"AI-Based Fitness Trainer Using Pose Estimation and Supervised Learning for Exercise Analysis"

AI FITNESS TRAINER

Pratham Mitesh Mehta
SVKM Mithibai College
Mumbai, India
prathamm313@gmail.com

Amol Joglekar
SVKM Mithibai College
Mumbai, India
amol.joglekar@mithibai.ac.in

Abstract:

Nowadays since a trend of working out using online stuff it has lead to a creation of an intelligent system to learn a exercise without the need of a trainer or an exercise without any equipment. Doing exercise wrongly can lead to injuries which can affect an individual badly. That is why we need automated fitness checkers that do not get in the way.

This article is about an AI fitness coach that uses cameras and computer programs to check out your workout videos to track where your joints are and to measure angles and distances between joints to determine how you are exercising. The rules are just how to count how many times you do each exercise, and how to judge whether the way you do it is bad, okay, or good; the software uses the judgment to train itself to classify how you do the exercise automatically. The software has been shown to accurately count repetitions and grade form, not slow down in the presence of other activities, and be intuitive to use. Its a cheap , user friendly to do proper training daily.

KEYWORDS:
AI FITNESS TRAINER, MediaPipe, Computer Vision, Supervised Learning, Body Movement Analysis, Convolutional Neural Networks (CNN), Angles Calculation, Workout Type Recognition, And Deep Learning Approaches, Real Time Pose Detection, Exercise Classification, Repetition Counting.

PROBLEM STATEMENT:

Nowadays many people do workout from home and without a professional they tend to do wrong exercise which may lead to injuries. There are many apps in the market that has fitness trackers or videos that help a individual to check form but most of them are paid.Are a hassle to use.Now we have computer systems that can look at how people move. These apps are not very user friendly so this leads to a creation of a new system that is user friendly and free to use. Basically it should be upload their own video and feedback should be given properly. It should also be able to count how times they do the move and tell them if they are doing it wrong while they are doing it. It should not need any special equipment to do all of this. Exercise performance and exercise form are very important, for home-based fitness and exercise performance.

INTRODUCTION:

Due to social network the entire world is coming very close to each other. Lots of activates are getting posted and updated with respect to many domains. Fitness is also not behind in this case. Due to technology and because of more workload people many not be hitting gym regularly and hence they are now focusing on something like tutoring various forms of exercise online. Physical exercise includes various types like weight training, cross fit, cardio, stretching etc. if you do these exercises without supervision there is a possibility that you end up doing the things wrong or in proper way leading to injuries.

In market there are many applications in market which can help you analyse understand the form of exercise and ask you to repeat the same as sets.

With the integration of computer vision and AI the proposed research work focuses on analysing your workout and by analysing your joint angles , spots system can ask you to modify form so that there will less error. The objective of research is to develop and design system which can track your exercise based on different forms like legs, chest etc and improvise. Proposed hypothesis:

Hypothesis 1

H0: System is unable to identify joints

H1: System correctly identify joints.

Hypothesis 2

Ho: The model is not able to achieve accuracy in identifying type of exercise form.

H1: The model able to achieve accuracy in identifying type of exercise form.

LITERATURE REVIEW

Nowadays there has a been a significant rise in use of Fitness based models using AI. It's because of their potential to improve the precision of fitness programs and health monitoring. It is a model which uses ML approach which does data analysis and uses predictive algorithms to create fitness plan, nutrition and also many health-based factors completely based on individual goals and preferences and scans all physical characteristics of an individual.

There are many uses of AI Fitness models like fitness tracking, sport analytics and medical rehabilitation. Further we can integrate our models into wearable devices like watches, rings etc, also in mobile apps, and many health monitoring systems which monitors progress levels and helps us examining everything. The recent progress in artificial intelligence, particularly in computer vision and deep learning, have profoundly supported to development of intelligent fitness training system.

A study by Cao et al. In 2017 created a system to find peoples poses in time. This system uses something called part affinity fields to accurately locate points on the human body. It has helped create modern applications that use body poses. However this work main focus was on finding poses not at giving feedback or any exercise. A study by Patil el in the year 2023 in which a system was created to analyze user movements using camera as input then give feedback. It struggled with limitations of requirement of large datasets and no complex movement detection.

A study by Lovanshi and Tiwari (2023) used benchmarking while assessing pose estimation using COCO and MPII which gives valuable insights that improves model performance. It does not integrate in real time interactive systems. Also there is one more research that tracked bicep curl and provided valid messages based on form. The maion limitation is its only restricted to one exercise only.

There are two studies based on CNN-GRU approach to understand human pose activities and exercise. In the study by Gupta et al. (2024) the study completely relied on wearable devices and the other study by Jain et al. (2024) it guided using the model that is first pose estimation then feedback activity but issue is high dependency on large dataset.

So summarizing existing systems there is a good progress but there are many things tha arev lacking like scalability, need of large datasets, cant work on real time etc. These cons tell us we need a proper and efficient solution of giving proper fitness form and exercise guidance which can be user friendly system which works properly and gives apt results in the real world. So I propose a real time model that can help people and also not relying on any training data or any sensor.

OBJECTIVES

1. We want a model that is smart enough to study human exercising movements through video input and analyzing it using computer vision and machine learning techniques in real time.
2. We want to use pose estimation method using MediaPipe to properly identify body joints and movements during exercises.
3. We want to get useful features i.e the correct angles of the joint distances, the movement patterns which help in correct and proper identication of the correct form of the respective user posture during the workout.
4. We want a rule-based system that can count reps of an exercise in many phases and don't count the wrong form ones and no counting the same rep twice.
5. We want to make and train a machine learning model which classifies the form into good , average or a poor based on the useful features we get from the video.
6. We want a model that provides result in all real time situations and gives proper advice to users where they are wrong an corrects the form which ensures that no injury is caused.

METHODOLOGY

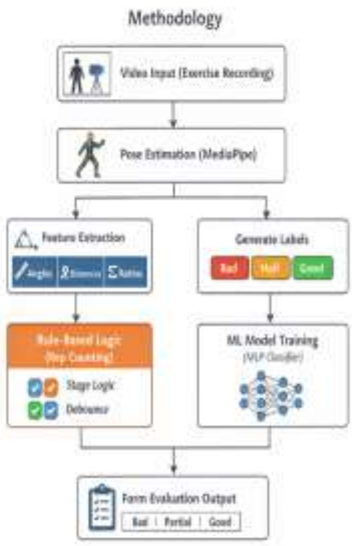

Figure 1: Methodology

My proposed work AI Fitness Trainer uses a simple idealogy i.e use video as a input then using libraries like computer vision and mediapipe and machine learning does all. Its very user friendly record yourself , upload it and then it shows the video with reps counted and shows valid feedback on each rep.

Once we have the video it goes through Pose estimation phase through MediaPipe library. MediaPipe is used to figure out the position of the body. It searches for the points of shoulders and the knees. We use this points to calculate how bent the joints are and apart from all the other body parts also. This points play a vital role in checking the perfection of the form of the exercise done by an individual.

After we get all this information the system does two things. It counts the repetition of the exercise by watching the body movement and breaks it down into different points. The system makes sure that one rep is not counted twice so it helps in perfect analyses of the form.

The second thing the system does is look at how the person is doing the exercise. It uses the information we got earlier to say if the person is doing it well of well or not well. The information we get is used further to train a machine learning model known as Multi-Layer Perceptron. The purpose of an MLP is to model complex relationships between inputs and outputs. In this model it uses the information to recognise the patterns and give final verdict about the form of the exercise. It also classifies the form as bad, partial or a good one.

So lastly the model counts the reps of the the exercise and understands how well is it performed by the person. It gives proper feedback based on the form and shows valid messages for each possibility an exercise can go wrong or correct. The main motto of the my proposed work is to do the exercise correctly in real time and with the correct posture, angles and prevents injuries. It always looks at the exercise performance. Giving feedback using the computer vision and machine learning techniques. The exercise system provides feedba

RESULTS

This section gives an evaluation of the AI-based fitness trainer. The experimental analysis looks at the model training behavior the classification performance, the confusion matrix interpretation and the exercise wise repetition counting shown in the plots. The AI-based fitness trainer works well when the AI-based fitness trainer combines pose estimation, rule based logic and supervised machine learning, for automated fitness analysis.

A. Dataset and Experimental Setup

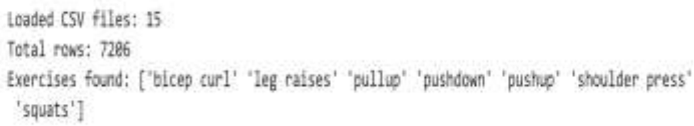
```
Loaded CSV files: 15
Total rows: 7206
Exercises found: ['bicep curl' 'leg raises' 'pullup' 'pushdown' 'pushup' 'shoulder press'
 'squats']
```

Figure 2: Dataset Created

When I ran the experiments I used pose-based datasets automatically generated from exercise videos. I processed 15 CSV files in the experiments. I generated 7,206 samples across seven exercises in the experiments. The exercises were bicep curls, leg raises, pull-ups, pushdowns, push-ups, shoulder press and squats. I recorded 154 features, for each data sample, such, as angles, inter-joint distances and normalized body ratios. I saw that the biomechanical features gave a picture of posture and movement dynamics. I saw that posture and movement dynamics helped form evaluation and repetition analysis.

B. Training Behavior and Early Stopping

```
Early stopping at epoch 48. Best epoch: 38 (val_loss=0.0624)

Final Validation Metrics (best epoch restored):
Validation Accuracy: 0.9750346740638003
Validation Macro F1: 0.9729601443230322
```

Figure 3: Training Behaviour Metrics

I trained the learning model with stopping to avoid overfitting. I stopped training the learning model at epoch 48. I found the learning model at epoch 38 which gave the lowest validation loss of 0.0624. I saw that the training loss curve and the validation loss curve both move smooth and steady. That shows the optimization works. I noticed the gap, between the training loss curve and the validation loss curve. That shows the supervised learning model works on data and is regularized.

C. Validation Performance Metrics

The restored best model got a validation accuracy of 97.50 percent and a macro F1-score of 0.9729. The macro F1-score is high and the macro F1-score shows that the model treats all exercise form classes the way of favoring one class. The validation. The macro F1-score show that pose-derived biomechanical features work well to tell incorrect, partial and correct exercise executions.

D. Classification Report Analysis

Classification Report:

	precision	recall	f1-score	support
0	0.98	0.97	0.98	363
1	0.94	0.98	0.96	354
2	0.99	0.98	0.98	725
accuracy			0.98	1442
macro avg	0.97	0.98	0.97	1442
weighted avg	0.98	0.98	0.98	1442

Figure 4: Classification Report

The classification report shows that the precision the recall and the F1-scores are high, for every class. The class analysis shows that the F1-scores are above 0.96 for each category and several classes are close to 0.98. The close match, between the macro-averaged scores and the weighted-averaged scores tells me that the classifier is stable and reliable when the class distribution changes.

E. Confusion Matrix Analysis

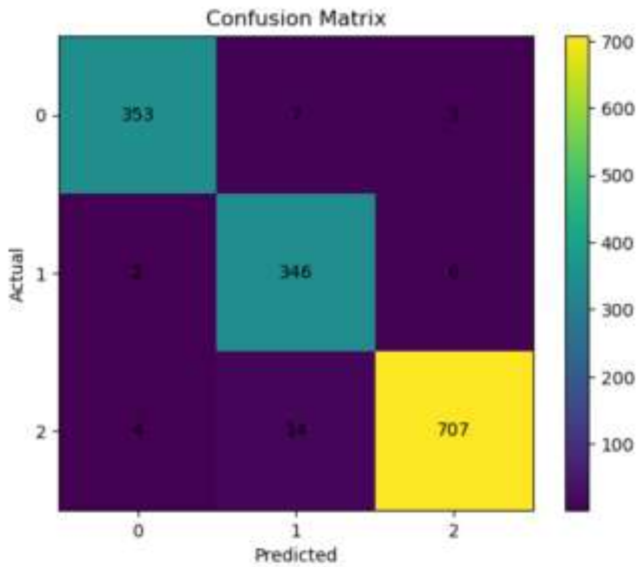

Figure 5: Confusion Matrix

I see the confusion matrix shows a line. I see the confusion matrix shows that most predictions match the labels so the model gets the answer most of the time. I see the confusion matrix shows that the Good form class has the number of predictions so the Good form class is recognized well for properly done exercises. I see the confusion matrix shows that most mistakes happen between classes. I see the confusion matrix shows that mistakes happen between Bad and Partial or, between Partial and Good and this makes sense because the movement changes gradually. I see the confusion matrix shows that severe mistakes are rare so the decision boundaries are cautious and reliable.

F. Exercise-wise Repetition Counting Analysis

In this part we look at the performance of rep counting with respective plots for each exercise. When we see a flat region and in each repetition we see the movement is changing or still because over time we can see the changes in the plot. Each step detects a repetition for each exercise.

F1. Bicep Curl

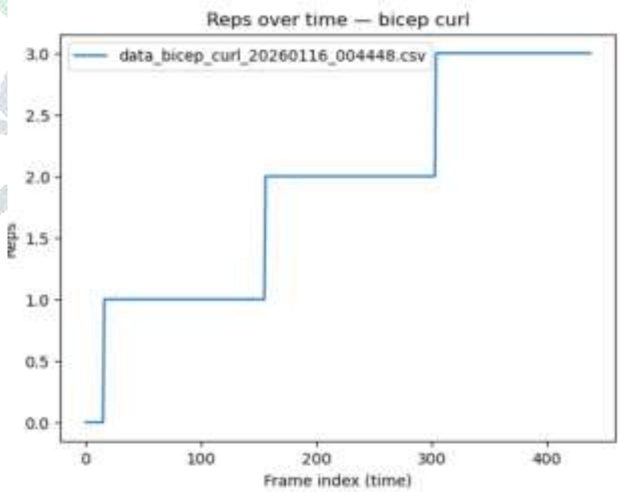

Figure 6: Bicep Curl

In this plot of bicep curl we can see full curl reps was recorded at frame intervals.If we observe any missing value it indicates noise data is filtered .This proves that tracking for this workout is successful.

F.2 Leg Raises

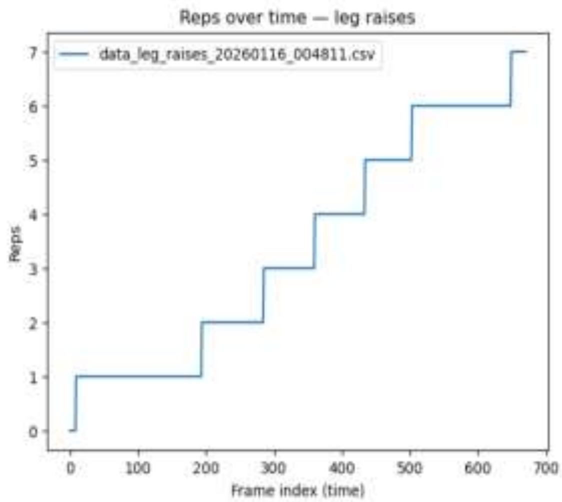

Figure 7: Leg Raises

In this plot for leg raises we can see a homogenous rhythmic staircase pattern which shows breakthrough till 7 repetition's. The horizontal plateau are consistent and flat which tells the model is working correctly resulting in correct visualization of the reps in a concentric cycle of the exercise performed.

F.3 Pull-ups

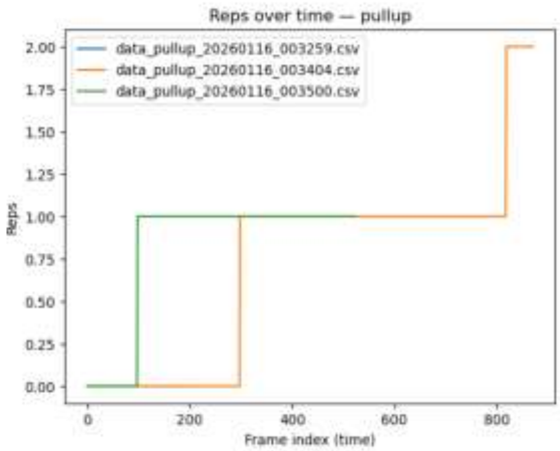

Figure 8: Pull Up

In this plot we see many datasets being used which shows how it handles different type of data which can be different resting and execution. In one dataset a single correct repetition is stored while in others there are two which proves training the model with dataset with different time and execution we can prove the model is reliable.

F.4 Pushdowns

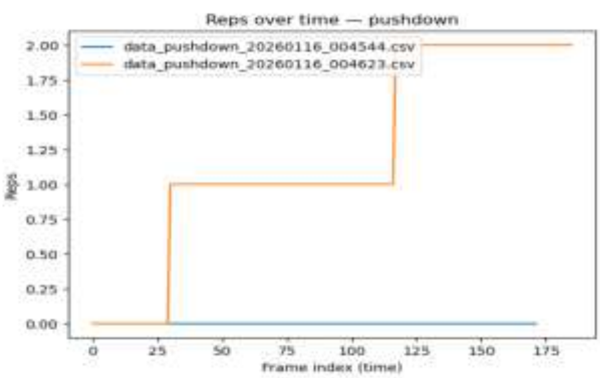

Figure 9: Pushdown

The pushdown plots detect the downward extension movements correctly. The pushdown plots only count the repetitions that meet the predefined angle thresholds. The pushdown plots result in step increments, for those repetitions. The pushdown plots filter out the extensions. The pushdown plots handle the noise and errors well.

F.5 Push-ups

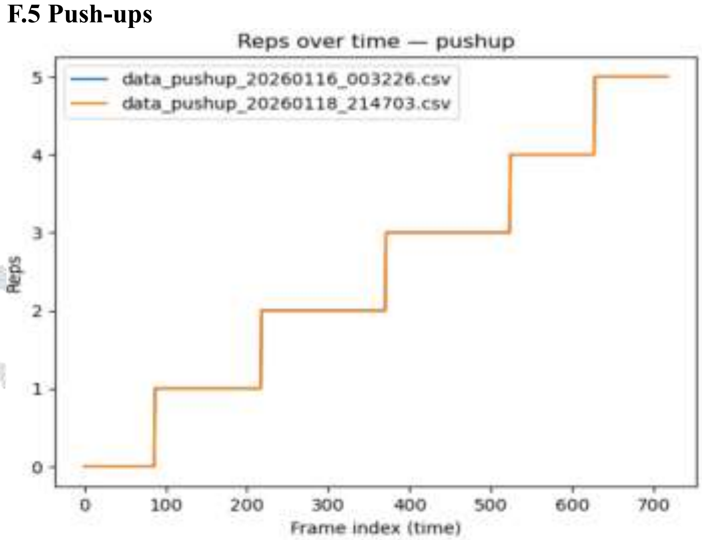

Figure 10: Pushup

I see the push-up repetition plots show a step, by step pattern that follows each down and up motion. The flat regions between the steps tell me that the transitional movements are not counted as a rep. The push-up repetition plots give a count of repetitions, for bodyweight exercises.

F.6 Shoulder Press

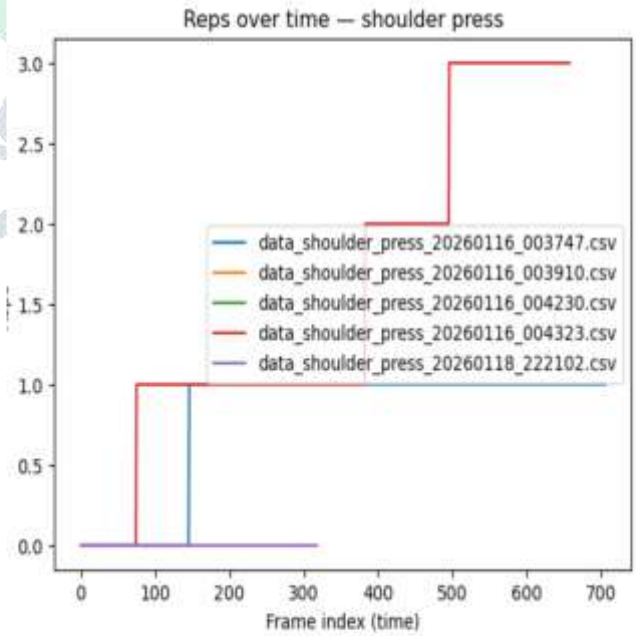

Figure 11: Shoulder Press

The shoulder press plots have trials. The shoulder press plots show ways and different speeds. The valid repetitions are always detected. The valid repetitions are counted each time. The insufficient range-of-motion attempts produce no increments. No increments are recorded for range-of-motion attempts. The robustness is confirmed for exercises. The overhead exercises involve coordination. The robustness works for exercises that need joint coordination.

F.7 Squats

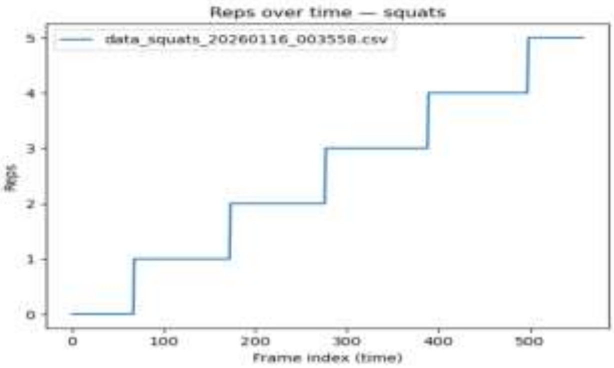

Figure 12: Squats

Squat plots show an increase that follows a squat cycle, including the down phase and the up phase. Squat plots have no positives, in the frames. Squat plots handle the range and the vertical movement, in the lower body exercises.

G. Cross-Exercise Consistency

I see that the repetition counting mechanism always gives a step-function pattern across all the exercise plots. The repetition counting mechanism gives the step-function pattern for upper-body, lower-body and compound exercises. The uniform behaviour of the repetition counting mechanism shows that the framework can work with movement patterns. The framework works.

H. Summary of Results

The test results show that the AI fitness trainer:
1.Achieves high classification accuracy and macro F1-score.
2.Demonstrates stable and well-regularized training behavior.
3.Reliably distinguishes between exercise form quality levels.
4.Accurately counts repetitions across multiple exercises using only video input.

These results prove that the effect and practical use of my model for the real world is useful . Its completely satisfies main aim of exercises without need of any professional.

CONCLUSION

The proposed work is about making a AI Fitness Trainer which uses a smart system that observes how people perform their workout by looking at them standing and moving. It extracts vital data points of the joints based on their movement and understand patterns and this data helps in identifying whether a person form is correct or wrong. It counts the reps of the exercise performed using rules like angles and thresholds and machine learning used to check its correct or wrong. This thing gives away feedback immediately so that eliminates the need of a professional correcting them.

The model is very user friendly because it does not need any special equipment or lot of data.This model gives accurate results helping people who exercise in their own house. It proves that we can use ai for people to make them get a healthy lifestyle and be fit.

There are some limitations that can be better in future like the video which is the input needs to be recorded in a good environment with good light. The video quality also has to be good or else the system will not extract information properly. To make the system better we can work on making it stronger and able to work in places and with different people. The system can be modified by adding new exercises to make feedback more accurate. This proposed work is very good for individuals to get in shape and live a healthy and fit lifestyle. It really helps people in real time.

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