A Project Report on

FormMatters:Posture Detection System using Computer Vision and Machine Learning during Workouts

Submitted in partial fulfillment of the requirements for the award of the degree of

Bachelor of Engineering

in

Information Technology

by

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Academic Year 2022-2023

Approval Sheet

This Project Report entitled ***" FormMatters:Posture Detection System using Computer Vision and Machine Learning during Workouts "*** Submitted by ***"Keval Kantilal Gada(20204002), Aadarsh Naresh Khant(20204003), Tanay Dilip Jain(20204004)"*** is approved for the partial fulfillment of the requirenment for the award of the degree of ***Bachelor of Engineering*** in ***Information Technology*** from ***University of Mumbai***.

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Place:A.P.Shah Institute of Technology, Thane

Date:

CERTIFICATE

This is to certify that the project entitled ***"FormMatters:Posture Detection System using Computer Vision and Machine Learning during Workouts"*** submitted by ***"Keval Kantilal Gada(20204002), Aadarsh Naresh Khant(20204003), Tanay Dilip Jain(20204004)"*** for the partial fulfillment of the requirement for award of a degree ***Bachelor of Engineering*** in ***Information Technology***,to the University of Mumbai,is a bonafide work carried out during academic year 2022-2023.

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Acknowledgement

We have great pleasure in presenting the report on **FormMatters:Posture Detection System using Computer Vision and Machine Learning during Workouts.** We take this opportunity to express our sincere thanks towards our guide **Prof.Manjusha Kashilkar** Department of IT, APSIT thane for providing the technical guidelines and suggestions regarding line of work. We would like to express our gratitude towards her constant encouragement, support and guidance through the development of project.

We thank **Dr.Kiran B. Deshpande** Head of Department,IT, APSIT for his encouragement during progress meeting and providing guidelines to write this report.

We thank **Prof.Sonal Jain** BE project co-ordinator, Department of IT, APSIT for being encouraging throughout the course and for guidance.

We also thank the entire staff of APSIT for their invaluable help rendered during the course of this work.We wish to express our deep gratitude towards all our colleagues of APSIT for their encouragement.

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Declaration

We declare that this written submission represents our ideas in our own words and where others' ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Abstract

Owing to the advent and dissemination of the COVID-19 Coronavirus pandemic in the world in 2020, lock downs and work from home have become commonplace. This has resulted in a huge dip in overall health due to minimal activity. A study has found less physical activity increases the likelihood of developing heart diseases, obesity, and type 2 diabetes. To increase daily activity and keep themselves fit and active people have resorted to indoor workouts. But due to lack of proper guidance, form, and execution, many individuals end up injuring themselves severely causing more harm than good. To alleviate this problem, we aim at creating a web application FormMatters that will aid users in correcting their form and posture. The web application will capture all the needed key points (left and right shoulder, arm, torso, knee, etc.) and angle on the human body and compare the user's current posture with the expected exercise posture, providing feedback in real-time. The user will get to know the inconsistency in the posture by comparing the value of the angle/key points of the particular part to that of the pre-trained model. We aim to use machine learning, temporal convolution neural networks, dynamic time warping, and image processing algorithms to solve the problem statement. The web application will be presented with a usable and accessible interface.

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List of Abbreviations

IDS:	Intrusion Detection System
CNN:	Convolutional Neural Network
GIF:	Graphics Interchange Form
RGB:	Red Green Blue
NW-UCLA:	Northwestern-UCLA Multiview Action
HMM:	Hidden Markov Mode
ANN:	Artificial Neural Network
2D:	Two Dimensional
3D:	Three Dimensional

Chapter 1

Introduction

Exercises such as squats, dead lifts, and shoulder presses are beneficial to health and fitness, but they can also be very dangerous if performed incorrectly. The heavy weights involved in these workouts can cause severe injuries to the muscles. Many people work out and perform these exercises regularly but do not maintain the proper posture. This could be due to a lack of formal training through classes or a personal trainer, or could also be due to muscle fatigue or using too much weight. For our course project, we seek to aid people in performing the correct posture for exercises by building Posture Trainer FormMatters, a web application that detects the user's exercise pose and provides useful feedback on the user's form, using a combination of the latest advances in pose estimation and machine learning. Our goal for FormMatters is to help prevent injuries and improve the quality of people's workouts with just a computer and a webcam. The first part of FormMatters uses human pose estimation, a difficult but highly applicable domain of computer vision. Given visual data, which could be an RGB image and/or a depth map, a trained model predicts a person's joints as a list of skeletal key points. Pose estimation is critical for problems involving human detection and activity recognition, and can also aid in solving complex problems involving human movement and posture. We use a state-of-the-art pose estimation deep neural network, OpenPose, within FormMatters for inference. The second part of our website involves detecting the quality of a user's predicted pose for a given exercise. Our full web application consists of the previously described components, combined into an end-to-end application that can take a video of an exercise and provide useful exercise form feedback to the user. For the scope of this project, we present FormMatters.

Chapter 2

Literature Review

- In paper[1] written by J. Kim and D. Lee[1],"Activity Recognition with Combination of Deeply Learned Visual Attention and Pose Estimation" , two dimensional and three dimension pose estimation is obtained for human activity recognition in a video sequence, and final activity is determined by combining it with an activity algorithm with visual attention. Soft visual attention and a multi-layer recurrent neural network using long short term memory is used. Test results are Penn Action 98.9%, NTU 87.9%, and NW-UCLA 88.6% - Activity Recognition with Combination of Deeply Learned.

- In paper[2] written by Z. Cao, G. Hidalgo, T. Simon, S. Wei, and Y.Sheikh[2],"OpenPose: Realtime Multi-Person 2D Pose Estimation Using Part Affinity Fields",vol. 43, no. 1, pp. 172-186, 2021.,proposes a 3D model rather than 2D skeletons and then measure the differences between the joint angles of the 3D skeletons. Deep latent variable models, and a positive-definite kernel are used to provide a more accurate pose estimation. Experimental results show the superiority of the proposed 3D pose estimation over the state-of-the-art baselines with a 77% accuracy on the Human3.6M database. - Robust Vision-Based Workout Analysis Using Diversified Deep Latent Variable Model.

- In paper[3] written by Ch eron, G.; Laptev, I.; Schmid, C. P-cnn:[4] Pose-based cnn features for action recognition they design a new action descriptor based on human poses. Provided with tracks of body joints over time, our descriptor combines motion and appearance features for body parts. Given the recent success of Convolution Neural Networks (CNN) [20, 23], they explore CNN features obtained separately for each body part in each frame and use appearance and motion-based CNN features computed for each track of body parts, and investigate different schemes of temporal aggregation.

- In paper[4] written byPi˜nero-Fuentes, E.; Canas-Moreno, S.; Rios-Navarro, M.; Sevillano, J.L.; Linares-Barranco, A. A Deep-Learning Based Posture Detection System for Preventing Telework-Related Musculoskeletal Disorders.They have proposed a system to detect a posture of a person sitting and working in front of his/her computer. They took a data set from COCODATASET and applied ResNet (CNN based model) to gather the information about the posture of a people and done their analysis in detecting Shoulder Alignment, Right and Left Arm abduction, Neck Lateral bend.

- In paper[5] CNN algorithms were used to classify the traditional African Dance with good accuracy. The pose sticks generated for the dance poses have been documented by the position of each of the joints per frame. The pose sticks were strung together in a lightweight Graphics Interchange Format (GIF) that can be placed in documents on various platforms. These pose sticks can be developed into three-dimensional artifacts that can be used for cultural learning, study, and preservation. These pose sticks are available to programmers and graphic artists for use in different ways. The use of deep learning techniques has made it easy to record poses without performers having to wearing sensors. This method expands the use of prerecorded videos for pose-related studies.

- In paper[6] Although this work was implemented and tested in a laboratory environment with a not very extensive dataset, the results are very promising. Moreover, this only reinforces the fact that there is still quite a lot to gain from automating and detailing the process. Future research may include real-time video processing with an automatic recommendation system, a collection of incorrect poses during real work sessions to improve overall postures, or even changes to the CNN used in order to obtain a more detailed pattern recognition that would allow for the checking of other parameters, such as the spine, which requires more than a single straight segment to be evaluated.

- In paper[7] In accordance to the paper Results showed a posture detectionaccuracy over 80% for the 4-class original problem, and more than 90% for the 2-classclassification system. On the other hand, the hardware platforms tested allows the systemto run in a real-time environment with low power consumption requirements. With thesetwo points in favor, we can conclude that the system can work completely autonomouslyand without the intervention of a computer, providing information in real time

- In paper[8] a system based on the postural detection of the worker is designed, implemented and tested, using a specialized hardware system that processes video in real time through convolutional neural networks. This system is capable of detecting the posture of the neck, shoulders and arms, providing recommendations to the worker in order to prevent possible health problems, due to poor posture. The results of the proposed system show that this video processing can be carried out in real time (up to 25 processed frames/sec) with a low power consumption (less than 10 watts) using specialized hardware, obtaining an accuracy of over 80% in terms of the pattern detected.

- In paper[9] While referring the paper which presents a comparison study with state-of-the-art in terms of accuracy. They also present the advantages and limitations of each system and suggest promising future ideas that can increase the efficiency of the existing posture recognition system. Finally, the most common datasets applied in these systems are described in detail. It aims to be a resource to help choose one of the methods in recognizing the posture of the human body and the techniques that suit each method. It analyzes more than 80 papers between 2015 and 2020

- In paper[10] the system aims to simplify the gymnastics training process, so as to research and implement a gymnastics action recognition system based on Kinect, so that trainers can efficiently learn various gymnastics items at home and understand their own deficiencies.The performance improvement of the traditional human action recognition algorithm is completed. Sports action is discriminated by utilizing the skeletal features of the Kinect sensor. Clustering based on the static K-means algorithm increases the accuracy of pose selection. Each pose is recognized by human action using artificial neural network(ANN) and hidden Markov model (HMM), which makes the system more intelligent and improves system performance and accuracy. Finally, it is evaluated on the public dataset UTK inectAction3D.

Objectives

- To create a user interface where end-user will be able to interact with the web-application using Django Framework.
- To identify and rectify the form/posture of a user performing exercises with the help of Deep-Learning (Convolution Neural Network).
- To give information to the user about form of the exercise they are performing by using Web Scarping.
- To provide the user the number of repetitions of the poses they are performing using OpenCV and Machine Learning.

Chapter 3

Project Design

3.0.1 Existing System

- Limited Feedback: While some fitness applications provide feedback on user progress, the feedback may be limited in scope, providing only basic information on calories burned or steps taken. This can make it difficult for users to make meaningful adjustments to their routines or understand how to improve their performance.
- Lack of Integration: Some fitness applications lack integration with other devices or platforms, limiting their ability to provide a comprehensive view of a user's health and fitness data. This can result in users having to manually enter data or switch between multiple applications to track their progress, leading to frustration and decreased engagement.
- Limited Variety: Some fitness applications may lack variety in the types of workouts or exercises offered, which can make it difficult for users to stay engaged and motivated over time. This can also limit the effectiveness of the application, as users may not be getting a well-rounded fitness experience.
- No Real-Time Feedback: While some fitness applications provide feedback on user progress, the feedback may not be provided in real-time, limiting the ability for users to make immediate adjustments to their workouts or technique.

3.0.2 Proposed System

- Hardware: The system would require a camera or webcam to capture video of the user during their home workout. The camera should be positioned to capture the user's full body.

- Software: The system would use OpenCV, a computer vision library, to process the video stream and detect the user's posture. A CNN model trained on a posture dataset would be used to classify the user's posture in real-time.

- User Interface: The system would have a simple user interface that displays the video stream and the detected posture. The user would be able to see their posture in real-time and make adjustments as needed to maintain proper form during their workout.

- Posture Detection: The system would use OpenCV to detect the user's body position and posture based on keypoints such as head, shoulders, elbows, hips, and knees. The CNN model would then classify the posture as correct or incorrect based on predefined criteria.

- Feedback: The system would provide feedback to the user if their posture is incorrect. This could be done through visual cues, such as highlighting the body part that needs adjustment, or through audio cues, such as a voice prompt. The feedback should be clear and concise, helping the user to make the necessary adjustments quickly and easily.

- Performance Metrics: The system would track the user's posture over time and provide performance metrics such as accuracy, precision, recall, and F1-score. This would allow the user to monitor their progress and identify areas for improvement.

- Data Collection: The system could collect data on the user's posture, no. of poses, and performance metrics. This data could be used to improve the posture detection model and to provide personalized recommendations for the user.

- Conclusion: The proposed posture detection system for home workouts would help users maintain proper form during their workouts, reducing the risk of injury and improving their overall fitness and performance. With the increasing popularity of home workouts, such a system could be a valuable tool for fitness enthusiasts of all levels.The user will be recommended with videos to correct their poses.

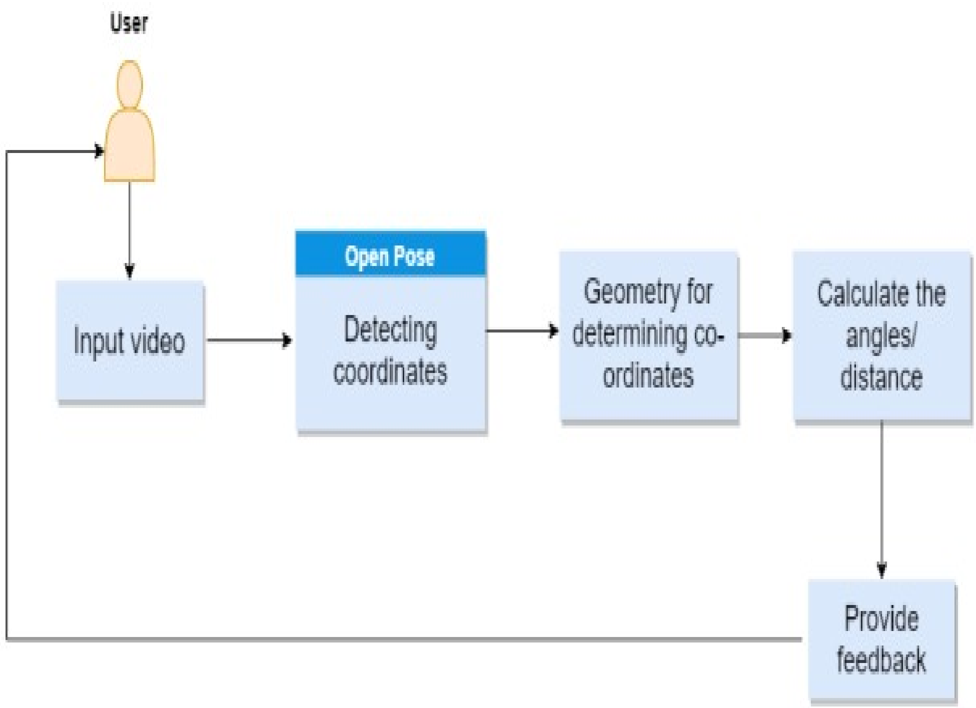

Figure 3.1: Flow of Project

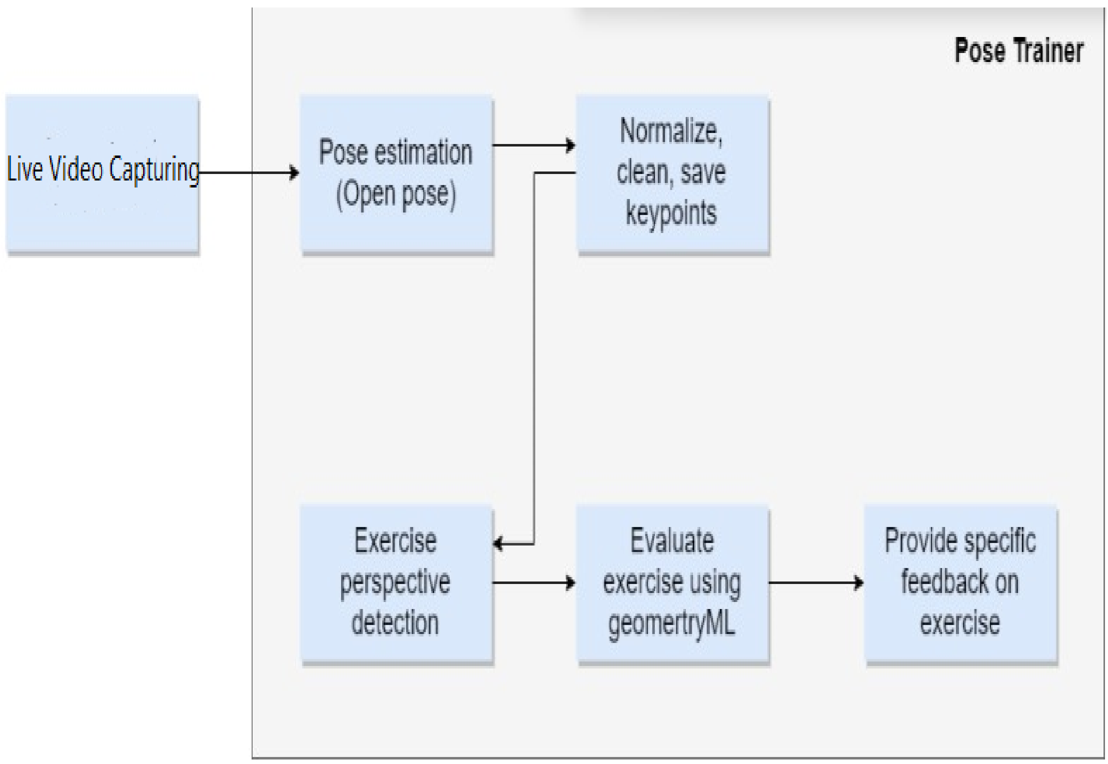

Figure 3.2: Project Flow

3.0.3 System Diagram

- Activity Diagram
  Activity diagram is basically a flowchart to represent the flow from one activity to another activity. The activity can be described as an operation of the system. The basic purposes of activity diagram is to capture the dynamic behavior of the system.

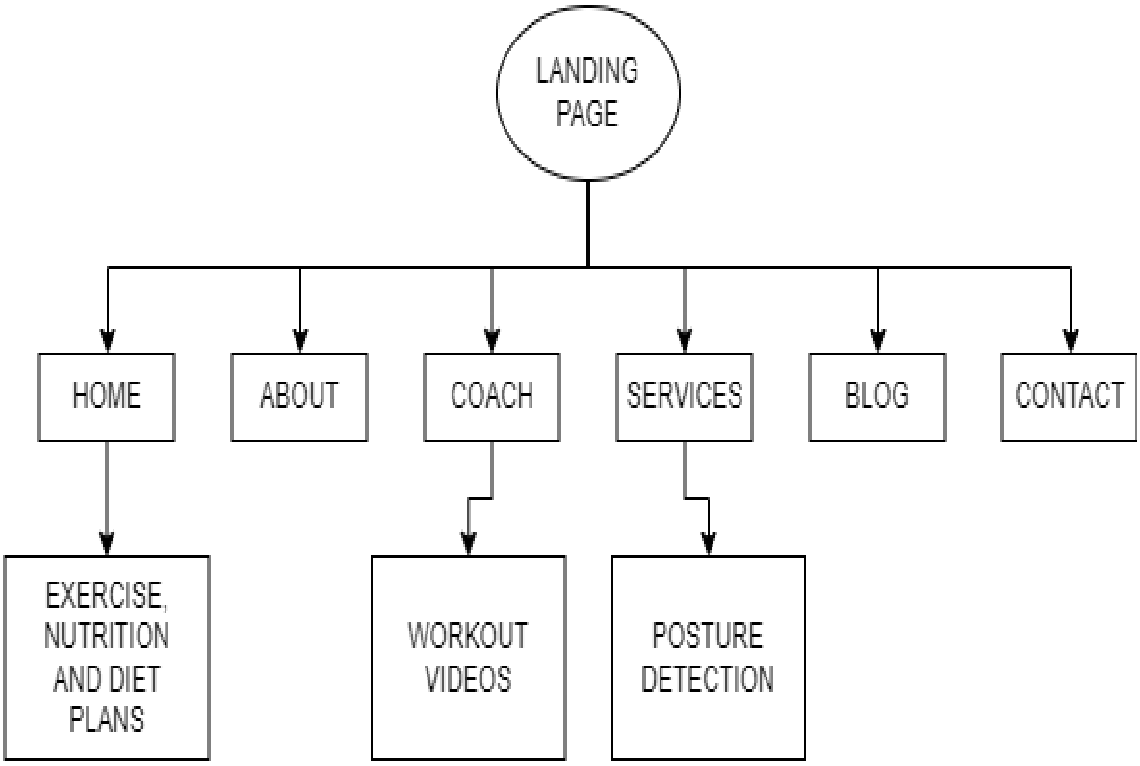

Figure 3.3: Activity Diagram

The figure shown is the complete system diagram of the proposed system. First the user will land on the website. The landing page has different sections such as home, about, coach, services, blog and contact. In the home section the user gets exercise, nutrition and diet plans. In the about section the user gets details about the website. In the coach section the user can watch the workout videos which they can refer for their workout. In the services section the user can use posture detection service for various exercises such as pushups, bicep workout, etc. In the blog section user can read various blogs. In the contact section the user will get the contact details.

- Sequence Diagram
  A sequence diagram is a Unified Modeling Language (UML) diagram that illustrates the sequence of messages between objects in an interaction. A sequence diagram consists of a group of objects that are represented by lifelines, and the messages that they exchange over time during the interaction. A sequence diagram shows the sequence of messages passed between objects. Sequence diagrams can also show the control structures between objects.

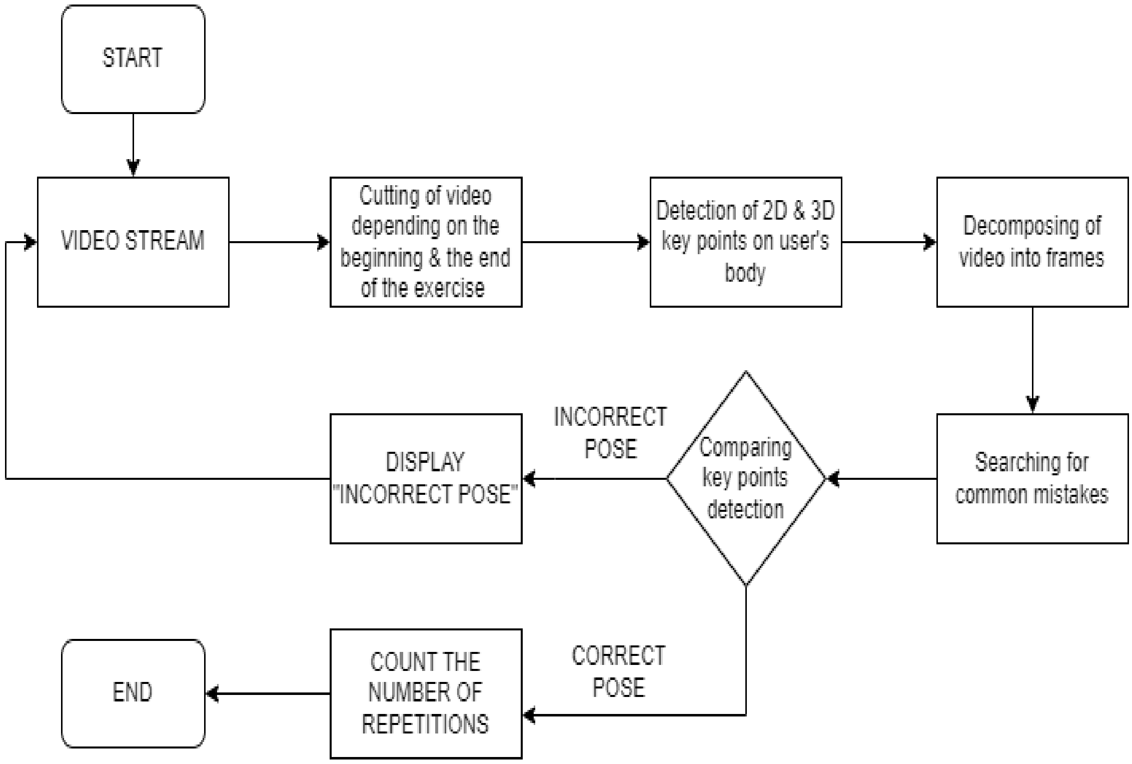

Figure 3.4: Sequence Diagram

This diagram shows the entire sequence of flow of the data in the system. In the initial step the camera will be opened to detect the live video of the person. Then the detected video trimmed into images. Once the video is trimmed into objects the 2D and 3D key points will be detected. Then the images will be compared with the images of the proper posture. The images will be be detected using OpenCV. After comparison if the posture is correct then the repetitions will be counted and displayed to the user else a message of ”Incorrect Pose” will be displayed and again comparison will be started.

Chapter 4

Project Implementation

4.0.1 Code Snippets

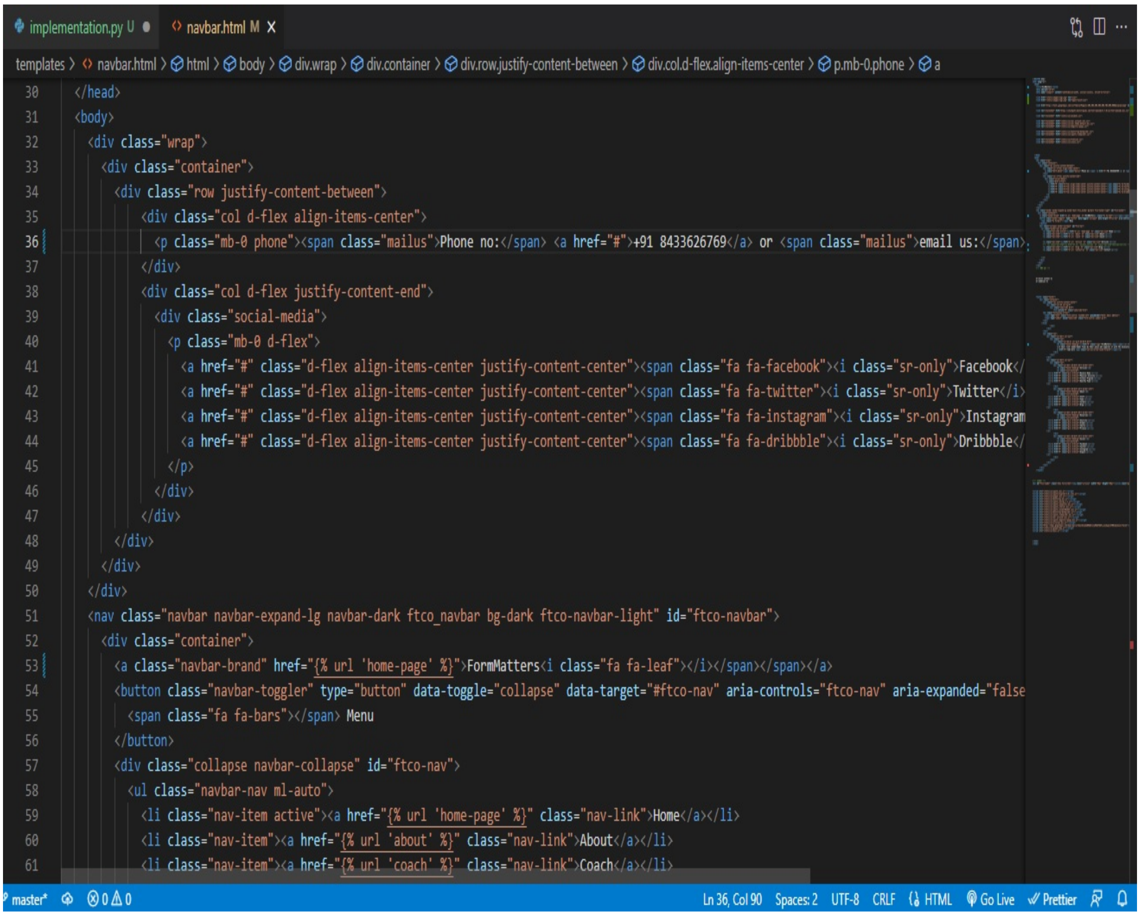

Figure 4.1: Homepage Code

This is the code for homepage of our website. In the above snippet, you can see the code for our landing page where user will get access to interact with different sections like About, Coach, Services, Blog, etc. Further, they also get access to Excercise Programme, Nutrition and Diet Plans.

```python
from django.contrib import admin
from .models import Contact,Bookapp
from django.apps import AppConfig
import cv2
import mediapipe as mp
import math
import numpy as np
from time import time
import matplotlib.pyplot as plt
from django.db import models
from datetime import datetime
from django.test import TestCase
from django.urls import path
from . import views
from django.shortcuts import render,get_object_or_404,redirect
from .implementation import execute_pushup, execute_bicep,executePoseEstimation
from django.contrib import messages
from django.core.mail import send_mail
from .models import Contact,Bookapp
```

Figure 4.2: Importing Libraries

Above image displays all the python libraries imported and used in the project.

```python
class poseDetector() :

    def __init__(self, mode=False, complexity=1, smooth_landmarks=True,
                 enable_segmentation=False, smooth_segmentation=True,
                 detectionCon=0.5, trackCon=0.5):

        self.mode = mode
        self.complexity = complexity
        self.smooth_landmarks = smooth_landmarks
        self.enable_segmentation = enable_segmentation
        self.smooth_segmentation = smooth_segmentation
        self.detectionCon = detectionCon
        self.trackCon = trackCon

        self.mpDraw = mp.solutions.drawing_utils
        self.mpPose = mp.solutions.pose
        self.pose = self.mpPose.Pose(self.mode, self.complexity, self.smooth_landmarks,
                                     self.enable_segmentation, self.smooth_segmentation,
                                     self.detectionCon, self.trackCon)


    def findPose (self, img, draw=True):
        imgRGB = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
        self.results = self.pose.process(imgRGB)

        if self.results.pose_landmarks:
            if draw:
                self.mpDraw.draw_landmarks(img,self.results.pose_landmarks,
                                           self.mpPose.POSE_CONNECTIONS)

```

Figure 4.3: Code for Posture Detection

The above code snippet is the Pose detector which will take input from the live camera and mark major points (Joints) of the user captured from the camera and detect

```python

def execute_pushup():


    cap = cv2.VideoCapture(0)
    detector =poseDetector()
    count = 0
    direction = 0
    form = 0
    feedback = "incorrect form"


    while cap.isOpened():
        ret, img = cap.read() #640 x 480
        #Determine dimensions of video - Help with creation of box in Line 43
        width  = cap.get(3)  # float `width`
        height = cap.get(4)  # float `height`
        # print(width, height)

        img = detector.findPose(img, False)
        lmList = detector.findPosition(img, False)
        # print(lmList)
        if len(lmList) != 0:
            elbow = detector.findAngle(img, 11, 13, 15)
            shoulder = detector.findAngle(img, 13, 11, 23)
            hip = detector.findAngle(img, 11, 23,25)

            #Percentage of success of pushup
            per = np.interp(elbow, (90, 160), (0, 100))

            #Bar to show Pushup progress
            bar = np.interp(elbow, (90, 160), (380, 50))
```

Figure 4.4: Code for Pushup Posture Detection

The above code snippet is from posture detection in which the system will alert the user about the correct and incorrect posture. If the posture is correct the count on repetitions will increase accordingly.

```python
def execute_bicep():

    mp_drawing = mp.solutions.drawing_utils
    mp_pose = mp.solutions.pose



    cap = cv2.VideoCapture(0)

    # Curl counter variables
    counter = 0
    stage = None

    ## Setup mediapipe instance
    with mp_pose.Pose(min_detection_confidence=0.5, min_tracking_confidence=0.5) as pose:
        while cap.isOpened():
            ret, frame = cap.read()

            # Recolor image to RGB
            image = cv2.cvtColor(frame, cv2.COLOR_BGR2RGB)
            image.flags.writeable = False

            # Make detection
            results = pose.process(image)

            # Recolor back to BGR
            image.flags.writeable = True
            image = cv2.cvtColor(image, cv2.COLOR_RGB2BGR)
```

Figure 4.5: Code for Bicep Posture Detection

The above code snippet is for "Bicep Curl" posture detection which will keep Adding "1" to the counter if the detected pose is correct.

```
<div class="col-md-6 col-lg-4 ftco-animate">
    <div class="staff">
        <div class="img-wrap d-flex align-items-stretch">
          <iframe width="500" height="345" src="https://www.youtube.com/embed/IODxDxX7oi4">
          </iframe>

        </div>
        <div class="text pt-3 px-3 pb-4 text-center">

            <span class="position mb-2">Squat</span>
            <div class="faded">
                <p>Weight training is a common type of strength training for developing the strength and size of skeletal muscles</p>
                <ul class="ftco-social text-center">
    <li class="ftco-animate"><a href="#" class="d-flex align-items-center justify-content-center"><span class="fa fa-twitter"></span></a></li>
    <li class="ftco-animate"><a href="#" class="d-flex align-items-center justify-content-center"><span class="fa fa-facebook"></span></a></li>
    <li class="ftco-animate"><a href="#" class="d-flex align-items-center justify-content-center"><span class="fa fa-google"></span></a></li>
    <li class="ftco-animate"><a href="#" class="d-flex align-items-center justify-content-center"><span class="fa fa-instagram"></span></a></li>
  </ul>
div>
```

Figure 4.6: Code for Coach Page

The coach page will contain links of videos of workout linked from youtube which user can access by clicking on them.

Chapter 5

Testing

5.1 Functional Testing

5.1.1 Unit Testing

Unit testing is the first level of testing, which is typically performed by the developers themselves. It helped us understand the desired output of each module, which we had broken down into separate units and in classifying the faces of users on the basis of algorithm that we have used.

5.1.2 Various Testcases

<table>
<tr><th>Test Case No.</th><th>Test Condition</th><th>Test Steps/ Procedure</th><th>Expected Results</th><th>Actual Results</th><th>Pass/Fail</th></tr>
<tr><td>1.</td><td>Working of UI</td><td>Launch the website</td><td>The UI should function properly</td><td>The UI is functioning properly</td><td>Pass</td></tr>
<tr><td>2.</td><td>Recommenda tion Videos</td><td>Click on thumbnails of videos</td><td>User should be shown the best recommended videos</td><td>User is able to watch the recommended videos</td><td>Pass</td></tr>
<tr><td>3.</td><td>Posture Detection for Pushup</td><td>Click on pushup button</td><td rowspan="3">Algorithm should be able to detect the posture and display the results.</td><td rowspan="2">Algorithm is successfully detecting the posture and displaying the results</td><td>Pass</td></tr>
<tr><td>4.</td><td>Posture Detection for Bicep Workout</td><td>Click on bicep workout button</td><td>Pass</td></tr>
<tr><td>5.</td><td>Posture Detection for Yoga</td><td>Click on yoga button</td><td>Not able to detect the yoga postures</td><td>Fail</td></tr>
</table>

Chapter 6

Result

Our system is able to detect the posture of the person and assist him/her accordingly.The user is able to get diet plans,nutrition plans and workout videos form the website.Following are the screenshots of the working of our project:

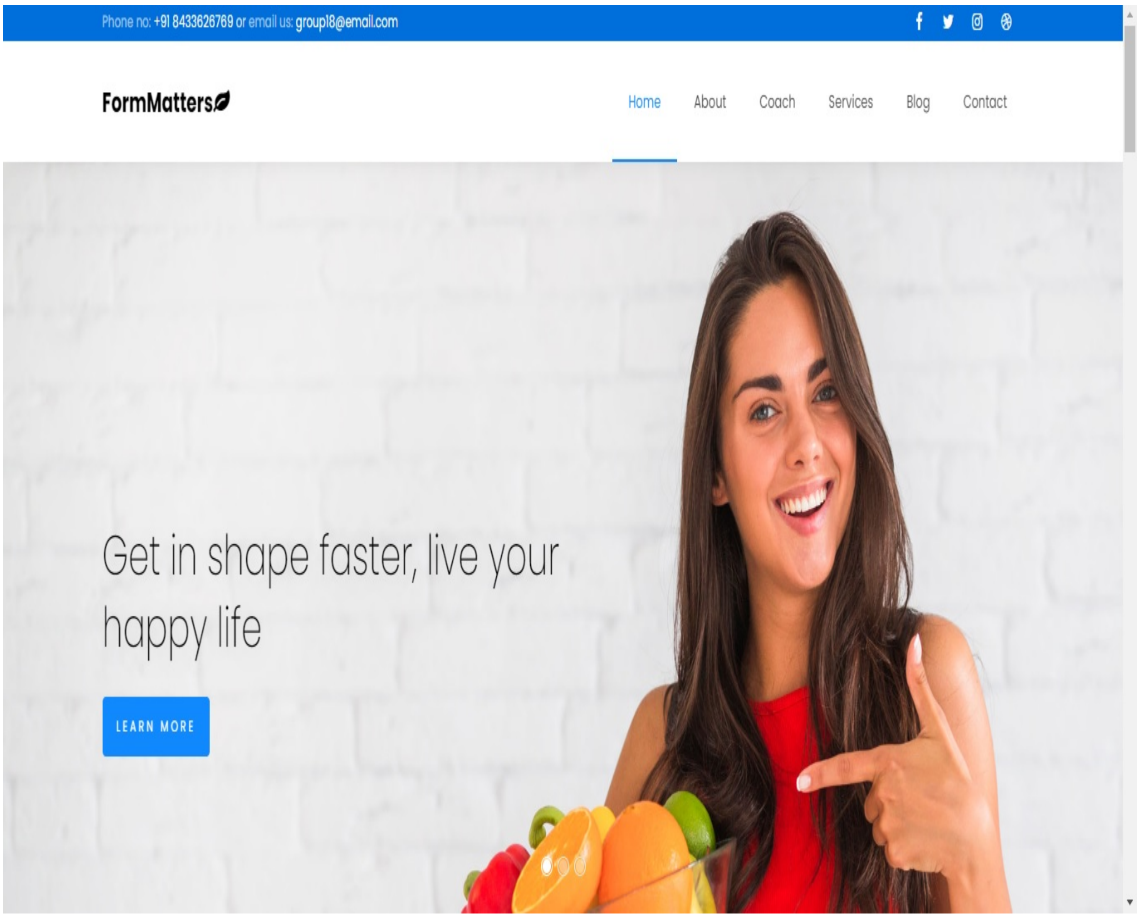

Figure 6.1: Landing Page

This is the landing page of the website. Here user will able to navigate to different sections which are home, about, coach, services, blog and contact.

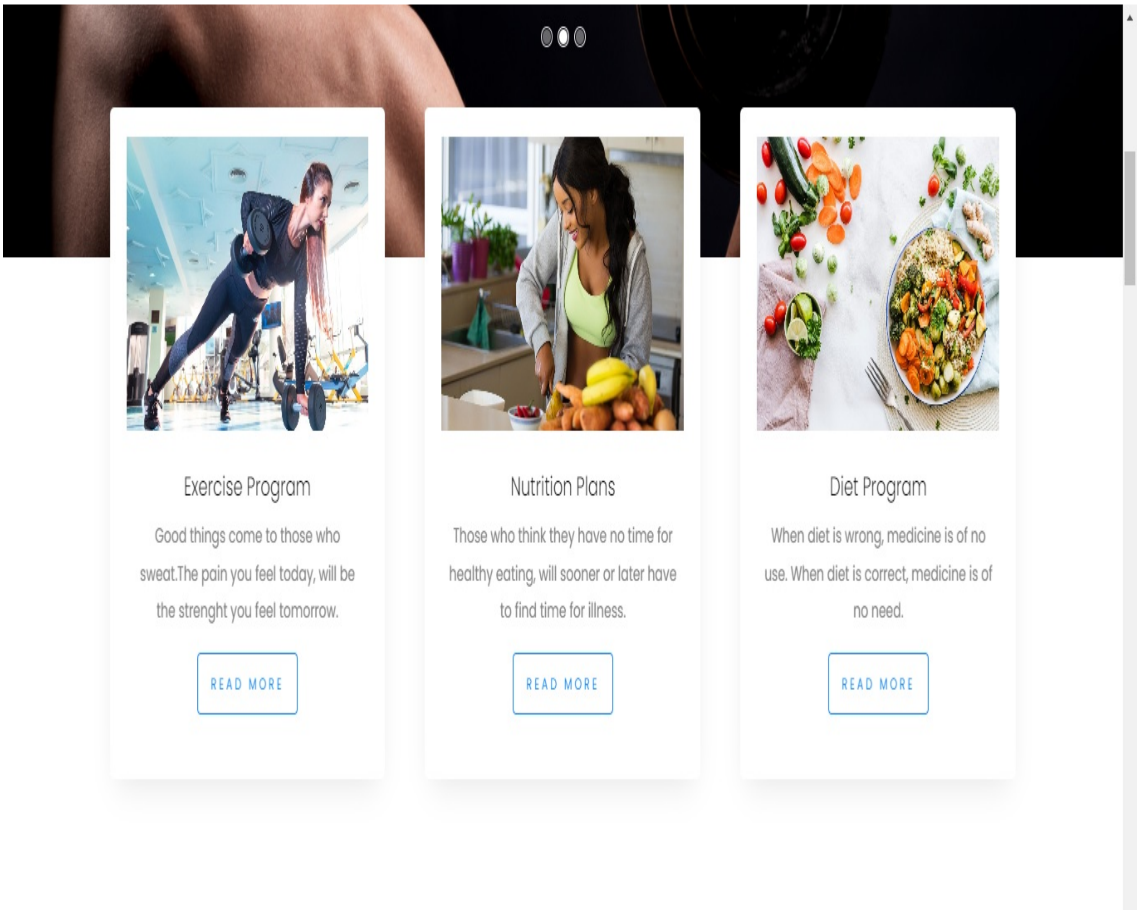

Figure 6.2: Different Programs

This is the home section of the web application. Here the user will be able to get different exercise programs, nutrition plans and diet programs according to their goals. This plans and programs will help the users achieve their goals.

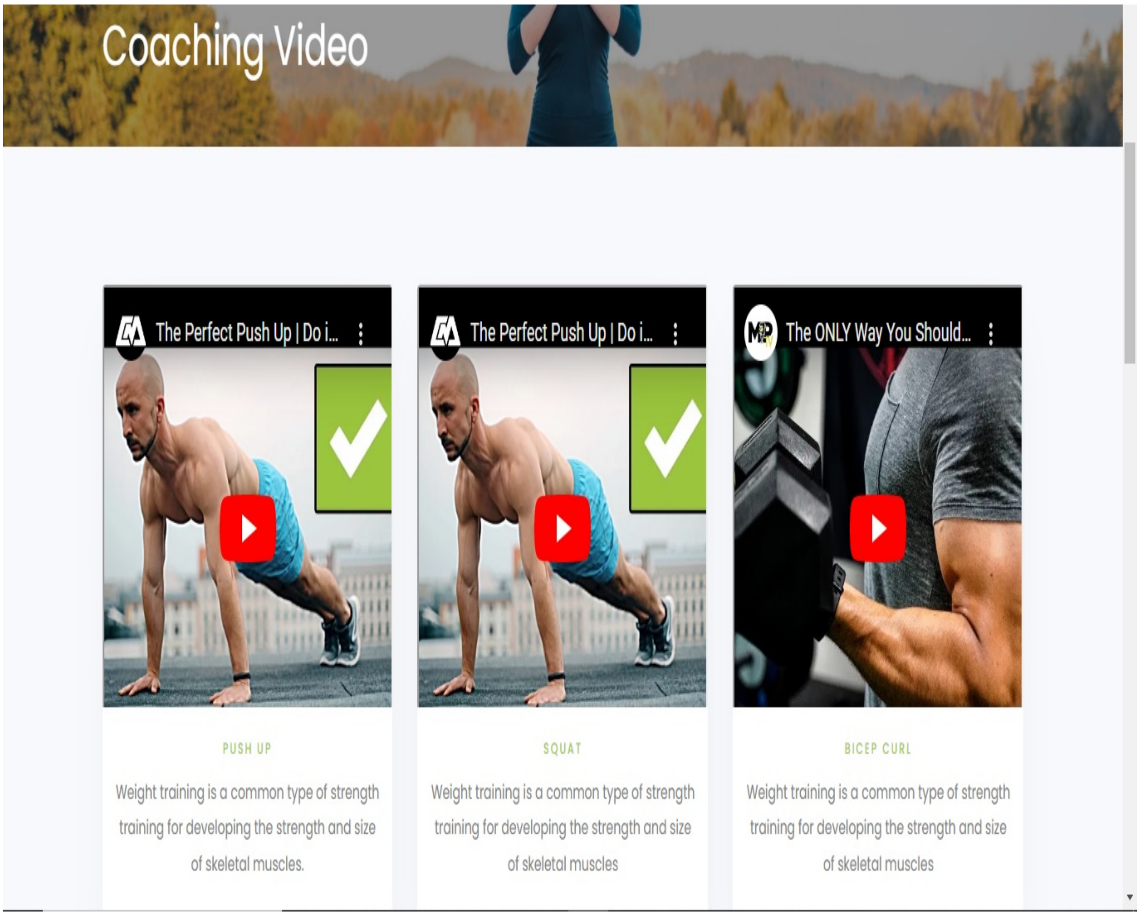

Figure 6.3: Coaching Page

In this section the user will get different workout videos from YouTube which he/she can refer to do the exercise.

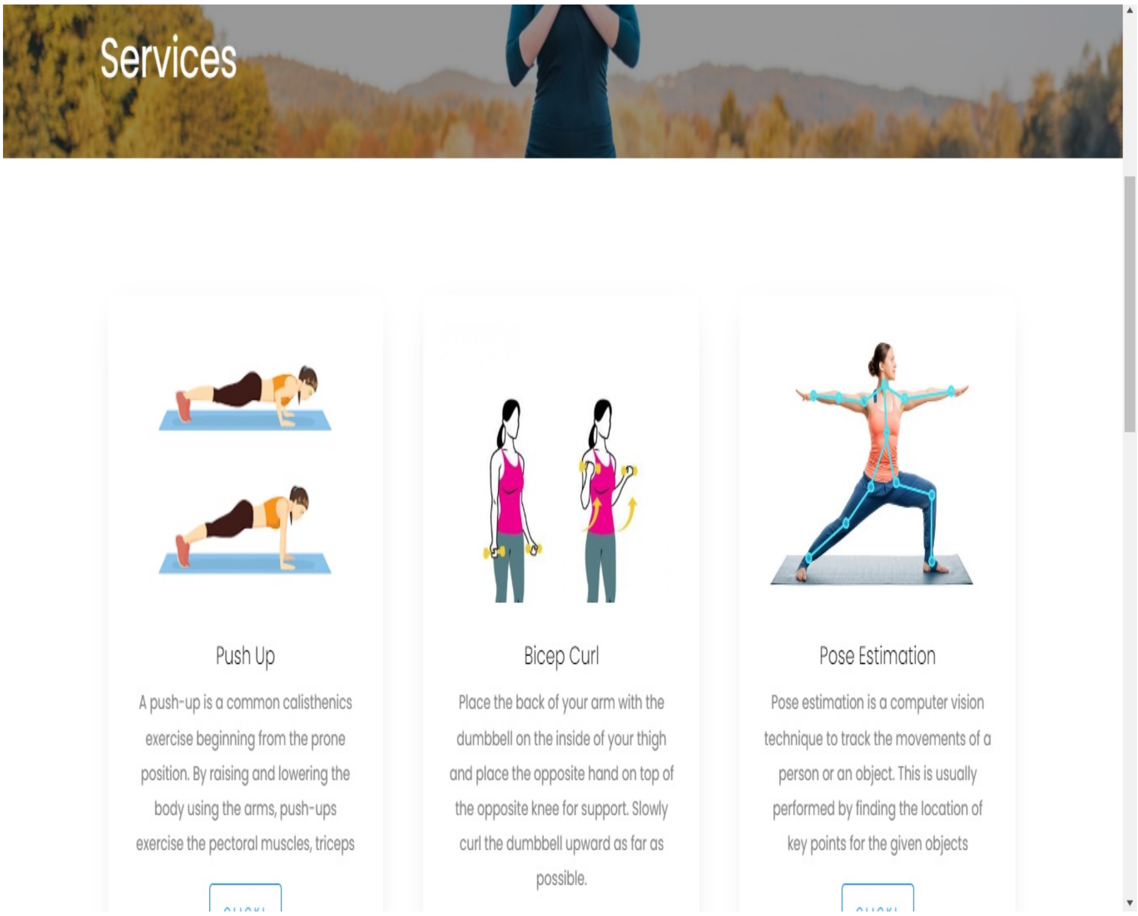

Figure 6.4: Exercises Page

In this section the user will be able to choose the exercise of which posture needs to be detected.

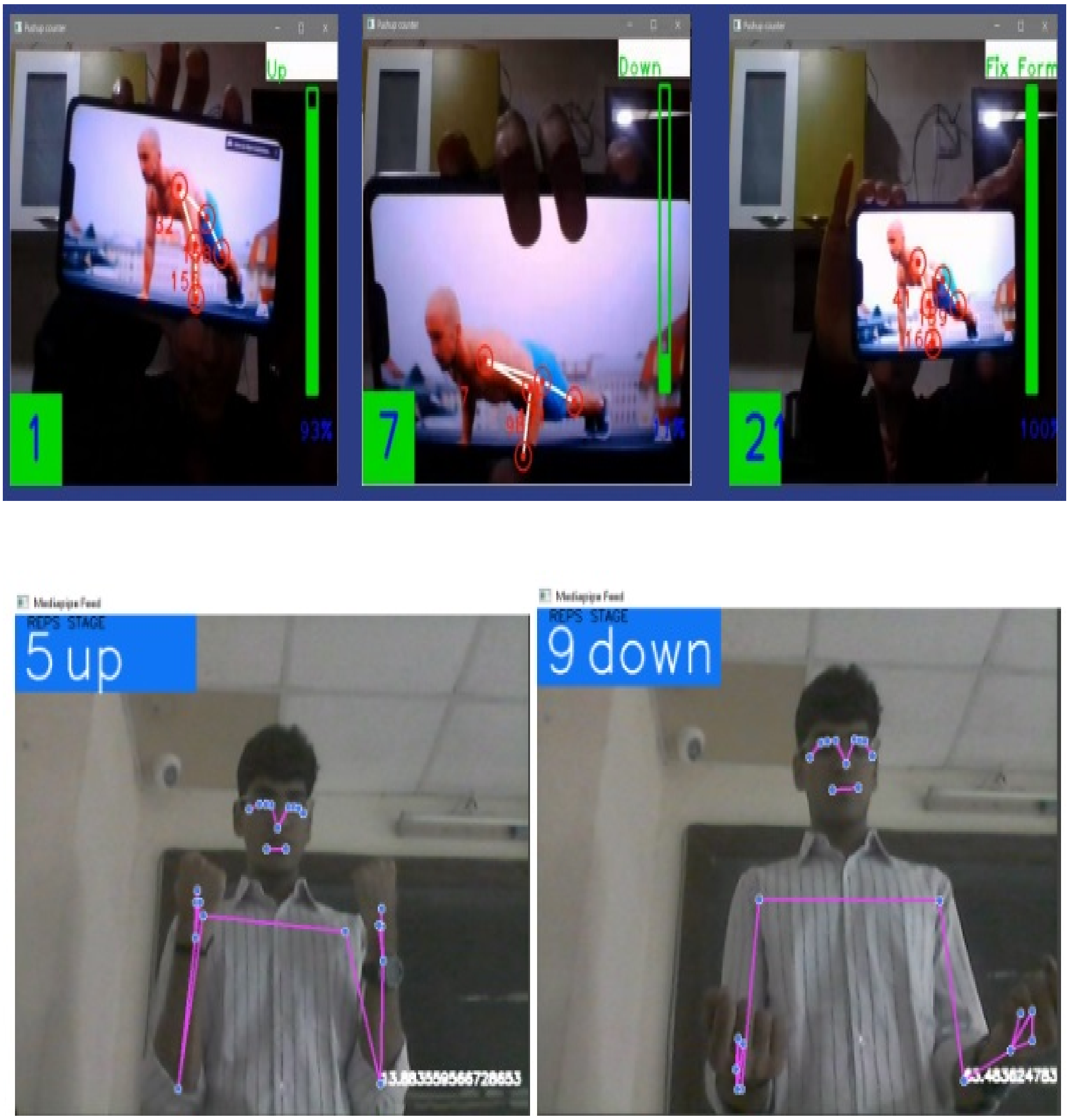

Figure 6.5: Posture Detection

Here the posture decetion will be done and user will be notified about the number of repetitions and whether the posture is correct or incorrect.

Chapter 7

Conclusions and Future Scope

In conclusion, the machine learning-based exercise learning website revolutionized the way people learn and perform exercises. By utilizing machine learning algorithms, this type of web application offered personalized feedback and guidance to users, helping them to improve their form, technique, and overall performance. This led to more effective workouts, better results, and increased motivation for users. The web application provided a wealth of exercise options, catered to individual preferences and difficulty levels, ensuring that users have access to a comprehensive workout experience. Overall, a machine learning-based exercise learning web application provided a powerful way for anyone looking to improve their fitness and live a healthier lifestyle.

In order to enhance user engagement and motivation, the system can offer rewards and incentives for meeting certain exercise goals and provide personalized encouragement based on user progress. The web application must also track user progress over time, adjust the exercise plan as needed based on user feedback and results. We must also ensure user privacy and data security, the system will use industry-standard encryption protocols and only collect user data with their consent. The system will also provide options for users to opt-out of data collection and provide transparency on how their data is being used.

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Appendices

Appendix-I:Python Libraries

1. from django.contrib import admin
2. from .models import Contact,Bookapp
3. from django.apps import AppConfig
4. import cv2
5. import mediapipe as mp
6. import math
7. import numpy as np
8. from time import time
9. import matplotlib.pyplot as plt
10. from django.db import models
11. from datetime import datetime
12. from django.test import TestCase
13. from django.urls import path
14. from . import views
15. from django.shortcuts import render,get_object_or_404,redirect
16. from .implementation import execute_pushup, execute_bicep,executePoseEstimation
17. from django.contrib import messages
18. from django.core.mail import send_mail
19. from .models import Contact,Bookapp

Publication

Paper entitled “FormMatters-Posture Detection System using Image Processing, Computer Vision and Machine Learning” is submitted at “ ICETET-SIP 23 (11th International Conference on Emerging Trends in Engineering & Technology-Signal and Information Processing)” and ”2023 IEEE International Conference on Computer, Electronics & Electrical Engineering and their applications (IC2E3)” by “Tanay Jain, Aadarsh Khant, Keval Gada and Prof.Manjusha Kashilkar ”.