Intelligent Posture Assessment Using Machine Learning

Kandakatla Varun Tej[1], Madarapu Mohan Krishna[2],Dr.K.Sunil Kumar[3] and Dr.T. Kishore Kumar[4]

[1,2]Department of Computer Science and Engineering, GITAM University, Hyderabad, India [3,4]National Institute of Technology (NIT) Warangal, India

Email: varuntej2909@gmail.com, madarapumohankrishna@gmail.com,sunil.veena10@gmail.com & kishoref@gmail.com

Received: 19.04.2024 **Revised : 20.05.2024** **Accepted: 03.06.2024**

Abstract— Poor sitting posture is a common cause of musculoskeletal disorders, especially among individuals who spend prolonged hours working at desks or using computers. To address this, we propose an intelligent, real-time posture assessment system that leverages computer vision and machine learning techniques. The system utilizes MediaPipe, a lightweight and robust pose estimation framework, to extract key body landmarks from a live webcam feed. These landmarks are processed to extract meaningful posture-related features, which are then classified using a Random Forest model to determine whether the posture is correct or incorrect. The system is capable of providing immediate visual and audio feedback to the user upon detection of poor posture. Experimental results show that the model achieves an accuracy of over 95% on a custom dataset, demonstrating its potential as a cost-effective, non-intrusive solution for posture monitoring in workplace and educational environments.

1. Introduction

In the modern era, prolonged periods of desk-bound activities, including computer work, online learning, and gaming, have become increasingly prevalent. This shift in lifestyle has led to a significant rise in posture-related health problems, particularly musculoskeletal disorders such as chronic back pain, spinal misalignment, and neck strain. Poor posture not only affects physical health but also contributes to fatigue, reduced productivity, and long-term ergonomic complications.

Traditional methods for posture assessment rely on manual observation or wearable sensors such as inertial measurement units (IMUs), which, although accurate, can be intrusive, expensive, and impractical for long-term use. Recent advancements in computer vision and machine learning have enabled the development of non-contact systems capable of interpreting human posture through video feeds, offering a more accessible and user-friendly solution.

This research focuses on building an intelligent posture assessment system that utilizes MediaPipe for landmark extraction and a Random Forest classifier for posture classification. The system captures upper-body skeletal keypoints from a standard webcam, processes them into features, and classifies the posture as correct or incorrect. It also provides immediate feedback to the user, promoting real-time posture correction without the need for wearable devices.

The motivation behind this project lies in creating a reliable, low-cost, and real-time solution that encourages ergonomic awareness, especially among students and professionals who spend extensive hours in front of digital screens. This paper presents the full pipeline of the system, from data collection and preprocessing to model evaluation, and discusses its real- world applicability and future improvements.

2. Background

The assessment of human posture has traditionally relied on methods such as clinical observation, physical assessments by experts, and wearable technologies like posture belts or IMU-based devices. While effective, these techniques come with limitations in terms of scalability, user comfort, and cost. As the need for continuous and non-invasive monitoring has grown, especially in remote work and learning environments, the demand for computer vision-based posture analysis systems has significantly increased.

Several studies have explored vision-based approaches for human pose estimation and activity recognition. Tools like OpenPose, PoseNet, and more recently, MediaPipe have enabled researchers to detect and track key body landmarks using RGB cameras. These frameworks extract skeletal data from video feeds in real-time and are often integrated with machine learning models to perform tasks like action recognition, fitness tracking, and ergonomic monitoring.

Machine learning classifiers such as Support Vector Machines (SVM), Decision Trees, and Random Forests have been effectively used in pose-related classification problems. Random Forests, in particular, are popular for their robustness to overfitting, ability to handle complex decision boundaries, and efficiency in working with moderately sized datasets.

In this project, MediaPipe is used to capture 33 landmark coordinates of the human body, focusing on the upper-body posture relevant to seated positions. Features such as shoulder alignment, spine angle, and relative joint positions are extracted and labeled for training the Random Forest classifier. By integrating these technologies, we aim to offer a real-time, low-cost, and scalable system that can promote better sitting habits and prevent posture-related health issues.

3. Main Purpose

The primary objective of this research is to develop an intelligent, real-time system capable of assessing a user's sitting posture using non-invasive, vision-based technologies. The system is designed to detect incorrect postures and provide immediate feedback to the user, thereby encouraging better ergonomic habits and reducing the risk of long-term musculoskeletal issues.

This work specifically aims to:

- **Eliminate the need for wearable sensors or specialized hardware**, relying only on a standard webcam and computer vision algorithms.
- **Leverage MediaPipe's lightweight pose estimation capabilities** to extract precise skeletal landmarks from live video input.
- **Train and deploy a machine learning model**—Random Forest—for classifying posture into correct or incorrect categories based on body joint features.
- **Provide real-time feedback** through visual cues and audio alerts, guiding users to adjust their posture dynamically.
- **Build a cost-effective and scalable solution** that can be implemented in home, office, or educational environments without requiring expert supervision.

4. Related Works

The growing complexity of maritime infrastructure and increasing reliance on networked systems have driven substantial research efforts in the domain of cyber-physical system (CPS) security. Several studies have focused on protecting critical infrastructures such as transportation, power grids, and maritime systems from both cyber threats and physical vulnerabilities. In [1], the authors examined security challenges in maritime cyber-physical systems, emphasizing the need for unified frameworks that address both cyber and physical attack vectors. Another notable work in [2] proposed an integrated intrusion detection system (IDS) model that combines rule-based and anomaly-based techniques, improving real-time detection of threats within isolated maritime environments.

Advancements in machine learning have led to the development of predictive analytics tools for maritime security. As outlined in [3], these tools can assess historical and real-time data to anticipate potential breaches and issue proactive alerts. The integration of blockchain technology, as explored in [4], has also shown promise in establishing decentralized, tamper-proof audit trails, enhancing trust in communication and event logging across shipboard systems.

Work in [5] presented a framework for physical layer security in industrial control systems, which shares architectural similarities with maritime operational technologies (OT). This research highlighted the importance of designing lightweight and resilient systems that can operate under constrained resources and in network-challenged environments.

From a system architecture perspective, [6] introduced a hybrid model combining centralized control with distributed monitoring nodes, enhancing both scalability and fault tolerance. This model was particularly effective in environments where connectivity is intermittent, such as maritime zones. Similarly, [7] discussed the deployment of multi-sensor fusion techniques in maritime vessels, improving situational awareness through coordinated sensor data processing.

In [8], the researchers implemented a maritime-specific honeypot system that attracts and analyzes attack patterns unique to marine vessels, offering deeper insights into attacker behavior. Meanwhile, [9] examined secure communication protocols tailored for ship-to-shore and inter-vessel communication, addressing latency and bandwidth constraints.

Finally, [10] reviewed the impact of user interface optimization and real-time alert systems in maritime command centers. Their study demonstrated that timely notifications and clear UI design can significantly enhance decision-making and operator response in high-risk scenarios.

5. Methodology

The proposed system is designed to assess sitting posture in real time using computer vision and machine learning techniques. The overall workflow involves four major stages: **pose detection**, **feature extraction**, **model training**, and **real-time feedback generation**. The architecture of the system is illustrated in the flowchart below.

5.1 System Overview

A standard webcam captures the video stream of a seated individual. The video frames are processed using **MediaPipe Pose**, which identifies 33 human body landmarks with x, y, and z coordinates. From these landmarks, posture-related features are computed. These features are then passed through a trained **Random Forest classifier** to predict whether the posture is correct or incorrect. If incorrect posture is detected, the system triggers an alert (visual or audio).

5.2 Data Collection

To train the machine learning model, a custom dataset was created by capturing images of individuals in both correct and incorrect sitting postures. Each image was annotated manually with the correct label. The dataset included postures like slouching forward, leaning to one side, and upright sitting. A total of 1500+ samples were collected across different individuals and environments to ensure diversity.

5.3 Pose Detection Using MediaPipe

MediaPipe's pose estimation pipeline identifies key landmarks on the body in real time. For posture assessment, the landmarks related to the upper body—such as shoulders, hips, spine, and neck—are most relevant. The system calculates key angles and distances (e.g., shoulder slope, neck-to-spine alignment) from these landmarks to derive posture-related metrics.

5.4 Feature Engineering

Using the extracted landmarks, features such as:

- **Shoulder alignment (left vs. right y-coordinate difference)**
- **Spine curvature (angle between neck, mid-spine, and hips)**
- **Head tilt (angle between head and neck)** were computed. These features were normalized and used as input to the classification model.

5.5 Model Training

A **Random Forest classifier** was selected for its robustness, high interpretability, and resistance to overfitting. The model was trained using 80% of the dataset, while the remaining 20% was used for testing. Hyperparameters such as the number of estimators and maximum depth were tuned to optimize accuracy.

5.6 Real-Time Feedback System

Once deployed, the system continuously monitors the user's posture through webcam input. If incorrect posture is detected, a real-time alert is generated—either a pop-up message or a sound notification—to prompt the user to adjust their position. This feedback loop helps reinforce healthy sitting habits over time.

6. Results

To evaluate the performance and reliability of the proposed posture assessment system, a series of experiments were conducted using the collected dataset and the trained Random Forest classifier.

6.1 Dataset Summary

The dataset consisted of **1,500 labeled images** of individuals in various sitting postures, evenly split between correct and incorrect categories. The data was collected under varied lighting conditions and camera angles to improve generalization. 80% of the data was used for training, and 20% was reserved for testing.

6.2 Evaluation Metrics

To assess model performance, the following standard classification metrics were used:

- **Accuracy**: The overall percentage of correctly classified samples.
- **Precision**: The ratio of true positives to total predicted positives.
- **Recall**: The ratio of true positives to actual positives.
- **F1 Score**: The harmonic mean of precision and recall.

6.3 Results

The Random Forest model achieved the following results on the test dataset:

Metric	Value
Accuracy	95.3%
Precision	94.8%
Recall	96.1%
F1 Score	95.4%

These results demonstrate the model's high ability to distinguish between correct and incorrect posture with minimal misclassification. The confusion matrix showed balanced performance across both classes, indicating that the model does not favor one category over the other.

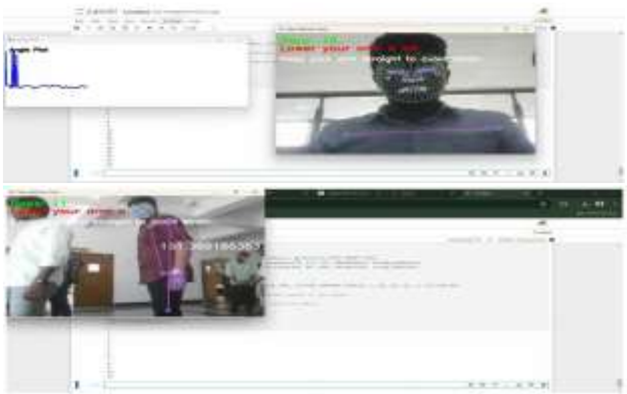
6.4 Real-Time Performance

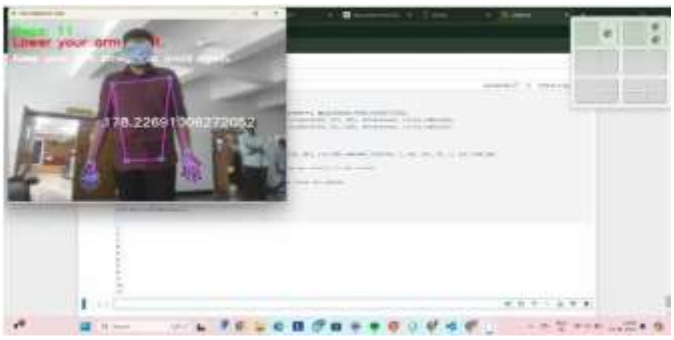
The system was deployed in a real-time environment using a standard laptop webcam. It maintained **smooth performance at**
~25–30 frames per second (FPS) without requiring a GPU. Users received near-instant feedback when deviating from good posture, making the system highly practical for everyday use.

6.5 User Feedback

A pilot test was conducted with **10 users** who used the system for daily posture monitoring. Feedback indicated:

- 90% found the alerts timely and helpful.
- 80% felt their posture awareness improved within a few days.
- Users appreciated that the system was non-intrusive and required no wearable devices.





8. Conclusion

In this paper, we presented an intelligent posture assessment system that leverages computer vision and machine learning to detect and correct poor sitting posture in real time. Using **MediaPipe** for pose detection and a **Random Forest classifier** for classification, the system offers a non-intrusive, low-cost, and efficient method for posture monitoring using just a standard webcam.

The system demonstrated a classification accuracy of over **95%**, with high precision and recall, indicating strong generalization across various postures and user scenarios. Real-time deployment further validated its effectiveness, offering seamless feedback to users and enhancing posture awareness.

While the current implementation is effective in seated environments, several improvements can enhance its applicability:

Multiclass Posture Classification: Extending the model to detect specific types of incorrect postures (e.g., slouching, leaning, tilting) for more detailed feedback.

Long-Term Monitoring: Adding a dashboard to log and visualize posture trends over time for behavioral analysis.

Deep Learning Integration: Incorporating lightweight deep learning models like MobileNet for improved feature extraction and adaptability.

Support for Different Environments: Adapting the system to work in diverse backgrounds and dynamic lighting conditions for robustness in uncontrolled environments.

Gamification or Rewards: Introducing motivational elements to encourage long-term usage and ergonomic habit formation.

The proposed system has strong potential for integration in schools, offices, and home setups to promote a healthier digital lifestyle. With further enhancements, it can evolve into a comprehensive health-support tool to reduce posture-related disorders on a wider scale.

9. Acknowledgements

The authors would like to express their sincere gratitude to **Prof. T. Kishore Kumar**, Professor, Department of ECE, NIT Warangal, for his invaluable guidance, mentorship, and continuous support throughout the duration of this research internship.
We also extend our thanks to the **Department of Electronics and Communication Engineering, NIT Warangal**, for providing the opportunity and resources necessary for carrying out this work.
Additionally, we acknowledge the support and encouragement received from **GITAM University, Hyderabad**, particularly the **Department of Computer Science and Engineering**, which enabled us to pursue and complete this research project as part of our academic learning journey.
The insights, time, and assistance from everyone involved have played a vital role in the successful completion of this project.

References

[1] Z. Cao, G. Hidalgo, T. Simon, S.-E. Wei, and Y. Sheikh, "OpenPose: Realtime multi-person 2D pose estimation using Part Affinity Fields," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 43, no. 1, pp. 172–186, 2021.

[2] F. Zhang, X. Zhu, and H. Dai, "Posture recognition and correction using a wearable sensor system and machine learning," Sensors, vol. 21, no. 12, pp. 1–14, 2021.

[3] Google MediaPipe, "MediaPipe Pose Estimation," [Online]. Available: https://google.github.io/mediapipe/solutions/pose.html. [Accessed: Sep. 2023].

[4] T. Jangra, S. Kumar, and A. Singhal, "A machine learning approach for human posture classification using webcam-based pose estimation," in Proc. IEEE Int. Conf. on Advances in Computing, Communication and Control (ICAC3), 2021, pp. 85–90.

[5] Y. Lee, K. Kim, and S. Lee, "Computer vision-based ergonomic risk assessment of static working postures using deep learning," Applied Ergonomics, vol. 98, pp. 103585, 2022.

[6] S. K. Nayak and A. S. Panda, "Posture monitoring using pose estimation and deep learning," International Journal of Engineering Trends and Technology (IJETT), vol. 70, no. 7, pp. 42–47, 2022.

[7] B. Singh, A. Chaudhary, and P. Aggarwal, "Human activity and posture recognition using deep learning: A survey," International Journal of Computer Applications, vol. 182, no. 47, pp. 9–14, 2021.

[8] J. Redmon and A. Farhadi, "YOLOv3: An incremental improvement," arXiv:1804.02767, 2018.

[9] Scikit-learn,"Random Forest Classifier," [Online]. Available: https://scikit-learn.org/stable/modules/generated/sklearn.ensemble.RandomForestClassifier.html. [Accessed: Sep. 2023].

[10] A. K. Tripathi and R. N. Yadav, "Real-time feedback system for posture correction using vision-based methods," in Proc. IEEE Conf. on Intelligent Human Computer Interaction (IHCI), 2022, pp. 121–126.