Enhanced Real-Time Gym Posture Monitoring and Correction System Using Multimodal Feedback and Personalized Recommendations

Santhosh Kumar Santhanam (21BCE1829)
B.tech in CSE
Vellore Institute of Technology
Chennai, India
santhosh.kumar2021@vitstudent.ac.in

Dennis Asir (21BCE1990)
B.tech in CSE
Vellore Institute of Technology
Chennai, India
dennis.asir2021@vitstudent.ac.in

Inban Azhagiri (21BCE5802)
B.tech in CSE
Vellore Institute of Technology
Chennai, India
inban.azhagiri2021@vitstudent.ac.in

Nikhil S. Shinde (21BCE1743)
B.tech in CSE
Vellore Institute of Technology
Chennai, India
nikhil.sshinde2021@vitstudent.ac.in

***Abstract*—This project introduces an innovative AI-driven Posture Recognition system designed for assessing injury risks during gym exercises. Leveraging advanced technologies such as computer vision and artificial intelligence, the system captures and analyzes the user's posture in real-time, providing immediate feedback to minimize the likelihood of injuries. Key components include pose estimation algorithms and machine learning models trained to recognize optimal and sub optimal postures. The proposed solution aims to enhance safety in gym workouts by offering personalized assessments, identifying potential risks, and suggesting corrective measures. The research explores the integration of this AI-driven system into gym environments to promote injury prevention and improve overall exercise effectiveness.**

***Index Terms*—AI-driven Posture Recognition, Injury Risk Assessment, Gym Exercises, Computer Vision, Machine Learning.**

I. Introduction

In the contemporary age of fitness, the integration of technology with health and wellness has led to the development of an AI-Based Virtual Gym Assistant, which is a significant leap forward. This innovative approach serves as a complete guide for fitness enthusiasts, offering real-time feedback, customized routines, and crucial injury prevention measures. By utilizing advanced technologies such as MediaPipe for precise pose detection through a camera feed, and Pyttsx3 for natural-sounding voice output, this virtual assistant bridges the gap between traditional gym training and cutting-edge AI solutions.

MediaPipe, a sophisticated tool for pose detection, enables the Virtual Gym Assistant to meticulously analyze the user's movements, ensuring proper form and technique during exercises. The real-time feedback feature of the system provides instant corrections to the users, which enhances the effectiveness of their workouts while minimizing the risk of injuries. Furthermore, Pyttsx3, a text-to-speech synthesis library, establishes a lifelike voice for the assistant, delivering clear and concise instructions tailored to each user's individual needs and preferences. This dynamic combination of technology not only facilitates a seamless user experience but also fosters engagement and motivation throughout the fitness journey.

Beyond its technical prowess, the AI-Based Virtual Gym Assistant represents a paradigm shift in how individuals approach exercise and wellness. By leveraging AI for personalized guidance and risk prevention, it empowers users to achieve their fitness goals with confidence and efficiency. Whether at home or in the gym, this virtual companion serves as a knowledgeable ally, adapting to the user's progress and preferences to deliver an unparalleled fitness experience. In an era where health is paramount, this fusion of AI and fitness heralds a new era of smart, accessible, and effective exercise guidance.

II. Contribution of the paper

The paper presents a pioneering solution that leverages the cutting-edge technologies of pose detection, natural language processing, and artificial intelligence to address critical challenges encountered by individuals engaging in physical activity. The study's contribution lies in its transformative impact on society's approach to fitness and wellness, which is achieved by enhancing exercise guidance, preventing injuries, and democratizing fitness opportunities.

The Virtual Gym Assistant significantly improves exercise guidance by providing real-time feedback and personalized routines that cater to individual needs and abilities. This level of customization fosters adherence to exercise regimens, leading to improved physical health outcomes and overall well-being. Furthermore, the integration of injury risk prevention measures ensures safer workout practices, reducing the likelihood of exercise-related injuries and promoting long-term engagement in physical activity.

The study's accessibility and convenience offered by the Virtual Gym Assistant democratizes fitness opportunities, making exercise guidance available to a broader segment of the population. By leveraging widely available technologies such as cameras and voice synthesis, the assistant transcends geographical and socioeconomic barriers, empowering users regardless of their location or resources.

Overall, the paper's contribution extends beyond technological innovation to encompass societal benefits, including improved public health outcomes, increased fitness participation, and enhanced quality of life for individuals of all ages and backgrounds. Through its integration of AI and fitness, the Virtual Gym Assistant represents a pivotal advancement in the pursuit of a healthier, more active society.

III. Literature Survey

This paper [1] introduces a machine learning-based posture classifier system to recognize exercise postures, addressing issues of pain and injury resulting from incorrect posture, particularly in the elderly. Using MediaPipe pose estimation, it achieves 100

Focusing on AI in fitness, this research [2] employs machine learning for human pose estimation in gym settings. By tracking joints, it aids in assessing gait cycles, athlete movements, and counting exercise repetitions during weightlifting. The Gym Tracker utilizes pose estimation to identify key points, measuring angles for accurate exercise monitoring, demonstrating potential applications in coaching and performance analysis.

Introducing a Gym Monitoring System using YOLOv5 and MediaPipe for deep learning-based activity monitoring and posture estimation, this paper [3] evaluates user behavior, optimizes exercise distances, and categorizes gym postures. By providing immediate feedback on joint angles, it aims to enhance exercise precision, comply with social distance norms, and revolutionize the fitness industry through the synergy of digital technology and physical activity.

Focusing on AI Gym Trainers, this research [4] proposes a robust posture estimation system using Mediapipe and OpenCV. Integrating these tools, it accurately assesses user postures in real-time, offering feedback and preventive measures to improve workout technique and prevent injuries. Tested on bicep curls, the system proves robust under various conditions, demonstrating potential as an effective AI-based fitness assistant.

Addressing current inefficiencies in exercise prescription methods, this paper [5] explores the integration of traditional Indian health techniques, Yoga, and meditation, with AI. It highlights the benefits of exercise in strengthening the immune system and reducing the risk of various diseases. Using a convolutional neural network, the system generates personalized exercise recommendations, aiming to promote health, lower healthcare costs, and combat sedentary behavior.

Focusing on human pose estimation using AI or machine learning, this paper [6] envisions a smart gym trainer software. By localizing joints in the human body through video or image analysis, it suggests applications such as analyzing gait cycles or tracking professional athletes. The proposed system aims to assist bodybuilders in achieving their fitness goals through intelligent guidance based on posture analysis.

This paper [7] explores the rising popularity of yoga during the COVID-19 lockdown, with a focus on AI integration in fitness apps. It highlights the use of artificial intelligence for personalized experiences in yoga apps and introduces an innovative concept of an AI-based Yoga Trainer, designed to remind, instruct, guide, and motivate users during their practice. The integration of AI in the fitness industry, including AI-enabled trainers and smart wearables, is gaining traction among health-conscious individuals. The study underscores the evolving role of AI in fostering physical and mental well-being through tech-driven fitness solutions.

This paper [8] introduces a novel human posture estimation system utilizing millimeter-wave (mmWave) radars. Designed for close-range detection (within two meters) in indoor environments, the system employs two mmWave radars and a neural network model. The neural network includes a part detector for joint position estimation and a spatial model capturing joint correlations. Real-time operation is enhanced with a temporal correlation step. Achieving 20 frames per second, the system provides accurate posture estimates with a mean localization error of 12.2 cm and an average precision of 71.3

This paper [9] addresses hand pose estimation from a single noisy depth image using a three-step pipeline. Operating efficiently at 12 frames per second with Kinect-type noisy depth images, the approach delivers accurate pose estimations for general motions.

This paper [10] introduces a Deep Neural Network (DNN)-based method for human pose estimation, framing it as a regression problem for body joints. Employing a cascade of DNN regressors, the approach yields high-precision pose estimates, leveraging holistic reasoning and benefiting from recent advancements in Deep Learning. Through empirical analysis, the method demonstrates state-of-the-art or superior performance on four real-world image benchmarks, showcasing its simplicity and effectiveness in achieving accurate human pose estimation.

This paper [11] introduces a real-time, single-view, range sensor-based approach for estimating and tracking articulated human poses. Employing a data-driven Markov Chain Monte Carlo (MCMC) method, it optimizes poses by comparing synthesized depth images to observed ones. Accelerating convergence, bottom-up detectors identify head, hand, and forearm candidates. Markov chain dynamics explore solutions around these parts, combining bottom-up and top-down processing. Achieving 10 frames per second, the algorithm outperforms a baseline ICP approach, as demonstrated through quantitative evaluations with annotated data. Additionally, the algorithm is adapted for subject-specific tracking by automatically estimating limb dimensions in short training sequences, yielding improved tracking performance.

This paper [12] explores the application of deep learning and machine learning techniques to satellite imagery for water monitoring, land cover, and tree cover visualization. Leveraging Python libraries like shapely, geopandas, and rasterio, the study focuses on analyzing data from Copernicus, World Bank's open data, and Landsat programs. The process involves defining regions of interest, downloading satellite imagery, cloud masking, extracting relevant features, and utilizing ground-truth data for reference. Detailed discussions on Python libraries and steps for analysis are provided, emphasizing the potential of machine learning insights for effective governance, decision-making, and policy formulation in Earth Observation applications.

This paper [13] introduces a novel facial key point estimation approach utilizing three-level convolutional networks for robust and accurate position estimation. The deep network structures enable extraction of global high-level features across the entire face, aiding precise key point localization during initialization. This approach leverages texture context information and implicitly encodes geometric constraints among key points, avoiding local minimum issues in challenging scenarios like occlusions, diverse poses, and extreme lighting. Subsequent levels refine initial predictions locally, limiting inputs to small regions. Experimental results demonstrate superior performance in both accuracy and reliability compared to existing state-of-the-art methods for facial point detection.

This paper [14] introduces PifPaf, a novel bottom-up approach for multi-person 2D human pose estimation, specifically tailored for urban mobility applications like self-driving cars and delivery robots. Leveraging Part Intensity Field (PIF) for body part localization and Part Association Field (PAF) for part association, the method excels in low resolution and challenging scenes through a composite field PAF encoding detailed information and Laplace loss for uncertainty incorporation. The fully convolutional, single-shot, box-free design proves effective, achieving performance comparable to the state-of-the-art on the COCO keypoint task and establishing new benchmarks in the transportation domain.

Realtime multi-person 2D pose estimation is a crucial task in computer vision, enabling machines to understand human activities in images and videos. The paper by Cao et al. presents OpenPose [15], a groundbreaking approach that achieves high accuracy and real-time performance in detecting the 2D pose of multiple people in images. OpenPose utilizes Part Affinity Fields (PAFs), a nonparametric representation, to associate body parts with individuals in the image. Unlike previous methods that refined both PAFs and body part locations simultaneously across training stages, OpenPose refines only PAFs, resulting in improved runtime performance and accuracy. Additionally, OpenPose introduces a combined body and foot keypoint detector, reducing inference time while maintaining accuracy. This release marks a milestone as the first open-source realtime system for multi-person 2D pose detection, covering body, foot, hand, and facial keypoints, making it a comprehensive tool for various applications in computer vision and human-computer interaction.

In this study [16], we present PostureCheck, a system designed for assessing exercise posture in physical therapy sessions. Utilizing the Microsoft Kinect camera, the system evaluates a person's upper body posture during exercises. PostureCheck employs Bayesian estimation and majority voting to classify sequences of postures as either correct or incorrect. Real-time recognition of incorrect postures is achieved, allowing immediate feedback to the user on corrective actions. The experiment demonstrates the system's effectiveness in identifying and addressing posture errors during exercise, highlighting its potential in enhancing physical therapy sessions.

This paper [17] introduces an AI-driven recommender system (RS) within a fitness assistance system (FAS) to guide both beginners and existing users. The RS employs Artificial Neural Network and Logistic Regression to predict suitable workouts for beginners. The agent, utilizing reinforcement learning in the Soar architecture, assists users in selecting workouts based on individual conditions. The paper aims to create an RS with learning, analysis, prediction, and communication abilities. Experimental results validate the utility application, showcasing the effectiveness of the proposed system in providing personalized workout suggestions and enhancing fitness support.

The fitness industry has expanded rapidly in recent years, with a significant portion of the population embracing regular training sessions. Alongside this growth, there has been a rise in gym and sports organizations offering technologically enhanced user-centric planning and management systems for sports activities. The fusion of fitness and technology has become increasingly prominent, particularly due to the impact of events like the COVID-19 pandemic, which emphasized the importance of home workouts. This paper by Thinh Nguyen

Truong et al. contributes to this domain by introducing a Deep Learning and Signal Processing-based system for pushup counting and evaluation. The system acts as a personal trainer for at-home workouts, providing real-time feedback to users to ensure correct push-up execution [18].

In response to the COVID-19 pandemic, this paper [19] introduces a real-time solution using YOLO object detection to enforce social distancing and mask-wearing in public. Achieving a mean average precision score of 94.75

This paper [20] introduces the Path Aggregation Network (PANet) to enhance information flow in proposal-based instance segmentation frameworks. PANet improves feature hierarchy by augmenting lower layers with accurate localization signals, shortening the path between lower and topmost features. Adaptive feature pooling facilitates direct propagation of valuable information from each level to subsequent proposal subnetworks. Additionally, a complementary branch captures diverse views for each proposal, enhancing mask prediction. These enhancements, requiring minimal computational overhead, propel PANet to 1st place in COCO 2017 Challenge Instance Segmentation and 2nd place in Object Detection tasks, demonstrating state-of-the-art performance on MVD and Cityscapes datasets without large-batch training.

The existing systems for posture monitoring and correction often face several drawbacks, including limited feedback, generic recommendations, lack of personalization, complexity, and a lack of real-time monitoring. Many systems provide basic visual cues or alarms, which may not effectively convey posture issues or corrective actions. Predefined exercises may not address individual needs, leading to low user engagement and motivation. Additionally, some systems are complex or require specialized equipment, limiting accessibility. The proposed work overcomes these drawbacks by providing enhanced feedback through real-time angle calculations and auditory feedback. It offers personalized suggestions using the ChatGPT API, ensuring tailored recommendations based on the user's specific posture dynamics. By leveraging widely accessible technology like MediaPipe's Pose Estimation model, the system is easy to implement without specialized equipment. Real-time monitoring capabilities allow users to receive immediate feedback during activities, promoting timely adjustments and corrections. Overall, the proposed system provides a comprehensive and user-friendly solution for posture monitoring and correction, addressing the limitations of existing systems with personalized, real-time feedback and recommendations.

IV. Proposed Methodology

A. Algorithms and Models Used

MediaPipe

MediaPipe is an open-source framework developed by Google Research for building cross-platform applications that process and analyze multimedia data such as video and audio. It provides a comprehensive set of tools and pre-built components for tasks like real-time pose estimation, hand tracking, object detection, and facial recognition. One of its key features is its versatility, enabling developers to easily integrate machine learning models and pipelines into their applications for tasks ranging from simple feature extraction to complex multi-modal analysis. MediaPipe's modular architecture and efficient implementation make it suitable for a wide range of use cases, from mobile and embedded devices to desktop and cloud environments. With its growing popularity and active community support, MediaPipe continues to evolve as a powerful tool for multimedia processing and machine learning applications.

LLM(OpenAI)

ChatGPT, a prominent example of Large Language Models (LLMs), epitomizes the transformative potential of these models in natural language understanding and generation. Trained on vast text corpora, ChatGPT harnesses sophisticated machine learning techniques to engage in human-like conversations, comprehend context, and generate coherent responses across a myriad of topics. LLMs, including ChatGPT, leverage their extensive knowledge and linguistic prowess to excel in a wide array of tasks, from text generation to sentiment analysis, revolutionizing human-computer interaction and paving the way for innovative applications across industries. However, their deployment also raises ethical considerations regarding biases and societal impact, underscoring the importance of responsible AI development and deployment. Nonetheless, the remarkable capabilities of ChatGPT and LLMs herald a new era in natural language processing, promising profound advancements in communication, knowledge dissemination, and user interaction.

B. Equations

Calculating Angles

The function calculateAngle(a, b, c) calculates the angle formed by the vectors ba and bc where a, b, and c are points in a 2D plane. This calculation is based on the mathematical representation of the angle between two vectors using the arctangent function and trigonometric properties.

Let a = (xa, ya), b = (xb, yb), and c = (xc, yc) be the coordinates of points a, b, and c respectively.

The vectors ba and bc are represented as follows:

$$ba = (xa - xb, ya - yb) \tag{1}$$

$$bc = (xc - xb, yc - yb) \tag{2}$$

Then, the angle between ba and bc can be calculated using the arctangent function as follows:

$$radians = atan2((yc - yb), (xc - xb)) - atan2((ya - yb), (xa - xb)) \tag{3}$$

Finally, the angle in degrees is obtained by converting radians to degrees:

$$angle = abs(radians180.0/\pi) \tag{4}$$

If the angle is greater than 180 degrees, it is adjusted to ensure it lies within the range of 0 to 180 degrees: if angle ¿ 180, then angle = 360 - angle

C. Architecture

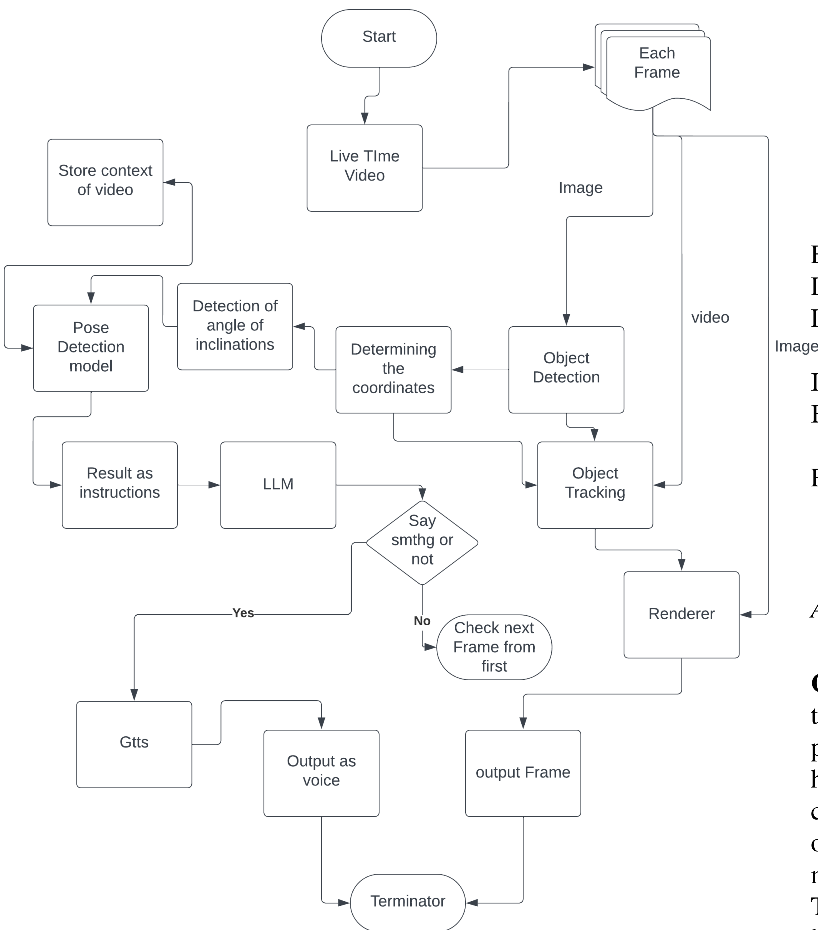

Fig. 1. Architecture Diagram

D. Pseudocode

Initialize VideoCapture from camera 0
Initialize Pose object from mediapipe with min_detection_confidence and min_tracking_confidence

Set flag bd to False

Initialize start_time with the current time
Loop until video capture is open:

- Read a frame from the video capture
- Convert frame to RGB color space
- Process the frame using the Pose object
- Convert the frame back to BGR color space

Try:

- Extract landmarks from the pose results
- Calculate angles for various body parts using calculateAngle function
- Display angles on the frame
- Check if time since start_time is greater than 2 seconds
- If right elbow angle is greater than 110 and bd is False:
  - Display ”Bad posture in Right ARM” message
  - Start a new thread to speak ”Bad Posture Detected”
  - Set bd to True
  - Update start_time with current time
- If right elbow angle is less than 110 and bd is True:
  - Set bd to False
- If left elbow angle is greater than 110:
  - Display ”Bad posture in Left ARM” message

End Try
Draw pose landmarks and connections on the frame
Display the frame

If ’q’ key is pressed:
Break out of the loop

Release the video capture and close all OpenCV windows

V. Results and Implementation

A. Dataset

Mediapipe Dataset
Coco
the COCO dataset, a groundbreaking resource designed to propel object recognition and scene understanding to new heights. By situating object recognition within the broader context of scene comprehension, COCO offers a collection of images capturing intricate everyday scenes, each brimming with common objects set in their natural environments. Through meticulous per-instance segmentations, precise object localization is facilitated. With an extensive catalog boasting 91 object types recognizable by a 4-year-old, COCO features a staggering 2.5 million labeled instances across 328,000 images. The dataset’s creation involved innovative crowd worker engagement via intuitive interfaces for category detection, instance spotting, and instance segmentation. A comprehensive statistical analysis comparing COCO to benchmarks like PASCAL, ImageNet, and SUN underscores its significance. Additionally, baseline performance evaluations utilizing a Deformable Parts Model illuminate the dataset’s potential for bounding box and segmentation detection advancements.
ChatGPT Dataset
The Common Crawl dataset consists of web pages crawled from the internet. It includes a wide variety of content, such as text, images, and metadata, from different domains and

languages. Common Crawl provides this dataset to the public for various purposes, including research, analysis, and machine learning

Graphs

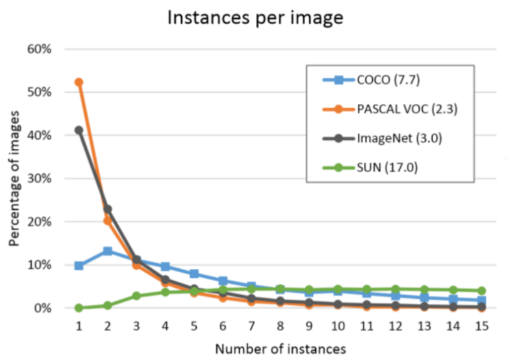

Fig. 2. Number of Instances

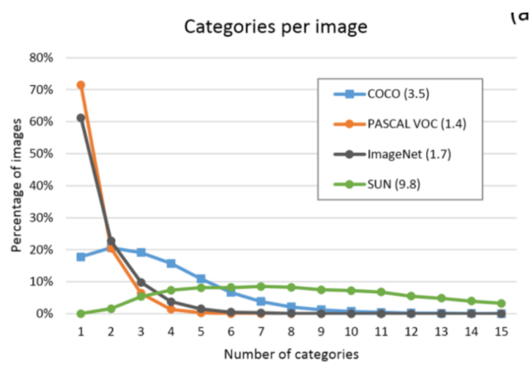

Fig. 3. Number of Categories

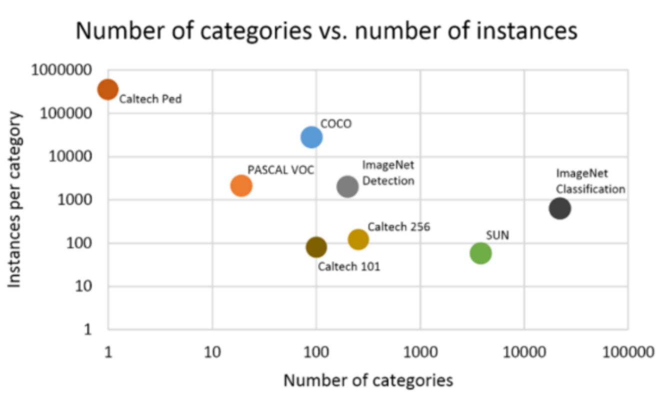

Fig. 4. Number of Categories vs. Number of Instances

Books Used For Training LLM Regarding Fitness

- The Complte Fitness: https://www.clemson.edu/business/departments/army-rotc/documents/fitness-handbook.pdf

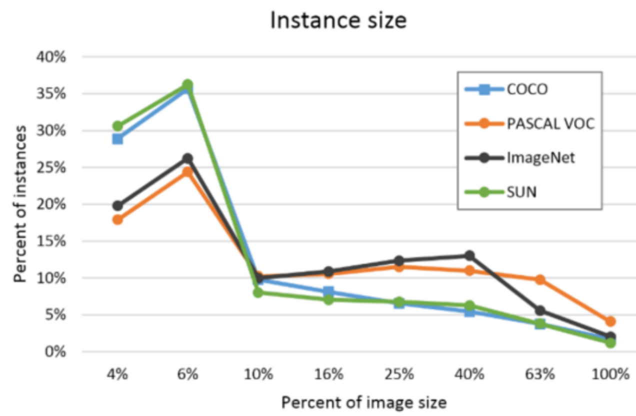

Fig. 5. Percentage Image Size

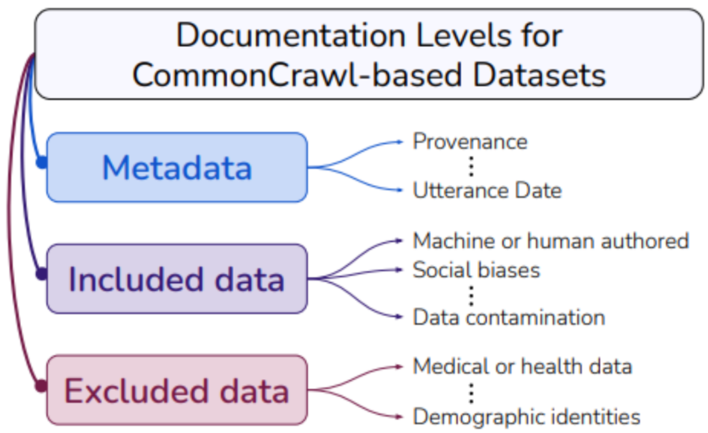

Fig. 6. CommonCrawl Dataset

- Health and Fitness: https://www.uakron.edu/armyrotc/MS1/15.pdf

B. Implementation

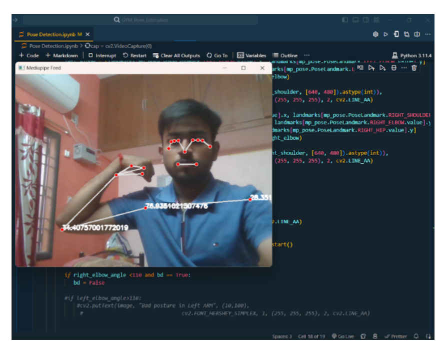

Fig. 7. Good Posture for Bicep Curl

VI. Conclusion

In conclusion, the integration of MediaPipe's Pose Estimation model, real-time angle calculations, and feedback

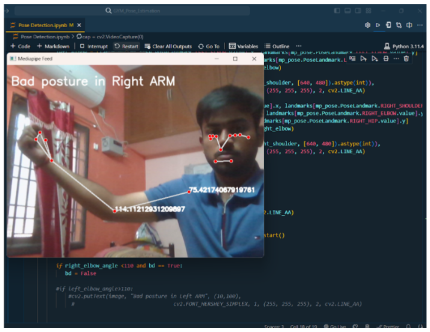

Fig. 8. Bad Posture for Bicep Curl

mechanisms like pyttsx3 presents a powerful solution for posture monitoring and correction. By accurately detecting human poses and analyzing critical joint angles, the system can provide timely feedback to users, helping them maintain correct posture during exercises or daily activities.

Moreover, the potential integration of the ChatGPT API adds another layer of personalization and interactivity to the system. With ChatGPT, users can receive tailored suggestions and reminders based on their specific posture dynamics, enhancing their overall posture correction experience.

This combined approach not only promotes better ergonomics and posture but also contributes to overall health and well-being, whether in professional or home environments. As technology continues to advance, such innovative solutions hold great promise in improving human-computer interaction and enhancing the quality of life.

REFERENCES

[1] W. Supanich, S. Kulkarineetham, P. Sukphokha, "Machine Learning-Based Exercise Posture Recognition System Using MediaPipe Pose Estimation Framework" in 2023 9th International Conference on Advanced Computing and Communication Systems (ICACCS), (March 2023), Publisher: IEEE

[2] N. Faujdar, S. Saraswat, S. Sharma, "Human Pose Estimation Using Artificial Intelligence with Virtual Gym Tracker" in 2023 6th International Conference on Information Systems and Computer Networks (ISCON), (March 2023), Publisher: IEEE

[3] R. Renugadevi, P. Arul, V. Subashree, "Deep Learning-Based GYM Monitoring System Using YOLOv5 and Pose Estimation Algorithm", in 2023 7th International Conference on Electronics, Communication, and Aerospace Technology (ICECA), (November 2023), Publisher: IEEE

[4] V. S. P. Bhamidipati, I. Saxena, D. Saisanthiya, "Robust Intelligent Posture Estimation for an AI Gym Trainer Using MediaPipe and OpenCV" in 2023 International Conference on Networking and Communications (ICNWC), (April 2023), Publisher: IEEE

[5] M. Balpande, J. Sharma, A. Nair, "AI Based Gym Trainer and Diet Recommendation System" in 2023 IEEE 4th Annual Flagship India Council International Subsections Conference (INDISCON), (October 2023), Publisher: IEEE

[6] G. Dsouza, D. Maurya, A. Patel, "Smart Gym Trainer Using Human Pose Estimation" in 2020 IEEE International Conference for Innovation in Technology (INOCON), (November 2020), Publisher: IEEE

[7] V. Agarwal, K. Sharma, A. K. Rajpoot, "AI Based Yoga Trainer - Simplifying Home Yoga Using Mediapipe And Video Streaming" in 2022 3rd International Conference for Emerging Technology (INCET), (May 2022), Publisher: IEEE

[8] H. Cui, N. Dahnoun, "Real-Time Short-Range Human Posture Estimation Using Mmwave Radars And Neural Networks" in IEEE Sensors Journal vol 22, issue 1, pg: 535 – 543 January 2022, Publisher: IEEE

[9] C. Xu, L. Cheng, "Efficient Hand Pose Estimation From A Single Depth Image" in 2013 IEEE International Conference on Computer Vision, (December 2013), Publisher: IEEE

[10] A. Toshev, C. Szegedy, "DeepPose: Human Pose Estimation Via Deep Neural Networks" in 2014 IEEE Conference on Computer Vision and Pattern Recognition, (June 2014), Publisher: IEEE

[11] M. Siddiqui, G. Medioni, "Human Pose Estimation From A Single View Point, Real-Time Range Sensor" in 2010 IEEE Computer Society Conference on Computer Vision and Pattern Recognition – Workshops, (June 2010), Publisher: IEEE

[12] A. Yadav, S. Saraswat, N. Faujdar, "Geological Information Extraction From Satellite Imagery Using Machine Learning" in 2022 10th International Conference on Reliability, Infocom Technologies and Optimizations (Trends and Future Directions) (ICRITO), (October 2022), Publisher: IEEE

[13] Y. Sun, X. Wang, X. Tang, "Deep Convolution Network Cascade for Facial Point Detection" in 2013 IEEE Conference on Computer Vision and Pattern Recognition (June 2013), Publisher: IEEE

[14] S. Kreiss, L. Bertoni, A. Alahi, "PifPaf: Composite Fields for Human Pose Estimation" in 2019 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), (June 2019), Publisher: IEEE

[15] Z. Cao, G. Hidalgo, T. Simon, S. -E. Wei and Y. Sheikh, "OpenPose: Realtime Multi-Person 2D Pose Estimation Using Part Affinity Fields," in IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 43, no. 1, pp. 172-186, 1 Jan. 2021, doi: 10.1109/TPAMI.2019.2929257. keywords: Two dimensional displays;Pose estimation;Detectors;Runtime;Kernel;Training;2D human pose estimation;2D foot keypoint estimation;real-time;multiple person;part affinity fields,

[16] E. Saraee, S. Singh, A. Joshi "PostureCheck: Posture Modeling For Exercise Assessment Using The Microsoft Kinect", in 2017 International Conference on Virtual Rehabilition (ICVR) ,(June 2017), Publisher: IEEE

[17] T. Tran, J. W. Choi, J. W. Kim "Recommender System with AI for Fitness Assistance System" in 2018 15th International Conference on Ubiquitous Robots (UR), (June 2018), Publisher: IEEE

[18] T. N. Truong, N. N. Xuan, T. N. Quoc and V. T. Hoang, "Pushup Counting and Evaluating Based on Human Keypoint Detection," 2022 9th NAFOSTED Conference on Information and Computer Science (NICS), Ho Chi Minh City, Vietnam, 2022, pp. 129-133, doi: 10.1109/NICS56915.2022.10013431. keywords: Performance evaluation;Industries;Deep learning;COVID-19;Training;Computational modeling;Sociology;Push-ups;Low pass filter;Human Exercises,

[19] K. Bhambani, T. Jain, K. A. Sultanpure "Real-time Face Mask and Social Distancing Violation Detection System using YOLO" in 2020 IEEE Bangalore Humanitarian Technology Conference (B-HTC), (October 2020), Publisher: IEEE

[20] S. Liu, L. Qi, H. Qin, "Path Aggregation Network for Instance Segmentation" in 2018 IEEE/CVF Conference on Computer Vision and Pattern Recognition, (June 2018), Publisher: IEEE

[21] Lugaresi, Camillo & Tang, Jiuqiang & Nash, Hadon & McClanahan, Chris & Uboweja, Esha & Hays, Michael & Zhang, Fan & Chang, Chuo-Ling & Yong, Ming & Lee, Juhyun & Chang, Wan-Teh & Hua, Wei & Georg, Manfred & Grundmann, Matthias. (2019). MediaPipe: A Framework for Building Perception Pipelines.

[22] Lin, TY. et al. (2014). Microsoft COCO: Common Objects in Context. In: Fleet, D., Pajdla, T., Schiele, B., Tuytelaars, T. (eds) Computer Vision – ECCV 2014. ECCV 2014. Lecture Notes in Computer Science, vol 8693. Springer, Cham. https://doi.org/10.1007/978-3-319-10602-1_48

[23] Dodge, Jesse et al. "Documenting Large Webtext Corpora: A Case Study on the Colossal Clean Crawled Corpus." Conference on Empirical Methods in Natural Language Processing (2021).