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POSEPERFECT: An Advanced Platform for Real Time Exercise Monitoring, Pose Estimation, and Correction

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ABSTRACT:

This research project focuses on the development of an innovative website dedicated to exercise pose estimation and correction, incorporating state-of-the-art models MediaPipe for accurate pose estimation, and employing KNN, RandomForest, and CNN models for posture prediction. The objective is to create a comprehensive platform catering to a diverse range of exercises, including gym workouts, standard exercises. The website utilizes cutting-edge pose estimation models MediaPipe, to precisely track key body landmarks and movements during real-time exercises. These models provide a robust foundation for analyzing and understanding user postures, ensuring accurate feedback and correction guidance. To enhance the user experience, posture prediction models, including KNN, RandomForest, and CNN, are employed to predict and correct exercise postures dynamically. This multifaceted approach not only ensures real-time feedback but also assists users in achieving optimal form during gym exercises, regular workouts, and yoga sessions. The website serves as a user-friendly interface, providing visual and audio cues for posture correction and exercise guidance. With a focus on inclusivity, the platform covers a wide spectrum of exercises to accommodate users with diverse fitness preferences. This project envisions a holistic and technologically advanced solution for exercise monitoring and correction, empowering users to engage in effective workouts with confidence and precision. The integration of multiple pose estimation and prediction models, coupled with the versatility of exercise options, positions this website as a comprehensive tool for individuals seeking a tailored and supportive approach to their fitness journey.

Keywords: MediaPipe, Convolutional neural network (CNN), K-Nearest Neighbors(KNN), MS Coco dataset, Machine Learning, Deep neural network

Introduction:

The integration of gym exercises, accompanied by technological advancements, has paved the way for a comprehensive approach to fitness. This amalgamation acknowledges the significance of physical well-being across various domains of life while leveraging innovative solutions to optimize workout routines. However, amidst this evolution, the challenge of potential injuries persists, highlighting the importance of precise body postures.

The Gym Exercise Pose Correction Model project represents a significant stride towards addressing this challenge. By harnessing cutting-edge machine learning methodologies, this initiative seeks to not only rectify posture discrepancies but also revolutionize injury prevention strategies. The project's core objective is to redefine the fitness landscape by offering real-time feedback on body postures during exercises, thereby fostering a safer and more effective workout environment.

In the realm of fitness and physical well-being, the significance of proper body posture cannot be overstated. Optimal posture not only enhances the effectiveness of workouts but also plays a pivotal role in injury prevention. Pose estimation and correction have emerged as indispensable tools in this pursuit, leveraging advanced algorithms and models to assess, analyze, and refine the alignment of body joints and positions in real-time.

By integrating these techniques into fitness routines, individuals can benefit from personalized guidance and feedback, ensuring that they perform exerciseswith precision and safety. This proactive approach not only minimizes the risk of injuries but also empowers individuals to optimize their workouts, thereby facilitating progress towards their fitness goals. Furthermore, the utilization of state-of-the-art tools underscores the commitment to innovation within the fitness industry.

By staying at the forefront of technological advancements, the Gym Exercise and Yogasanas Pose Correction Model project not only addresses existing challenges but also anticipates future needs, thereby setting a new standard for holistic fitness solutions. In essence, this transformative journey represents a paradigm shift in how we approach fitness, blending traditional practices with contemporary technology to create a more inclusive, accessible, and effective exercise experience. Through continuous refinement and innovation, initiatives like the Gym Exercise and Yogasanas Pose Correction Model project are shaping the future of fitness, empowering individuals to lead healthier, happier lives.

Pose Estimation:

Pose estimation involves the identification of key points or joints in the human body during various movements or postures. Advanced computer vision techniques, such as those employed by models like OpenPose and PoseNet, enable the detection of key body landmarks like shoulders, elbows, knees, and ankles. The output is a detailed representation of the body's skeletal structure, providing insight into the user's current pose. This technology can be applied to static images, recorded videos, or live camera feeds, making it adaptable to diverse scenarios.

Significance for Exercise Monitoring:

Integrating pose estimation and correction into exercise monitoring systems adds a dynamic layer of interaction and personalization. Users can receive visual or auditory cues, aiding them in real-time adjustments for better performance and reduced injury risks. The fusion of technology and fitness exemplified by these techniques exemplifies a proactive approach to personalized and effective exercise regimens, promoting overall health and wellness. As advancements continue, pose estimation and correction stand poised to revolutionize the way individuals engage with their fitness routines, fostering a more informed, interactive, and results-driven approach to physical activity.

Dataset:

The success of any AI model hinges on the quality of its training data. Our project is dedicated to developing a robust pose estimation and correction system tailored for gym-goers, with the primary goal of averting injuries resulting from improper posture and heavy lifting. To achieve this, we have meticulously curated a unique dataset comprising video recordings sourced from diverse channels, ensuring a comprehensive and accurate model.

Human bodies exhibit a wide spectrum of shapes and sizes, influenced by genetics, lifestyle, and age-related changes. From adolescence to older adulthood, significant transformations occur, impacting muscle mass, bone density, and metabolic rates. Leveraging this understanding, our dataset includes concise video clips showcasing various gym exercises, providing a clear view of form execution across different age groups and fitness levels. Utilizing cutting-edge technology like MediaPipe, our system extracts vital information from these videos, precisely identifying key body joints crucial for movement. Each video frame undergoes meticulous keypoint detection, generating a detailed dictionary capturing the X, Y, and Z coordinates of each joint. This comprehensive representation allows for a thorough analysis of joint placement and movement patterns throughout the exercise routine, ensuring precise correction guidance.

Moreover, by leveraging the rich keypoint data, our system delves into human kinematics, calculating dynamic angles between body segments. Focusing on pivotal joints like ankles, knees, hips, shoulders, and elbows, we construct a detailed map of joint angles, offering insights into biomechanical aspects of exercise execution.

This intricate analysis enables us to provide real-time feedback on posture adjustments, enhancing users' understanding and performance while mitigating injury risks. In summary, our project integrates advanced technology with comprehensive data analysis to deliver a robust pose estimation and correction system tailored for gym enthusiasts of all ages and fitness levels. By prioritizing accuracy, clarity, and real-time feedback, we aim to empower users to exercise safely and effectively, promoting overall well-being and fitness.

Purpose of Project:

PosePerfect stands as a pioneering platform designed to transform exercise monitoring, pose estimation, and correction in real-time. At its core, PosePerfect endeavors to provide users with unparalleled insights into their workouts through sophisticated sensor technologies, such as motion capture and wearable devices. By meticulously tracking and recording users' movements during exercise routines, PosePerfect offers a window into their performance, facilitating progress tracking and ensuring adherence to proper form and technique.

Moreover, PosePerfect's advanced computer vision algorithms and machine learning techniques enable precise pose estimation, identifying and tracking key body landmarks and joints in real-time. This capability not only enhances user’s awareness of their posture and alignment but also lays the foundation for real-time feedback and correction mechanisms. Through instant detection of deviations from proper form, PosePerfect delivers personalized feedback, be it visual cues, audio prompts, or haptic feedback, aiding users in optimizing their technique and minimizing the risk of injury.

- Real-time Exercise Monitoring: PosePerfect employs advanced sensor technologies like motion capture or wearable devices to track and record users' movements during workouts in real-time. This feature enables users to monitor their performance, track progress, and ensure proper form and technique adherence.
- Pose Estimation: Using computer vision algorithms and machine learning, PosePerfect accurately estimates users' poses by analyzing input from cameras or sensors. It identifies and tracks key body landmarks and joints, providing detailed feedback on posture and alignment during exercises.
- Pose Correction: Beyond estimation, PosePerfect offers real-time feedback and correction mechanisms. Its algorithms detect deviations from proper form and provide instant feedback through visual cues, audio prompts, or haptic feedback, aiding users in maintaining correct posture.
- Performance Analysis and Feedback: PosePerfect provides comprehensive performance analysis, including metrics like range of motion, stability, personalized recommendations to optimize users' workouts for effectiveness and safety.

- Customization and Adaptability: PosePerfect is highly customizable to cater to individual needs, whether users are beginners or advanced athletes. It adapts feedback strategies dynamically based on users' progress, performance history, and fitness goals, ensuring relevance and effectiveness.

Methodology:

1. MODEL DEVELOPMENT AND WORKING:

1.1 Dataset Collection and Creation:

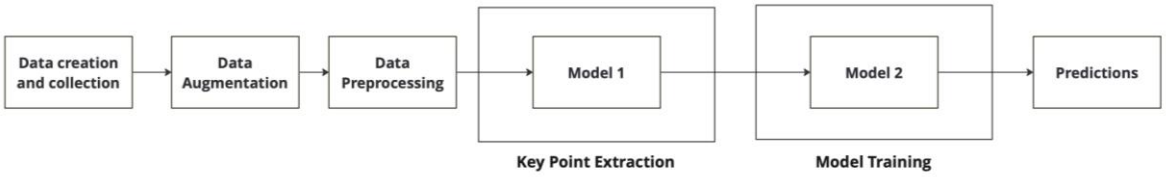

Figure: Model Training Pipeline

For dataset, we obtained videos featuring 18 different exercise (Barbell Bench Press, Barbell Deadlift, Dumbbell Bicep Curl, Pull ups, Leg Press, Lat Pulldown, Chest Dip, Overhead Shoulder Press, Leg Curl, Face Pull, Cable Crossover, Battle Rope Wave, Dumbbell Flyes, Leg Extension, Military Press, Smith Machine Lunges) comprising 15 correct posture videos (600 images each) and 8 wrong posture videos (300 images each) of duration 5 to 15 seconds. This process generated a comprehensive dataset of exercise related images, providing a diverse representation of various movements and postures.

1.2 Keypoint Dataset Extraction:

Utilizing MediaPipe's advanced pose estimation model, we extract keypoint information from the exercise image dataset, comprising 33 keypoints per frame. MediaPipe precisely identifies major joints, providing X, Y, and Z coordinates for each keypoint and a visibility factor to account for occlusions. This detailed dictionary acts as a blueprint for pose analysis, enabling comprehensive assessment of joint placement and movement dynamics throughout the exercise. A keypoints dataset is created having 16,200 rows in the csv file. The csv file is having columns:
[‘Pose', ‘Category', ‘Path', ‘Orientation', ‘View', ‘MOUTH_LEFT', ‘MOUTH_RIGHT', ‘LEFT_SHOULDER',' RIGHT_SHOULDER’, ‘LEFT_ELBOW', ‘RIGHT_ELBOW',' LEFT_WRIST’, ‘RIGHT_WRIST', ‘LEFT_PINKY', ‘RIGHT_PINKY', ‘LEFT_INDEX', ‘RIGHT_INDEX', ‘LEFT_THUMB', ‘RIGHT_THUMB', ‘LEFT_HIP', ‘RIGHT_HIP', ‘LEFT_KNEE', ‘RIGHT_KNEE', ‘LEFT_ANKLE', ‘RIGHT_ANKLE', ‘LEFT_HEEL', ‘RIGHT_HEEL', ‘LEFT_FOOT_INDEX', ’RIGHT_FOOT_INDEX’]

1.3 Joint Angle Dataset Extraction:

We outline the process of extracting a joint angle dataset from the keypoint information obtained using MediaPipe. Specifically, we focus on calculating angles between key joints crucial for understanding body movement during exercises. Let A (x1, y1), B (x2, y2) and C (x3, y3) be the coordinates of points A, B, and C, respectively.

Distances between these points:

$$AB = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

$$BC = \sqrt{(x_3 - x_3)^2 + (y_3 - y_3)^2}$$

$$AC = \sqrt{(x_3 - x_1)^2 + (y_3 - y_1)^2}$$

Calculating angle:

$$\angle(rad) = \arccos\left(\frac{AB^2 + BC^2 - AC^2}{2 \cdot AC \cdot BC}\right)$$

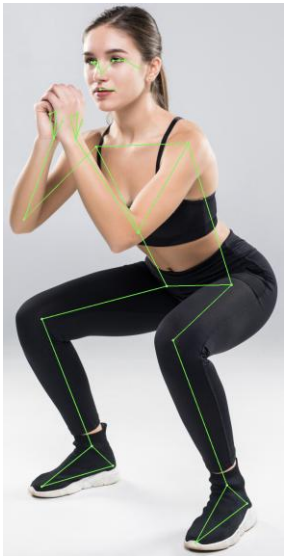

Figure: Keypoints (Joints)

Additionally, we introduce a novel approach where we derive the left-perpendicular-point from the intersection of the x-coordinate of the left hip and the y-coordinate of the left shoulder. Similarly, the right-perpendicular-point is determined by the intersection of the x-coordinate of the right hip and the y-coordinate of the right shoulder. This innovative method enhances the granularity of our dataset, providing additional insights into the biomechanics of exercise execution and movement patterns. This innovative method enhances the granularity of our dataset, providing additional insights into the biomechanics of exercise execution and movement patterns.

Table: Joint Angle Calculation

JOINT NAME	JOINT 1	JOINT 2	JOINT 3
Left-ankle	Left-foot-index	Left-ankle	Left-knee
Right-ankle	Right-foot-index	Right-ankle	Right-knee
Left-knee	Left-hip	Left-knee	Left-ankle
Right-knee	Right-hip	Right-knee	Right-ankle
Hip	Left-knee	Hip	Left-shoulder
Left-torso	Left-shoulder	Left-torso	Left-perpendicular-point
Right-torso	Right-shoulder	Right-torso	Right-perpendicular-point
Left-shoulder	Left-hip	Left-shoulder	Left-elbow
Right-shoulder	Right-hip	Right-shoulder	Right-elbow
Left-elbow	Left-wirst	Left-elbow	Left-shoulder
Right-elbow	Right-wrist	Right-elbow	Right-shoulder
Left-wrist	Left-idex	Left-wrist	Left-elbow
Right-wrist	Right-index	Right-wrist	Right-elbow

1.3 Training Models:

We proceed to train our models using the joint angle dataset, comprising essential columns such as Pose, Category, Path, Orientation, View, LEFT-ANKLE, RIGHT-ANKLE, LEFT-KNEE, RIGHT-KNEE, HIP, LEFT-TORSO, RIGHT-TORSO, LEFT-SHOULDER, RIGHT-SHOULDER, LEFT-ELBOW, RIGHT-ELBOW, LEFT-WRIST, RIGHT-WRIST, OUTPUT, WRONG. Notably, the dataset includes an "OUTPUT" column denoting correctness, where a value of 1 signifies a correct pose classification and 0 indicates otherwise, represented by "1" and "0" respectively.

Leveraging this labeled dataset, we train three distinct models: K-Nearest Neighbors (KNN), Random Forest, and a self-built Convolutional Neural Network (CNN). Through extensive training on this comprehensive dataset, each model learns to accurately classify exercise poses, paving the way for robust and effective automated exercise monitoring and analysis. Also, the ‘WRONG’ column includes the wrong joints to help the model to predict wrong joints.

WEBSITE DEVELOPMENT AND WORKING:

2.1 Frontend:

Development of POSEPERFECT websites user interface begins with a thorough understanding of the project requirements. This includes detailed discussions with stakeholders to identify key features such as the Homepage layout, authentication system, user profile management, and exercise categories.

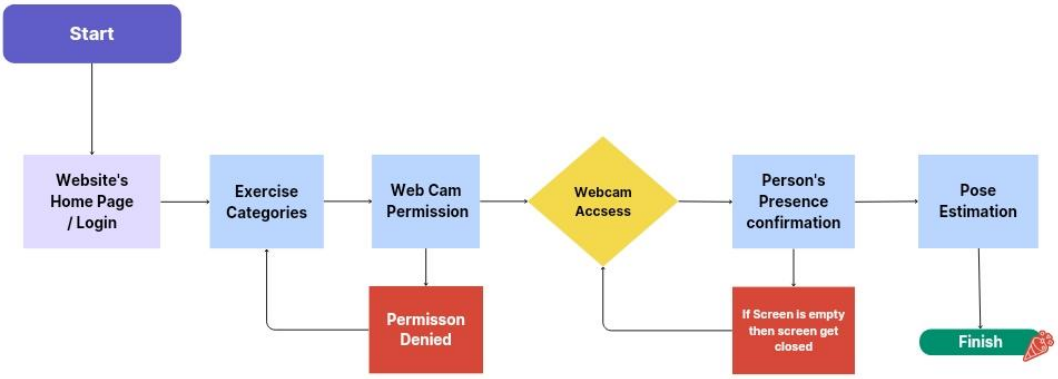

Figure: Website Working

2.2 Backend:

Django is used to build the backend of web applications. It handles data models, business logic, and provides a RESTful API using Django REST Framework (DRF) models define the structure of data stored in the database. Views handle incoming requests and return responses, often in the form of JSON data. Serializers in DRF convert complex data types, such as querysets and model instances, to native Python datatypes. They are crucial for processing data to and from JSON format, making it easy to work with data in the frontend. React.js is utilized for the frontend of the web application. It handles user interface components and interactions. Components in React.js are reusable building blocks that encapsulate a piece of UI functionality. They can fetch data from the backend via AJAX requests to Django's RESTful API.

Results

Result of Models:

The models, including KNN, Random Forest, and CNN, were trained and evaluated on a dataset comprising 16,200 rows and 16 features. Each model underwent rigorous testing to assess its performance in accurately predicting exercise poses and detecting anomalies in posture. Through meticulous analysis, the models showcased varying degrees of effectiveness in capturing the intricate nuances of human movement, with CNN demonstrating promising capabilities in leveraging spatial information for pose estimation.

Table: Accuracy of Random forest, KNN, and CNN models

MODEL	TRAINING ACCURACY	TESTING ACCURACY
Random Forest	81.2%	82.5%
KNN	80.7%	65.7%
CNN	92.75%	90.48%

Obtained Result in Real Time:

In real-time monitoring, the PosePerfect system accurately tracks and evaluates the execution of dumbbell bicep curls. It provides instant feedback on key metrics such as arm positioning, elbow angle, and range of motion, ensuring users maintain proper form throughout each repetition. Through visual cues and auditory prompts, PosePerfect guides users in adjusting their posture to optimize muscle engagement and minimize the risk of injury.

Similarly, during barbell deadlifts, PosePerfect offers real-time analysis and correction of technique. By monitoring key parameters such as hip hinge angle, spine alignment, and grip strength, the system provides immediate feedback to users on their lifting mechanics. Through visual overlays and feedback indicators, PosePerfect assists users in maintaining a neutral spine, distributing weight evenly, and executing the lift with optimal efficiency and safety viability of our proposed system, contributing to the advancement of emotion recognition technologies.

Conclusion :

In conclusion, the development of our web application, integrating React.js for the frontend and Django for the backend, marks a significant step forward in personalized fitness training. By harnessing the power of computer vision technology through MediaPipe, coupled with a Convolutional Neural Network (CNN) model, we've created a virtual assistant capable of providing real-time feedback on exercise form and technique. Users can seamlessly select exercises from a comprehensive list and have their device's camera dynamically adjust to their height, ensuring accurate feedback tailored to their unique physiology. Through the detection of keypoints and subsequent analysis by the CNN model, our system offers users actionable insights into the correctness of their joint angles, fostering safer and more effective workout experiences. This project not only showcases the potential of cutting-edge technology in fitness training but also lays the groundwork for future advancements in personalized virtual coaching and exercise guidance.

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