AI-Based Virtual Gym Assistant for Exercise Guidance and Injury Risk Prevention

BCSE306L – ARTIFICIAL INTELLIGENCE

SLOT – C1 + TC1

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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 suboptimal 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.

Keywords: AI-driven Posture Recognition, Injury Risk Assessment, Gym Exercises, Computer Vision, Machine Learning.

Literature Review

Machine Learning-Based Exercise Posture Recognition System Using MediaPipe Pose Estimation Framework
LINK: https://ieeexplore.ieee.org/document/10112726

This paper 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% accuracy in detecting postures from video data, offering an affordable alternative to personal trainers for monitoring and correcting body postures during exercise.

Human Pose Estimation using Artificial Intelligence with Virtual Gym Tracker
LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/10112064

Focusing on AI in fitness, this research 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.

Deep Learning-Based GYM Monitoring System using YOLOv5 and Pose Estimation Algorithm

LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/10394921

Introducing a Gym Monitoring System using YOLOv5 and MediaPipe for deep learning-based activity monitoring and posture estimation. This system 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.

Robust Intelligent Posture Estimation for an AI Gym Trainer using Mediapipe and OpenCV

LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/10127264

Focusing on AI Gym Trainers, this research 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.

AI-Based Gym Trainer and Diet Recommendation System

LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/10270066

Addressing current inefficiencies in exercise prescription methods, this paper 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.

Smart gym trainer using Human pose estimation

LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/9298212

Focusing on human pose estimation using AI or machine learning, this paper 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.

AI based Yoga Trainer - Simplifying home yoga using mediapipe and video streaming

LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/9824332

This paper 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.

Real-Time Short-Range Human Posture Estimation Using mmWave Radars and Neural Networks

LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/9614192

This paper 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 approach leverages mmWave radar advantages for high-resolution, non-intrusive human activity recognition.

Efficient Hand Pose Estimation from a Single Depth Image

LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/6751541

This paper addresses hand pose estimation from a single noisy depth image using a three-step pipeline. It begins with an initial estimation of hand orientation and 3D location, followed by candidate generation from a Hough voting space using rotational invariant depth features. The final 3D hand pose is determined through optimization. The method

analyzes depth noise, offering tips to mitigate its impact. Operating efficiently at 12 frames per second with Kinect-type noisy depth images, the approach delivers accurate pose estimations for general motions. Comparative experiments demonstrate its competitiveness with or even superiority to state-of-the-art methods utilizing additional RGB images.

DeepPose: Human Pose Estimation via Deep Neural Networks
LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/6909610

This paper 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.

Human pose estimation from a single view point, real-time range sensor
LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/5543618

This paper 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.

Geological Information Extraction from Satellite Imagery Using Machine Learning
LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/9964623

This paper 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.

Deep Convolution Network Cascade for Facial Point Detection ***LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/6619290***

This paper 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.

PifPaf: Composite Fields for Human Pose Estimation
LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/8953198

This paper 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.

Human pose estimation from a single view point, real-time range sensor. LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/ document/5543618

This paper presents a real-time, single-view, range sensor-based system for estimating and tracking articulated human poses. Utilizing a data-driven Markov Chain Monte Carlo (MCMC) approach, it optimizes poses by comparing synthesized depth images to observed ones. The convergence speed is enhanced by bottom-up detectors generating candidate head, hand, and forearm locations, combining bottom-up and top-down processing. Achieving 10 frames per second, the algorithm exhibits substantial improvement over a baseline ICP approach, quantitatively validated with hand-annotated data. Furthermore, the algorithm is adapted for subject-specific tracking, automatically estimating limb dimensions in short training sequences, and its tracking performance is quantitatively evaluated using person-specific trained models.

Elham Saraee, Saurabh Singh, Ajjen Joshi and Margrit Betke, PostureCheck: Posture Modeling for Exercise Assessment Using the Microsoft Kinect, 2017.
LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/10270066/references#references

In this study, 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.

T. Tran, Jea-Won Choi and Jong-Wook Kim, "Recommender System with AI for Fitness Assistance System", *International Conference on Ubiquitous Robots(UR)*, 2018.
LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/10270066/references#references

This paper 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.

Real-Time Feedback&injury Prevention

LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/10394921

Presenting a revolutionary GYM Monitoring System utilizing deep learning techniques, YOLOv5 for activity monitoring, and MediaPipe for posture estimation. In the first phase, bounding box and Euclidean distance assess user behavior, ensuring adherence to social distance norms. The second phase employs keypoint detection to determine joint angles, categorizing gym postures and offering instant feedback. This system enhances exercise precision, minimizes overuse injuries, and ensures compliance with social distancing. By seamlessly blending digital technology with physical activity, it heralds a groundbreaking era in the fitness industry, setting new standards for safety and performance.

Real-time Face Mask and Social Distancing Violation Detection System using YOLO

LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/9297902

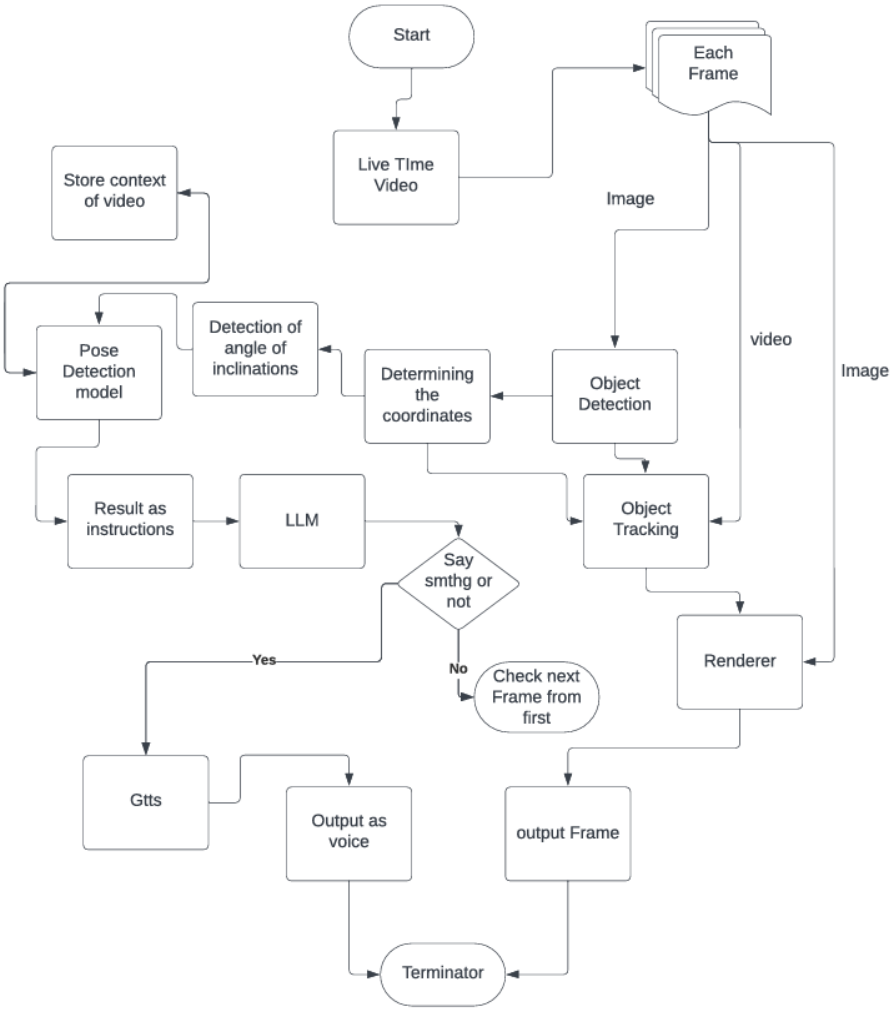
In response to the COVID-19 pandemic, this paper introduces a real-time solution using YOLO object detection to enforce social distancing and mask-wearing in public. Following WHO guidelines of maintaining 3ft or 1m distance, the proposed model exhibits superior robustness and detection speed compared to competitors. Achieving a mean average precision score of 94.75% and an impressive 38 FPS on video, the system ensures real-time accuracy in complex scenarios. The method proves effective in detecting masked faces and human subjects, offering a practical tool for enforcing preventive measures and contributing to public health during the ongoing pandemic.

Path Aggregation Network for Instance Segmentation

LINK: https://ieeexplore-ieee-org.egateway.chennai.vit.ac.in/document/8579011

This paper 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.

Architecture Diagram



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