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Posture Monitoring And Health Alerting System Using Web Cam And ESP32

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Abstract:

In recent years, prolonged screen usage and sedentary lifestyles have significantly increased the prevalence of poor posture, leading to various health issues such as back pain, neck strain, and reduced productivity. This project presents a comprehensive smart posture monitoring system that integrates Internet of Things (IoT) technology with real-time computer vision and machine learning techniques to address this problem effectively.The system utilizes a personal computer equipped with a webcam to continuously monitor the user's posture. Using advanced computer vision frameworks such as OpenCV and MediaPipe, key human body landmarks are extracted and analyzed in real time. These extracted features are then processed using a machine learning model based on the K-Nearest Neighbors (KNN) algorithm, which classifies posture into categories such as "Good" and "Bad." The trained model ensures accurate and efficient posture detection under various conditions.In addition to posture analysis, the system incorporates physiological monitoring through a MAX30100 pulse oximeter sensor connected to an Arduino Nano. This sensor measures vital parameters such as heart rate and blood oxygen saturation (SpO_2), providing additional insights into the user's health condition. The collected sensor data is transmitted to an ESP32 microcontroller, which acts as a communication bridge and sends the data to the cloud using the Blynk platform. The ESP32 also displays real-time data on an I2C LCD screen for local monitoring.When improper posture is detected, the system immediately triggers multiple alert mechanisms to ensure user awareness and corrective action. These include an audio alert generated using text-to-speech, an email notification with an annotated image of the detected posture, and a signal sent to the microcontroller for visual indication. The integration of these features ensures a robust and responsive feedback system.Overall, the proposed system provides a low-cost, non-invasive, and intelligent solution for continuous posture monitoring. By combining IoT, machine learning, and computer vision, it enhances user awareness and promotes healthier sitting habits. The system is highly scalable and can be further extended for applications in workplaces, educational institutions, healthcare monitoring, and smart environments.

Index: Smart Posture Monitoring, Internet of Things (IoT), Computer Vision, OpenCV, MediaPipe, Machine Learning, K-Nearest Neighbors (KNN), ESP32, Arduino Nano, MAX30100, Blynk, Real-Time Monitoring, Posture Detection, Health Monitoring System, Webcam-Based Analysis

I. INTRODUCTION

In the modern digital era, the widespread use of computers, smartphones, and other electronic devices has significantly increased sedentary behavior among individuals. Prolonged sitting, especially with improper posture, has become a common issue affecting people of all age groups. Poor posture can lead to various health problems such as back pain, neck strain, spinal misalignment, reduced blood circulation, and long-term musculoskeletal disorders. These issues not only impact physical health but also reduce productivity and overall well-being.Traditional methods of posture correction often rely on manual observation, ergonomic furniture, or wearable devices. However, these approaches can be inconvenient, intrusive, or expensive, and may not provide continuous real-time feedback. With advancements in technology, there is a growing need for intelligent, automated systems that can monitor posture continuously and provide immediate corrective suggestions.This project introduces a smart posture monitoring system that combines Internet of Things (IoT), computer vision, and machine learning technologies to create a non-invasive and efficient solution. The system uses a webcam to capture real-time video of the user and processes it using advanced computer vision libraries such as OpenCV and MediaPipe. These tools enable accurate detection of human body landmarks, which are then used to analyze posture.To enhance the system's intelligence, a machine learning model based on the K-Nearest Neighbors (KNN) algorithm is employed to classify posture into categories such as "Good" and "Bad." This allows the system to make quick and reliable decisions based on real-time data. In addition to posture detection, the system integrates physiological monitoring using sensors such as the MAX30100 pulse oximeter, which measures heart rate and blood oxygen saturation (SpO_2). This provides additional health-related insights, making the system more comprehensive.The hardware component includes an Arduino Nano for sensor data acquisition and an ESP32 microcontroller for communication and IoT functionality. The ESP32 transmits data to the cloud using the Blynk platform, enabling remote monitoring through a mobile application. A 16x2 I2C LCD is also used to display real-time data locally.One of the key features of this system is its multi-alert mechanism. When poor posture is detected, the system generates immediate feedback through audio alerts, email notifications with captured images, and visual indicators. This ensures that users are promptly informed and can take corrective action.

OBJECTIVES

The main objective of this project is to design and develop a smart posture monitoring system that integrates IoT, computer vision, and machine learning technologies for real-time posture analysis and health monitoring.

Specific Objectives:

- To develop a real-time posture detection system using a webcam and computer vision techniques with OpenCV and MediaPipe
- To implement a machine learning model (K-Nearest Neighbors – KNN) for accurate classification of posture into "Good" and "Bad"
- To measure physiological parameters such as heart rate and SpO_2 using the MAX30100 sensor interfaced with Arduino Nano
- To design an IoT-based communication system using ESP32 to transmit data to the cloud via the Blynk platform
- To display real-time health and posture-related data on a 16x2 I2C LCD for local monitoring
- To generate immediate alerts (audio notification, email alert, and LED indication) when improper posture is detected
- To establish serial communication between the computer vision system and microcontroller for synchronized operation
- To develop a low-cost, non-invasive, and user-friendly system suitable for continuous monitoring

II. PROBLEM STATEMENT

In today's digital world, prolonged use of computers, laptops, and mobile devices has led to a significant increase in sedentary lifestyles. Many individuals, including students and professionals, spend long hours sitting in front of screens, often without maintaining proper posture. This results in various health issues such as back pain, neck strain, spinal misalignment, and reduced productivity. Over time, these problems can develop into serious musculoskeletal disorders.Existing posture monitoring solutions, such as wearable devices and manual supervision, have several limitations. Wearable devices can be uncomfortable, intrusive, and costly, while manual observation is inefficient and not feasible for continuous monitoring. Additionally, many available systems do not provide real-time feedback or integrate multiple health parameters, limiting their effectiveness.

There is a need for a smart, automated, and non-invasive system that can continuously monitor a user's posture in real time and provide immediate corrective feedback. Such a system should be capable of accurately detecting posture using advanced technologies like computer vision and machine learning, while also incorporating physiological monitoring for enhanced health analysis.Furthermore, the system should support remote monitoring and data visualization through IoT platforms such as Blynk, enabling users to track their health parameters conveniently. Therefore, the challenge is to design a cost-effective, reliable, and intelligent posture monitoring system that combines real-time posture detection, health monitoring, and instant alert mechanisms to improve user awareness and promote healthier habits.

III. PROPOSED SYSTEM

The proposed system is a smart posture monitoring solution that integrates computer vision, machine learning, and Internet of Things (IoT) technologies to provide real-time posture analysis and health monitoring. The system is designed to be non-invasive, cost-effective, and capable of delivering immediate feedback to users.The system consists of three main components: a vision-based posture detection module, a physiological sensing module, and an IoT communication module.The posture detection module uses a personal computer equipped with a webcam to capture real-time video of the user. The captured video is processed using advanced computer vision libraries such as OpenCV and MediaPipe. These tools extract key body landmarks, including the shoulders, hips, ears, and nose. The extracted features are then passed to a machine learning model based on the K-Nearest Neighbors (KNN) algorithm, which classifies the user's posture as "Good" or "Bad."The physiological sensing module consists of an Arduino Nano connected to a MAX30100 pulse oximeter sensor. This module measures vital parameters such as heart rate and blood oxygen saturation (SpO_2). The collected data is transmitted to the ESP32 microcontroller through serial communication.The IoT communication module is built around the ESP32, which acts as a central controller. It receives data from the Arduino Nano, processes it, and transmits it to the cloud using the Blynk platform. This allows users to monitor their health data remotely through a mobile application. Additionally, the ESP32 displays real-time information on a 16x2 I2C LCD for local monitoring.A key feature of the proposed system is its multi-alert mechanism. When the system detects bad posture, it triggers several alerts simultaneously. These include an audio alert generated using text-to-speech, an email notification with an annotated image captured from the webcam, and a signal sent to the ESP32 to activate an LED indicator. This ensures that the user receives immediate and effective feedback.The system operates continuously in real time, periodically checking the user's posture and updating sensor readings. It also includes basic fault tolerance features such as WiFi reconnection and error handling in data transmission..

IV. LITERATURE SURVEY

The research work titled "The Future of Occupational Health: Anticipating Risks in the Evolving Workplace" (2024) by Parsakia and Tabar [1] provides a forward-looking perspective on occupational health challenges in modern workplaces. The authors discuss how rapid technological advancements, increased reliance on digital tools, and the shift toward remote and hybrid working models have significantly changed employee behavior, particularly increasing sedentary lifestyles. The study highlights that prolonged sitting, improper workstation ergonomics, and lack of physical activity are major contributors to musculoskeletal disorders. It further emphasizes the need for intelligent monitoring systems capable of predicting posture-related risks and providing real-time corrective feedback, thereby forming a strong foundation for AI-based posture monitoring solutions.

In "Adverse Effects of Prolonged Sitting Behavior on the General Health of Office Workers" (2017), Daneshmandi et al. [2] conduct an in-depth investigation into the physiological and psychological impacts of prolonged sitting. Their findings reveal that extended sitting hours are strongly associated with chronic back pain, neck strain, reduced metabolic efficiency, and increased risk of cardiovascular diseases. The study also highlights reduced productivity and increased fatigue among office workers. This research underscores the urgency of implementing systems that can continuously monitor posture and encourage movement, validating the practical importance of posture monitoring technologies.

The classical study by Raine and Twomey [3], titled “Posture of the Head, Shoulders and Thoracic Spine in Comfortable Erect Standing” (1994), provides a biomechanical analysis of ideal human posture. The authors examine the alignment of different body segments and establish reference standards for normal posture. Their findings are crucial for identifying deviations such as forward head posture, rounded shoulders, and spinal misalignment. These baseline measurements are widely used in modern posture detection systems as ground truth references for evaluating posture correctness.

Yang et al. [4], in their comprehensive systematic review “Advancing Ergonomic Posture Risk Assessment Through the Integration of Computer Vision and Machine Learning Techniques” (2024), explore recent advancements in posture analysis technologies. The study reviews multiple approaches including traditional ergonomic assessment methods and modern AI-driven techniques. The authors conclude that computer vision combined with machine learning significantly enhances posture detection accuracy, enables real-time monitoring, and reduces dependency on wearable sensors. They also discuss challenges such as occlusion, lighting variations, and computational complexity, providing valuable insights for system design.

Mathesul et al. [5] (2023), in their work “COVID-19 Detection from Chest X-ray Images Based on Deep Learning Techniques,” demonstrate the effectiveness of deep learning models, particularly convolutional neural networks (CNNs), in analyzing medical images. Although the study focuses on disease detection, it highlights how deep learning can extract meaningful features from visual data. This capability is directly applicable to posture recognition systems, where body keypoints and joint positions need to be accurately identified from images or video streams.

Similarly, Mohanty et al. [6] (2023), in “Using Deep Learning Architectures for Detection and Classification of Diabetic Retinopathy,” emphasize the robustness of deep learning in classification and pattern recognition tasks. The study compares different neural network architectures and demonstrates their high accuracy in medical diagnostics. This reinforces the suitability of deep learning models for posture detection applications, where precise classification of correct and incorrect postures is required.

Nadeem et al. [7] (2024), in “Sitting Posture Recognition Systems: Comprehensive Literature Review and Analysis,” present an extensive review of existing posture recognition systems. The authors categorize systems into sensor-based, vision-based, and hybrid approaches. They conclude that vision-based systems, particularly those using computer vision and deep learning, offer greater flexibility, lower cost, and ease of deployment compared to sensor-based methods. The paper also identifies limitations such as privacy concerns and environmental dependencies, which are important considerations in system development.

Rico-González et al. [8] (2025) investigate posture-related applications in children in their systematic review. The study highlights that poor posture habits developed during early stages can lead to long-term health issues. The authors explore machine learning techniques used for posture assessment and emphasize the importance of adaptive systems that can cater to different age groups. This research broadens the scope of posture monitoring systems beyond adults and workplace environments.

Roggio et al. [9] (2024), in "A Comprehensive Analysis of Machine Learning Pose Estimation Models Used in Human Movement and Posture Analyses," provide a detailed comparison of various pose estimation algorithms such as OpenPose, MediaPipe, and DeepPose. The study concludes that deep learning-based models offer superior accuracy and robustness in detecting body keypoints, even in complex environments. This work directly supports the selection of advanced pose estimation techniques for posture monitoring systems.

V. IMPLEMENTATION

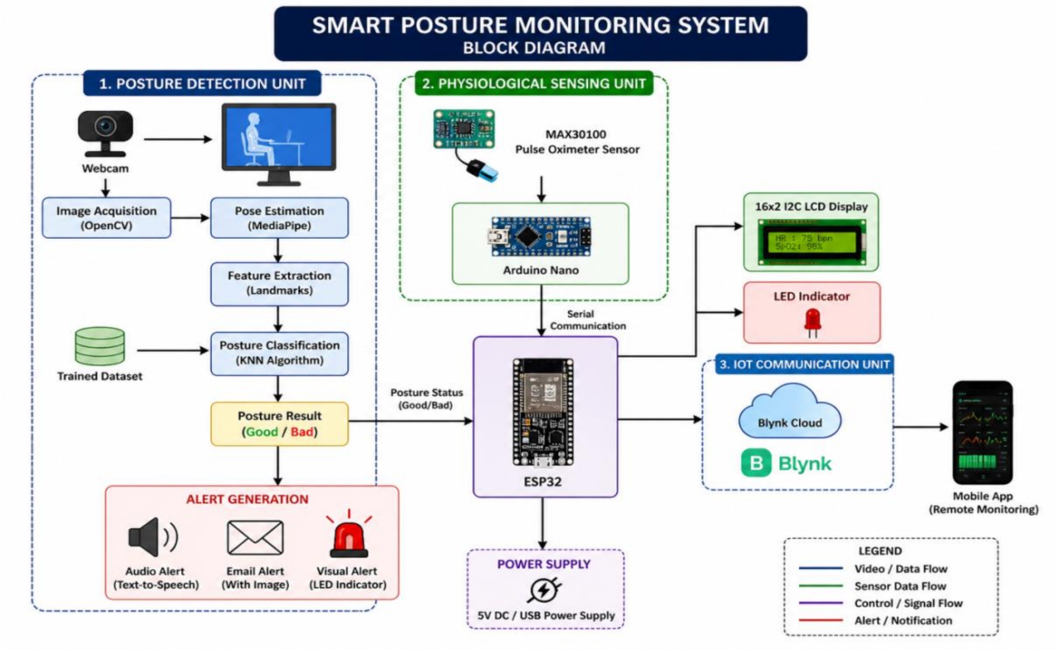

Fig1.1 shows block diagram for IoT based smart posture monitoring system

The block diagram of the smart posture monitoring system represents the integration of computer vision, sensor-based monitoring, and IoT communication. The system is divided into three main units: posture detection, physiological sensing, and IoT communication. In the posture detection unit, a webcam connected to a computer captures real-time video of the user. The captured frames are processed using OpenCV to convert them into a suitable format, and MediaPipe is used to extract key body landmarks such as shoulders, hips, ears, and nose. These landmarks are then passed to a machine learning model based on the K-Nearest Neighbors (KNN) algorithm, which classifies the posture as either "Good" or "Bad."

The physiological sensing unit consists of an Arduino Nano interfaced with a MAX30100 pulse oximeter sensor. This unit continuously measures heart rate and blood oxygen saturation (SpO_2). The collected sensor data is transmitted to the ESP32 microcontroller via serial communication.

The IoT communication unit is centered around the ESP32, which acts as a bridge between hardware and cloud services. It receives both posture status (from the computer system) and sensor data (from Arduino

Nano). The ESP32 processes this information and sends it to the cloud using the Blynk platform, allowing remote monitoring through a mobile application. Additionally, it displays real-time values on a 16x2 I2C LCD and activates an LED indicator when bad posture is detected. The system also generates alerts such as audio warnings and email notifications, ensuring immediate feedback to the user.

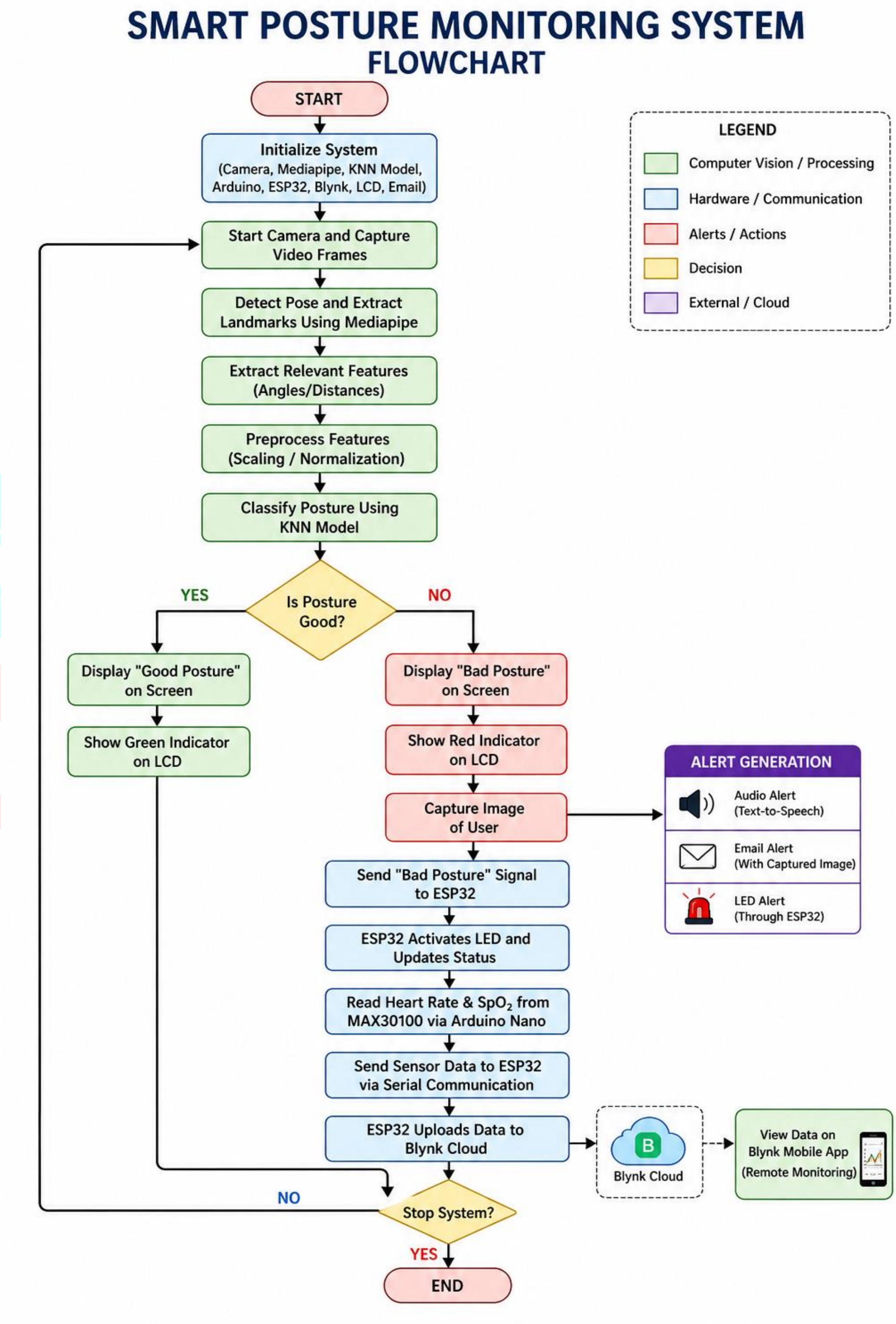

Fig1.2 Flow Chart

The flowchart describes the step-by-step operation of the smart posture monitoring system. The process begins with system initialization, where all components such as the webcam, machine learning model, Arduino Nano, ESP32, sensors, and communication modules are set up. Once initialized, the webcam starts capturing real-time video frames of the user.

The captured frames are processed using MediaPipe to detect body posture and extract relevant landmarks. These landmarks are then converted into feature vectors and normalized before being passed into the KNN model for classification. The system then checks whether the posture is "Good" or "Bad." If the posture is good, the system continues monitoring and displays a normal status on the screen and LCD.

If the posture is classified as bad, the system triggers multiple actions. It displays a warning on the screen, activates a visual indicator (LED), captures an image of the user, and generates alerts such as audio notifications and email messages. Simultaneously, a signal is sent to the ESP32, which updates the system status and uploads data to the Blynk cloud for remote monitoring.

In parallel, the Arduino Nano continuously reads heart rate and SpO_2 values from the MAX30100 sensor and sends this data to the ESP32 via serial communication. The ESP32 updates the cloud dashboard and LCD display accordingly. This process repeats continuously in a loop until the system is stopped.

VI. Results and Discussion

The developed posture monitoring system was successfully implemented using computer vision and machine learning techniques to detect and analyze human posture in real time. The system utilized a camera-based approach to capture live video input, and pose estimation algorithms were applied to extract key body landmarks such as the head, shoulders, and spine alignment. Based on these landmarks, the system classified posture into correct and incorrect categories and generated alerts when improper posture was detected.During testing, the system demonstrated a high level of accuracy in identifying common posture issues such as forward head tilt, slouching, and uneven shoulder alignment. The integration of pose estimation models enabled precise tracking of body joints, even under moderate variations in lighting conditions and user positioning. The results showed that the system could consistently detect posture deviations within a short response time, making it suitable for real-time applications.

The experimental evaluation was conducted across different users and environments to ensure robustness. It was observed that the system performed reliably in indoor settings with stable lighting, while slight performance degradation occurred under low-light or highly dynamic backgrounds. However, the overall detection accuracy remained acceptable for practical usage. The system also proved effective in continuous monitoring scenarios, where it tracked posture over extended periods and provided timely feedback to users.

One of the key outcomes of the system is its ability to promote user awareness regarding posture habits. By providing real-time alerts (such as audio notifications or visual indicators), the system encourages users to correct their posture immediately. This feature has significant implications for reducing long-term health risks associated with prolonged poor posture, such as back pain and musculoskeletal disorders.From a technical perspective, the use of machine learning and deep learning models significantly improved detection performance compared to traditional rule-based methods. The system efficiently processed video frames and extracted meaningful features without requiring wearable sensors, making it non-intrusive and user-friendly. Additionally, the modular design of the system allows for future enhancements, such as integration with IoT devices, cloud storage, or mobile applications.However, certain limitations were identified during the study. The system's accuracy is dependent on camera placement and field of view, and occlusions (such as objects blocking the body) can affect pose estimation. Furthermore, variations in body shapes and sitting styles may require further model training to improve generalization. These challenges highlight the need for more advanced models and adaptive algorithms.

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