Multi-Modal Exercise & Pain Management Recommendation System in Real-Time

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Context

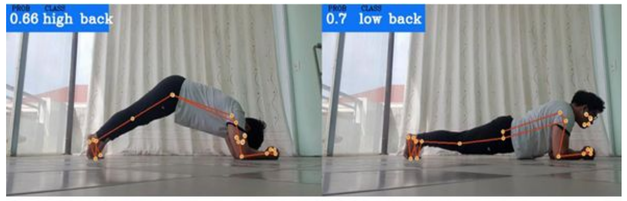
Primary Goal : To reduce risk of injury from physical exercise routines, especially among novice and intermediate experienced individuals who may not have access to a personal trainer or coach to assist with proper technique

Sport & Exercise related injuries are on the rise especially among teenage and young adults:
“the number of injuries increased 8% in 2023 (482,886 injuries in 2023 compared to 445,642 injuries in 2022), the age group with the highest injury rate is 15- to 24-year-olds”

The application seeks to not only prevent exercise related injuries through correction of technique but additionally to mitigate the impacts of exercise through pain management.

Errors are detected in real-time and feedback is provided by the LLM using vector data stored by the mediapipe models along with a corpus of user data and exercise science material which we have curated.

Below are examples of real time error detection of four exercises, plank, squat, bicep curl, and lunge.



Plank error detection

Squat error detection

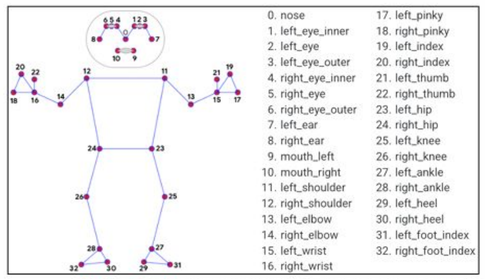
Bicep Curl error detection

Lunge error detection

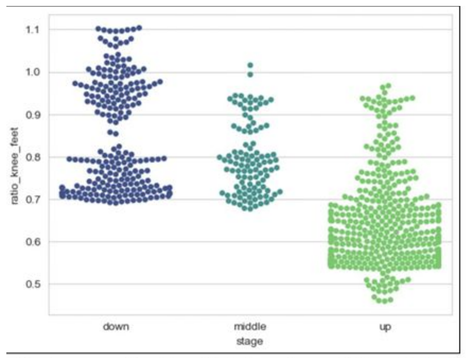
Methodology

Data: primarily collected from videos showing both correct and incorrect forms, covering multiple angles for each exercise. For exercises with limited movement, such as planks, additional data were sourced from open datasets on platforms like Kaggle

Model Training: Different machine learning models were trained for each exercise using key landmarks identified with MediaPipe Pose. For example, squats are detected using the ratio of knee width and feet width in three stages for correct form



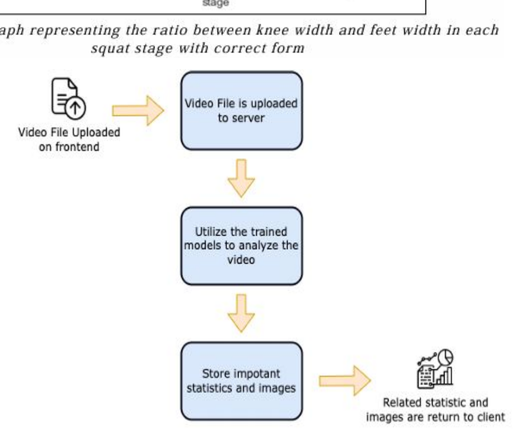
The 33 landmarks model in MediaPipe Pose predicts [8]



Graph representing the ratio between knee width and feet width in each squat stage with correct form

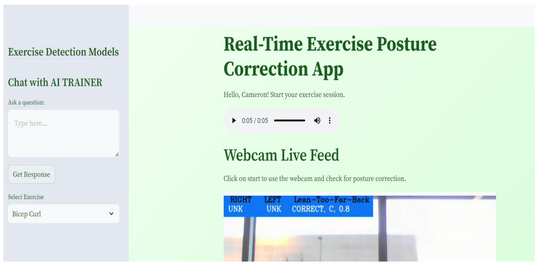
Data Pipeline: The video file is uploaded or streamed real time through the web application where the trained models are deployed on the video.

From that point, the model results and relevant user data is sent from the web app to MongoDB where the data is stored for later context retrieval and also for real-time analysis.



Web server - Video analyzing process

Application UI: Real-Time web app that uses a webcam (with optional ability to upload media as well) to detect and offer feedback on user exercises. There is also an interface to interact with the AI trainer chat which utilizes the user history and exercise performance metrics to answer questions and provide recommendations



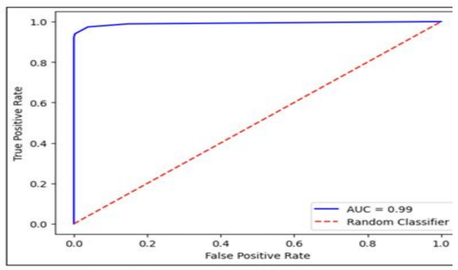
Main page with option to select exercise and chat with AI trainer

Clickable human anatomy that allows the user to indicate where pain is being experienced

Results

Results:

Various metrics were used to evaluate the models, including precision, recall, and F1 score



Bicep curl error - ROC curve

Model Performance Metrics

Bicep Curl –
Precision: 0.976
Recall: 0.968
F1 Score: 0.971
Plank:
Precision: 0.996
Recall: 0.996
F1 Score: 0.996
Squat:
Precision: 0.994
Recall: 0.994
F1 Score: 0.995
Lunge:
Precision: 0.972
Recall: 0.972
F1 Score: 0.972

Impact & Future Work

Future Work:

Extension to additional exercises or more nuance for types of errors in exercises

Inclusion of more quality data to reduce model bias and increase accuracy

Automated rep count in model detection that doesn’t require manual logging by the user