2D Pose Estimation and Joint Stress Analysis and Injury Prevention for Home Workout

Project Report Submitted to the
SRM University-AP, Andhra Pradesh
for the partial fulfillment of the requirements to award the degree of

Bachelor of Technology
in
Computer Science & Engineering
School of Engineering and Sciences

submitted by

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Dec 2025

DECLARATION

I undersigned hereby declare that the project report **2D Pose Estimation and Joint Stress Analysis and Injury Prevention for Home Workout** submitted for partial fulfillment of the requirements for the award of degree of Bachelor of Technology in the Computer Science & Engineering, SRM University-AP, is a bonafide work done by me under supervision of Dr. Guide Name. This submission represents my ideas in my own words and where ideas or words of others have been included, I have adequately and accurately cited and referenced the original sources. I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not previously formed the basis for the award of any degree of any other University.

Place	: Amaravati, Guntur	Date	: December 3, 2025
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CERTIFICATE

This is to certify that the report entitled **2D Pose Estimation and Joint Stress Analysis and Injury Prevention for Home Workout** submitted by **Harshit Chowdary Jasty, Praneetha Bolneti** to the SRM University-AP in partial fulfilment of the requirements for the award of the Degree of Bachelor of Technology in the Department of Computer Science & Engineering is a Bonafide record of the project work carried out under my/our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

Project Guide

Name : Dr. Susmitha Kumari | Name : Dr. Murali Krishna Enduri

7/12/25

Signature: ....

ACKNOWLEDGMENT

I wish to record my indebtedness and thankfulness to all who helped me prepare this Project Report titled **2D Pose Estimation and Joint Stress Analysis and Injury Prevention for Home Workout** and present it satisfactorily.

I am especially thankful for my guide and supervisor Dr. Guide Name in the Department of Computer Science & Engineering for giving me valuable suggestions and critical inputs in the preparation of this report. I am also thankful to Dr. Murali Krishna Enduri, Head of Department of Computer Science & Engineering for encouragement.

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ABSTRACT

Current methods examining movement during physical activity use tracking of position in two forms combined with assessment of force on body parts. This approach provides the main means for analysis of motion, particularly in settings where individuals conduct exercise without direct oversight. The summary of research work presents the central focus and main findings in a form that allows other individuals to determine the value of the study. This component appears at the initial point of the paper and provides the basis for further discussion of methods that track position, methods that measure physical demands, and approaches that reduce risk of harm to the body. Systems that organize research in areas including visual analysis, physical performance, and health applications use these summaries to identify studies examining tools for exercise that individuals conduct on their own, with focus on three specific movements that include the curl of the arm, the lowering position, and the hold that supports the body. Work in this area uses the summary to describe developments in approaches such as methods that identify points on the body in real time, methods that estimate levels of force in muscle, and systems using adaptive programs that adjust training based on assessment of individual risk. In most cases, the summary functions as a separate unit that shows the content of the work, allowing those who review research to select which studies receive presentations at meetings focused on interaction between people and systems, medical applications of technology, or research on physical activity. Because search systems often store only the summary rather than the complete paper, these brief descriptions provide access to findings that typically require payment or membership to obtain.

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Chapter 1 INTRODUCTION TO THE PROJECT

1.1 Overview of Pose Estimation and Injury Prevention

The approach that finds main body points in images or video shows positions that include points such as the upper body connection points, the points that allow arm movement, the points that connect to the lower body, and the points that allow leg movement. The method that identifies these points provides means to measure angles between the points and to examine how the body moves. This analysis that combines point position data with basic stress assessment indicates whether movement occurs in a form that appears safe. The approach shows patterns that suggest problems before these problems produce strain in the body.

Recent data show that large numbers of individuals conduct physical training in the home because this context provides advantages in time use and in access. Training in the home occurs without direct observation by an individual with training knowledge, and this condition allows movement patterns that differ from correct form. This system indicates when form differs from the correct pattern, and this indication allows the individual to change the movement in a response that occurs in the same training session.

1.2 Importance of Home Workout Monitoring

Most individuals that conduct training in the home perform movement without observation, and this condition suggests that these individuals may not observe small differences between the form that appears in the movement and the form that the movement should show. These small differences that continue across multiple training sessions produce problems that appear in time that follows the training. The example that shows the back structure moving in a form that exceeds the correct position during a movement that lowers the body, or the example that shows the lower body connection points in a position that differs from correct alignment, indicates how patterns that appear incorrect apply pressure to the body points that connect structures.

Chapter 2 MOTIVATION

The work examines reasons for developing methods that follow body position and measure stress on joints when individuals exercise at home. Individuals who exercise without guidance from trainers show higher rates of injury, and systems using analysis may indicate issues at early stages. Technology that continues to develop allows applications that provide instruction on form and limit harm to become more useful in practice. The focus in this work relates to using basic approaches that allow training without supervision to occur with greater safety across time.

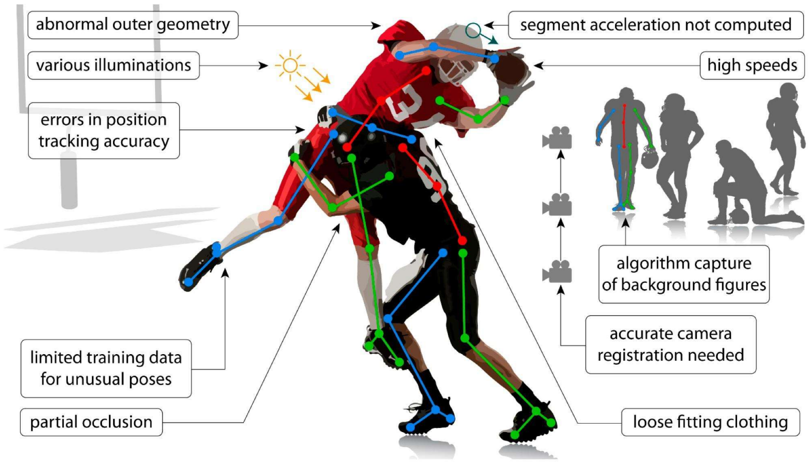

Figure 2.1: Motive behind the System

2.1.1 Need for AI-Based Home Workout Assistance

The change to exercise at home shows that methods providing guidance become more important when trainers are not present. Individuals use recorded material or applications on devices to follow exercise routines instead of relying on experts, but these approaches cannot identify poor positioning or provide responses that occur immediately. This limitation means that errors in movement appear often during repetitions, and these errors reduce outcomes from exercise while increasing the likelihood that injury will occur.

Systems that use artificial intelligence address this issue by following body position using technology that analyzes movement with considerable capability. That way, people get quick alerts if they're off track, helping them stay aligned and balanced through each session - one step toward smarter, safer training from your living room.

2.1.2 Rising Injuries in Home Fitness Practices

Suppose you plan to work on a blockchain project or any embedded project; you can read the research pacers or journals to understand the recent technological advancements. It helps you derive insightful findings and bring exciting solutions to pitch for various projects. It will help you acquire the required information from the resources for your quality project ideas and dive deep into concepts to derive solutions.

These research papers help you know the latest tech trends related to your project domain. You can acquire information from various journals, tutorials, training programs, etc. It helps build project portfolios built on prototypes or ideas to enhance your learning experience.

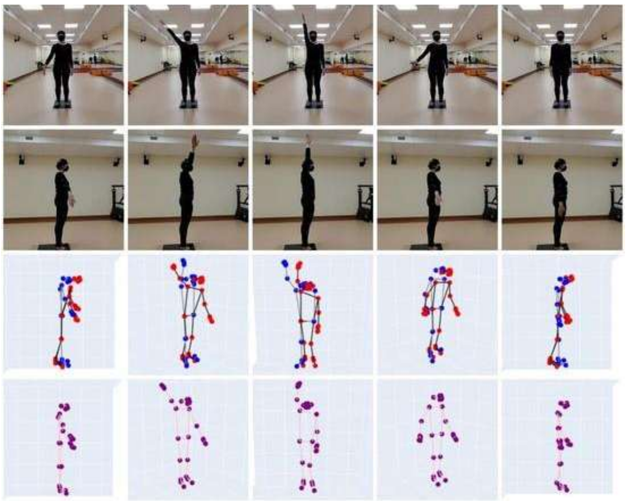

Figure 2.2: 2D- Representation by System.

2.1.3 Role of Pose Estimation in Preventing Workout Errors

Pose estimation spots workout mistakes by tracking where your major joints are in each video frame. It checks how your body lines up, judging if you're doing moves right. Small shifts in joint positions might make workouts less effective - or cause harm over time. Instead of guessing, the system compares your stance to the best version of the move.

2.1.4 Significance of Joint Stress Analysis

The analysis of joint stress provides valuable information about body movements which helps users track their workouts by demonstrating the amount of work each joint performs during exercise. The wrong execution of exercises leads to excessive joint stress which results in swelling and pain and potentially causes permanent damage. People can determine their exercise form safety through joint angle measurements combined with load predictions. People who receive feedback through this system develop safer training practices which reduces their risk of developing chronic injuries from repetitive strain. Home exercise routines become safer through this addition which requires no additional work.

2.1.5 Benefits of the Fitness Influencers

The rise of home workouts began when fitness stars started sharing their workout content online. The videos from these creators motivate numerous viewers to maintain their physical activity while following their established workout plans. The creators help people stay motivated through their content which demonstrates fundamental exercises yet their videos lack the ability to provide hands-on correction of your posture. The combination of smart pose-tracking technology with popular trainer videos enables fans to receive both motivational energy and immediate form assessment without any unnecessary content. The system enhances workout experiences through improved performance and safety and accessibility for additional users. The combination of technological expertise with their content makes creators more trustworthy because their material appears more substantial.

Chapter 3 LITERATURE SURVEY

Previous studies have studied related areas including 2D pose tracking, joint stress analysis, and systems designed to reduce exercise related injuries. Studying this literature helps explain the methodologies commonly used and specific challenges addressed by researchers. Furthermore, it highlights voids in present knowledge and reports the selection of best suitable approaches for the current study.

literature review usually does not deliver unknown findings. Rather, it synthesizes prior research to determine key themes and advances within the field. In disciplines such as artificial intelligence, digital health, and sports technology, literature reviews assist researchers in refining methodologies. For the current project, the review of prior work informed the selection of pose-tracking techniques, approaches to joint load calculation, and the identification of limitations in existing exercise-monitoring systems.

3.1 Existing Methods in Pose Estimation

With the improvement of deep learning, more advanced approaches such as OpenPose, MediaPipe, HRNet, and other neural-network-based models became widely used. These modern tools detect body joints more accurately because they learn the structure of the human body from large datasets. They are now used in many areas including fitness tracking, rehabilitation support, sports analysis, and gesture-based applications. Most studies agree that deep-learning-based models offer much better performance, especially for real-time applications.

3.2 Studies on Joint Stress Prediction and Analysis

Recent research has focused on estimating joint load using computer-vision methods. These studies make use of pose-estimation data and mathematical models to predict how much stress a joint experiences during a movement. Such approaches are useful because they provide injury-risk information without requiring specialised lab instruments. Several papers highlight that joint-stress prediction can help detect unsafe movements early and guide users toward safer exercise habits.

3.3 Current Limitations of Home Workout Assessment Tools

Most fitness applications available today only demonstrate how an exercise should look and do not analyse the user's form. They mainly rely on pre-recorded videos and general tips, which cannot adjust to each person's movements. As a result, posture mistakes may go unnoticed. Some apps identify broad movement patterns, but they rarely detect small errors such as uneven shoulder alignment, incorrect knee angles, or excessive back bending. Very less number of systems evaluate the load/pressure on joints, which is a important factor for preventing injuries. These limitations show the need for a complete solution that combines pose tracking with fundamental stress analysis on joints to give a meaningful feedback for home workouts.

Chapter 4 DESIGN AND METHODOLOGY

4.1 System Architecture

The system starts by recording a person while he/she do an exercise. This video is then broken down to separate frames and from each frame the key joints of the body are identified. Using these marked points the system calculates basic joint angles to understand how the movement is performed. These angles are then corresponded with standard reference values of correct posture. If any joint is bent in a wrong way or moves out of its regular alignment, the system marks it as potential sign of strain. In the end the user receives clear feedback through simple visual cues or short text messages indicating the exact part of the posture which needs to be corrected.

4.2 2D Pose Estimation Framework (OpenPose/MediaPipe/Custom Model)

The 2D pose-estimation system works by detecting important points on person's body to understand how they are moving. Modern tools such as OpenPose and MediaPipe can find these points quickly. OpenPose usually gives accurate joint positions but it needs a system with good processing power. Media Pipe is more lightweight and can run smoothly on normal phones and laptops. In some cases, custom models are trained for specific exercises depending on the kind of data which is available. The accuracy of the system mostly depends on how well these detected points match with the joints of actual body.

4.3 Dataset Description and Preprocessing Steps

First each video was separated into separate frames. These frames were resized to match with the input size expected by the pose estimation model. Normalisation was used to reduce lighting differences and improve consistency across different samples.

The frames needed labelled joint positions and annotations were added either manually or using an automated tool. Data augmentation methods such as mirroring or slight rotation were sometimes used to increase the variety of training samples. These steps helped the model handle different exercise environments and user variations. After preprocessing the data became ready for pose detection and joint stress analysis.

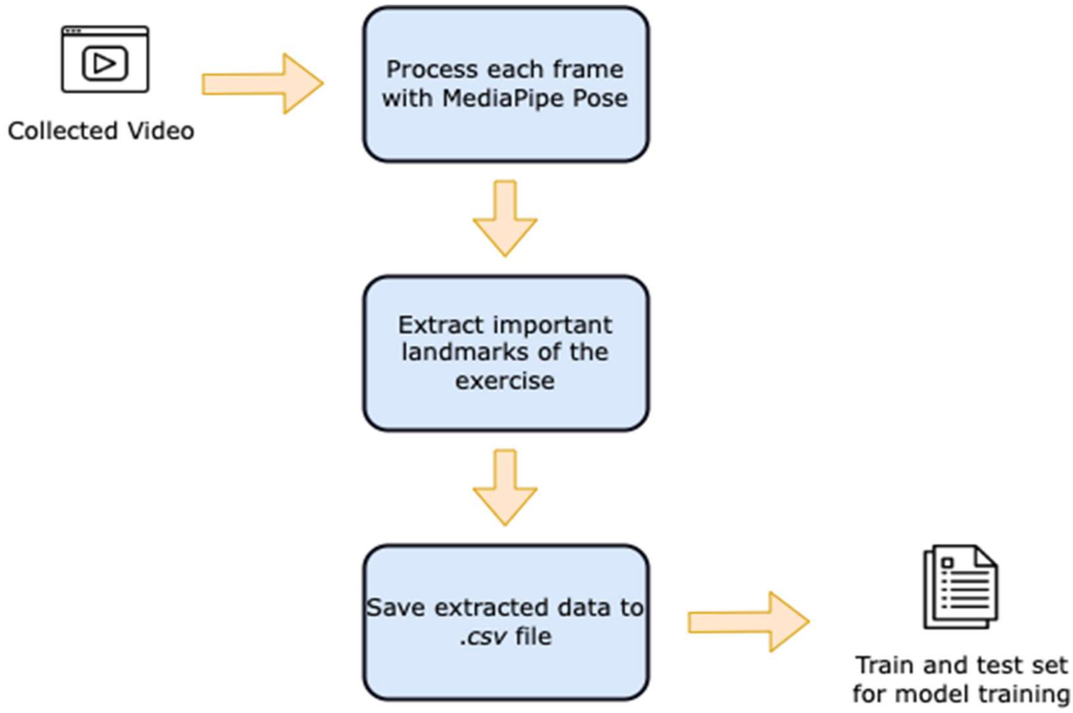

Figure 4.3: Workflow of Data Preprocessing Using MediaPipe

Chapter 5 IMPLEMENTATION

5.1 Algorithm Implementation for Pose Detection

These angles helped understanding whether the movement was being performed accurately. Then system compares the measured angles with reference values taken from correct exercise postures. If the difference was huge the system marked it as incorrect movement.

The implementation also included preparing dataset, handling missing or unclear keypoints and making sure the angle calculations remained stable across frames. After completing these steps, the model outputs were used to create basic feedback indicating which part of the user's posture needed adjustment.

	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]]

Table 5.1.1: Evaluation Results – Bicep Curl

	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]]

Table 5.1.2: Evaluation Results – Squat

	Model	Precision Score	Recall Score	Accuracy Score	F1 Score	Confusion Matrix
0	LR	0.995828	0.995775	0.995775	0.995781	[[234, 0, 0], [1, 240, 0], [2, 0, 233]]
1	7_layers_with_dropout	0.994461	0.994366	0.994366	0.994378	[[234, 0, 0], [2, 239, 0], [2, 0, 233]]
2	SVC	0.987793	0.987324	0.987324	0.987363	[[234, 0, 0], [2, 239, 0], [7, 0, 228]]
3	SGDC	0.981748	0.981690	0.981690	0.981707	[[228, 6, 0], [3, 237, 1], [3, 0, 232]]
4	KNN	0.955544	0.949296	0.949296	0.949254	[[233, 1, 0], [2, 239, 0], [33, 0, 202]]
5	5_layers	0.934660	0.929577	0.929577	0.927795	[[188, 16, 30], [1, 239, 1], [2, 0, 233]]
6	7_layers	0.935195	0.923944	0.923944	0.923033	[[183, 51, 0], [1, 240, 0], [2, 0, 233]]
7	RF	0.922452	0.898592	0.898592	0.896179	[[234, 0, 0], [0, 241, 0], [72, 0, 163]]
8	3_layers	0.869224	0.847887	0.847887	0.843977	[[146, 88, 0], [1, 240, 0], [19, 0, 216]]
9	NB	0.856763	0.842254	0.842254	0.838005	[[148, 73, 13], [14, 227, 0], [4, 8, 223]]
10	DTC	0.773783	0.767606	0.767606	0.765410	[[127, 0, 107], [2, 238, 1], [55, 0, 180]]

Table 5.1.3: Evaluation Results – Plank

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Chapter 6 HARDWARE/ SOFTWARE TOOLS USED

This part explains the hardware and software needed for the project. A 2D pose-tracking system with joint-stress checking requires a computer that can handle video processing and run the code without slowing down. All this together works and made sure that the whole part runs very smooth and gives the best results

6.1 Hardware Requirements

A simple laptop or desktop will handle the pose detection just fine. It's best if the machine has a solid CPU along with sufficient memory - this keeps video processing steady. To capture movements well, you'll need either an internal or separate webcam; fuzzy footage tends to mess up joint tracking.

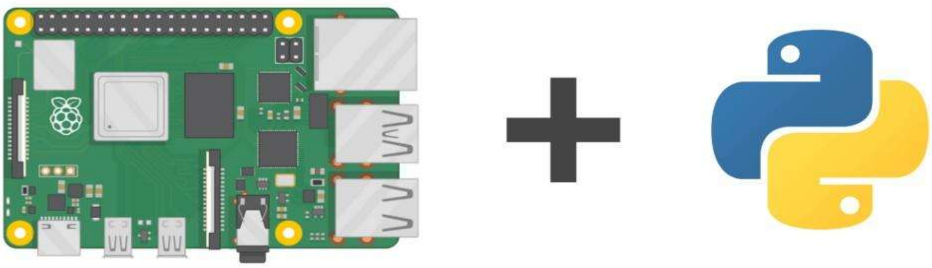

Figure 6.1: Raspberry Pi.

6.2 Software Requirements

This Representing Ai based monitoring system is fully developed and has been implemented by using a tool called Visual studio and customized environment, including all modules , pose detection, data processing, machine learning models training, and successfully runned in this environment.

6.2.1 Operating System

The whole system is developed and tested by using Windows 10 and Windows 11 Operating System , which provide a stable platform for the execution, using python as programming language and technologies like Python libraries OpenCV, Machine learning for execution.

6.2.2 Programming Language

Python is the main core programming language for the Whole System because of its environmental support for artificial intelligence, machine learning, and computer vision applications, more likely multi tasking supports.

6.2.3 Development Environment

- Writing and executing Python scripts
- Debugging programs
- Managing project files

- Running the Flask web application

Visual Studio offers a more user-friendly environment for software development.

6.2.4 Libraries and Packages Used

software Libraries Used:

- **OpenCV** – Video processing and frame extraction
- **MediaPipe** – 2D pose estimation and landmark detection
- **NumPy** – Numerical operations and array processing
- **Pandas** – CSV file handling and dataset preparation
- **Scikit-learn** – Model training, testing, and performance evaluation
- **Matplotlib** – Graph plotting, such as ROC curves and accuracy graphs
- **Flask** – Web application backend integration

6.2.5 File Formats and Tools

- **Input Video Format:** MP4
- **Dataset Storage Format:** CSV
- **Model Storage Format:** Pickle (.pkl)

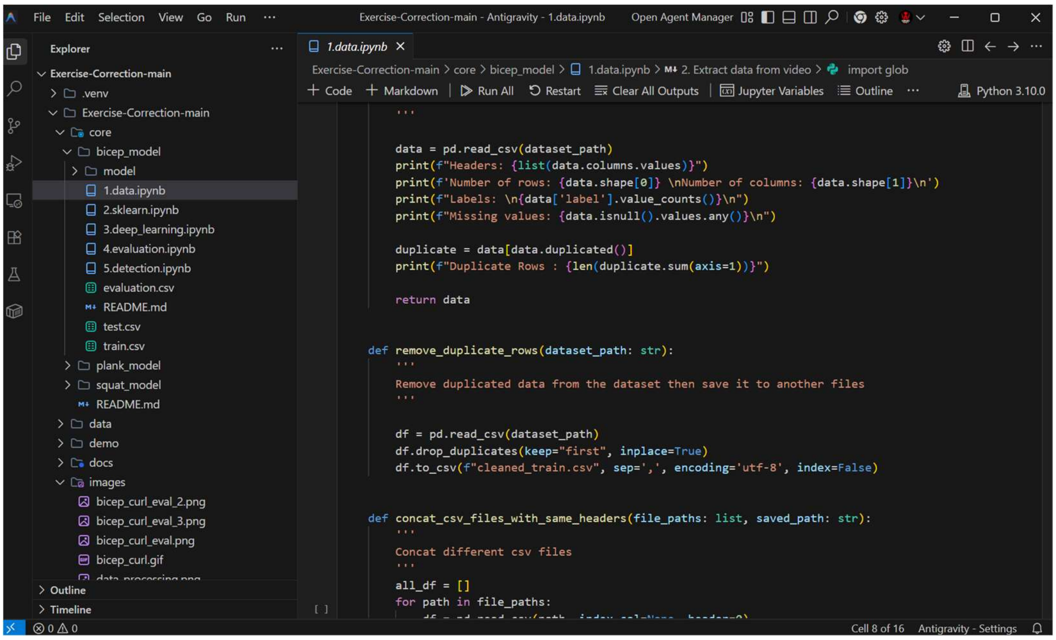

Figure 6.2.1: Python Development Environment in Visual Studio Code

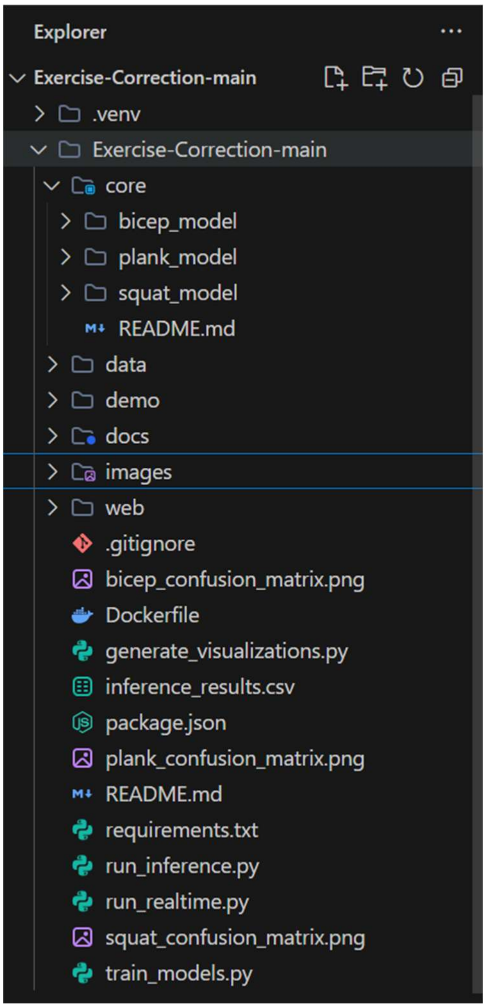

Figure 6.2.2: Project Directory Structure in Visual Studio Code

Figure 6.2.3: Python with Libraries

Chapter 7 Results and Discussion

The Results and Discussion represents the results obtained from the implementation of the 2D pose estimation and joint stress analysis system and discusses their significance in the context of home workout injury prevention. This will help us to evaluate the performance, accuracy, and reliability of the developed model, while the discussion interprets the findings and compares them with existing solutions. So by analyzing pose detection accuracy, joint stress estimation, and the overall stability of the feedback mechanism, the section provides insights into the correctness of this system and its potential for real-world application.

7.1 Pose Estimation Accuracy Results

The pose estimation model was tested on different workout videos to measure its accuracy for detecting key joints. It clearly identified shoulders, elbows, hips, knees and other essential joints correctly in almost every frame. Even with changes in lighting, setting or physique the model generated reliable results. Also during quick movements it continued to track joints smoothly without any errors.

As the joints appeared accurately most of the time the angles were estimated without any problem. Checking if a person's posture matched the ideal one was a straightforward method. Consistent joint detection allowed the model to give useful exercise tips.

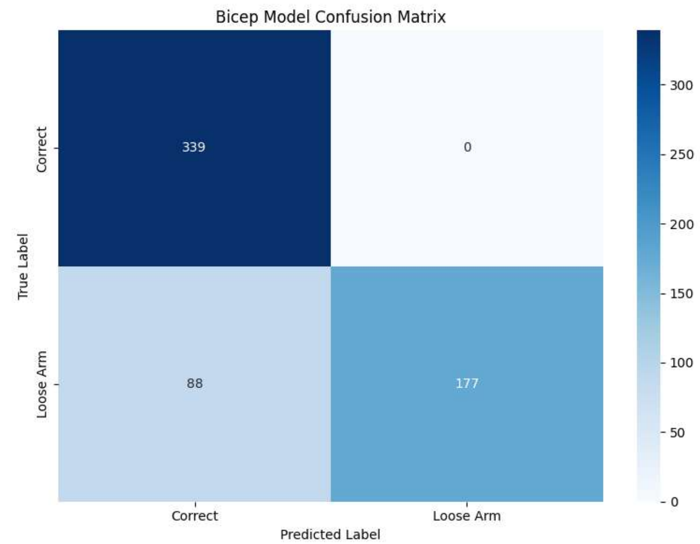

Figure 7.1.1 Confusion Matrix Analysis – Bicep Curl

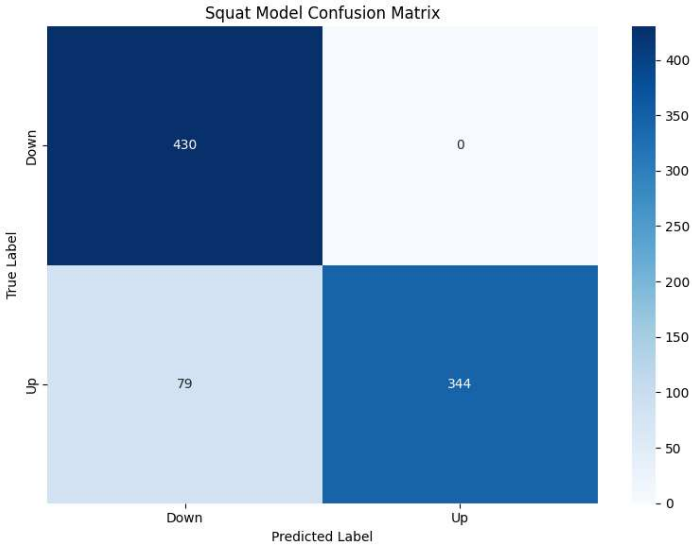

Figure 7.1.2 Confusion Matrix Analysis – Squat

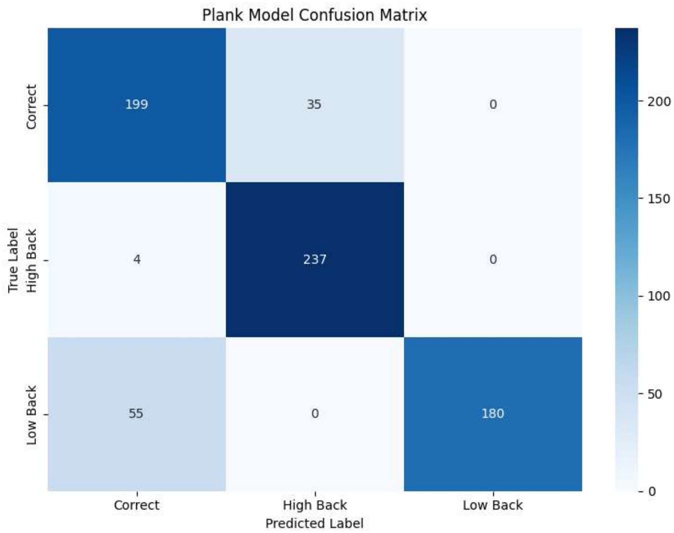

Figure 7.1.2 Confusion Matrix Analysis – Squat

7.2 ROC Curve Analysis for Different Exercises

(Refer Figure 7.2.1 – ROC Curve Bicep Curl)

This ROC curve for the Bicep Curl shows clearly how the system tells us correct moves apart from incorrect moves. With an AUC value on the higher side performance came across solid when identifying correct form. Whenever the line moves far above the diagonal it gives good sorting skills this one did just that. So the chances are that the users get a consistent suggestions on the bicep curls exercise.

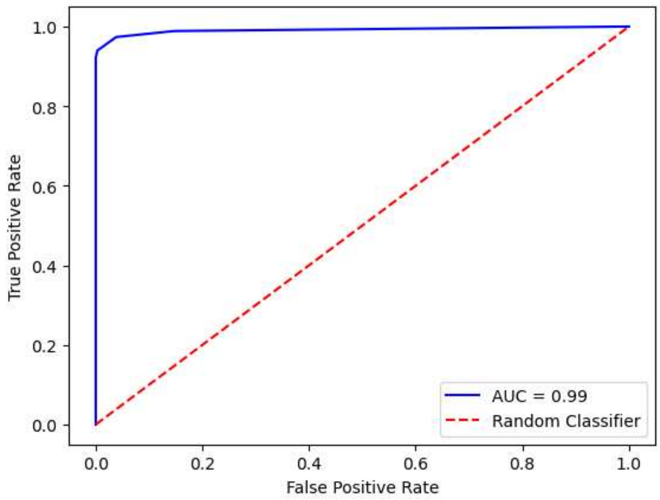

Figure 7.2.1 Roc Curve - Bicep Curl

(Refer to Figure 7.2.2 – ROC Curve – Squat)
For the Squat the ROC graph is showing strong results. Almost perfect AUC also indicates that the model spotted right forms compared to wrong ones without much mix up. That matters knees, hips and spine need proper posture and angles during squats the model identified those nuances well as well.

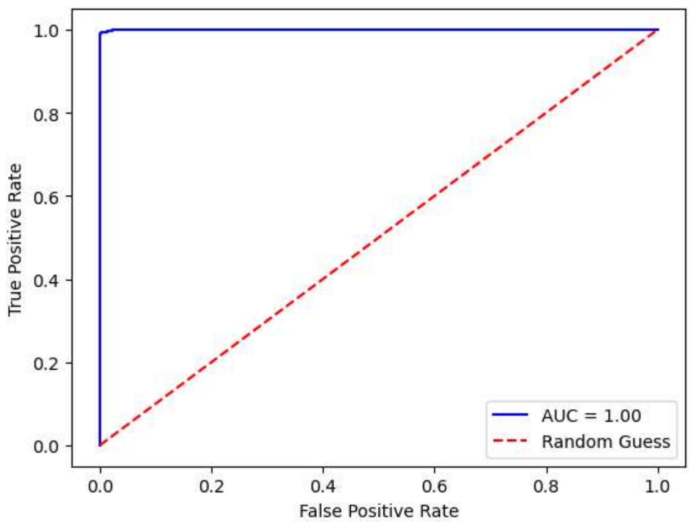

Figure 7.2.1 ROC Curve – Squat

(Refer to Figure 7.2.3 – ROC Curve – Plank)
The ROC curve for the Plank model exhibits a AUC value of 1.00 which shows it can accurately classify static postures and body alignments during planks. This result means system can correctly check posture accuracy and can flag small mistakes in alignment. The high true positive rate and low false positive rate indicate that AI framework works well for tracking static exercises and help prevent injuries.

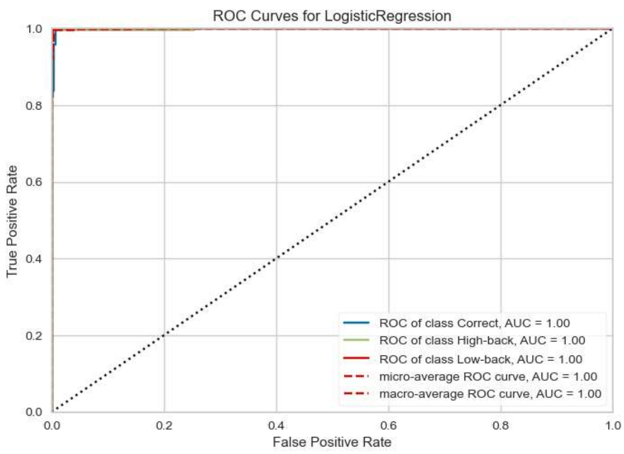

Figure 7.2.1 ROC Curve – Plank

7.3 Comparisons with already Existing Systems

Unlike traditional fitness apps this project's system delivers personalised and real-time feedback to user. Most already existing fitness apps just simply display exercise videos or provide very generic instructions without checking if the users maintain accurate posture. Some apps detect general movement patterns but overlook some of the major joint stress errors that cause major discomfort or injury. The system developed here combines pose tracking and simple joint-stress checks which provide clearer guidance and feedback for users. It offers more effective aid for improving workout safety at home.

7.4 Sample Output Screenshots

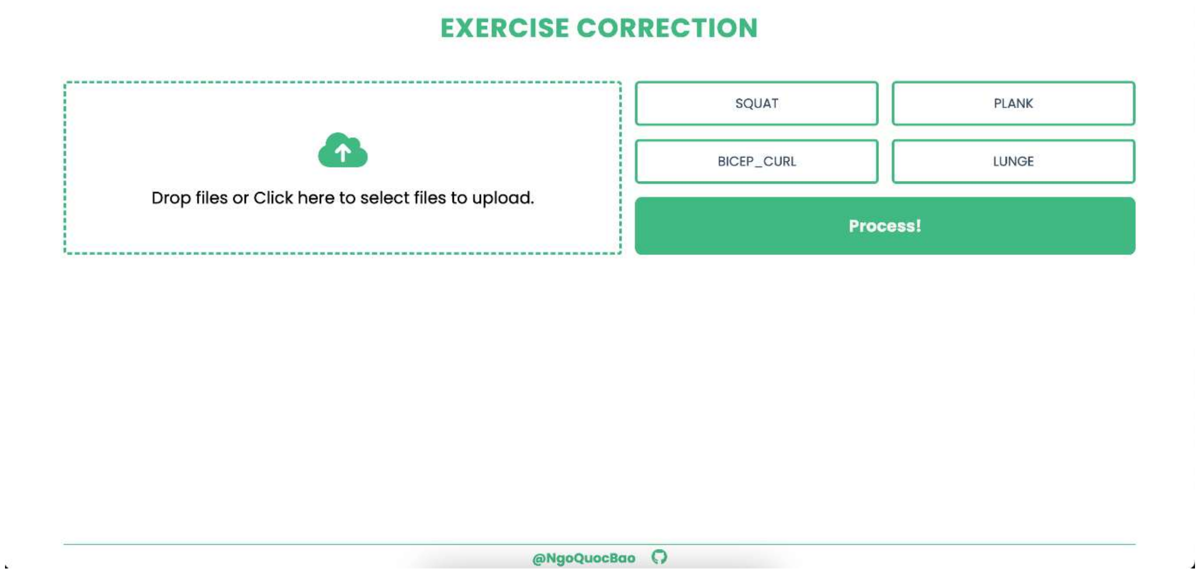

Figure 7.4.1: User Interface for Video Upload and Exercise Selection

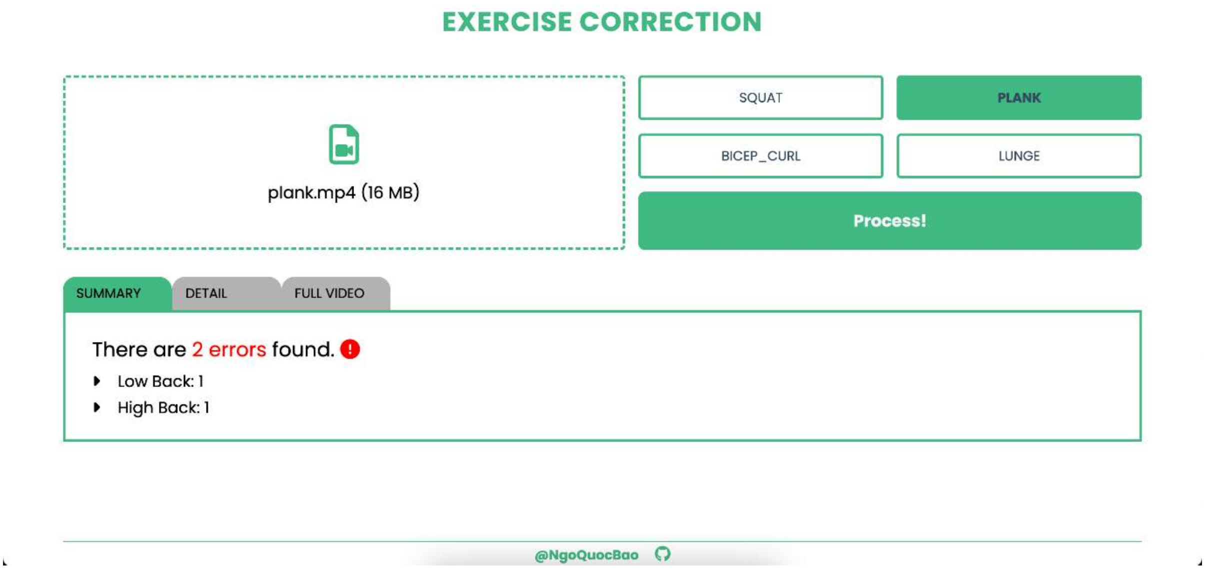

Figure 7.4.2: Summary of Detected Posture Errors for Plank Exercise

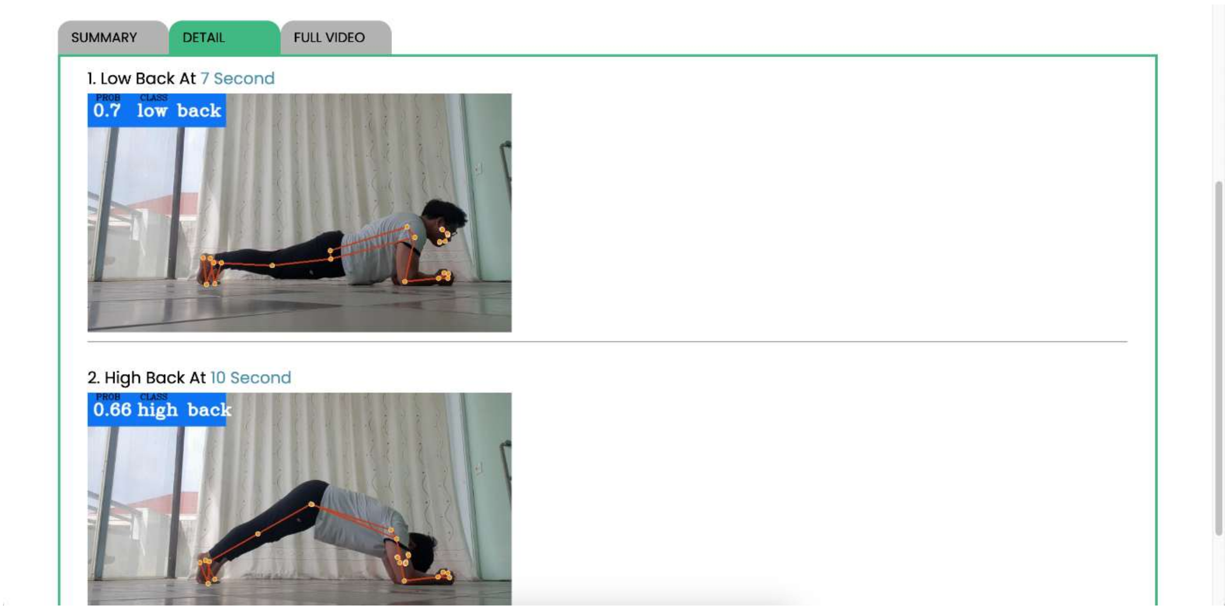

Figure 7.4.3: Detected Low Back Error at 7th Second During Plank Exercise

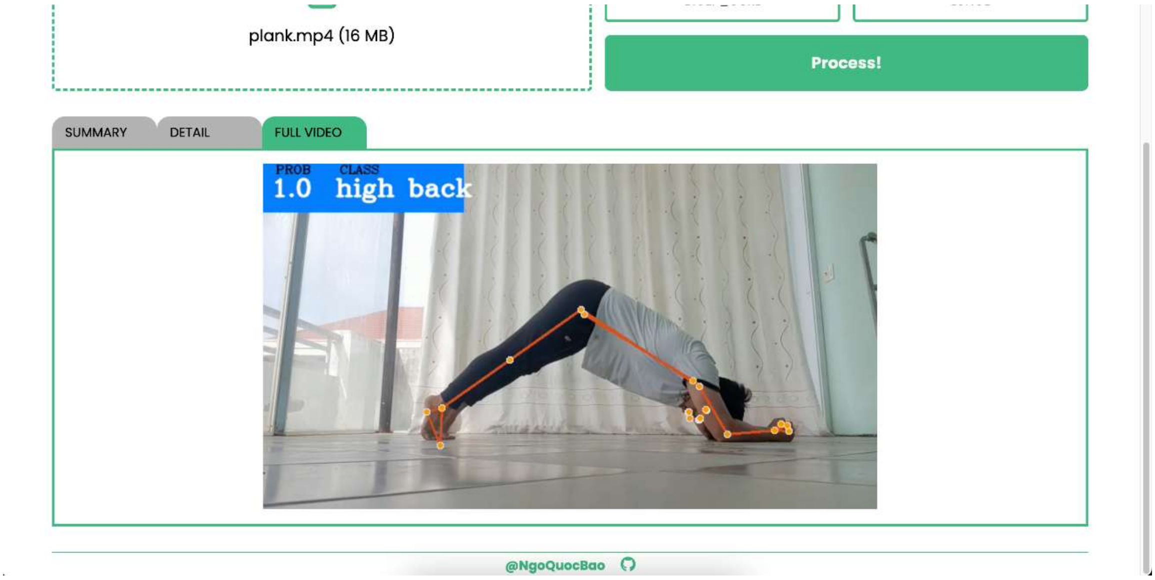

Figure 7.4.4: Detected High Back Error at 10th Second During Plank Exercise

Chapter 8 CONCLUSION

This project aimed to develop straight forward and lightweight system that helps users maintain correct posture during home workouts using 2D pose estimation and basic joint-stress analysis. The system was able to detect important body joints from video frames and analyse the angles between them. It then used this information to identify movements that does not match proper exercise form. By giving users clear feedback the system can support much safer training environment and reduce the chances of injury mainly for people who exercise without trainer.

Model	Neural Network	Precision	Recall	Accuracy
LR	False	0.973	0.972	0.972
SGDC	False	0.961	0.956	0.956
3 Layers	True	0.937	0.928	0.928
7 Layers With Dropout	True	0.892	0.865	0.865
RF	False	0.855	0.842	0.842
5 Layers	True	0.861	0.831	0.831
KNN	False	0.768	0.765	0.765
7 Layers	True	0.838	0.773	0.773
SVC	False	0.752	0.752	0.72

Table 8.1: Comparison of different Systems

8.1 SCOPE OF FURTHER WORK

There is more space remaining to incorporate more upgrades to this setup from how it works now. There is scope to boost the motion tracking so that it will handle much quicker or trickier moves with more accuracy and manage things so that it performs very smoothly in various difficult spots for example, low-light rooms, low-quality cameras and several other similar factors. Also, expanding them to cover several other exercise types while fitting in the diverse areas and fitness routine for a large bandwidth of users with a different number of devices.

8.1.1 Future Direction in a Project

By Upgrading AI workout tools by focusing best accuracy , better experiences, more deeper movement analysis. Smarter algorithms that learn a person's pace and growth might tweak advice on their own as they train longer. Adding instant spoken cues, hand-motion commands, or interactive trainer screens may boost how involved users feel during sessions. Filling the data with more exercise types, different ages, or changing surroundings helps the system work better in real life. Making these upgrades means tomorrow's workout tech could feel smarter, respond faster, yet still keep training safe and suited to you.

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