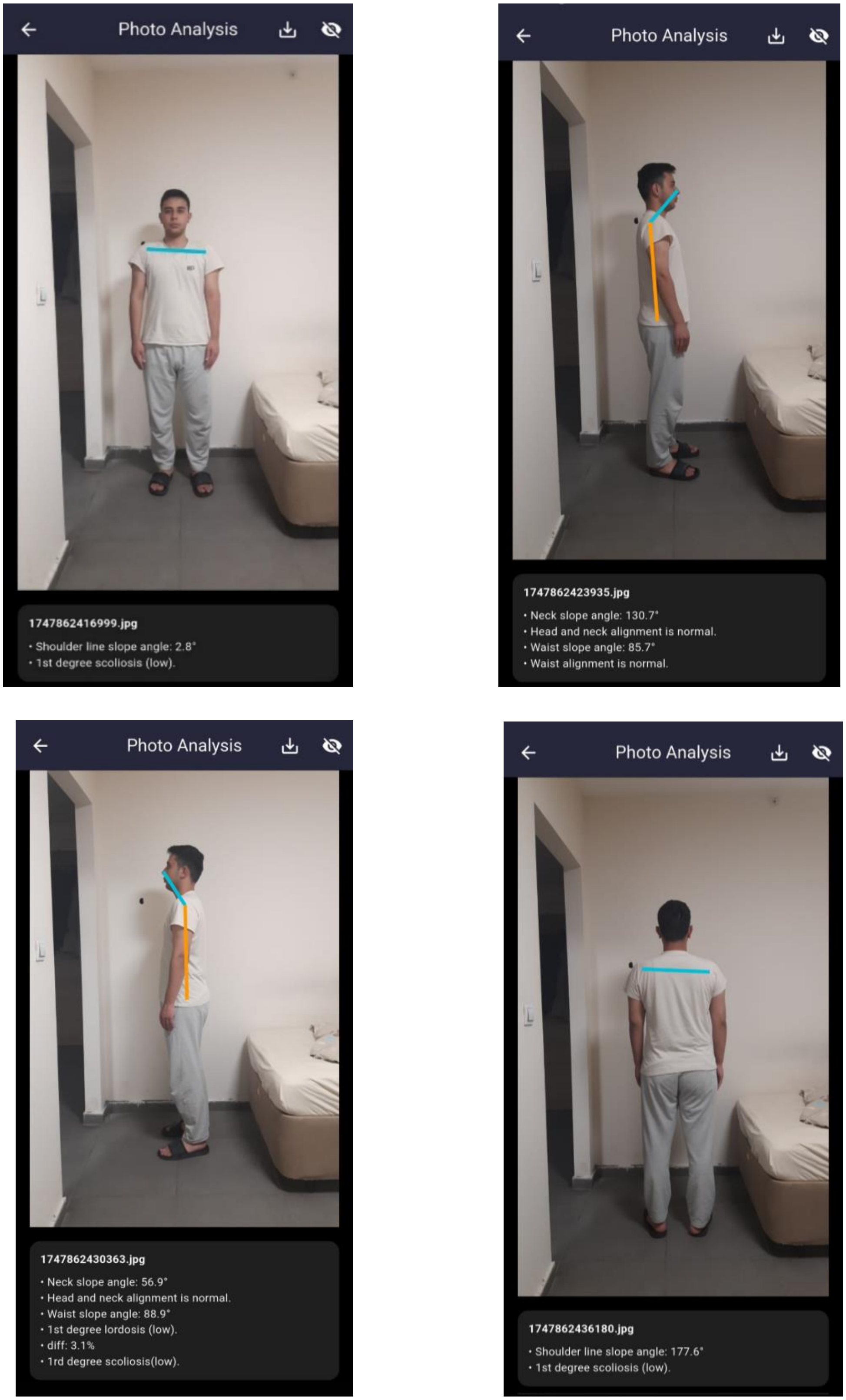



*Figure 18: Posture analysis results*

When the analysis is completed, the save button is pressed to save the analysis results as the date entered in the text file, as seen in Figure 19. In this way, the aim is to enable the user to follow the change in the analysis results over time.

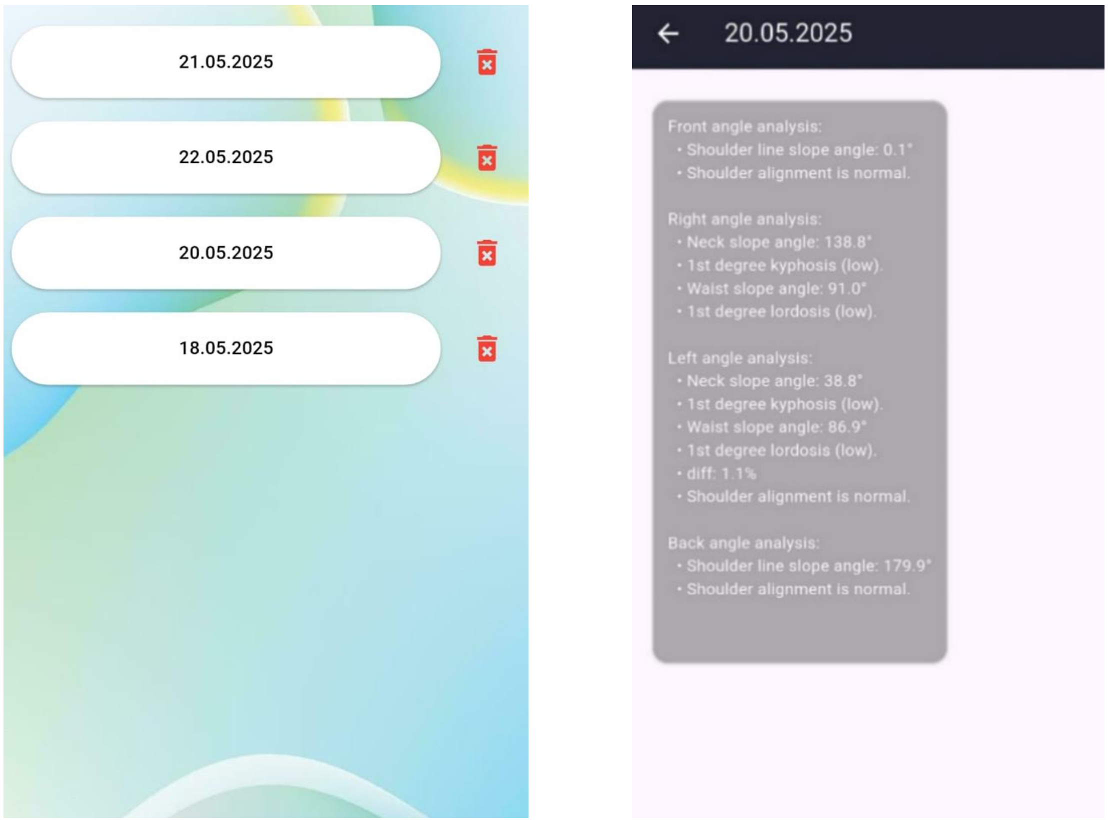



*Figure 19: Saved analysis results*

### 6.2.2 Flutter

Flutter is an open-source user interface (UI) library developed by Google that allows you to build native performance applications on Android, iOS, web, and desktop platforms with a single codebase. Flutter builds all UI elements around the concept of "widgets" using the Dart language; each visual component is defined as a widget, which makes it possible to design a flexible, reusable, and hierarchical interface. Thanks to the HotReload feature, changes made to the code are instantly displayed on the emulator or device, allowing for fast and interactive progress in the development process. Drawing using Flutter's own graphics engine (Skia) ensures that the application runs with a consistent appearance and high frame rate on every platform. As a result, Flutter offers cross-platform solutions that reduce development time, reduce maintenance costs, and do not compromise on user experience [21]. Figure 20 shows a section of the Flutter interface.

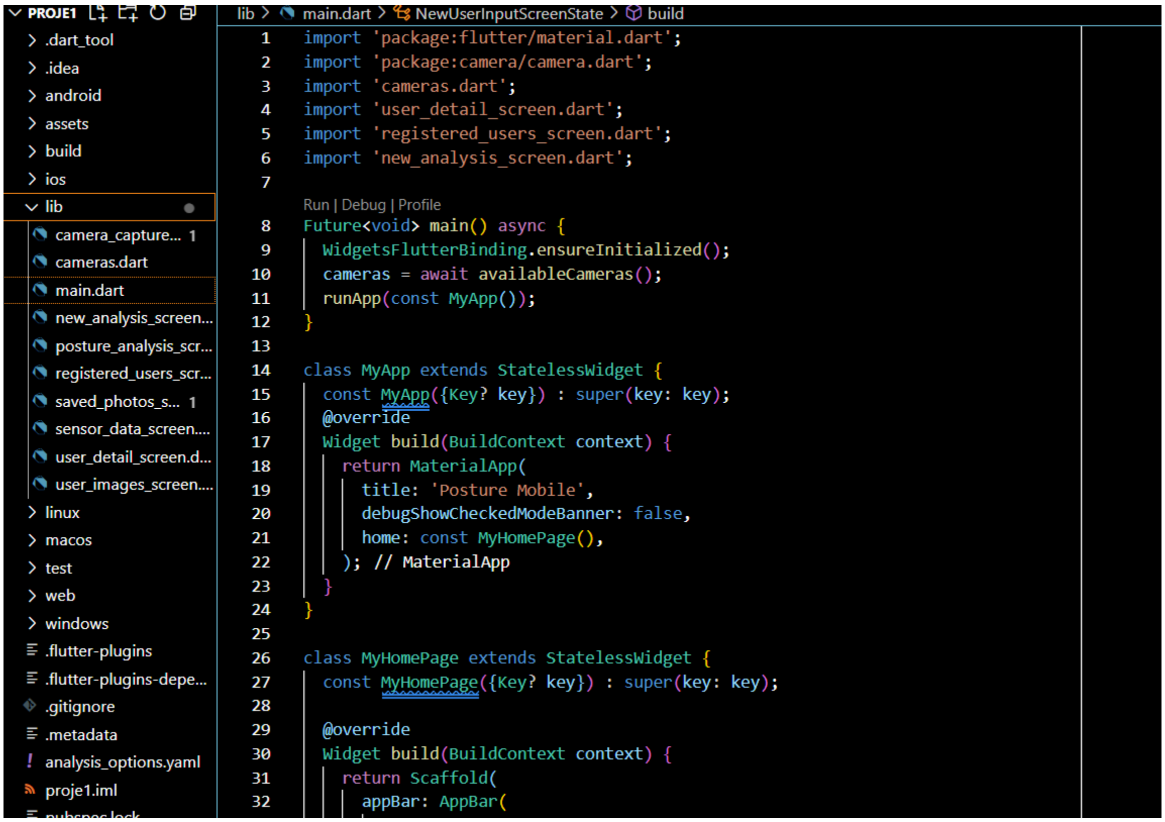



*Figure 20: Flutter main.dart file*

### 6.3 Tools

- Visual Studio Code
- Android Studio
- Python
- Arduino IDE
- Microsoft Office Programs

## 7. EXPERIMENTS

### 7.1 Device Test

After the circuit shown in Figure 21 was built, a series of basic tests were carried out to verify whether the MPU6050 sensor and ESP32 module, placed on the breadboard, were functioning correctly following the system setup. In the initial stage of these tests, I2C communication between the MPU6050 and ESP32 was successfully established, and data transmission from the sensor was monitored via the serial port. When the sensor was kept stationary, the data remained stable; when the sensor was moved, instantaneous changes were observed in the accelerometer and gyroscope values. This indicated that the sensor was operating correctly and was responsive to environmental movements.

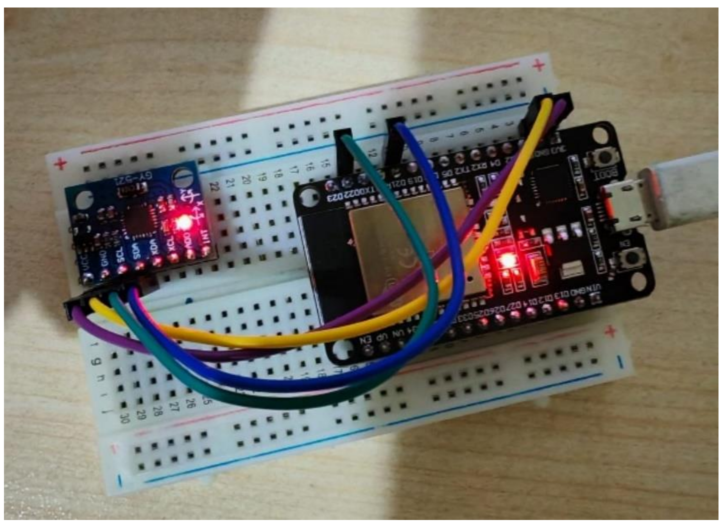


*Figure 21: MPU650 test on breadboard*

It was then confirmed that the data was being updated multiple times per second and that the system was capable of providing real-time data. Additionally, as shown in Figure 22, the Wi-Fi connectivity of the ESP32 module was tested. The connection to the specified wireless network was successfully established, and the IP address assigned to the ESP32 was displayed via the serial port. The stability of the connection demonstrated that the system was ready to transmit data to external environments over the network.

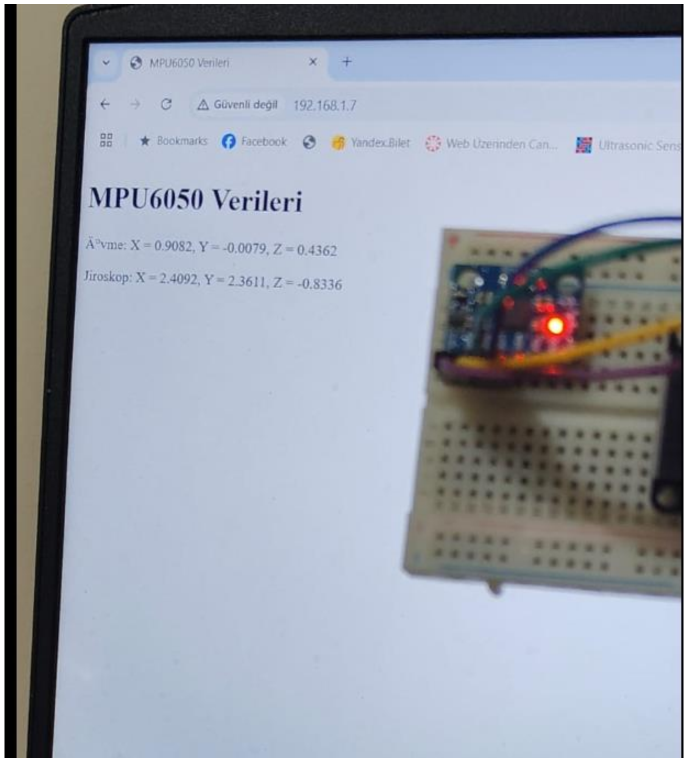



*Figure 22: Wi-Fi connection test*

In the later stages of testing, two MPU6050 sensors were placed on the user's body—between the right shoulder and the back, and between the left shoulder and the back—for practical testing. With this placement, the angles formed between each shoulder and the back were monitored separately, and the symmetry of the shoulder positions was evaluated. When the user maintained a forward-leaning or unbalanced posture for a certain period of time, the accelerometer and gyroscope data from the sensors were analyzed to detect postural deviations. The system was designed to activate a warning mechanism when predefined threshold values were exceeded in such cases.

During the tests, if the poor posture persisted beyond a certain duration, the buzzer and vibration motor connected to the ESP32 were activated, providing both audible and tactile feedback to alert the user. As a result of these tests, it was observed that the sensor placement was effective and that the alert system functioned as expected. Figure 23 illustrates the testing process conducted on a human subject.

*Figure 23: Test on human*

### 7.2 Application Test

The mobile application was tested many times on project members and different users. During these trials, photos of users were taken in different positions to be able to analyze lordosis, kyphosis and scoliosis. After many tests, the correct body points were determined. For scoliosis, the inclination angle of the line drawn from the left shoulder point to the right shoulder point was used. For kyphosis, the inclination angle of the lines drawn from the nose point to the right and left shoulder points was used. For lordosis, the inclination angle of the lines drawn from the hip point to the right and left shoulder points was used. And finally, scoliosis was detected by comparing the lengths of the lines drawn from the shoulder point to the hip point from the photos taken from the right and left angles. This type of imaging method may not be accurate normally. In order to obtain definitive results, users need to see a doctor and be identified with imaging methods such as MRI and X-ray. However, the main purpose of this study is for users to use this application at home and get results before going to the doctor. Application tests were conducted on different users as shown in Figure 24.

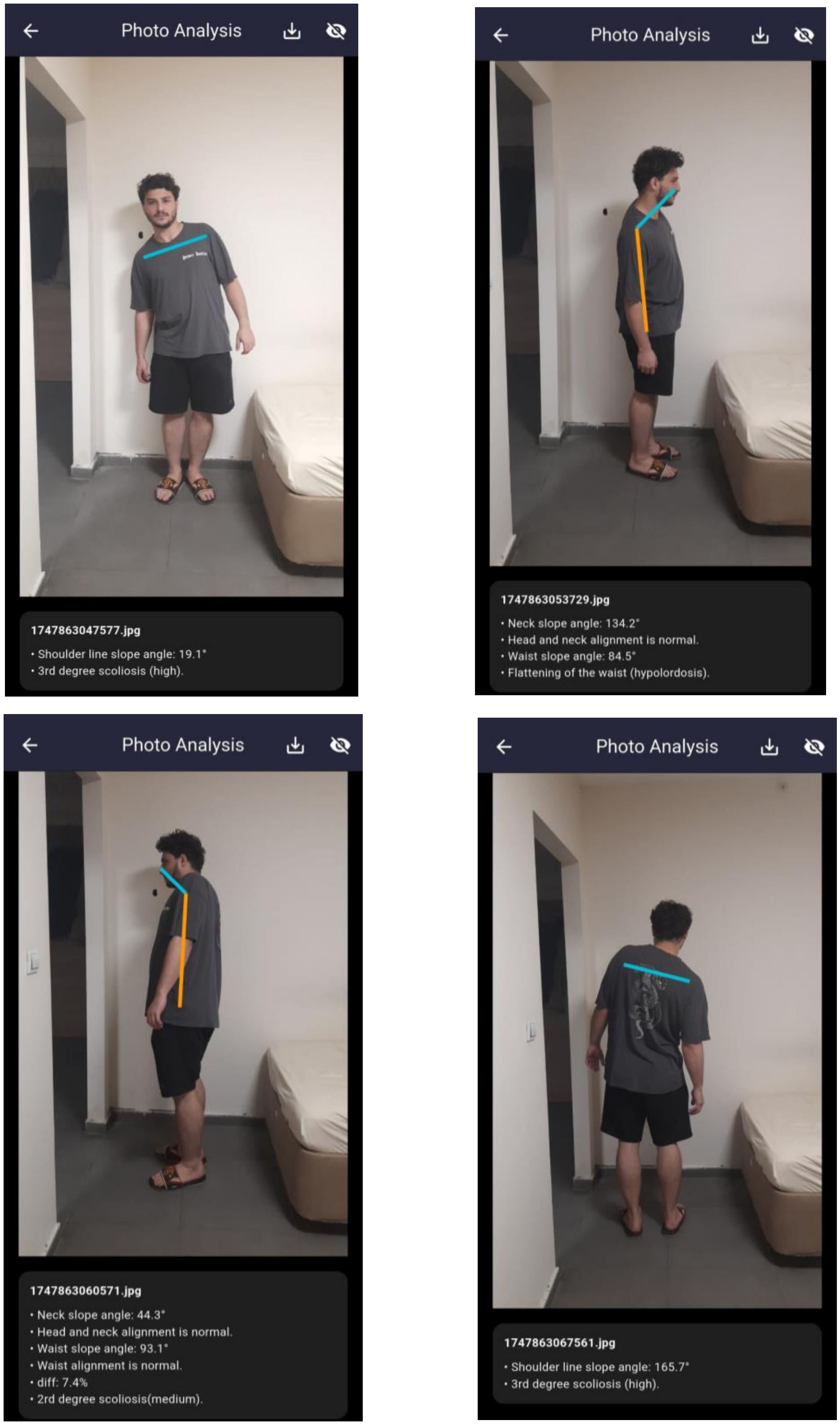



*Figure 24: Application tests*

## 8. PROJECT PLAN

- **Work Package 1–System Research and Planning:** This phase included the examination of existing posture monitoring systems through an extensive literature review. Based on the findings, appropriate components such as MPU6050 sensors and the ESP32 microcontroller were selected. A preliminary requirement analysis was conducted, and the overall system architecture was designed. A block diagram was prepared to visualize the flow of data between the components and the mobile interface.
- **Work Package 2–Hardware Integration and Sensor Processing:** In this phase, the MPU6050 sensors were connected to the ESP32 via I2C communication. Sensor data such as acceleration and angular velocity were collected through the serial port. Calibration techniques were applied to minimize noise, and Euler angles were computed to determine the orientation of the body. A threshold-based trigger system was implemented to detect posture deviations and activate feedback mechanisms, including a buzzer and vibration motor.
- **Work Package 3–Mobile Application Development:** A Flutter-based mobile application was developed to provide users with a real-time interface. The app allowed users to monitor live sensor data, save daily posture records, and access past data through persistent storage. A reset system was implemented to automatically clear the daily counter at midnight (00:00), enabling consistent daily posture tracking. The interface was designed to be simple, responsive, and accessible for everyday use.
- **Work Package 4–Vision-Based Analysis (ML Kit Integration):** To strengthen the reliability of the system, image-based posture analysis was added using Google ML Kit. Photos taken from the front, back, left, and right sides of the user were analyzed through ML Kit's pose detection model. Key joint coordinates were extracted and used to assess body symmetry and alignment. This approach served as a secondary verification method, complementing sensor-based angle analysis.
- **Work Package 5–System Testing, Evaluation and Final Design:** In the final stage, all system components—hardware, mobile app, and ML integration—were tested as a whole. The system was tested on real users, and their feedback was gathered to identify

usability issues and performance gaps. Based on these insights, design optimizations were made. This phase concluded with the preparation of the final report, project documentation, and presentation materials for academic submission.

*Table 1: Project Plan by week*

| | **Week** | **Task** |
|---|---|---|
| 1 | Week 1 | Project planning and literature review |
| 2 | Week 2 | Component research and hardware selection |
| 3 | Week 3 | Ordering and preparing hardware (ESP32, MPU6050) |
| 4 | Week 4 | Basic communication tests between ESP32 and MPU6050 |
| 5 | Week 5 | Sensor data collection via serial monitor |
| 6 | Week 6 | Sensor calibration and noise filtering |
| 7 | Week 7 | Euler angle calculation and sensor fusion |
| 8 | Week 8 | System design and architecture setup |
| 9 | Week 9 | Trigger mechanism design (threshold-based) |
| 10 | Week 10 | Integration of buzzer and vibration motor |
| 11 | Week 11 | Real-time monitoring system setup |
| 12 | Week 12 | Mobile app (Flutter) UI design |
| 13 | Week 13 | Wi-Fi communication between ESP32 and mobile app |
| 14 | Week 14 | Live data display in mobile app |
| 15 | Week 15 | Daily counter and data saving functionality in app |
| 16 | Week 16 | Research on ML Kit for pose detection |
| 17 | Week 17 | Photo capture and dataset preparation |
| 18 | Week 18 | ML Kit integration and keypoint extraction |
| 19 | Week 19 | User testing and data analysis |
| 20 | Week 20 | Final design adjustments |

# 9. CONCLUSION

In this study, a multi-layered system was developed to detect users' postural disorders. As the core component, real-time angular posture data was monitored using two MPU6050 inertial sensors placed on the upper body and controlled via an ESP32 microcontroller. Specifically, pitch and roll angles obtained from the shoulder-back alignment were evaluated using Euler angles, and posture deviations were analyzed based on predefined threshold values. When poor posture was detected, the ESP32 activated an audible and haptic feedback mechanism to alert the user.

On the software side, a mobile application developed using Flutter enabled users to monitor sensor data in real time and save daily posture data using a “Save Data” button. The counter resets automatically at 00:00 each day, and the total of the previous day is stored separately. Additionally, the app includes persistent data storage, allowing users to access and analyze past posture records at any time.

Furthermore, a second layer of the system provided **image-based posture analysis**. In this part, photos of the user taken from four different angles (front, back, left, right) were analyzed using **Google ML Kit**. The pose detection model of ML Kit identified key body joints, and using the coordinates of these points, the alignment of the body was evaluated. This method enabled posture analysis not only through sensor data but also through visual assessment, increasing the reliability of the system.

As a result of the conducted tests, it was observed that both the hardware and software components were successfully integrated, the mobile application enhanced the user experience, and the ML Kit-based visual analysis improved the overall system accuracy. The developed system stands out as a low-cost, portable, multi-analysis, and expandable posture monitoring solution. In the future, it is planned to enhance the system with AI-supported learning models to provide personalized posture recommendations and integrate with health professionals for advanced use.

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