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Real Time Exercise Form Correction using Machine Learning and Computer Vision

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ABSTRACT: The form correction in exercises is a good foundation of fitness training and injury prevention. The paper will describe a real-time exercise form correction system by applying ideas taken from machine learning and computer vision techniques. The system will focus on commonly performed exercises, such as squats, bicep curls, planks, and lunges. Rather than analyzing posture and movement, the proposed system utilizes live video input. The combination of open traditional feature extraction and deep learning models will give a promising form deviation detection solution. Real-time errors and corrections are given.

www

The history tracking module provides data about previous interactions between the user and the system and past performance metrics with accompanying feedback received. All this information is structured and constantly updated in a record. The system makes use of historical data for its conversational AI assistant by Gemini, providing customized advice and recommendations based on the user's profile and progress.

The experiment results indicate that the full system has a high accuracy in form detection and user engagement. This work centers on the opportunity of integrating machine learning with computer vision and personalized AI chatbots to create intelligent fitness solutions that learn based on individual needs.

KEYWORDS: MediaPipe, Machine Learning, Langchain

I. INTRODUCTION

Problem Description

It has revolutionized our daily lives with unmatched artificial intelligence and computing powers. This computer science field enables developing machines that can understand the processing, analysis, and interpretation of visual data like images and videos through a human eye. It relies on pixel-level data analysis by advanced algorithms to extract, process, and then derive meaningful insights from visual information in computer vision systems.

Physical activities are very important in the development of total health and well-being. These help develop a fit brain, effectively control weight, reduce the risk of chronic diseases, build up bones and muscles, and better function in the course of day-to-day activities. Proper formation makes the performance shine while conserving energy and minimizing the risk of injury. Quality is of more importance than the quantity done. Indeed, the first-timer or a solitary trainer usually finds himself with poor forms, greater chances of getting hurt, and lower efficiency in working out as he lacks experience and no information on how to do the exercise properly.

It gives instant feedback for correcting the form while exercising. The focus is on exercising such as squats, bicep curls, planks, and lunges. It has a feature with machine learning along with computer vision techniques. It applies features by using its functionalities in the live video input to detect any deviation in the proper form. Training frameworks based on MediaPipe and OpenCV are developed for the feature extraction and performance optimizations.

It further has a personalization module that captures the interaction history by users, such as past performance metrics and corrective feedback. This then gets integrated with a conversational AI chatbot powered by Gemini. Therefore, it provides personalized advice and recommendations tailor-fit to each user's needs and progress. The aim here is an

intelligent fitness platform that can provide real-time corrections yet adapt to individual profiles to provide tailored training.

This work contributes to existing knowledge bodies of fitness technology, computer vision, and personalized AI within a robust solution that helps ensure better exercise form with reduced risk of injury and overall user engagement.

Purpose of the Study

In this work, the design of an intelligent system by using those algorithms of machine learning and computer vision that bases on the tracking effects to correct the form in real-time for the most common four exercises that include squats, bicep curls, plank, and lunge, shall be presented. The proposed system here detects poor movements and gives actionable information to the user during the performance of exercise.

There is also an online platform that integrates the learned models so that real-time analysis and feedback from the forms will be allowed. Apart from that, there is also a tracking history where all interaction and performance metrics can be recorded with time. This will lead to better personalization because one gets an automated conversational AI assistant designed with the help of Gemini whereby personalized guidance and recommendations can be forwarded based on the understanding of the course of progress.

The objective is to make the study incorporate technical innovation and user-centric design to build up a holistic fitness solution, improving quality exercise without risking any injuries and generally looking to improve general user engagement.

II. LIMITATION AND SCOPE

This research explores deep learning knowledge in, among other areas, computer vision, neural network, and MediaPipe framework. This study uses the Python programming language, the OpenCV library for image processing, Sci-kit learn library and Keras library to build a machine learning model, React framework and Django framework for the web application that will use the trained model to provide feedback on a wrong form to exercise videos, MongoDB to store user data ,feedback and previous conversations, and the Gemini API using Langchain to build a personalized bot for the users.

III. RELATED WORKS

In March 2018, a study “Pose Trainer: Correcting Exercise Posture using Pose Estimation” is published by Steven Chen and Richard Yang (both from Stanford University) [5] with the intention to use machine learning in fitness exercise for helping prevent injuries and im-prove the quality of people’s workouts with just a computer and a webcam. The report of the study introduces Pose Trainer, an end-to-end computer vision application that uses pose estimation, visual geometry, and machine learning to provide personalized feedback on fitness exercise form. The study worked with 4 different exercises (bicep curl, front raise, shoulder shrug and shoulder press) recording training videos for each, and use both geometric heuristic algorithms to provide personalized feed-back on specific exercise improvements, as well as machine learning algorithms to automatically determine posture correctness using only labeled input videos.

IV. IMPLEMENTATION

1>Bicep Curl

First of all the first step to correct an exercise is to identify the most common 2-3 errors that persons face with it, reducing its effectiveness and even leading to injury.

After much discussion and research we decided to focus our efforts on these aspects

1>Number of Repetitions

2>Right & Left Peak Contraction Error

3>Right & Left Loose Upper Arm Error

4>Lean Back Error

so let’s discuss each error

Errors Detection Method:

a. Loose upper arm Can be detected by calculating the angle between the elbow, shoulder and the shoulder’s projection on the ground. Through my research, if the angle is over 40 degrees, the movement will be classified as a “loose upper arm” error.

b. Weak peak contraction Can be detected by calculating the angle between the wrist, elbow and shoulder when the performer’s arm is coming up. Through my research, if the angle is more than 60 degrees before the arm comes down, the movement will be classified as a “weak peak contraction” error.

c. Lean too far back Due to its complexity, machine learning is used for this error. Videos of participants with and without this error are used as data for the training model. Figure 1 is a visual graph representing the number of frames gathered from the videos and their classes. There are a total of 15372 images, in which, there are 8238 samples (53.6%) belong to class correct posture (C) and 7134 (46.4%) samples belong to class lean back (L). Every datapoint in the dataset consists of 37 columns which are formed based on its class and the important landmarks.

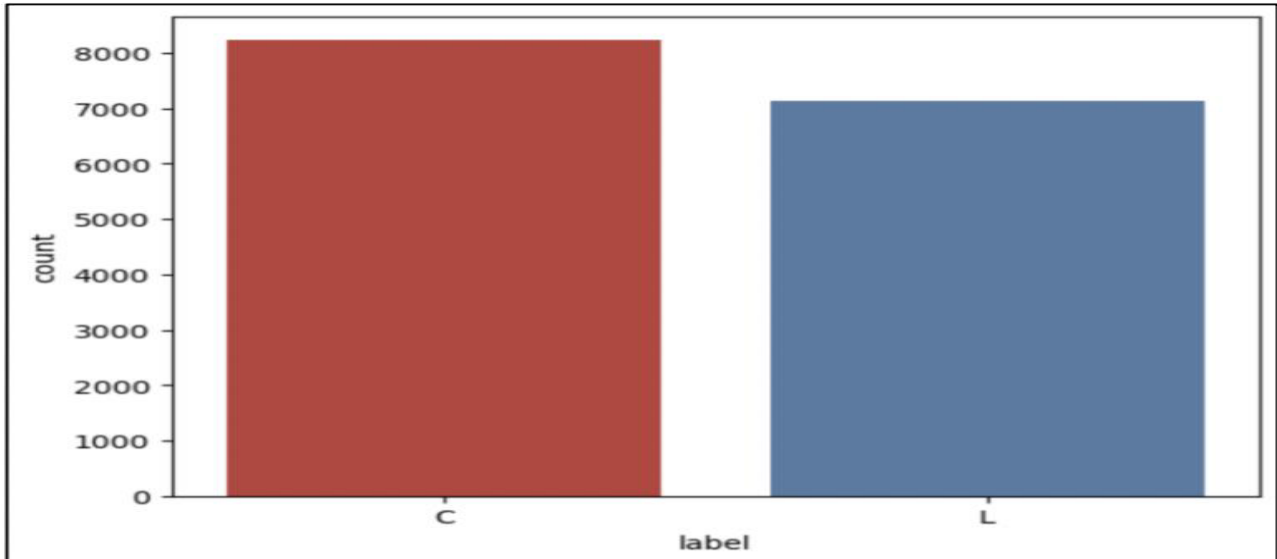


Figure 1: Number of C vs L class labels in Dataset

	Model	Precision Score	Recall Score	Accuracy Score	F1 Score	Confusion Matrix
0	KNN	0.975401	0.968336	0.971854	0.971230	[[338, 1], [16, 249]]
1	7_layers	0.972145	0.962264	0.966887	0.966066	[[339, 0], [20, 245]]
2	5_layers	0.963115	0.949057	0.955298	0.954012	[[339, 0], [27, 238]]
3	SVC	0.929966	0.933762	0.932119	0.931420	[[312, 27], [14, 251]]
4	RF	0.947230	0.924528	0.933775	0.931329	[[339, 0], [40, 225]]
5	7_layers_with_dropout	0.935873	0.924462	0.930464	0.928583	[[330, 9], [33, 232]]
6	3_layers	0.939165	0.920515	0.928808	0.926411	[[335, 4], [39, 226]]
7	LR	0.792694	0.737775	0.761589	0.740550	[[316, 23], [121, 144]]
8	SGDC	0.712457	0.715011	0.715232	0.712937	[[243, 96], [76, 189]]
9	DTC	0.684255	0.650782	0.675497	0.647579	[[289, 50], [146, 119]]
10	NB	0.797368	0.564151	0.617550	0.486650	[[339, 0], [231, 34]]

Figure 2: Results of Model Training

As we can see, I used various methods to rank the effectiveness of models like Precision, Recall, Accuracy Score, F1-Score and confusion matrix. This ensures that the model performs well on all aspects.

2> Plank

Since this is an easy exercise we could only found 2 common errors committed by users in this

1>High Lower Back

2>Low Lower Back

Error Detection Method:

I got videos of people performing Plank Exercise from kaggle

<https://www.kaggle.com/datasets/hasyimabdillah/workoutfitness-video>

additionally we recorded videos of us doing exercises wrong in order to target this error

In the end we got around 28,623 images in which, there are 9630 samples (33.6%) belong to class correct form (C), 8982 samples (31.4%) belong to class high back (H) and 10011 (35%) samples belong to class low back (L). Every datapoint in the dataset consists of 69 columns which are formed based on its classed and the important landmarks.

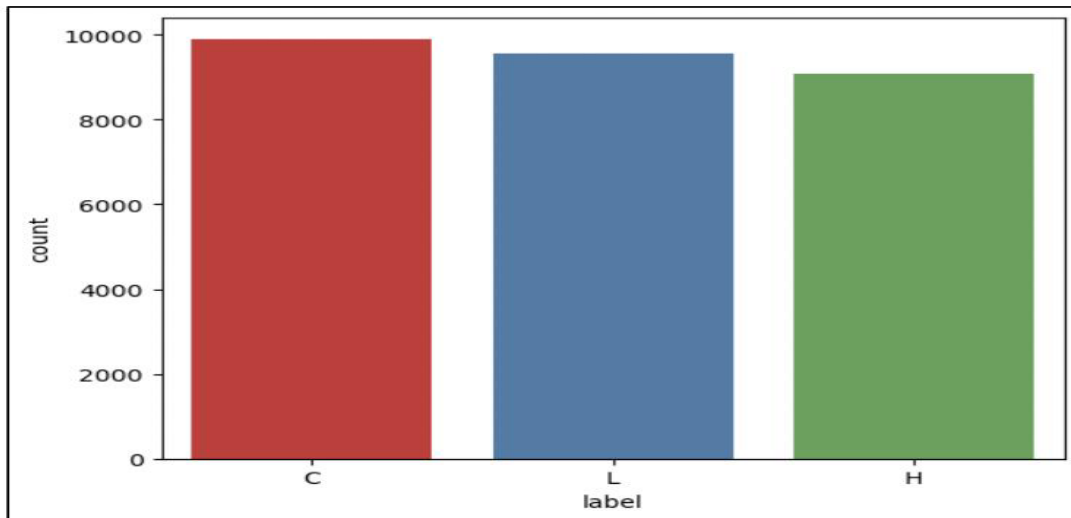


Figure 3: Number of C vs L vs M labels in Dataset

The result of training the models on this dataset are as follows

	Model	Precision score	Accuracy score	Recall score	F1 score	Confusion Matrix
0	LR	0.994141	0.994138	0.994138	0.994138	[[428, 2], [3, 420]]
1	SGDC	0.993063	0.992966	0.992966	0.992965	[[430, 0], [6, 417]]
2	KNN	0.985207	0.984760	0.984760	0.984754	[[430, 0], [13, 410]]
3	SVC	0.977595	0.976553	0.976553	0.976536	[[430, 0], [20, 403]]
4	DTC	0.254120	0.504103	0.504103	0.337902	[[430, 0], [423, 0]]
5	NB	0.254120	0.504103	0.504103	0.337902	[[430, 0], [423, 0]]
6	RF	0.254120	0.504103	0.504103	0.337902	[[430, 0], [423, 0]]

Figure 4: Results of Model Training

These ML models are then used to predict the errors and correct them.

3>Squat

One lower body strength exercise that works the quadriceps, hamstrings, glutes, and core is the squat. One of the most natural sitting and standing motions is dropping the hips from a standing position and then raising them back up. Maintaining a straight back, aligned knees, and an even weight distribution across the feet are all components of proper form.

There are 3 popular errors of basic squat that will be targeted in this thesis:

Foot Placement: In the squat position, foot placement is quite crucial. The two feet should be positioned so that their width is roughly equivalent to that of two shoulders.

knee placement: can be hazardous if done improperly when subjected to heavy loads. The knee should be wider open than the foot during the exercise's "down" phase.

Stage Detection Method:

Unlike other exercises there are two stages in which exercise is performed “up “ and “down” and it is necessary to discriminate between these two stages as Squat exercise behaves differently in these two stages and so does their detection and error correction.

We decided to track stage of exercise through use of machine learning. A total of 356 images were gathered with different stages and it's landmarks were extracted to get a dataset as a result there were total of 37 columns in dataset

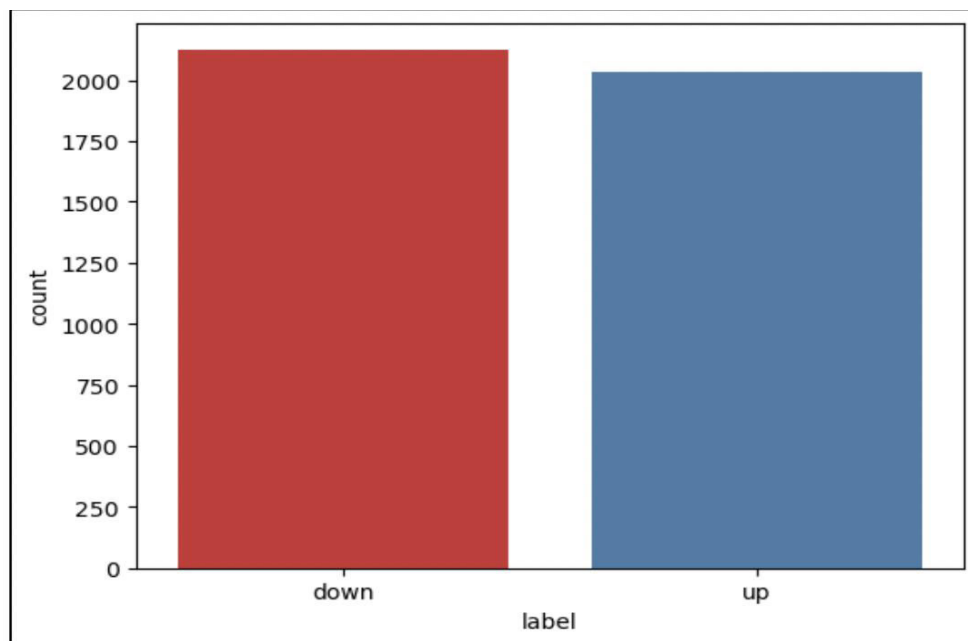


Figure 5: Number of down vs up labelled Datasets

the results of model training are as follows

Model	Neural Network	Precision	Recall	Accuracy
LR	False	0.994	0.994	0.994
5 layers	True	0.994	0.993	0.993
SGDC	False	0.993	0.993	0.993
3 layers	True	0.99	0.992	0.992
KNN	False	0.985	0.985	0.985
7 layers	True	0.985	0.982	0.982
7 layers with dropout	True	0.981	0.985	0.985
SVC	False	0.978	0.977	0.977
RF	False	0.254	0.504	0.504

Figure 6

Error detection methods

a. Feet placement Can be detected by calculating the ratio between the distance of 2 feet and the distance of 2 shoulders. To precisely choose the correct ratio, videos of contributors performing proper form of a squat are analyzed. In that respect, 851 data points are gathered.

x is the ratio between feet width and shoulder width: - $1.2 \leq x \leq 2.8$: correct foot placement - $x < 1.2$: foot placement is too tight - $x > 2.8$: foot placement is too wide

b. Knee placement Can be detected by calculating the ratio between the distance of 2 knees and 2 feet. Similar to the previous error, videos of contributors are analyzed to determine a correct threshold. Due to the dynamic movement of the knee during the exercise, the calculated ratio from the data will be separated into 3 stages: up, middle and down.

assume that x is the ratio between feet width and shoulder width: - At “down” stage: $0.7 \leq x \leq 1.1$: correct knee placement $x < 0.7$: knee placement is too tight $x > 1.1$: knee placement is too wide - At “middle” stage: $0.7 \leq x \leq 1$: correct knee placement $x < 0.7$: knee placement is too tight $x > 1$: knee placement is too wide - At “up” stage: $0.5 \leq x \leq 1.1$: correct knee placement $x < 0.5$: knee placement is too tight $x > 1.1$: knee placement is too wide

4>Lunge

The lunge is a lower-body exercise targeting the glutes, hamstrings, quadriceps, and calves. To perform, step forward with one leg, lowering your hips until both knees form 90-degree angles. Ensure your front knee stays above your ankle and your torso remains upright. Alternate legs for balanced strength and flexibility.

There are 2 prominent errors on which we will be focussing

- 1>Knee Angle
- 2>Knee over the Toe Error

Error Detection Methods:

a>Knee Angle

The angle of two knees should be roughly 90 degrees when the body is lowered. When doing the lunge, a performer may be taking too big or too small of a step if their knee angle is too wide or too tight.

We can easily achieve this using openCV and calculating angle between the two body parts

b>Knee Over the Toe Error

Particularly while carrying more weight, the performer typically leans too far forward while the body is in a low position, causing the knee to pass the toes. This common error may cause the performer to become unbalanced or sustain a knee injury.

A machine learning model is constructed using videos of participants performing this exercise in both its normal form and knee-over toe form. A visual graph showing the quantity of frames collected from the videos and their classes may be found in Figure 15. 8793 samples (49.1%) of the 17907 photos fall into the class proper form (C), while 9114 samples (51.9%) fall into the class knee-over toe (L). Each datapoint in the collection has 53 columns that are created according to its classification and significant landmarks.

In my research and exploration, the important MediaPipe Pose landmark for lunge are: nose, left shoulder, right shoulder, left knee, right knee, right hip, left hip, left ankle, right ankle, left heel, right heel, left foot index and right foot index.

V. EXPERIMENTAL RESULTS

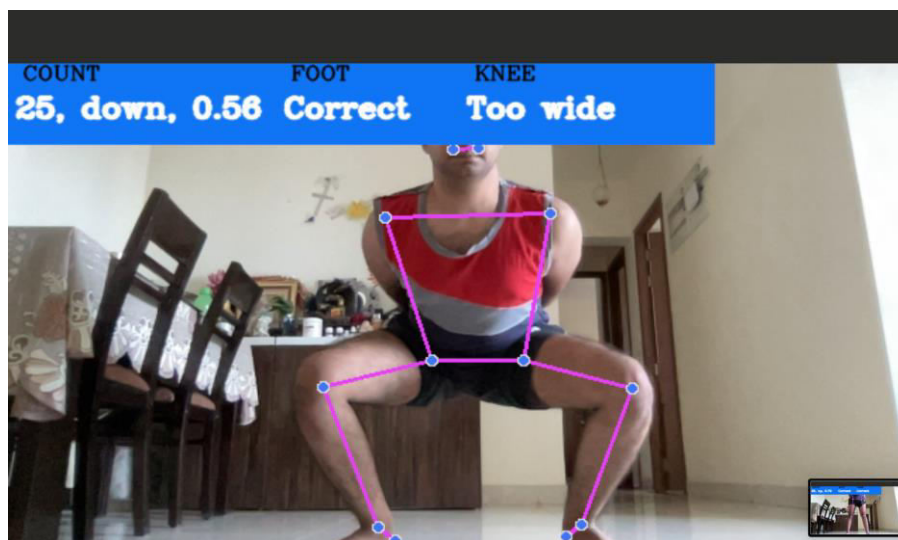


Figure 6: Sample Squat Exercise Result

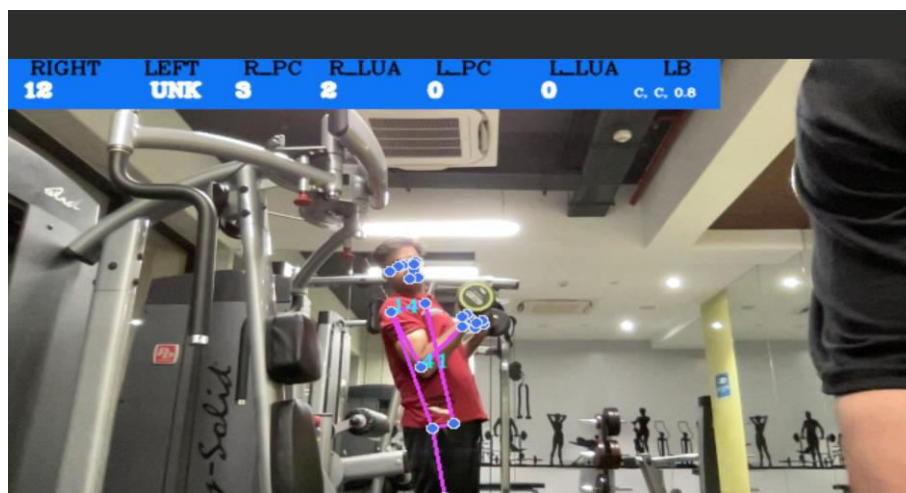


Figure 7: Sample Bicep Curl Result

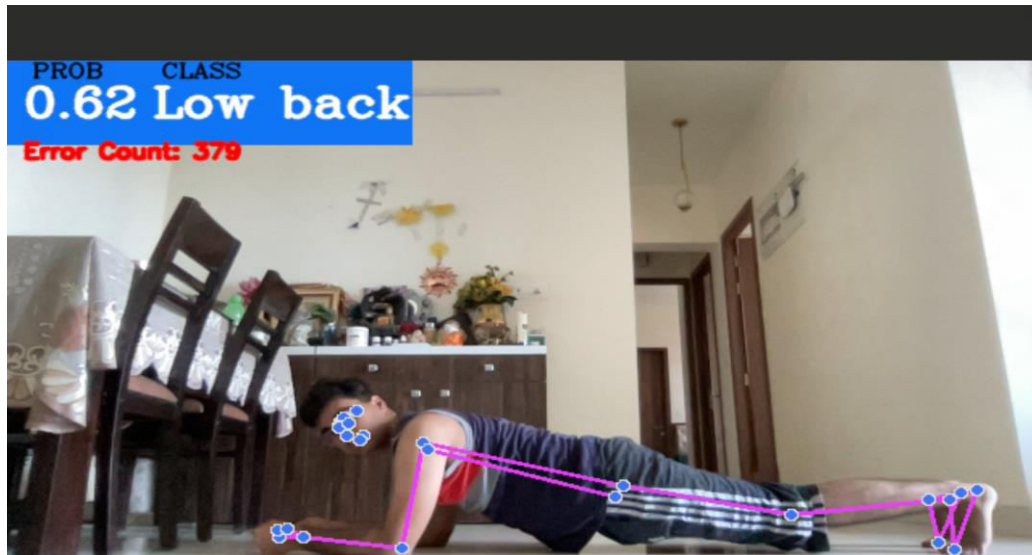


Figure 7: Sample Plank Result

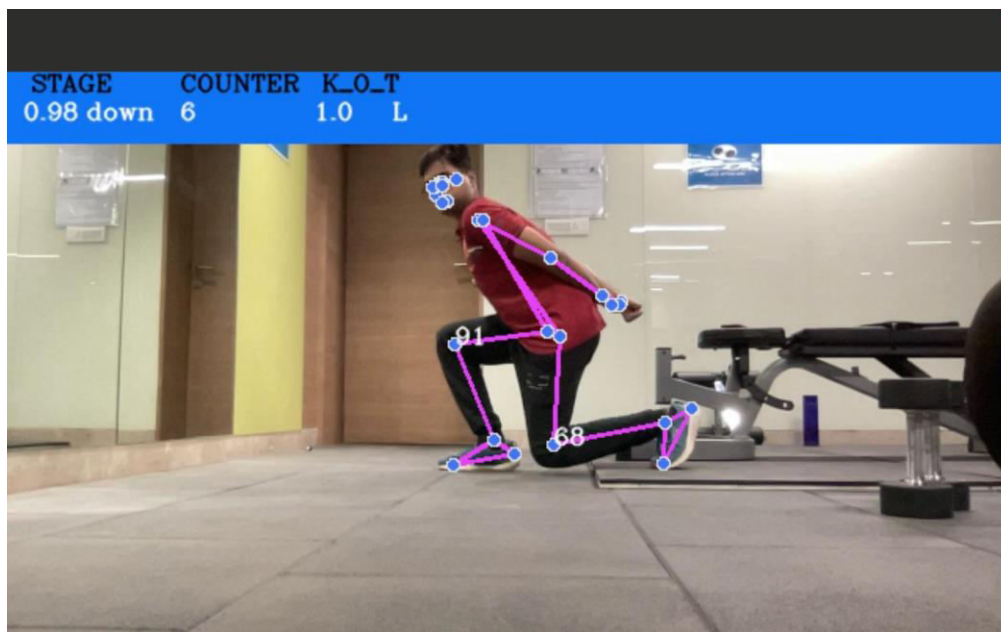


Figure 8: Sample Lunge Result

VI. WEB BASED APPLICATION

We created our web application using React, Django, and MongoDB. React allows us to record using devices' webcams and send frames to the backend in Django via HTTP sockets. We respond to these by providing them with status and error messages, which are also stored in MongoDB for Chatbots reference. The user name and all the information, including the previous chatbot interaction and the most recent exercise form correction data fed into chatbot with prompt templates to personalise the responses, are contained in a MongoDB database.

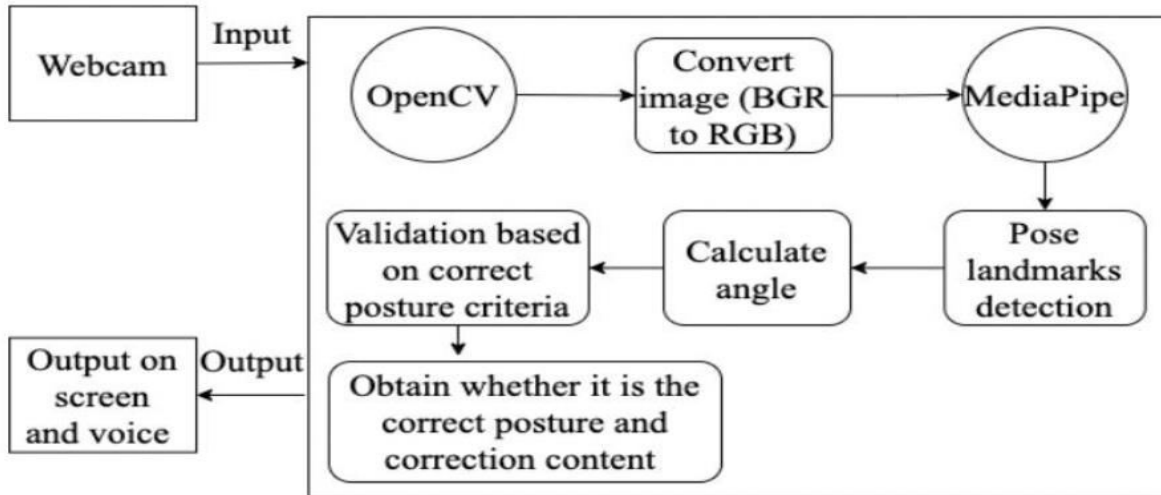


Figure9: Real time Detection Architecture

VII. CONCLUSION

We were able to become acquainted with a wide range of machine learning ideas, methods, and technologies during my study and thesis development. Every trained model that used the MediaPipePose methodology yielded outcomes that satisfied my requirements.

They can effectively identify or categorise mistakes in four exercises: the lunge, basic squat, basic plank, and biceps curl.

It should be mentioned, though, that the majority of the data—both in the training and testing sets—comes from my own self-recorded films, which undoubtedly influenced the models' training process and could account for their high accuracy.

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