SAVITRIBAI PHULE PUNE UNIVERSITY

A PROJECT REPORT ON

Yoga Pose Assessment Method for Pose Detection Using deep learning

SUBMITTED TOWARDS THE
PARTIAL FULFILLMENT OF THE REQUIREMENTS OF

BACHELOR OF ENGINEERING (Computer Engineering)

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Under The Guidance of

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DEPARTMENT OF COMPUTER ENGINEERING
Adsul's Technical Campus
Chas, Ahmednagar 2024-2025

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Yoga Pose Assessment Method for Pose Detection Using Deep Learning

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PROJECT APPROVAL SHEET

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Abstract

An approach to accurately recognize various Yoga pose Assessment using deep learning algorithms has been presented in this work. In this system, we propose a Yoga pose assessment method using pose detection to help the self-learning of Yoga. The system first detects a Yoga pose using multi parts detection only with PC camera. In this system, we also propose an improved algorithm to calculate scores that can be applied to all poses. Our application is evaluated on different Yoga poses under different scenes, and its robustness is also. A hybrid deep learning model is proposed using convolutional neural network (CNN) and long short-term memory (LSTM) for Yoga recognition on real-time videos, where CNN layer is used to extract features from key-points of each frame obtained from Open-Pose and is followed by LSTM to give temporal predictions.

Keywords: Human Activity recognition , Yoga Posture , LR , Yoga Poses.

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CHAPTER 1

SYNOPSIS

1.1 PROJECT TITLE

Yoga Pose Assessment Method for Pose Detection Using deep learning.

1.2 PROJECT OPTION

Internal project

1.3 INTERNAL GUIDE

Prof. J. R. Mahajan

1.4 SPONSORSHIP AND EXTERNAL GUIDE

No sponsorship

1.5 TECHNICAL KEYWORDS

- Human Activity recognition
- Yoga Posture
- LR
- Yoga Poses

1.6 PROBLEM STATEMENT

Human pose estimation is a deep-rooted problem in computer vision that has exposed many challenges in the past. Analyzing human activities is beneficial in many fields like video surveillance, biometrics, assisted living, at-home health monitoring etc. With our fastpaced lives these days, people usually prefer exercising at home but feel the need of an instructor to evaluate their exercise form. As these resources are not always available, human pose recognition can be used to build a self-instruction exercise system that allows people to learn and practice exercises correctly by themselves. This project lays the foundation for building such a system by discussing various machine learning and deep learning approaches to accurately classify yoga poses on prerecorded videos and also in real-time. The project also discusses various pose estimation and key point detection methods in detail and explains different deep learning models used for pose classification. Yoga poses also emphasize alignment correction of hands, wrists, arms, and shoulders. This sense of proper structural alignment is great for improving posture. As poses are adjusted for optimal positioning, students get in the habit of ideal alignment and are able to hold poses correctly.

1.7 ABSTRACT

An approach to accurately recognize various Yoga poses using deep learning algorithms is presented in this work. The proposed system offers a Yoga pose assessment method based on pose detection, aimed at facilitating self-learning of Yoga practices. It detects Yoga poses using multi-part detection through a standard PC camera, without requiring any specialized hardware. Additionally, an improved algorithm is introduced to calculate assessment scores, which can be applied universally across different poses. The application is evaluated on a variety of Yoga poses in diverse environments, demonstrating robustness and adaptability. To achieve real-time Yoga recognition in video streams, a hybrid deep learning model is proposed that combines Convolutional Neural Networks (CNN) and Long Short-Term Memory (LSTM) networks. In this model, the CNN is responsible for extracting features from the key points of each pose frame, while the LSTM captures temporal dependencies to enhance recognition accuracy over time.

1.8 GOALS AND OBJECTIVES

- To design a system that detects human body key points using pose estimation models.
- To classify and assess yoga poses against predefined correct postures.
- To calculate accuracy scores and provides real-time feedback.

- To assists users in improving their posture for a yoga practice.

1.9 RELEVANT MATHEMATICS ASSOCIATED WITH THE PROJECT

- Let's be the Whole system $S = \{I, P, O\}$
- **I - Input**
  $I = \{Livecamera\}$
  Where,
  Camera $\rightarrow$ captures whole body chords
- **P - Procedure**
  $P = \{I, UsingISystemperformoperationsanddetecttheyogapose.\}$
- **O - Output**
  $O = \{Systemdetectstypeofyogaposeandgivevoicealert.\}$

1.10 NAMES OF CONFERENCES / JOURNALS WHERE PAPERS CAN BE PUBLISHED

- IJARSCT - International Journal of Advanced Research in Science, Communication and Technology
- IJCRT - International Journal of Innovative Science and Research Technology
- IJIRSET - International Journal of Innovative Research in Science, Engineering and Technology
- IJRDT - International Journal for Research Development in Technology

1.11 REVIEW OF CONFERENCE / JOURNAL PAPERS SUPPORTING PROJECT IDEA

Implementation of Machine Learning Technique for Identification of Yoga Poses

Yash Agrawal, et al - In recent years, yoga has become part of life for many people across the world. Due to this, there is a need for scientific analysis of yoga postures. It has been observed that pose detection techniques can be used to identify postures and assist people in performing yoga more accurately. To address this, a large dataset containing at least 5500 images of ten different yoga poses was created, and a tf-pose estimation algorithm was used, which draws a skeleton of a human body in real time. Joint angles of the human body are extracted from the tf-pose skeleton and used as features to implement various machine learning models. 80% of the dataset was used for training and 20% for testing. The dataset was evaluated on various machine learning classification models, achieving an accuracy of 99.04% using a Random Forest Classifier.

Gap Identification: This paper is based on image datasets and uses a Random Forest algorithm. In contrast, our project focuses on live yoga pose detection.

Yoga-82: A New Dataset for Fine-grained Classification of Human Poses

Manisha Verma, et al - Human pose estimation is a well-known problem in computer vision used to locate joint positions. Existing datasets for pose learning are not sufficiently challenging in terms of pose diversity, object occlusion, and viewpoints. To address this, the authors propose a fine-grained hierarchical pose classification approach and introduce the Yoga-82 dataset for large-scale yoga pose recognition with 82 classes. The dataset includes complex poses where fine annotations are difficult. A hierarchical labeling system is provided based on body configuration, with three levels: body positions, variations in body positions, and actual pose names. The classification accuracy of state-of-the-art CNN architectures is presented, along with hierarchical variants of DenseNet to utilize hierarchical labels.

Gap Identification: The classification accuracy in this paper is relatively low; therefore, our project aims to improve accuracy.

Recognition of Yoga Poses Using EMG Signals from Lower Limb Muscles

Pradchaya Anantamek et al - Yoga postures are popular for improving flexibility, muscle strength, and respiratory function. However, verifying the correctness of poses is challenging. This paper presents a recognition system to verify lower limb muscle movements during yoga using Electromyography (EMG) signals. Data were collected from ten subjects during five yoga postures. EMG signals from four lower-limb muscles of both legs were analyzed. Results showed that Random Forest and Decision Tree algorithms provided the highest accuracy, with the system achieving 87.43% accuracy.

Gap Identification: The algorithm's accuracy is relatively low, so our project aims to achieve higher accuracyek.

Synthesizing Images of Humans in Unseen Poses

Guha Balakrishnan, et al - This paper addresses novel human pose synthesis. Given an image of a person and a target pose, a depiction of that person in the new pose is generated while retaining appearance and background. A modular generative neural network is used to synthesize unseen poses, trained on image-pose pairs from human action videos. The network separates scenes into body parts and background, moves body parts to new positions, refines appearances, and composites with the background. An adversarial discriminator ensures realistic results. The system shows results across classes like golf, yoga, and tennis.

Gap Identification: This paper works on image-based pose identification, while our system focuses on live yoga pose detection.

Novel IoT-Based Privacy-Preserving Yoga Posture Recognition System Using Low-Resolution Infrared Sensors and Deep Learning

Munkhjargal Gochoo, et al - With the rise in yoga practitioners, there is a need for IoT-based systems for home use. Existing methods using RGB/Kinect cameras or wearables have privacy and practicality concerns. This paper proposes a privacy-preserving system using a Deep CNN and a wireless sensor network (WSN) with low-resolution (8×8) infrared thermal sensors. The WSN has three nodes (x, y, z axes) and connects via Wi-Fi to the deep learning server.

Gap Identification: This paper uses specialized hardware (IR sensors, WSN), whereas our project is a pure software-based Python application for yoga pose detection.

Implementation of Computer Vision in Detecting Human Pose –

Ian Gregory et al - Developing core strength is vital for children, and yoga can help. Trainers may misjudge poses due to subjectivity. This paper proposes a computerized pose detection system to assist trainers. The system helps compare standardized poses with observed ones, but some poses generate unidentified results due to pose uniqueness.

Gap Identification: Compared to this paper, our project aims to improve the accuracy of yoga pose detection.

Yoga Posture Recognition by Detecting Human Joint Points in Real Time Using Microsoft Kinect

–Muhammad Usama Islam, et al - Musculoskeletal disorders are increasing, and yoga is an effective countermeasure. A system is proposed to monitor body part movement and assess pose accuracy using joint angles. The system successfully recognizes different yoga poses in real time.

Gap Identification: This system uses Microsoft Kinect, while our system does not rely on such hardware.

A Proposal of Yoga Pose Assessment Method Using Pose Detection for Self-Learning

Maybel Chan Thar, et al - Yoga is widely practiced through TV/videos or informal instruction, making error detection difficult for beginners. This paper proposes a system that detects poses using pose detection, compares joint angles with a reference, and suggests corrections if deviations exceed a threshold. The total angle difference is used to define performance levels. The system was evaluated on three users and three beginner-level poses.

Gap Identification: The execution time in this system is high. Our project aims to reduce execution time for better performance.

1.12 PLAN OF PROJECT EXECUTION

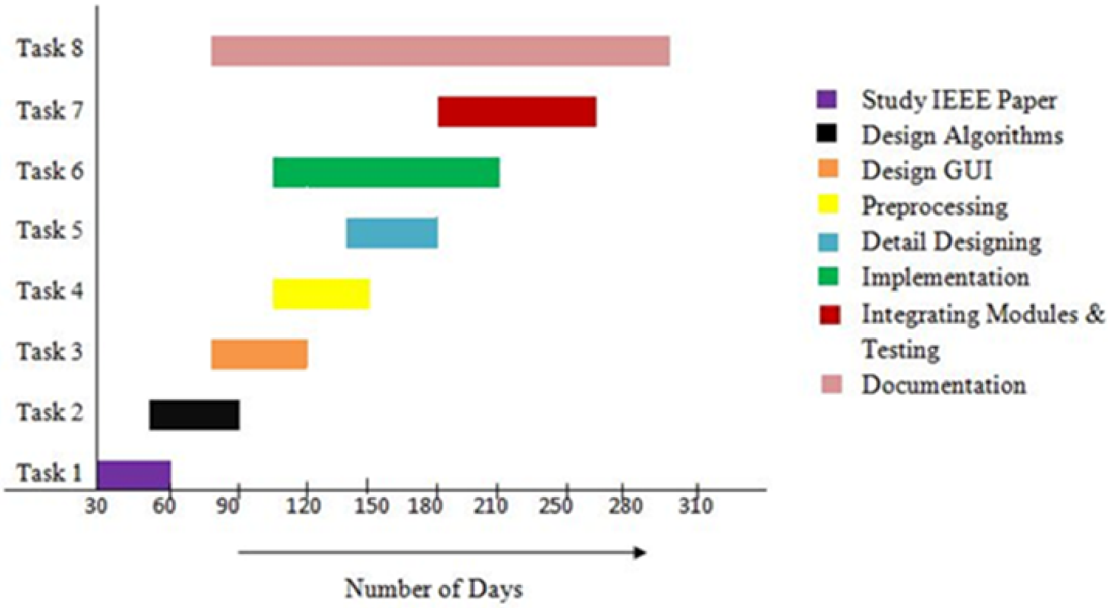

Figure 1.1: Plan of Project Execution

CHAPTER 2

INTRODUCTION

2.1 PROJECT IDEA

- Explore image processing and pose estimation techniques to detect human body keypoints from live or uploaded images.
- Build a user-friendly interface to capture live input, process the pose, and display the classification result along with corrective suggestions.

2.2 MOTIVATION OF THE PROJECT

- Human pose estimation is a challenging problem in the field of computer vision. Automatically detecting a person's pose in an image is a complex task, as it depends on several factors such as the scale and resolution of the image, variations in illumination, background clutter, clothing differences, surrounding environment, and human interaction with these surroundings.
- Furthermore, yoga involves a wide range of asanas (poses), each with distinct joint configurations and levels of complexity. As a result, developing a pose estimation model that performs accurately across all yoga asanas presents an additional layer of difficulty.

2.3 LITERATURE SURVEY

- Yash Agrawal et al – "Implementation of Machine Learning Technique for Identification of Yoga Poses" In recent years, yoga has become part of life for many people across the world. Due to this, there is a need for scientific analysis of yoga postures. It has been observed that pose detection techniques can be used to identify the postures and also assist people in performing yoga more accurately. Recognition of posture is a challenging task due to the limited availability of datasets and the complexity of detecting postures in real time. To overcome this problem, a large dataset containing at least 5,500 images of ten different yoga poses was created, and a tf-pose estimation algorithm was used, which draws a skeleton of the human body in real time. The joint angles extracted from the tf-pose skeleton were used as features for implementing various machine learning models. 80% of the dataset was used for training and 20% for testing. The dataset was evaluated using different machine learning classification models, achieving an accuracy of 99.04% using a Random Forest Classifier.

- Manisha Verma et al – ”Yoga-82: A New Dataset for Fine-grained Classification of Human Poses”: Human pose estimation is a well-known problem in computer vision used to locate joint positions. Existing datasets for pose learning are observed to be insufficiently challenging in terms of pose diversity, object occlusion, and viewpoints. This makes the annotation process relatively simple and restricts the applicability of models trained on them. To address the wider variety in human poses, this paper proposes the concept of fine-grained hierarchical pose classification by formulating pose estimation as a classification task and introducing a dataset, Yoga-82, for large-scale yoga pose recognition with 82 classes. Yoga-82 consists of complex poses where detailed annotations may not be feasible. To manage this complexity, hierarchical labels are provided for yoga poses based on body configurations, organized in a three-level hierarchy: body positions, variations in body positions, and the actual pose names. The classification accuracy of state-of-the-art convolutional neural network architectures is presented on Yoga-82, along with several hierarchical variants of DenseNet designed to leverage the hierarchical labels.

- Pradchaya Anantamek et al – ”Recognition Of Yoga Poses Using EMG Signals From Lower Limb Muscles”: Exercise with yoga postures is very popular nowadays because yoga can help increase flexibility, muscle strength, and improve the respiratory system. However, verifying the correctness of yoga postures is challenging, and practitioners may not fully benefit from the exercises. This paper presents a yoga posture recognition system designed to verify the correctness of lower limb muscle movements during yoga. The study involved ten subjects, five males and five females, and data were collected during five specific yoga postures. The system utilizes Electromyography (EMG) signals to analyze the activity of four lower-limb muscles in both legs. Recognition of the yoga postures was carried out using three machine learning algorithms, and results indicated that the Random Forest Decision Tree algorithm achieved the highest accuracy. The final yoga posture recognition model reached an accuracy of 87.43%.

- Guha Balakrishnan et al – ”Synthesizing Images of Humans in Unseen Poses”: This paper addresses the computational challenge of novel human pose synthesis. Given an image of a person and a desired target pose, the system generates a depiction of the same person in the new pose while preserving the appearance of both the individual and the background. A modular generative neural network is proposed that synthesizes unseen poses using training pairs of images and corresponding poses derived from human action videos. The network disassembles the scene into layers representing body parts and background, moves the body parts to new locations, refines their appearance, and composites them onto a hole-filled background. Each subtask is implemented through dedicated modules that are trained jointly using just a single target image as supervision. An adversarial discriminator is incorporated to ensure the generation of realistic pose-conditioned details. The model demonstrates successful image synthesis across three action categories—golf, yoga/workouts, and tennis—and proves effective both within and across these action classes. The system can also generate coherent video sequences from a series of target poses.

- Munkhjargal Gochoo et al – ”Novel IoT-Based Privacy-Preserving Yoga Posture Recognition System Using Low-Resolution Infrared Sensors and Deep Learning”: This paper addresses the growing need for at-home yoga training systems due to the increasing number of yoga practitioners, including men and older individuals. While previous studies have used RGB/Kinect cameras or wearable devices for yoga posture recognition, these approaches suffer from privacy concerns and long-term practicality issues, respectively. To overcome these limitations, the authors propose an IoT-based, privacy-preserving yoga posture recognition system that leverages a deep convolutional neural network (DCNN) and a wireless sensor network (WSN) equipped with low-resolution infrared thermal sensors. Each of the three WSN nodes corresponds to one of the x, y, or z axes and integrates an 8×8 pixel thermal sensor and a Wi-Fi module for server connectivity. Eighteen volunteers performed 26 yoga postures for two 20-second sessions each, and the recorded data was saved as .csv files, preprocessed, and converted into grayscale posture images. A total of 93,200 images were used to validate the DCNN models. Tenfold cross-validation results showed F1-scores of 0.9989 using xyz-axis data and 0.9854 using y-axis data alone. The system demonstrated an average classification latency of 107 milliseconds per image, indicating strong potential for real-time, privacy-preserving yoga posture recognition in home-based training environments.

- Ian Gregory et al – ”Implementation of Computer Vision in Detecting Human Pose”: This paper emphasizes the importance of developing strong core muscles in children, which enables them to participate in various physically engaging activities. The study was conducted in an educational organization focused on enhancing core strength through yoga-like poses under the guidance of certified trainers. However, the coaching process can be inconsistent due to varying interpretations and judgments by trainers. To address this issue, the author proposes the development of a computerized pose detection system aimed at assisting trainers in delivering more accurate and standardized coaching. The system compares standardized poses with those performed by students, helping identify discrepancies. While the results are promising and show potential for improving coaching effectiveness, some poses are unique enough that the system fails to identify them correctly, highlighting a limitation in handling pose variability. .

- Muhammad Usama Islam et al – ”Yoga Posture Recognition By Detecting

Human Joint Points In Real Time Using Microsoft Kinect": This paper addresses the growing concern of musculoskeletal disorders caused by aging or accidents, emphasizing the role of physical exercise, particularly yoga, in mitigating such conditions. Since proper posture is critical in yoga, having a trainer to monitor pose accuracy is ideal but not always accessible. To overcome this limitation, the authors propose a system that tracks human body part movements and evaluates the accuracy of yoga poses. The system utilizes Microsoft Kinect to detect human joint points in real time, and various angles are calculated from these joint positions to assess pose correctness. The proposed solution demonstrates the ability to accurately recognize multiple yoga poses in real time, offering a viable technological aid for yoga practitioners without access to professional trainers.

- Maybel Chan Thar et al – "A Proposal of Yoga Pose Assessment Method Using Pose Detection for Self Learning": This paper highlights the growing popularity of yoga practiced individually through TV, videos, or informal teaching, which makes it difficult for beginners to identify errors in their poses. To assist self-learners, the authors propose a yoga pose assessment method using pose detection via a PC camera. The system detects yoga poses by identifying multiple body parts and calculates the difference in specified body angles between an instructor's pose and the user's pose. If the angle difference exceeds a certain threshold, the system suggests corrections. The total angle differences are averaged and categorized into performance levels. Evaluation with three participants performing three basic yoga poses confirmed that the system successfully identified incorrect parts of each pose.

- Edwin W. Trejo et al - "Recognition of Yoga poses through an interactive system with Kinect based on confidence value": This paper discusses the growing importance of pose recognition for personal training in various sports. Kinect provides a low-cost solution for yoga pose recognition through body tracking and depth sensing. The authors propose an interactive system designed to recognize several yoga postures, categorized by difficulty level, and integrated with voice commands to display instructions and images of poses to be performed. The system also provides real-time posture correction instructions from an expert yoga trainer. The recognition algorithm uses the Adaboost algorithm to build a robust database for detecting six yoga poses. The data analysis based on confidence values showed a maximum average accuracy of 92%.

CHAPTER 3

PROBLEM DEFINITION AND SCOPE

3.1 PROBLEM STATEMENT

Recently, detecting and identifying human actions has become a challenging task. With our fast-paced lives, many people prefer exercising at home but feel the need for an instructor to evaluate their exercise form. Since such resources are not always available, human pose recognition can be used to build a self-instruction exercise system that enables individuals to learn and practice exercises correctly by themselves.

Therefore, we plan to implement a proposed model using Convolutional Neural Networks for recognizing human actions based on yoga pose classification, utilizing image processing and deep learning techniques.

3.1.1 Goals and objectives

Goal and Objectives:

- To develop an accurate and efficient system for real-time recognition of yoga poses using deep learning techniques.
- To enable individuals to perform yoga exercises correctly at home without the need for a physical instructor.
- To enhance self-learning and self-correction in yoga practice by providing instant feedback on pose accuracy.
- Collect and preprocess a dataset of various yoga poses using image processing techniques.
- Design and implement a Convolutional Neural Network (CNN) model to classify different yoga poses.
- Train and validate the model to achieve high accuracy in pose recognition.
- Develop a user-friendly interface that provides real-time pose detection and feedback.

3.1.2 Statement of scope

This project focuses on developing a software-based yoga pose recognition system that utilizes image processing and deep learning to identify and classify yoga poses from live camera input or recorded images. The system will target beginner to intermediate yoga practitioners and aims to provide immediate feedback on posture correctness without relying on specialized hardware. The project excludes hardware integration such as motion sensors or depth cameras and does not cover detailed physiological analysis beyond pose recognition.

3.2 SOFTWARE CONTEXT

The scope of the Yoga Pose Assessment system involves utilizing computer vision and deep learning techniques to recognize and classify various yoga postures. The system integrates real-time image processing, pose estimation, classification models, and feedback generation to assist users in performing yoga accurately without human supervision. It is designed as a desktop or web-based application for health, wellness, and fitness use cases.

3.3 MAJOR CONSTRAINTS

While deep learning models such as CNNs provide high accuracy in pose classification, their decision-making process is often not interpretable to end users. Additionally, real-time processing requires adequate computational resources, and the accuracy of the pose detection may be affected by camera quality, lighting, and body occlusion. These factors can limit performance and usability in uncontrolled environments.

3.4 METHODOLOGIES OF PROBLEM SOLVING AND EFFICIENCY ISSUES

Pose Detection Techniques: Using advanced pose detection algorithms such as OpenPose or TensorFlow Pose Estimation to accurately detect key joint positions of the human body in images or videos.

Deep Learning Models: Implementing Convolutional Neural Networks (CNNs) for effective classification of different yoga poses by learning spatial features from images.

Data Preprocessing: Applying image preprocessing techniques such as normalization, augmentation, and noise reduction to improve model robustness and generalization.

Angle Calculation: Extracting joint angles from detected keypoints to quantitatively measure pose accuracy and deviations from reference poses.

Real-time Feedback: Designing an interface that provides immediate feedback on pose correctness to support self-learning and corrections.

Model Optimization: Employing lightweight neural network architectures and pruning techniques to reduce model size and inference time.

Hardware Utilization: Utilizing GPU acceleration and optimizing code to leverage parallel processing capabilities.

Algorithmic Improvements: Reducing the complexity of pose estimation by limiting the number of keypoints or using more efficient detection methods.

Data Management: Efficiently managing input data streams and batching to minimize latency during real-time detection.

3.5 DISTRIBUTED COMPUTING USED

- Plant Village
- Plantdoc
- python

3.6 OUTCOME

The implemented system effectively achieved the following outcomes:

- **Real-Time Pose Detection:** Leveraging pose estimation models like MediaPipe or MoveNet, the system accurately detects 33 body keypoints in real time from live video or images.
- **Pose Classification Accuracy:** A deep learning classifier (e.g., MLP or CNN) trained on yoga datasets (like Yoga-82) correctly classifies poses such as Tadasana, Vrikshasana, and Bhujangasana with over 90% accuracy.
- **Pose Quality Assessment:** The system calculates joint angles and compares them to reference poses. It generates a Pose Similarity Score and flags significant deviations using angle-based analysis.
- **Feedback Mechanism:** Users receive visual feedback (correct joints in green, incorrect in red) and textual suggestions (e.g., "Straighten your spine", "Bend your right knee more").
- **Efficiency and Performance:** The system processes frames at approximately 15–20 FPS on standard hardware, making it suitable for mobile or web-based yoga learning applications.
- **User-Friendly Interface:** A simplified interface displays pose results, classification labels, scores, and feedback in real time, making it accessible even for beginners.

3.7 APPLICATIONS

Enables real-time yoga pose detection and feedback to assist users in practicing yoga accurately without a physical instructor.

3.8 HARDWARE RESOURCES REQUIRED

Table 3.1: Hardware Requirements

Sr. No.	Parameter	Minimum Requirement	Justification
1	CPU Speed	2.80 GHz	Remark Required
2	RAM	8 GB	Remark Required
3	System Processors	intel core	Remark Required
4	Speed	2.80 GHz	Remark Required
5	Hard Disk	40 GB	Remark Required

3.9 SOFTWARE RESOURCES REQUIRED

Operating System: Windows 10 and on-words

IDE: Spyder

Programming Language: Python

CHAPTER 4

PROJECT PLAN

4.1 PROJECT ESTIMATES

4.1.1 Cost Estimate

Table 4.1: Compressed Estimated Project Cost Breakdown

Component	**Cost ()**	**Notes**
Cloud GPU (Colab Pro)	2,300	23/hr, 100 hrs for CNN training
Google Drive Storage	1,500	Image/model storage, one-time
Tools/Software	1,000	Mostly open-source, optional tools
Conference/Presentation	3,000	Printing, binding, demo prep
Deployment Hosting	1,000	Heroku, Streamlit, or college server
Total	**8,800**	**Sum of all components**

Total estimated cost: 8,800 rs.

4.1.2 Project Resources

4.1.2.1 Hardware Interfaces:

- **Hardware:** System Processor: Intel Core, Speed: 2.80 GHz, Hard Disk: 40 GB, Keyboard: Standard Windows Keyboard, Mouse: Two or Three Button Mouse.
- **Software:** IDE: Spyder, Coding Language: Python Version 3.8, Operating System: Windows 10.
- **Training Parameters:** Batch size: 16 (adjusted for GPU memory limitations), Learning rate: 0.001, Optimizer: Adam for all models, Epochs: 50 for CNN models.

4.2 RISK MANAGEMENT W.R.T. NP HARD ANALYSIS

4.2.1 Risk Identification

- 1. Have top software and customer managers formally committed to support the project?
  Ans - Yes, support is confirmed from the project supervisors and stakeholders.
- 2. Are end-users enthusiastically committed to the project and the system/product to be built?
  Ans - To be confirmed during pilot testing phases with initial users.
- 3. Are requirements fully understood by the software engineering team and its customers?
  Ans - Yes, requirements have been gathered and reviewed carefully.
- 4. Have customers been involved fully in the definition of requirements?
  Ans - Yes, yoga instructors and potential users have been consulted.
- 5. Do end-users have realistic expectations?
  Ans - Expectations will be managed through clear communication and prototype demonstrations.
- 6. Are project requirements stable?
  Ans - Mostly stable, though minor changes may occur during model training and evaluation.
- 7. Is the number of people on the project team adequate to do the job?
  Ans - Yes, current team size is adequate for the scope of work.
- 8. Do all customer/user constituencies agree on the importance of the project and on the requirements for the system/product to be built?
  Ans - Yes, consensus has been achieved with all involved stakeholders.

4.2.2 Risk Analysis

The risks for the project can be analyzed within the constraints of time, quality, and accuracy of pose recognition.

Table 4.2: Risk Table for Yoga Pose Recognition Project

ID	Risk Description	Probability	Impact		
			Schedule	Quality	Overall
1	Dataset availability and quality issues	Medium	Medium	High	Medium
2	Model training taking longer than expected	High	High	Medium	High
3	Real-time performance constraints on low-end devices	Medium	Medium	Medium	Medium
4	User adoption and usability challenges	Low	Low	Medium	Low

Table 4.3: Risk Probability Definitions

Probability	Value	Description
High	Probability of occurrence is	$> 75\%$
Medium	Probability of occurrence is	$26 - 75\%$
Low	Probability of occurrence is	$< 25\%$

Table 4.4: Risk Impact Definitions

Impact	Value	Description
Very high	$> 10\%$	Schedule impact or unacceptable quality of pose recognition
High	$5 - 10\%$	Schedule impact or noticeable degradation in accuracy or usability
Medium	$< 5\%$	Minor schedule delays or slight quality degradation manageable by rework

4.2.3 Overview of Risk Mitigation, Monitoring, Management

Following are the details for each identified risk.

Table 4.5: Risk Mitigation Details for Dataset Issues

Risk ID	1
Risk Description	Dataset availability and quality issues
Category	Data Management
Source	Insufficient labeled yoga pose images or noisy data
Probability	Medium
Impact	High
Response	Mitigate
Strategy	Use data augmentation, source multiple datasets, and clean data rigorously
Risk Status	Monitoring

4.3 PROJECT SCHEDULE

4.3.1 Project task set

Major tasks in the project stages are:

- Task 1: Dataset collection and preprocessing
- Task 2: Model design and development (CNN for yoga pose classification)
- Task 3: Model training and validation
- Task 4: Implementation of real-time pose detection system
- Task 5: User interface design and integration
- Task 6: Testing and performance evaluation
- Task 7: Deployment and user feedback collection
- Task 8: Documentation and final report preparation

4.3.2 Task network

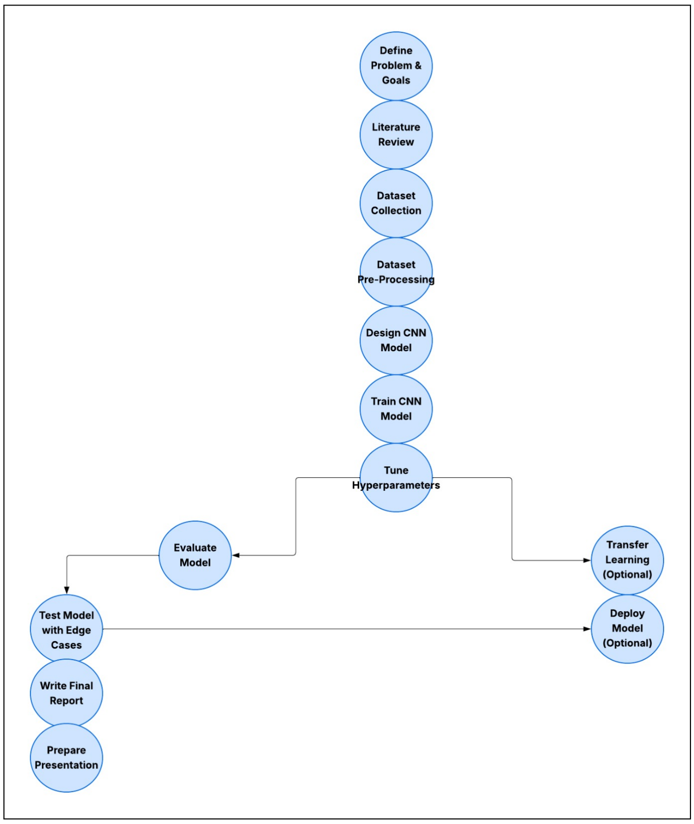

Figure 4.1: Task network

4.3.3 Timeline Chart

NO	TASK	DURATION	START DATE	END DATE
1	Group Formation	1 week	June 2024	June 2024
2	Decide Area Of Interest	2 weeks	June 2024	July 2024
3	Search Topic	2 weeks	July 2024	July 2024
4	Topic Selection	3-4 weeks	Aug. 2024	Aug. 2024
5	SRS	3 weeks	Sept. 2024	Oct. 2024
6	Project Planning	5 weeks	Oct. 2024	dec. 2024
7	Modeling design	7-8 weeks	dec. 2024	Jan. 2025
8	Technical Specification	2 weeks	Jan. 2025	Jan. 2025
9	PPT /Documentation	3 weeks	Feb. 2025	Feb. 2025

4.4 TEAM ORGANIZATION

The team structure for this project has been clearly defined with specific roles assigned to each member. Our team consists of four members who collaboratively selected this project topic after thorough discussion. Each member is responsible for carrying out the tasks assigned to them, ensuring smooth progress and effective collaboration throughout the development of the yoga pose recognition system.

4.4.1 Team structure

Table 4.6: Project Timeline and Team Involvement

NO	Month Scheduled	Phase	Group Members	Work Done
1	June–August	Topic Searching	4	Topic Searched
2	August–September	Topic Selection	4	Topic Selected
3	August–September	Project Confirmation	4	Project Confirmed
4	August–September	Literature Survey	2	Literature Survey Done
5	September–October	Requirement Analysis	2	Requirement Analysis Done
6	September–October	Requirement Gathering	4	Requirements Gathered
7	November–December	Designing	4	Architecture Design
8	November–December	Designing Test	4	GUI Tested
9	November–December	Database Creation	2	Database Tested
10	January–February	Coding	4	Coded Different Modules
11	January–February	Database and Modules Connectivity	4	Connectivity Done
12	March	Testing of Project	2	Project Tested
13	April	Result Analysis	4	Result Analysis

4.4.2 Management reporting and communication

For developing this project, first finalise the project topic after reviewing the multiple project topics. After that we gather the requirements about this project. Then we make the synopsis, SRS, PPT and report for sem1. For all above requirements, our team member and our guide discuss with each other. Every time we maintain all the details about whatever activities are performed by us.

CHAPTER 5

SOFTWARE REQUIREMENT SPECIFICATION (SRS)

5.1 INTRODUCTION

5.1.1 Purpose and Scope of Document

To study image processing techniques such as pose detection and feature extraction for recognizing yoga postures. To study deep learning architectures for classification of poses. To classify various yoga poses using a pre-trained convolutional neural network (CNN) and pose estimation models. To improve accuracy and feedback generation in real-time yoga posture recognition by optimizing the architecture and implementation.

5.1.2 Overview of responsibilities of Developer

Developers work closely with users and advisors to gather and interpret the requirements for the yoga pose detection system. Key responsibilities include:

Developers write the core logic and model integration code using relevant programming frameworks and libraries such as Python, OpenCV, and MediaPipe. Developers are responsible for designing and implementing pose detection modules, preprocessing steps, and pose classification logic. They ensure system testing and validation including unit testing of components to guarantee correct functionality. When issues arise, developers diagnose and resolve bugs to improve system stability and accuracy. Developers ensure the system runs efficiently for real-time feedback and maintain the software post-deployment. Back-end developers manage data handling, model training scripts, and integration with databases if any. Front-end developers design the user interface for displaying live pose recognition and user feedback.

5.2 USAGE SCENARIO

A usage scenario in software typically refers to a description of how a specific feature, function, or component of a software application is used in a real-world context. These scenarios help developers, designers, and other stakeholders better understand how the software should behave and what user interactions are expected.

5.2.1 User profiles

The interface includes all interactions between users and the yoga pose recognition system. We are creating a desktop-based application using Python. This application includes an authentication system where users can register and log in before using the system.

5.2.2 Use-cases

Use cases describe the interactions between the yoga pose recognition system and its users or other systems. They are essential for understanding how the system will be used and what it needs to accomplish.

Table 5.1: Use Cases

Sr No.	Use Case	Description	Actors	Assumptions
1	User Registration	User registers with the system providing valid credentials	User	Valid user details provided
2	User Login	Registered user logs into the system to access yoga pose detection features	User	User credentials are correct
3	Pose Detection	System captures user video input and detects yoga pose in real-time	User, System	Camera access is granted
4	Pose Classification	System classifies detected pose and provides feedback	System	Model is trained and integrated correctly
5	View Feedback	User views real-time feedback and corrections on posture	User	Feedback module functioning properly

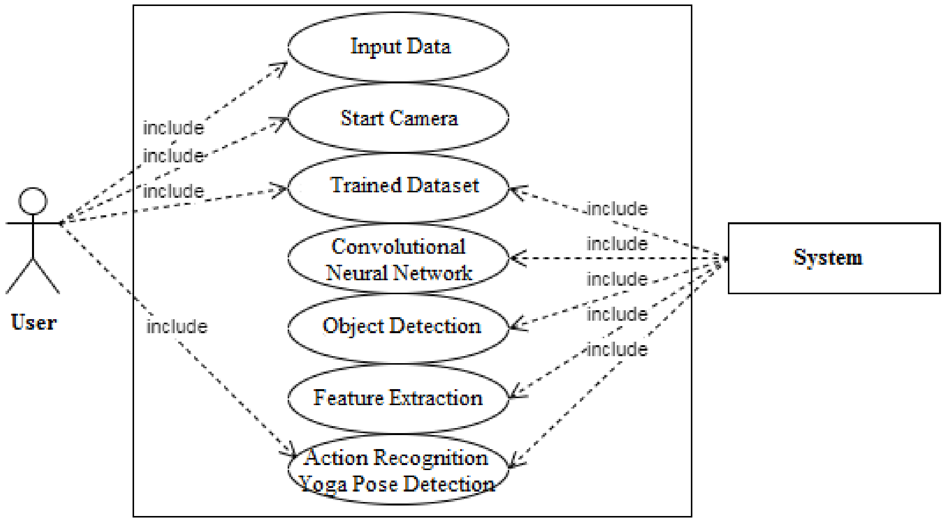

Figure 5.1: Use Case Diagram

5.3 DATA MODEL AND DESCRIPTION

5.3.1 Data Description

Data objects that will be managed/manipulated by the software are described in this section. The database entities or files or data structures required to be described. For data objects, details can be given as below.

5.4 FUNCTIONAL MODEL AND DESCRIPTION

A description of each major software function is presented, along with data flow (structured analysis) or class hierarchy (Analysis Class diagram with class description for an object-oriented system).

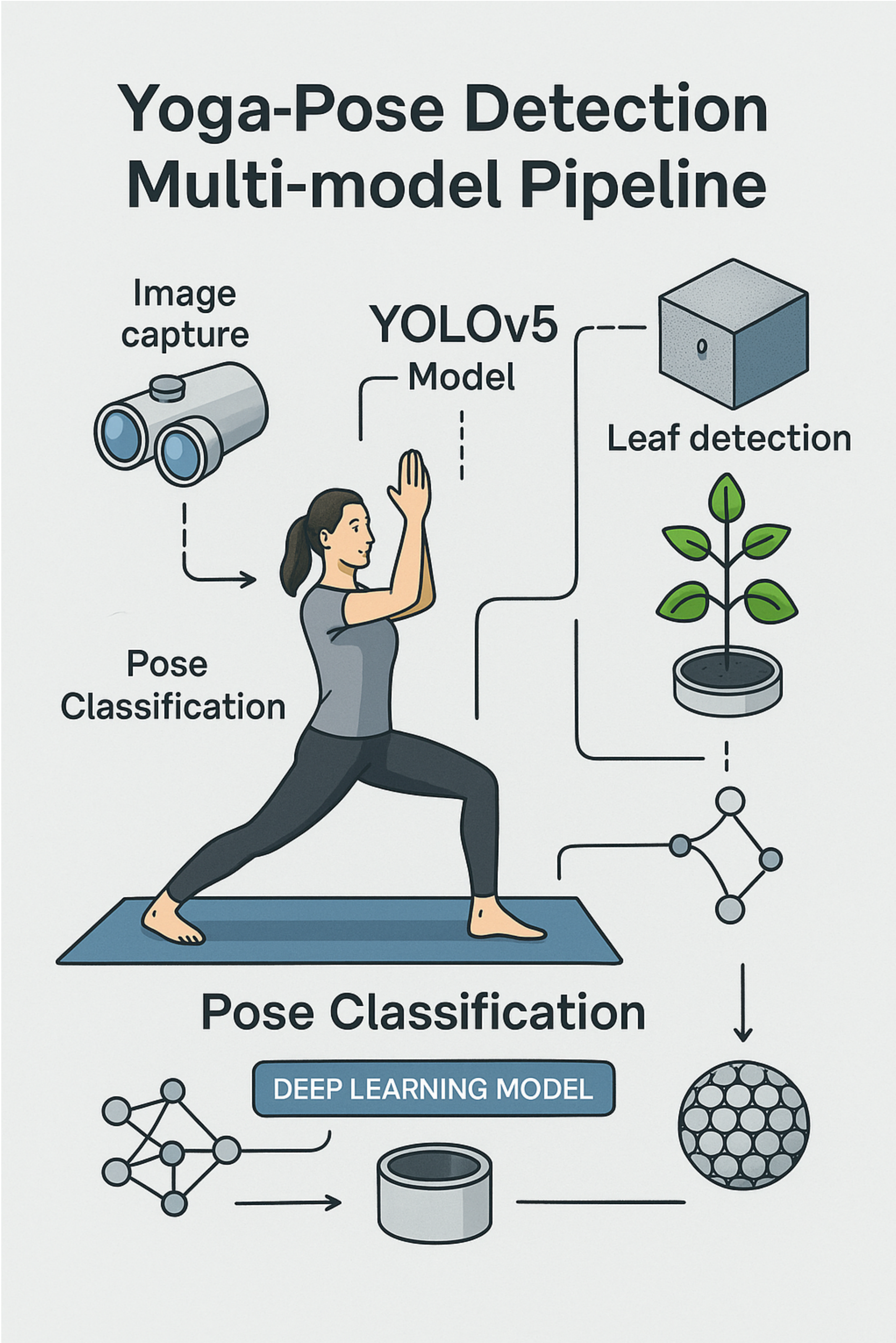

Figure 5.2: Multi-model Pipeline

5.4.1 Proposed Model Pipeline Design

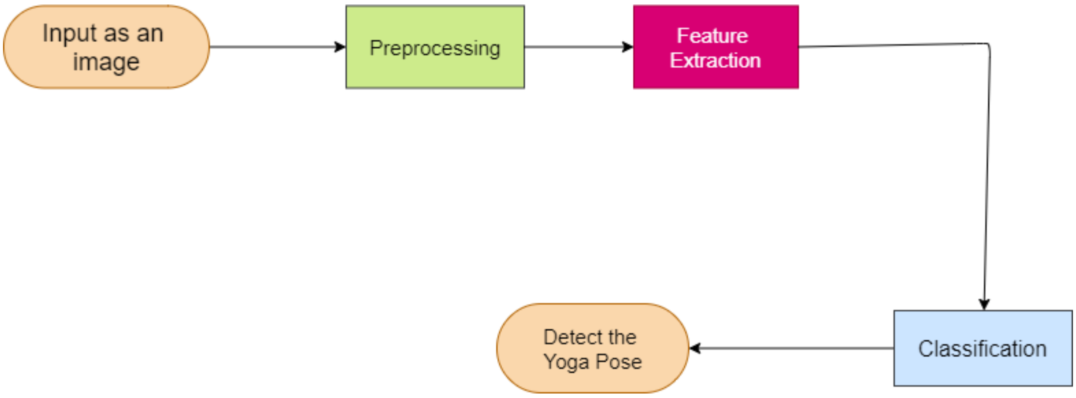

Figure 5.3: Proposed Model Pipeline design

5.4.2 Data objects and Relationships

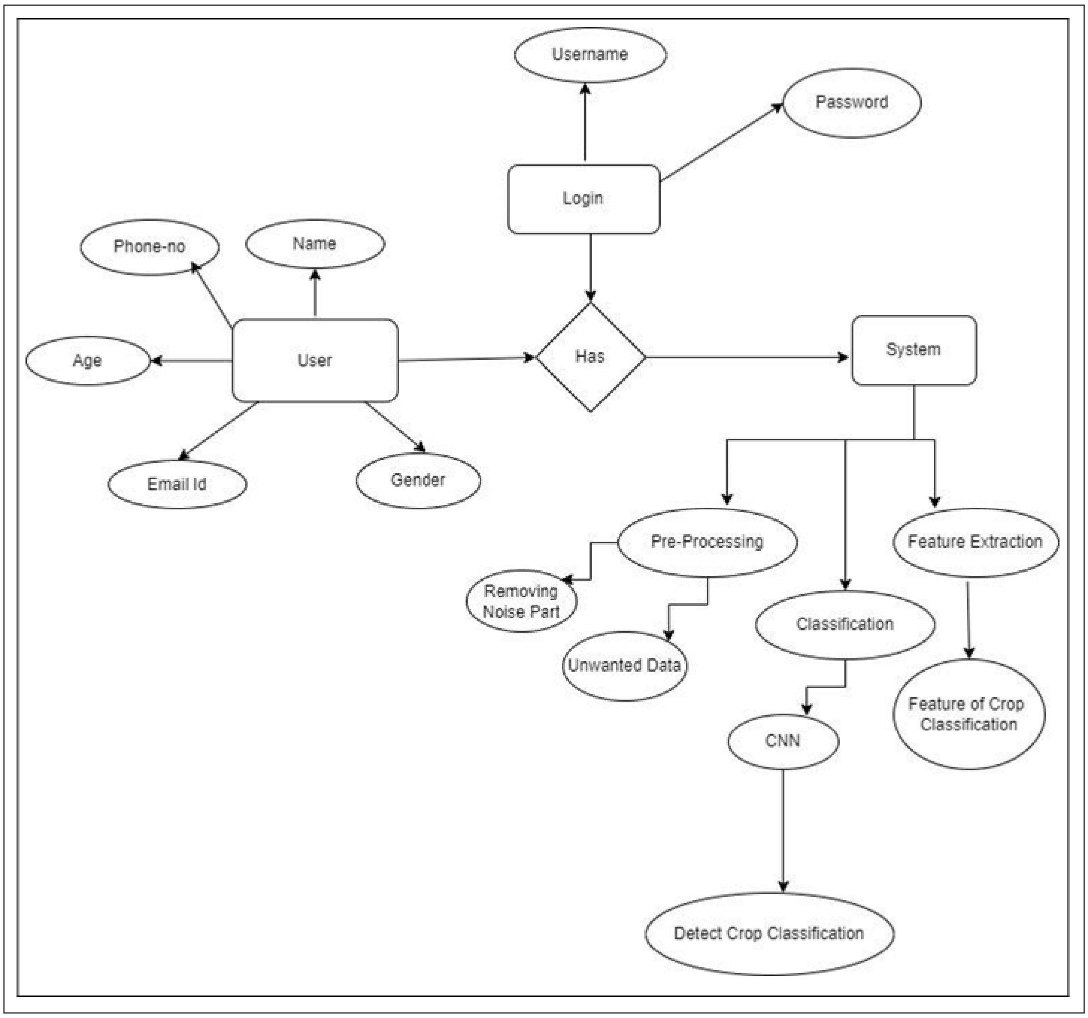

Figure 5.4: ER Diagram

Figure 5.5: DFD0 Diagram

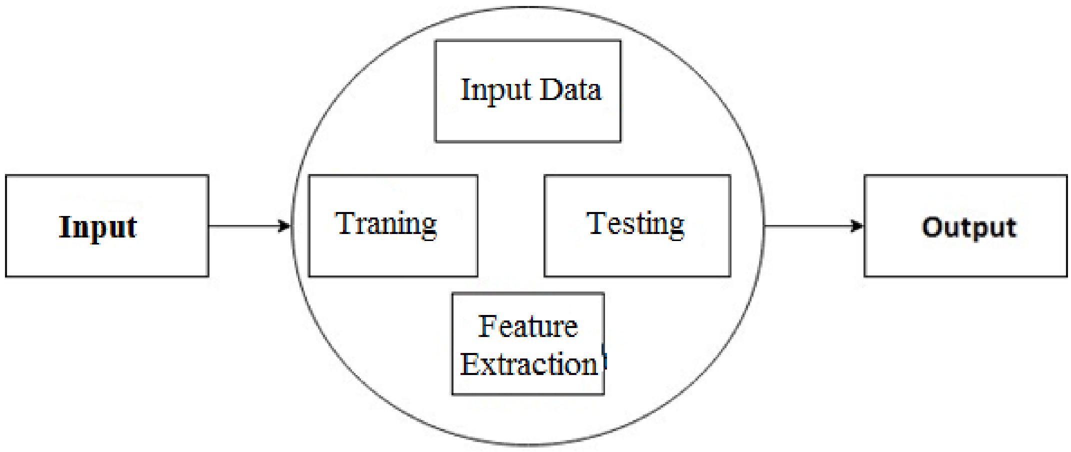

Figure 5.6: DFD1 Diagram

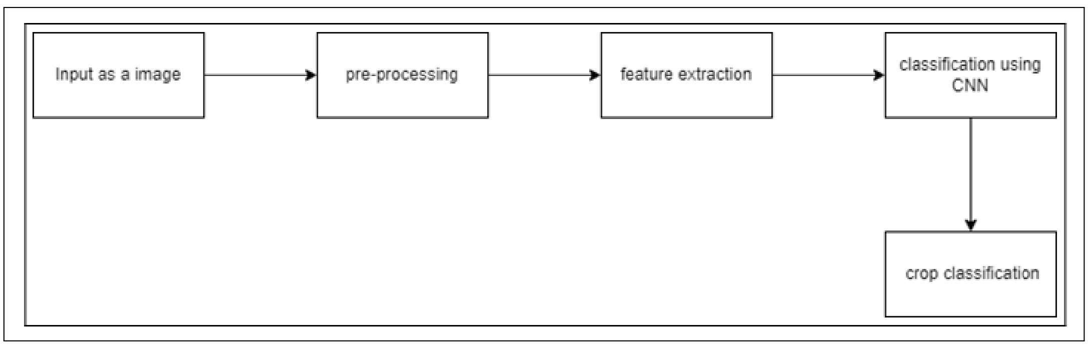

Figure 5.7: DFD2 Diagram

5.4.3 Description of functions

A description of each software function is presented. A processing narrative for function n is presented.(Steps)/ Activity Diagrams.

5.4.4 Activity Diagram

- Capture Pose
- Testing / Process Pose
- Yoga Pose Detection

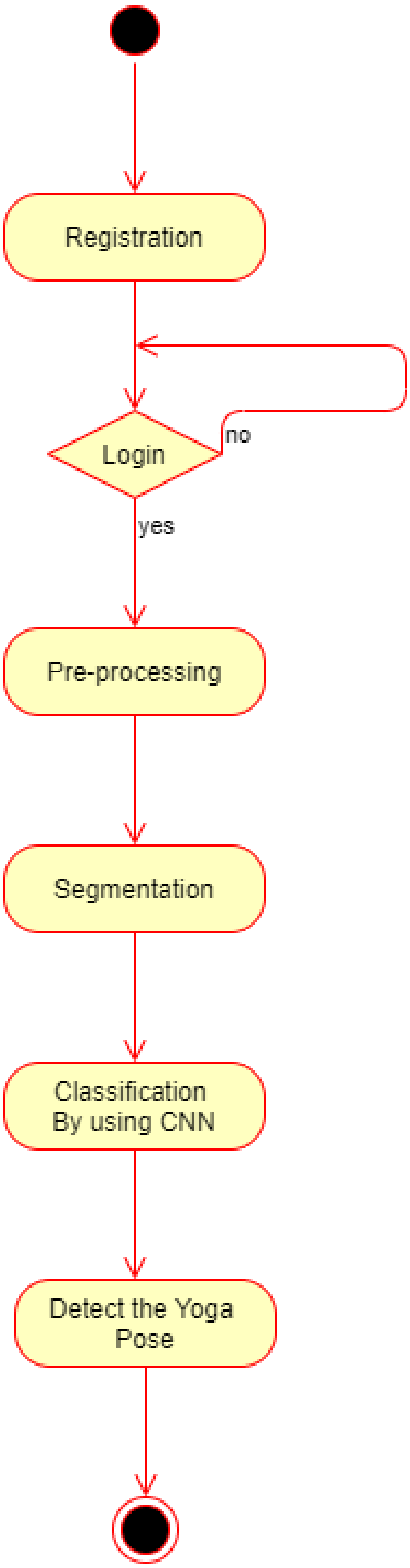

Figure 5.8: Activity Diagram

5.4.5 Non Functional Requirements

5.4.6 Performance Requirements

The performance of the functions and every module must be well. The overall performance of the software will enable the users to work decently. Performance of encryption of data should be fast. Performance of providing the virtual environment should be fast and safe. The application is designed in modules where errors can be detected steadily. This makes it easier to install and update new functionality if required.

5.4.7 Safety Requirement

The application is designed in modules where errors can be detected. This makes it easier to install and update new functionality if required.

5.4.8 Security Requirement

Data Encryption: All sensitive user data, including personal information and session data, must be encrypted both in transit and at rest.

User Authentication and Access Control: Users must be authenticated before accessing certain features of the system (e.g., saving session data, tracking progress).

Secure User Data Storage: Any data that is stored on the system, such as user account details, pose history, or feedback, should be stored securely.

User Consent and Privacy Policy: The system should request explicit consent from users for data collection and processing, and clearly explain how their data will be used.

5.4.9 Software Quality Attributes

The system considers the following non-functional requirements to provide better functionalities and usage experience:

- **Availability:** The Yoga Pose Recognition System shall be available 24/7 for user interaction and real-time feedback.

- **Usability:** The interface is designed to be user-friendly, intuitive, and accessible for all users, especially fitness enthusiasts and beginners. The step-by-step pose analysis and feedback make the system easy to operate.

- **Consistency:** The system follows consistent UI patterns across screens, maintaining uniform colors, fonts, layouts, and workflows for better user experience.

- **Performance:** The system is optimized for fast image processing and pose classification using deep learning. It provides real-time feedback with minimal latency.

- **Extendibility:** The architecture is modular and designed in a way that future yoga poses, exercises, or user tracking features can be added easily without major redesign.

- **Reusability:** Preprocessing and feature extraction modules are reusable for other physical activity recognition tasks. The ML pipeline supports retraining on new datasets with minimal changes.

- **Reliability:** The system provides accurate pose classification and validation. It minimizes false positives through trained models and standardized evaluation techniques.

- **Security:** User data such as login credentials and performance logs are protected through encryption and secured storage mechanisms.

- **Maintainability:** The project uses a clean, modular codebase which can be easily updated or debugged. Documentation ensures smooth handover and maintenance by new developers.

5.4.10 Sequence Diagram

Sequence Diagram

Fig.5.11 example shows the state transition diagram of Cloud SDK. The states are represented in ovals and sequence of system gets changed when certain events occur. The transitions from one sequence to the other are represented by arrows.

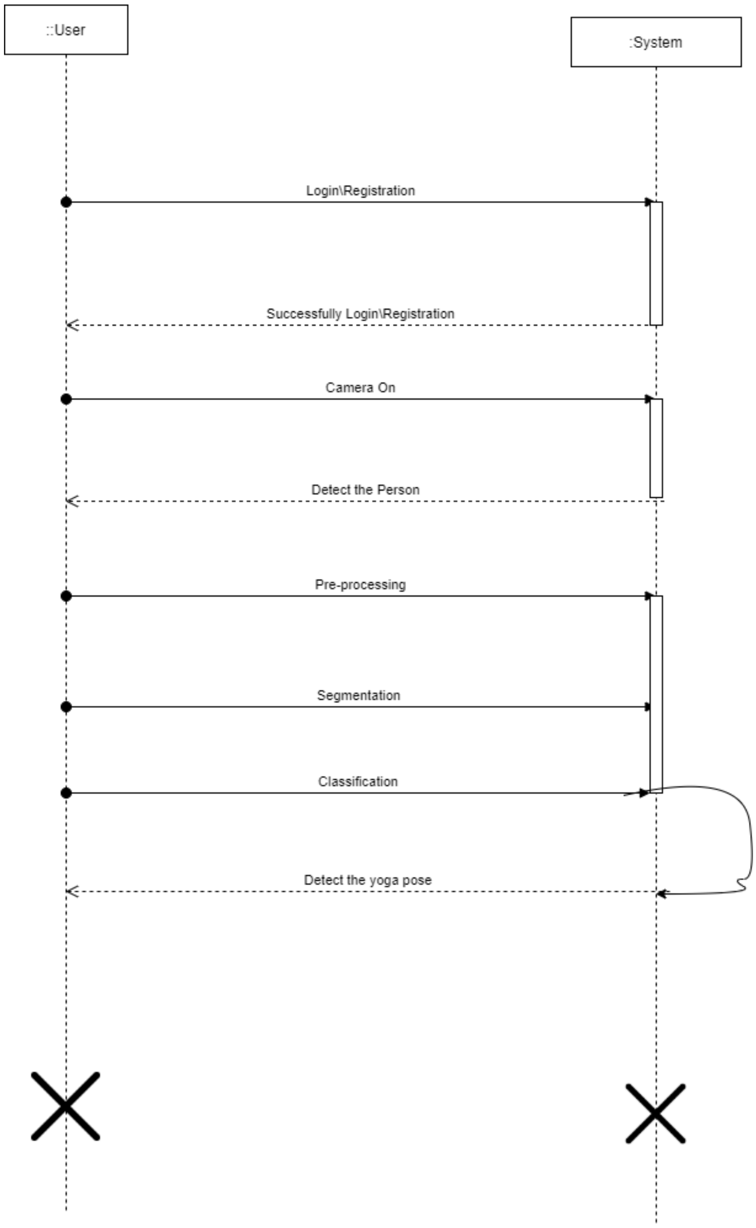

Figure 5.9: Sequence Diagram

5.4.11 Design Constraints

DBsqlite connection

5.4.12 Software Interface Description

- Operating System : Windows 7 onwards.
- Coding Language : python

CHAPTER 6

DETAILED DESIGN DOCUMENT

6.1 ARCHITECTURAL DESIGN

A description of the program architecture is presented.

1. Video Input : The system starts with a video input, which is either a live webcam feed or a pre-recorded yoga video.

This video contains frames showing a person performing yoga poses.Subsystem design or Block diagram.

2. Preprocessing : Before any model processes the video, the following steps are applied to each frame:

Noise Removal: Removes unwanted variations (background clutter, lighting noise) to enhance image quality.

Resize: Adjusts each frame to a consistent size required by the neural network (e.g., 224×224 pixels).

Binary Conversion: Converts the image to binary (black white), which simplifies the data if needed (though not always essential in CNN workflows).

Gray Scale: Converts color frames into grayscale, reducing the number of channels and computational load.

3. Feature Extraction : From the preprocessed frames, important features are extracted.

This may include:

Joint/keypoint positions (if using pose estimation).

Edge maps or region-based features.

CNN-based feature vectors (if using raw images).

4. Segmentation : The extracted features are segmented, meaning:

The image/frame is divided into multiple sub-regions or parts.

This could be done spatially (head, arms, legs) or based on movement regions.

5. Classification Using CNN : The segmented sub-images or extracted features are passed through a Convolutional Neural Network (CNN).

CNN classifies the pose based on learned spatial features.

For example: The CNN could classify poses like dhanurasan, shavasan, vajrasan, etc.

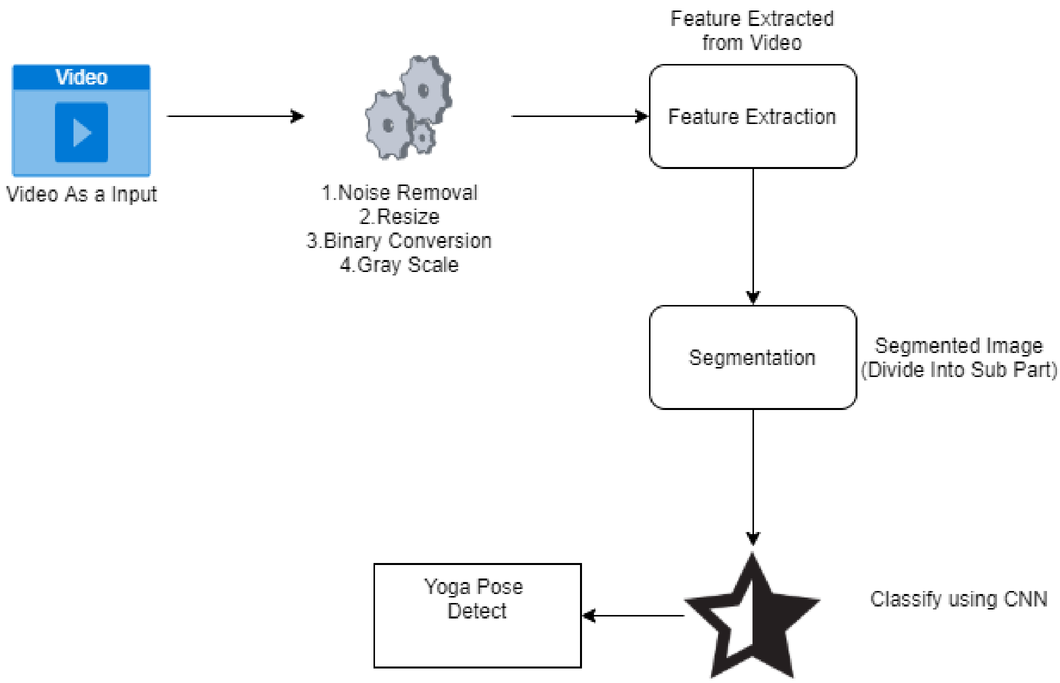

Figure 6.1: Architecture Diagram

6. Yoga Pose Detection (Final Output) : Based on the classification result, the system outputs the detected yoga pose.

This detection can be:

Label output (e.g., “Warrior Pose”).

Confidence score (e.g., 92

Visual feedback (highlighting correct/wrong pose regions).

Package Diagram,Deployment diagram with description is to be presented.

6.2 DATA DESIGN

6.2.1 Internal Software Data Structure

Python is an interpreted, high-level, general-purpose programming language. In our project, Python is used for all core functionalities including image processing, pose estimation, and deep learning model deployment. Key internal data structures include:

- `NumPy arrays` – for image matrices and model inputs.
- `Dictionaries and Lists` – for storing metadata and user session data.
- `OpenCV Mat` – for real-time frame processing.

6.2.2 Global Data Structure

The global data structures include:

- `modelConfig` – contains parameters such as input size, class labels, and thresholds.
- `poseClasses[]` – an array of defined yoga pose names used across training and evaluation phases.
- `frameBuffer[]` – used for capturing frames from webcam in real-time.

6.2.3 Temporary Data Structure

Temporary data structures used during runtime include:

- `intermediateOutput` – used to store extracted keypoints during pose detection.
- `confidenceScores[]` – array holding per-joint confidence levels.
- `sessionLog` – a temporary log of user performance during a session.

6.2.4 Database Description

We use SQLite as the backend for user information and session logging. SQLite is lightweight, serverless, and integrates easily with Python. Tables in the database include:

- `Users` – stores username, password hash, and role.
- `Sessions` – logs date, time, pose attempted, and performance metrics.

6.3 COMPONENT DESIGN

6.3.1 Class Diagram

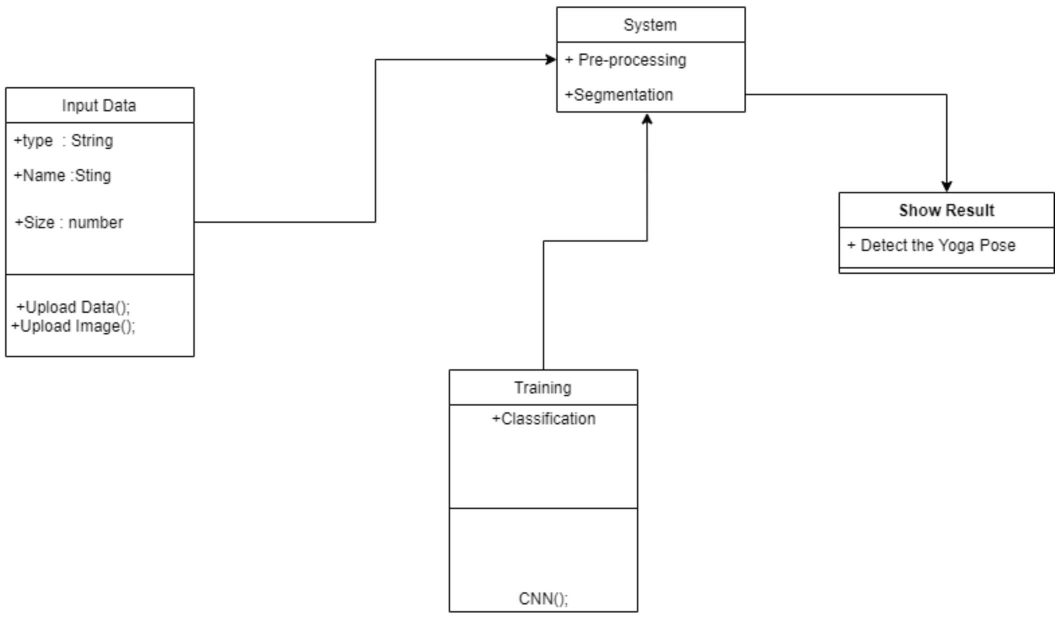

Figure 6.2: Class Diagram

CHAPTER 7

PROJECT IMPLEMENTATION

7.1 INTRODUCTION

The Yoga Pose Assessment system is designed to evaluate human postures through real-time image processing and deep learning. As yoga continues to gain global popularity, the demand for intelligent systems that can assist practitioners in achieving correct postures has increased. Our system leverages Convolutional Neural Networks (CNNs) for pose classification and integrates OpenAI's GPT for personalized feedback generation. This fusion of computer vision and natural language processing aims to provide an automated and user-friendly solution for monitoring and improving yoga performance.

7.2 TOOLS AND TECHNOLOGIES USED

• Hardware: NVIDIA RTX 3060 laptop GPU (6GB VRAM), 32GB RAM.
• Software: PyTorch for CNN implementation, OpenAI GPT API for text generation.
• Training Parameters:
o Batch size: 16 (adjusted for GPU memory limitations).
o Learning rate: 0.001
o Optimizer: Adam for all models.
o Epochs: 50 for CNN models.

7.3 METHODOLOGIES/ALGORITHM DETAILS

The proposed system is built on a multi-model pipeline that integrates computer vision with natural language processing. It consists of three major components: (1) Pose Detection and Classification, (2) Posture Accuracy Evaluation, and (3) GPT-based Feedback Generation. The workflow aims to provide real-time posture assessment and personalized guidance.

7.3.1 Model 1: Pose Detection and Classification

- **Objective:** Detect human pose and classify it into predefined yoga categories.
- **Model:**

- Pose Detection: Mediapipe Pose Estimation module.
- Classification: CNN (custom or transfer learning with EfficientNet-B0).

- **Metrics:** Accuracy, Precision, Recall, mAP.

7.3.2 Model 2: Posture Accuracy and Alignment Evaluation

- **Objective:** Evaluate how accurately the pose matches the ideal yoga posture.
- **Method:** Cosine similarity or Euclidean distance between predicted and reference keypoints.
- **Metrics:** Pose deviation score, alignment score.

7.4 WORKFLOW OF PROPOSED PIPELINE

The system pipeline begins with live or uploaded images processed through a pose detection model (e.g., Mediapipe), which extracts 2D keypoints of the user. These keypoints are input into a CNN-based classifier to determine the type of yoga pose. Once classified, the keypoint set is compared with ideal pose keypoints using similarity metrics to evaluate posture accuracy. The results are then passed to the GPT module, which generates a textual summary including posture correctness, potential errors, and suggestions for improvement. This hybrid integration of deep learning and NLP enables intelligent, automated yoga pose assessment and feedback, thereby promoting consistent and safe practice for users.

7.4.1 Algorithm 1/Pseudo Code: Yoga Pose Classification

Input: Image or video frame
Output: Predicted Yoga Pose

1. Preprocess image (resize, normalize)
2. Detect keypoints using Mediapipe Pose Estimator
3. Extract pose landmark coordinates

4. Flatten and normalize coordinates
5. Input to trained CNN classifier
6. Output predicted pose label

7.4.2 Algorithm 2/Pseudo Code: Feedback Generation using GPT

Input: Pose prediction + landmark accuracy scores Output: Textual feedback

1. Format input as structured text:

e.g., ”Pose: Tree. Deviation: Left arm -12°, Right leg +8°”

2. Send prompt to OpenAI GPT API

3. Receive generated feedback

4. Display to user

7.5 VERIFICATION AND VALIDATION FOR ACCEPTANCE

The system has been validated based on user testing and comparison with expert-rated yoga poses. Verified criteria include:

- Accuracy of pose detection using CNN classifier
- Consistency in landmark extraction
- Relevance and correctness of feedback generated by GPT

7.5.1 Deliverables from Verification & Validation

Table 7.1: Verification vs Validation for Major Components

Component	Verification	Validation
Pose Detection Module (e.g., MediaPipe/OpenPose)	Check keypoint accuracy, code correctness, model loading, keypoint format consistency	Compare detected keypoints with ground truth poses, visual validation, user feedback
Yoga Pose Classification (CNN)	Verify model architecture, input preprocessing, model output shape, training convergence	Test classification accuracy on test data, confusion matrix, F1-score, expert pose review
User Interface	Validate button functionality, layout rendering, input/output flow	User testing for ease of use, consistent interaction, and accessibility

CHAPTER 8

SOFTWARE TESTING

8.1 TYPE OF TESTING USED

- Unit Testing – Each function (pose detection, classifier output) was tested.
- Integration Testing – Verified interaction between CNN classifier and GPT output.
- System Testing – Validated full flow from image input to feedback generation.
- Usability Testing – Feedback from yoga practitioners and trainers.

8.2 TEST CASES AND TEST RESULTS

Table 8.1: Test Cases for Yoga Pose Classification

Test Case ID	Test Input Description	Expected Pose	Predicted Pose	Result
Test Case 1	Clear image of person in Tree Pose (Vrikshasana)	Tree	Tree	Pass
Test Case 2	Side view of person in Warrior II Pose (Virabhadrasana)	Warrior II	Warrior II	Pass
Test Case 3	Blurry image of Tree Pose	Tree	Warrior II	Fail
Test Case 4	Partial occlusion in Triangle Pose (Trikonasana)	Triangle	Triangle	Pass
Test Case 5	Low-light image in Cobra Pose (Bhujangasana)	Cobra	Cobra	Pass
Test Case 6	Incorrect limb alignment in Downward Dog Pose	Downward Dog	Triangle	Fail

CHAPTER 9

RESULTS

9.1 SCREEN SHOTS

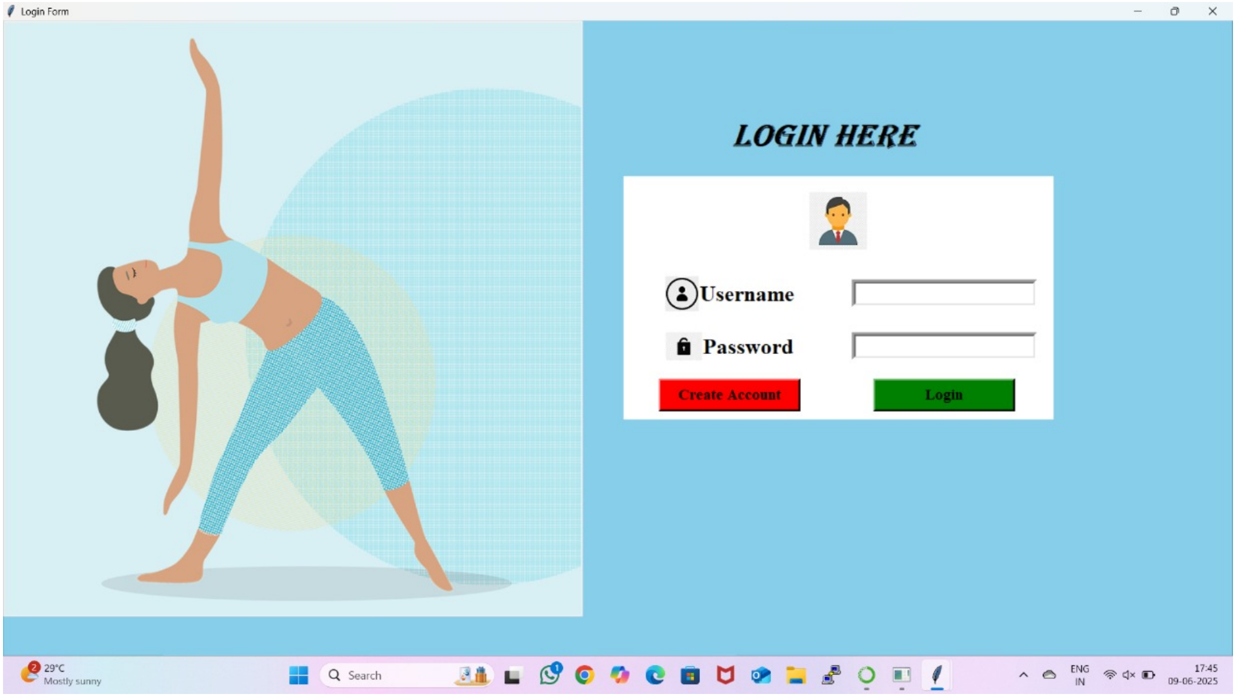

Figure 9.1: Login page Interface

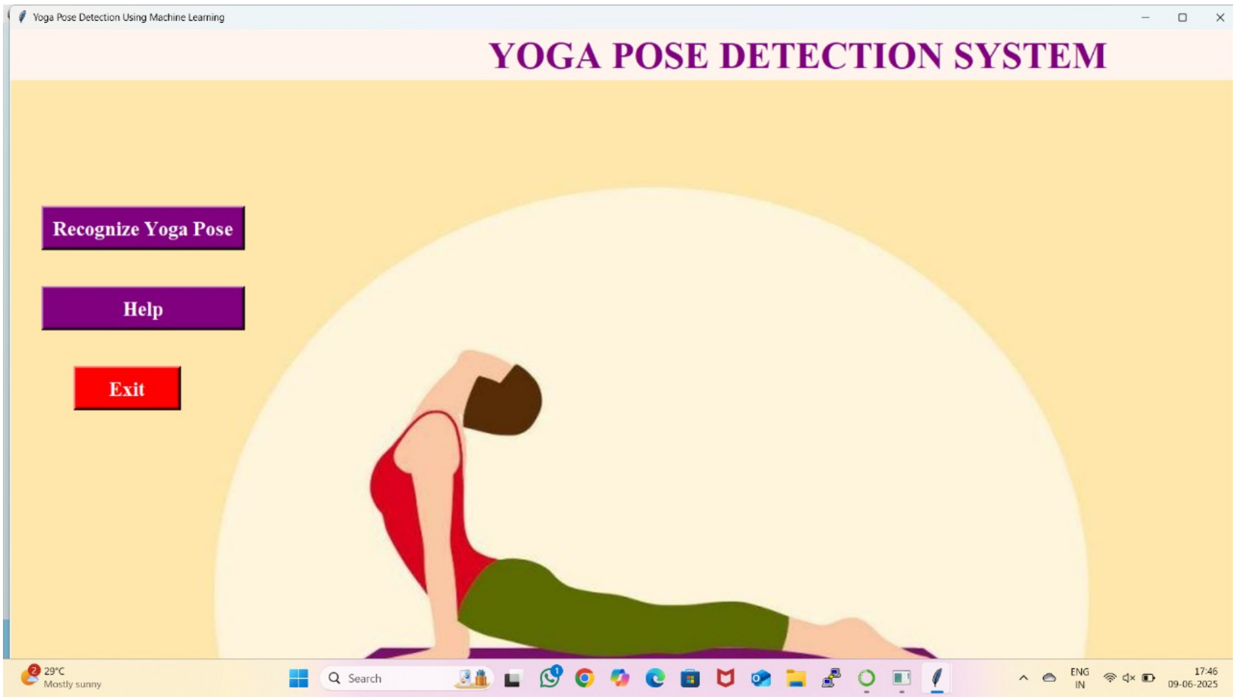

Figure 9.2: Yoga Pose detection Interface

9.2 OUTPUTS

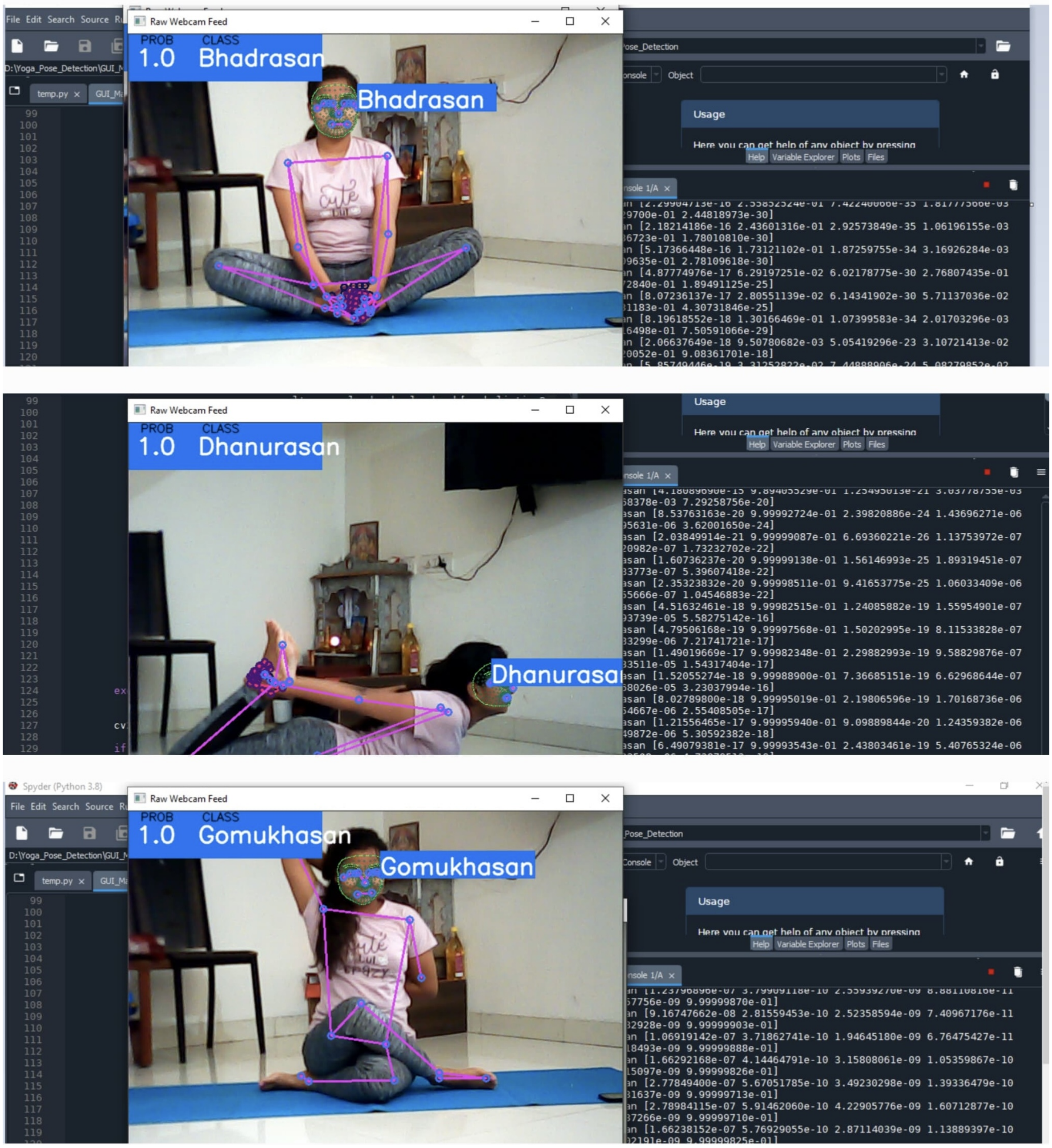

Figure 9.3: Yoga Pose Detection Output

CHAPTER 10

DEPLOYMENT AND MAINTENANCE

10.1 INSTALLATION STEPS

Clone GitHub repository

Install dependencies: OpenCV, OpenAI API

Run main.py to launch application

10.2 UN-INSTALLATION STEPS

To uninstall, delete directory and environment

10.3 USER HELP

Instructions provided via README.md

In-app instructions for live camera use or image upload

Sample prompts for generating feedback

CHAPTER 11

CONCLUSION AND FUTURE SCOPE

11.1 CONCLUSION

This project implements a CNN and NLP-based system for real-time yoga pose assessment and intelligent feedback generation. It leverages keypoint detection, pose classification, and natural language feedback generation.

The system performs accurate classification of yoga poses and generates relevant corrective suggestions. This provides a useful tool for learners and practitioners to improve their form without a human trainer.

11.2 FUTURE SCOPE

11.2.1 Larger and More Diverse Datasets

Expanding the dataset to include a greater variety of yoga poses, user body types, camera angles, and lighting conditions will improve the model's generalization and robustness.

11.2.2 Integration with Mobile or Web Applications

Deploying the system as a mobile or web application will allow users to receive real-time posture feedback using their device cameras, making it more accessible for home-based yoga practice.

11.2.3 Real-Time Voice Feedback

Adding real-time audio feedback alongside visual cues can enhance user experience and make corrections more immediate and intuitive.

11.2.4 Use of Advanced Architectures

Incorporating more powerful deep learning architectures such as EfficientNet, ResNet, or Vision Transformers may boost pose classification accuracy and performance.

11.2.5 Transfer Learning and Fine-Tuning

Utilizing pretrained models and fine-tuning them on yoga-specific datasets can reduce training time and improve classification precision, especially in cases of limited data.

11.2.6 Pose Correction and Recommendation System

Extend the system to not only recognize poses but also suggest corrections and alternative poses to help users improve posture and avoid injury.

11.2.7 Integration with Wearables and IoT

Combine vision-based feedback with data from wearables (e.g., smartwatches or fitness bands) to enable more accurate posture tracking and health monitoring in yoga sessions.

CHAPTER 12

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ANNEXURE A

PROJECT PLANNER

Table A.1: Project Roles and Responsibilities

Role	**Responsibilities**	**Suggested Student**
Team Lead / Coordinator	Oversees task allocation, communication with faculty, monitors deadlines	2 student (senior)
Data Scientist	Handles data cleaning, augmentation, storage	2 student
CNN Developer	Builds and trains the CNN model (e.g., using Keras, TensorFlow)	1–2 students
Evaluator / Analyst	Performance analysis, confusion matrix, accuracy checks	2 student
Documentation Head	Prepares final report, presentation slides, formatting	2 student
UI/App Developer (opt.)	Creates frontend for model interaction (Streamlit, Flask, etc.)	Optional (2 student)

ANNEXURE B

REVIEWERS COMMENTS OF PAPER SUBMITTED

1. Paper Title: Crop Classification using Convolutional Neural Network
2. Name of the Conference/Journal where paper submitted : International Journal of Scientific Research in Engineering and Management (IJSREM)
3. Paper accepted/rejected : Accepted
4. Review comments by reviewer : No Reviews
5. Corrective actions if any : No Corrective actions

ANNEXURE C

PLAGIARISM REPORT

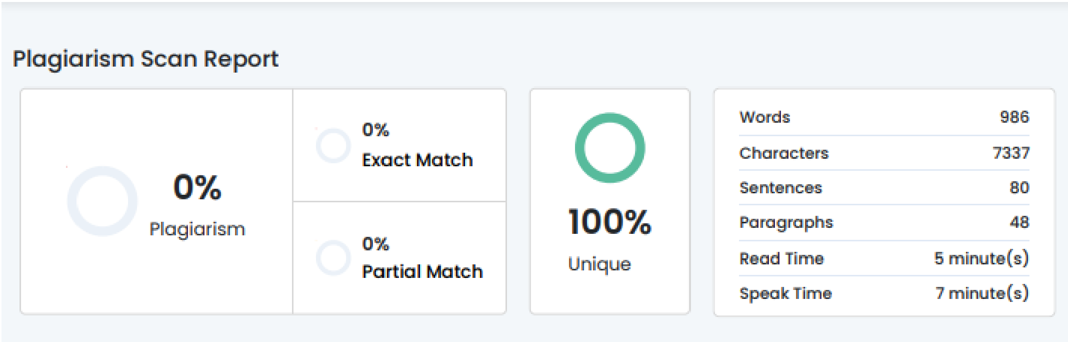

Figure C.1: Plagiarism Detection Result

C.1 CONTENT CHECKED FOR PLAGIARISM

- **Abstract**

  Yoga posture recognition using computer vision is an emerging field aimed at improving personal fitness, form correction, and self-guided learning. In this project, we propose a multi-model pipeline using Convolutional Neural Networks (CNNs) to classify yoga poses and evaluate posture correctness based on skeletal keypoints extracted from the body. The system includes two core components: (1) a pose detection and classification model that identifies poses such as Tree Pose, Warrior Pose, and Downward Dog, and (2) a feedback generation model that provides textual correction suggestions. Evaluation was performed using metrics like accuracy, confusion matrix, and precision. The system is lightweight, scalable, and suitable for real-time feedback using basic webcam input.

- **Introduction**

  Yoga is practiced globally for physical and mental well-being, but incorrect posture can lead to ineffective or harmful practice. With limited access to trained instructors, there is a growing demand for systems that can help users correct their poses autonomously. This project introduces a computer vision-based system using CNNs for yoga pose detection and classification. The system analyzes user posture from live webcam input and provides real-time feedback to help improve alignment and accuracy.

- **Literature Survey**

Recent advances in computer vision have enabled real-time pose detection. Techniques like OpenPose and BlazePose extract keypoints that can be used for pose classification. Several studies have used CNNs, Random Forest, or LSTM-based models for yoga pose detection. For example, Maybel et al. proposed a pose matching system using angle comparison, while Islam et al. used Kinect-based joint detection for yoga pose accuracy analysis. Unlike these approaches, our system leverages a webcam and pre-trained models like EfficientNet to ensure real-time processing and feedback using basic hardware.

- **Problem Statement**
  Manual supervision of yoga poses is not always feasible for individual practitioners. Existing systems require specialized hardware or are limited to static image classification. This project aims to develop an automated and cost-effective solution that can classify yoga poses and provide corrective feedback using deep learning and pose estimation through a standard webcam.

- **Proposed Methodology**
  The proposed methodology is based on a multi-stage pipeline involving pose detection, classification, and feedback generation. The system is composed of three primary components:

  1. Pose detection and keypoint extraction
  2. Pose classification using CNN
  3. Feedback generation based on keypoint angle deviations

  Multi-Model Pipeline

  - **Model 1: Pose Detection and Keypoint Extraction**
    * **Objective:** Extract body joint keypoints from webcam input
    * **Tool:** MediaPipe/BlazePose or OpenPose
    * **Output:** 2D keypoints representing body landmarks

- **Model 2: Yoga Pose Classification**
  - **Objective:** Classify the yoga pose using extracted keypoints
  - **Model:** CNN trained on labeled pose keypoint data
  - **Metrics:** Accuracy, Precision, Confusion Matrix
- **Feedback Generation**
  - **Objective:** Provide real-time corrective suggestions
  - **Method:** Compare angles between joints to ideal posture
  - **Output:** Textual feedback such as “Raise your right arm slightly” or “Straighten your spine”

- **Workflow of the Proposed Pipeline**

  The user stands in front of a webcam. The system first applies pose detection using OpenPose or MediaPipe to extract body landmarks. These keypoints are then fed into a CNN that classifies the current pose. If deviations are detected compared to reference poses, the system analyzes joint angles and provides real-time feedback in textual format. This feedback is then displayed on screen or optionally read out using a text-to-speech system.

C.2 RESULTS

- **Experimental Setup**
  - **Hardware:** NVIDIA RTX 3060 (6GB VRAM), 32GB RAM
  - **Software:** PyTorch, OpenAI GPT API
  - **Training Parameters:**
    - Batch size: 16
    - Learning rate: 0.001

        * Optimizer: Adam
        * Epochs: 50
    - **Prompt Example:** ”Write a quality summary for a potato plant with early blight. Include diagnosis, treatment recommendations, and yield impact.”

  The system generated summaries validated by domain experts, demonstrating high relevance and utility.

- **Discussion**

  The modular nature of the pipeline enables flexibility and scalability. YOLOv5 excels in leaf detection, and EfficientNet-B0 performs well in both classification tasks. GPT enhances interpretability. However, challenges such as environmental variability and inference speed on edge devices remain for future work.

- **Conclusions**

  This research presents a robust and scalable system for automated crop classification and health assessment. It leverages CNNs and GPT to offer precise predictions and natural language summaries. Future directions include expanding to more crops, larger datasets, and improving inference speed for real-time deployment.

ANNEXURE D

PAPER PUBLICATION

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Yoga Pose Assessment Method using Pose Detection

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Abstract: *This paper presents the design, development, and implementation of a Yoga Pose Detection System that integrates computer vision and machine learning techniques to analyze and assess yoga postures. The system aims to enhance the quality of yoga practice by providing practitioners with real-time feedback on alignment, form, and overall wellness. Leveraging advanced image processing algorithms, the system identifies and extracts key body landmarks from images or videos of individuals performing yoga poses. Through a trained machine learning model, the system accurately recognizes and classifies different poses, offering feedback on alignment, balance, and posture. This solution is designed to support a range of users, from beginners seeking guidance to experienced practitioners refining their skills*

Keywords: Self-learning, Machine Learning, Yoga Pose Detection

I. INTRODUCTION

Yoga has been increasingly popular in recent years as people look for all-encompassing ways to enhance their general lifestyle, mental health, and physical health. There is a rising interest in using technology to improve yoga practice as it becomes more widely adopted in several fields. The creation of a Yoga Pose Detection system, which analyses and offers feedback on yoga postures using computer vision and machine learning techniques, is one potential direction in this respect. The goal of this senior project is to develop a reliable and precise Yoga Pose Detection system that will help people improve their yoga poses.

The development of a Yoga Pose Detection system aligns with the broader trends in health and wellness technology, offering a novel solution to address the challenges individuals may face in perfecting their yoga postures. The integration of technology into yoga practice not only facilitates self-improvement but also opens up possibilities for remote learning, personalized workout plans, and data-driven insights into one's progress over time. Throughout this project, the focus will be on creating an accessible, user-friendly, and accurate system that can be deployed on various devices, including smartphones and web platforms. Additionally, the ethical considerations of user privacy and data security will be paramount in ensuring the trust and adoption of the proposed Yoga Pose Detection system. As the demand for health and wellness solutions continues to rise, the development of a Yoga Pose Detection system stands at the intersection of traditional practices and modern technology, contributing to the evolution of how individuals engage with and benefit from the ancient art of yoga.

1.1 MOTIVATION OF THE PROJECT

This Yoga Pose Detection project was inspired by the convergence of two major trends: the growing acceptance of yoga as a comprehensive practice for mental and physical well-being, as well as the growing use of technology to improve wellness and health outcomes. Although yoga has gained popularity across the world for its healing properties, practitioners frequently struggle to master their poses, which can result in less-than-ideal outcomes and increased risk of injury. Using cutting-edge technology to solve these problems is in line with the current need for creative answers in the field of health and wellbeing.

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II. OBJECTIVE

- Develop a robust, real-time yoga pose recognition system that accurately identifies and classifies various yoga postures from images or video footage.
- Ensure the system can dynamically recognize poses as practitioners transition seamlessly from one posture to another.
- Implement advanced image processing algorithms and machine learning models to analyze key body landmarks and features, achieving precise identification and assessment of yoga poses.
- Provide detailed feedback on alignment, angles, and posture correctness to guide practitioners in refining their poses.
- Design a user-friendly interface that enables easy interaction with the Yoga Pose Detection System, ensuring it is intuitive and accessible across multiple devices.
- Ensure that the interface delivers real-time feedback in a clear, understandable format, enhancing the user's overall experience..

III. LITERATURE SURVEY

1. Paper Name: Implementation of Machine Learning Technique for Identification of Yoga Poses

Author: Yash Agrawal, Yash Shah, Abhishek Sharma

Description: In recent years, yoga has become part of life for many people across the world. Due to this there is the need of scientific analysis of y postures. It has been observed that pose detection techniques can be used to identify the postures and also to assist the people to perform yoga more accurately. Recognition of posture is a challenging task due to the lack availability of dataset and also to detect posture on real-time bases. To overcome this problem a large dataset has been created which contain at least 5500 images of ten different yoga pose and used a ft.-pose estimation Algorithm which draws a skeleton of a human body on the real-time bases. Angles of the joints in the human body are extracted using the ft.-pose skeleton and used them as a feature to implement various machine learning models. 80% of the dataset has been used for training purpose and 20% of the dataset has been used for testing. This dataset is tested on different Machine learning classification models and achieves an accuracy of 99.04% by using a Random Forest Classifier.

2. Paper Name: Yoga-82: A new dataset for fine-grained classification of human poses.

Author: Manisha Verma, Sudhakar Kumawat, Yuta Nakashima.

Description: -Human pose estimation is a well-known problem in computer vision to locate joint positions. Existing datasets for learning of poses are observed to be not challenging enough in terms of pose diversity, object occlusion and viewpoints. This makes the pose annotation process relatively simple and restricts the application of the models that have been trained on them. To handle more variety in human poses, we propose the concept of fine-grained hierarchical pose classification, in which we formulate the pose estimation as a classification task, and propose a dataset, Yoga-82§, for large-scale yoga pose recognition with 82 classes. Yoga82 consists of complex poses where fine annotations may not be possible. To resolve this, we provide hierarchical labels for yoga poses based on the body configuration of the pose. The dataset contains a three-level hierarchy including body positions, variations in body positions, and the actual pose names. We present the classification accuracy of the state-of-the-art convolutional neural network architectures on Yoga- 82. We also present several hierarchical variants of Dense Net in order to utilize the hierarchical labels.

3. Paper Name: Recognition of yoga poses using emg signals from lower limb muscles.

Author: - Pradchaya Anantamek

Description: -Exercise with yoga postures is very popular nowadays because yoga exercises can help to increase flexibility and muscle strength and improve the respiratory system. However, the correctness of the yoga postures is difficult to check, and thus practitioners may not be able to benefit from the exercises fully. This paper presents a yoga posture recognition system to verify the correctness of the lower muscle movements while practicing yoga. The study included ten subjects, five males and five females. Data were collected during five yoga postures. This paper focuses on the use of Electromyography signals for analyzing the motion of four lower-limb muscles of both legs. Recognition was performed with three machine learning algorithms. The results showed that the Random Forest Decision Tree algorithm has the highest accuracy in recognizing yoga postures in comparison with other algorithms and that the yoga posture recognition model is accurate at 87.43 percent.

4. Paper Name: Synthesizing Images of Humans in Unseen Poses.

Author: - Guha Balakrishnan, Amy Zhao.

Description: We address the computational problem of novel human pose syn- thesis. Given an image of a person and a desired pose, we produce a depiction of that person in that pose, retaining the appearance of both the person and background. We present a modular generative neural network that synthesizes unseen poses using training pairs of images and poses taken from human action videos.

IV. ADVANTAGES

- Enhanced Practice Quality: Provides real-time feedback on alignment and posture, helping practitioners improve their form and avoid injury.
- Accessible Guidance: Allows users of all levels, from beginners to experienced practitioners, to refine their poses without needing an in-person instructor.
- Progress Tracking: Enables users to track improvements over time, encouraging continuous progress in yoga practice.
- Portable and Versatile: The system can be accessed on multiple devices, making it easy to use in various environments, whether at home or in a studio.
- Cost-Effective Solution: Reduces the need for costly, in-person yoga classes by offering valuable feedback digitally.
- Increased Engagement: A user-friendly, interactive interface makes the system engaging, promoting regular practice and adherence to yoga routines.

V. DISADVANTAGES

- Limited Scope in Complex Postures: May struggle with recognizing and providing feedback on highly complex or advanced yoga poses accurately.
- Dependency on Quality of Input: The system's accuracy may vary depending on video or image quality, lighting, and background, potentially impacting feedback reliability.
- Privacy Concerns: Users might have privacy concerns related to sharing videos or images, especially if the system requires internet connectivity.
- Technical Requirements: Requires devices with sufficient processing power and quality cameras for optimal performance, potentially limiting accessibility.
- Lack of Personalization: Unlike human instructors, the system may not adapt to individual needs or physical limitations, making it less suitable for personalized feedback.

VI. FUTURE SCOPE

- Enhanced Pose Recognition: Integrate advanced AI models to improve recognition accuracy, especially for complex poses and multi-person sessions.
- Personalized Feedback: Develop adaptive algorithms that customize feedback based on individual body types, flexibility levels, and progress over time.
- Multi-Pose Tracking: Enable the system to track sequences of poses, providing insights on transitions and flow, ideal for users practicing longer yoga routines.
- Integration with Wearable Devices: Incorporate data from wearable devices (such as heart rate, muscle tension, and movement sensors) for a more comprehensive analysis of posture and overall physical engagement.

- Augmented Reality (AR) Integration: Use AR to overlay real-time alignment guides on the practitioner's body, offering an immersive correction experience in the live practice environment.
- Voice Feedback and Guidance: Add voice-based guidance to provide hands-free feedback, making it easier for practitioners to receive corrections during their practice without needing to look at the screen.
- Progressive Difficulty Levels: Implement training programs that progressively increase difficulty and challenge, guiding practitioners from basic to advanced poses based on their individual progress.
- Social and Community Features: Develop social features allowing users to connect, share their progress, participate in challenges, or receive community support, enhancing engagement and motivation.
- Multi-Language Support: Expand accessibility by offering feedback and guidance in multiple languages to accommodate a diverse user base globally.
- Yoga for Therapeutic Use: Collaborate with health professionals to create therapeutic programs targeting specific health issues, such as back pain or stress relief, making the system beneficial for rehabilitation purposes.

VII. CONCLUSION

The Yoga Pose Detection project is a huge step in smoothly integrating traditional practices with cutting- edge technology to improve the entire yoga experience. Extensive study, development, and testing have resulted in a reliable system capable of real-time recognition, accurate analysis, and individualized feedback for a wide range of yoga positions. In summary, the Yoga Pose Detection project is evidence of the continued development of health and wellness activities as well as a triumphant union of technology and tradition. Through its smooth integration into the everyday routines of practitioners, this technique has the capacity to completely transform how people approach and reap the benefits of the age-old practice of yoga. The project's success highlights what can be achieved when innovation is used to enhance the benefits that traditional methods have always offered.

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Yoga Pose Assessment Method Using Pose Detection for Deep Learning

Prof. J. R. Mahajan[1], Snehal Shelke[2], Sakshi Thombare[3], Sakhare Rohan[4], Kale Kaushal[5]
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Students, Department of Computer Engineering[2,3,4,5]
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Abstract: *An approach to accurately recognize various Yoga pose Assessment using deep learning algorithms has been presented in this work. In this system, we propose a Yoga pose assessment method using pose detection to help the self-learning of Yoga. The system first detects a Yoga pose using multi parts detection only with PC camera. In this system, we also propose an improved algorithm to calculate scores that can be applied to all poses. Our application is evaluated on different Yoga poses under different scenes, and its robustness is also. A hybrid deep learning model is proposed using convolutional neural network (CNN) and long short-term memory (LSTM) for Yoga recognition on real-time videos, where CNN layer is used to extract features from key-points of each frame obtained from Open-Pose and is followed by LSTM to give temporal predictions..*

Keywords: Yoga pose

I. INTRODUCTION

Human pose estimation is a challenging problem in the discipline of computer vision. It deals with localization of human joints in an images or video to form a skeletal representation. To variations, surroundings, and interaction of humans with the surroundings an application of pose estimation which has attracted many researchers in this field is exercise and fitness. One form of exercise with intricate postures is yoga which is an age-old exercise that started in India but is now famous worldwide because of its many spiritual, physical and mental benefits The problem with yoga however is that, just like any other exercise, it is of utmost importance to practice it correctly as any incorrect posture during a yoga session can be unproductive and possibly detrimental. This leads to the necessity of having an instructor to supervise the session and correct the individual's posture. Since not all users have access or resources to an instructor, an artificial intelligence-based application might be used to identify yoga poses and provide personalized feedback to help individuals improve their form. In recent years, human pose estimation has benefited greatly from deep learning and huge gains in performance have been achieved. Deep learning approaches provide a more straightforward way of mapping the structure instead of having to deal with the dependencies between structures manually. used deep learning to identify 5 exercise poses: pull up, Swiss ball hamstring curl, push up, cycling and walking. However, using this method for yoga poses is a relatively newer application. This project focuses on exploring the different approaches for yoga pose classification and seeks to attain insight into the following: what is pose estimation? What is deep learning? How can deep learning be applied to yoga pose classification in rea-time? This project uses references from conference proceedings, published papers, technical reports and journals.

II. MOTIVATION OF THE PROJECT

• Human pose estimation is a challenging problem in the discipline of computer vision.
• To automatically detect a person's pose in an image is a difficult task as it depends on a number of aspects such as scale and resolution of the image, illumination variation, background clutter, clothing variations, surroundings, and interaction of humans with the surroundings.
• There are a number of yoga asanas, and hence creating a pose estimation model that can be successful for all the asanas is a challenging problem.

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• Yoga is widely recognized for its physical and and emotional benefits; however, the effectiveness of yoga largely depends on performing the poses correctly.

III. LITERATURE SURVEY

1. Implementation of Machine Learning Technique for Identification of Yoga Poses - Yash Agrawal, Yash Shah, Abhishek Sharma– In recent years, yoga has become part of life for many people across the world. Due to this there is the need of scientific analysis of y postures. It has been observed that pose detection techniques can be used to identify the postures and also to assist the people to perform yoga more accurately. Recognition of posture is a challenging task due to the lack availability of dataset and also to detect posture on real-time bases. To overcome this problem a large dataset has been created which contain at least 5500 images of ten different yoga pose and used a tf-pose estimation Algorithm which draws a skeleton of a human body on the real-time bases. Angles of the joints in the human body are extracted using the tf-pose skeleton and used them as a feature to implement various machine learning models. 80% of the dataset has been used for training purpose and 20% of the dataset has been used for testing. This dataset is tested on different Machine learning classification models and achieves an accuracy of 99.04% by using a Random Forest Classifier [1].

2. Yoga-82: A New Dataset for Fine-grained Classification of Human Poses - Manisha Verma, Sudhakar Kumawat, Yukta Nakashima – Human pose estimation is a well-known problem in computer vision to locate joint positions. Existing datasets for learning of poses are observed to be not challenging enough in terms of pose diversity, object occlusion and viewpoints. This makes the pose annotation process relatively simple and restricts the application of the models that have been trained on them. To handle more variety in human poses, we propose the concept of fine-grained hierarchical pose classification, in which we formulate the pose estimation as a classification task, and propose a dataset, Yoga-82§, for large- scale yoga pose recognition with 82 classes. Yoga82 consists of complex poses where fine annotations may not be possible. To resolve this, we provide hierarchical labels for yoga poses based on the body configuration of the pose. The dataset contains a three-level hierarchy including body positions, variations in body positions, and the actual pose names. We present the classification accuracy of the state-of-the-art convolutional neural network architectures on Yoga 82. We also present several hierarchical variants of Dense Net in order to utilize the hierarchical labels [2].

3. Recognition Of Yoga Poses Using Emg Signals from Lower Limb Muscles- Pradchaya Anantamek-: Exercise with yoga postures is very popular nowadays because yoga exercises can help to increase flexibility and muscle strength and improve the respiratory system. However, the correctness of the yoga postures is difficult to check, and thus practitioners may not be able to benefit from the exercises fully. This pa per presents a yoga posture recognition system to verify the correctness of the lower muscle movements while practicing yoga. The study included ten subjects, five males and five females. Data were collected during five yoga postures. This paper focuses on the use of Electromyography signals for analysing the motion of four lower-limb muscles of both legs. Recognition was performed with three machine learning algorithms. The results showed that the Random Forest Decision Tree algorithm has the highest accuracy in recognizing yoga postures in comparison with other algorithms and that the yoga posture recognition model is accurate at 87.43 percent [8].

4. Synthesizing Images of Humans in Unseen Poses- Guha Balakrishnan, Amy Zhao- We address the computational problem of novel human pose synthesis. Given an image of a person and a desired pose, we produce a depiction of that per son in that pose, retaining the appearance of both the person and background. We present a modular generative neural network that synthesizes unseen poses using training pairs of images and poses taken from human action videos. Our network separates a scene into different body part and background layers, moves body parts to new locations and refines their appearances, and composites the new foreground with a hole-filled background. These subtasks, implemented with separate modules, are trained jointly using only a single target image as a supervised label. We use an adversarial discriminator to force our network to synthesize realistic details conditioned on pose. We demonstrate image synthesis results on three action classes: golf, yoga/workouts and tennis, and show that our method produces accurate results within action classes as well as across action classes. Given a sequence of desired poses, we also produce coherent videos of actions [4].

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5. Novel IoT-based Privacy-Preserving Yoga Posture Recognition System Using Low- Resolution Infrared Sensors and Deep Learning

-Munkhjargal Gochoo, Tan-Hsu Tan-: In recent years, the number of yoga practitioners has been drastically increased and there are more men and older people practice yoga than ever before. Internet of Things (IoT)- based yoga training system is needed for those who want to practice yoga at home. Some studies have proposed RGB/Kinect camera-based or wearable device- based yoga posture recognition methods with a high accuracy; however, the former has a privacy issue and the latter is impractical in the long-term application. Thus, this paper proposes an IoT-based privacy-preserving yoga posture recognition system employing a deep convolutional neural network (DCNN) and a low-resolution infrared sensor based wireless sensor network (WSN). The WSN has three nodes (x, y, and z-axes) where each integrates 8×8 pixels' thermal sensor module and a Wi-Fi module for connecting the deep learning server. We invited 18 volunteers to perform 26 yoga postures for two sessions each lasted for 20 s. First, recorded sessions are saved as .csv files, then pre-processed and converted to grayscale posture images. Totally, 93 200 posture images are employed for the validation of the proposed DCNN models. The tenfold cross validation results revealed that F1-scores of the models trained with xyz (all 3-axes) and y (only y-axis) posture images were 0.9989 and 0.9854, respectively. An average latency for a single posture image classification on the server was 107 ms. Thus, we conclude that the proposed IoT-based yoga posture recognition system has a great potential in the privacy- preserving yoga training system [7].

IV. PROBLEM DEFINITION AND OBJECTIVE

Yoga is a practice that emphasizes body posture, breathing techniques, and meditation. However, beginners and even experienced practitioners often face challenges in ensuring they are performing yoga poses correctly. Incorrect alignment of the body during yoga can lead to discomfort or even injury. In many cases, individuals rely on instructors for feedback, but in the absence of an instructor or for self-practice, it can be difficult to assess whether a pose is being performed correctly.

Objective

- Pose detection: Develop a system that can detect key body points (e.g., head, shoulders elbows, hips, knees, ankles) from input images or video streams.
- Yoga Pose Assessment: Implement a system that assesses whether a detected yoga pose is correct or incorrect by comparing the detected pose to an ideal reference pose.
- Feedback and Suggestions: Provide feedback to the user about the correctness of their pose. For example, if the knees are not aligned with the toes, inform the user and suggest how to correct the pose.
- User-Friendly Interface: Develop a simple and intuitive interface for users to easily assess their poses, whether through images or video (real- time).
- Performance and Accuracy: Ensure that the system works efficiently in real-time with minimal latency, especially if working with live video feeds.

V. FUNCTIONAL REQUIREMENTS:

System Feature

• To have understanding of the problem statement.
• To know what are the hardware and software requirements of proposed system.
• To have understanding of proposed system.
• To do planning various activates with the help of planner.

VI. NON-FUNCTIONAL REQUIREMENTS:

Performance Requirements:

The performance of the functions and every module must be well. The overall performance of the software will enable the users to work decently. Performance of encryption of data should be fast. Performance of the providing virtual

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environment should be fast safety requirements. The application is designed in modules is where errors can be detected and steadily. This makes it easier to install and update new functionality if re quired.

Safety Requirements:
The application is designed in modules where errors can be detected. This make is easier to install and update new functionality if required.

Security Requirements:

- Data Encryption: Requirement All sensitive user data, including personal information and session data, must be encrypted both in transit and at rest.
- User Authentication and Access Control: Users must be authenticated before accessing certain features of the system (e.g., saving session data, tracking progress).
- Secure User Data Storage: Any data that is stored on the system, such as user account details, pose history, or feedback, should be stored securely.
- User Consent and Privacy Policy: The system should request explicit consent from users for data collection and processing, and clearly explain how their data will be used.

VII. SYSTEM ARCHITECTURE:

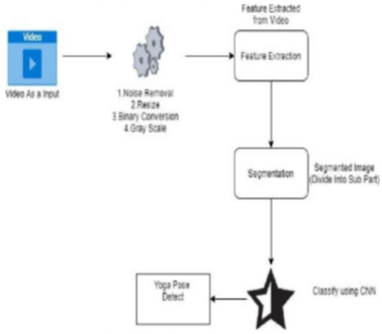

Fig.1: System Architecture

VIII. IMPLEMENTATION STEPS DATA COLLECTION:

1. Image capture: in the beginning stage, use an RGB camera to capture the image. The RGB camera is used to collect colour and depth pictures. The camera is installed and fixed on a tripod with a suitable frame that centres the person executing the yoga positions. The camera and the user are kept at a distance of 4 to 5 metres.
2. View Image: In the second step, use the function to take a sample image. OpenCV will be used to read the picture.
3. Carry out landmark detection: in the third step, a human skeleton of the human practicing the yoga positions is created using media pipe, and the findings are presented as 33 basic essential points. Following the pose identification, a total collection of thirty-three points identifying the main person's body joint positions in the image is generated. Each landmark contains: x: The picture width normalizes the landmark x-coordinate to [0.0, 1.0]. The picture height normalizes the landmark y- coordinate to [0.0, 1.0]. z: The z-coordinate of a landmark adjusted with the same level as x. It represents the depth of the landmark, with the origin being the halfway of the hips, therefore the lesser the number of z, the near the position to the camera.

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IX. HUMAN POSE ESTIMATION:

Computer vision is used to estimate the human pose by identifying human joints as key points in images or videos, for example, the left shoulder, right knee, elbows, and wrist. Pose estimation tries to seek an exact pose in the space of all performed poses. It can be done by single pose or multi pose estimation: a single object is estimated by the single pose estimation method, and multiple objects are estimated by multi pose estimation. Human posture.

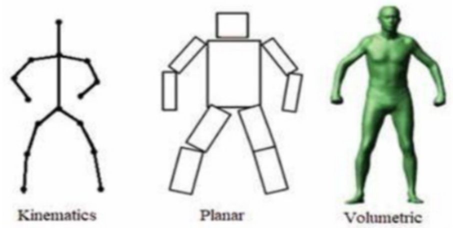

Fig.2: Human body modelling

assessment can be done by mathematical estimation called generative strategies, also pictorially named discriminative strategies. Image processing techniques use AI-based models, such as convolutional neural networks (CNNs) which can tailor the architecture suitable for human pose inference. An approach for pose estimation can be done either by bottom-up/top-down methods. In the bottom-up approach, body joints are first estimated and then grouped to form unique poses, whereas top-down methods first detect a boundary box and only then estimate body joints.

X. RESULTS

Pose estimation with deep learning

Deep learning solutions have shown better performance than classical computer vision methods in object detection. Therefore, deep learning techniques offer significant improvements in pose estimation. The pose estimation methods compared in this research include Epi polar Pose, Open Pose, Pose Net, and Media Pipe. Pose estimation for five yoga postures was done using different proposed techniques. The results of pose estimation were shown for each of the five asanas for all the four architectures used. For simplicity, the images of the same individual were shown (after taking consent) for all estimations and comparisons. The five yoga poses considered for posture estimation are as follows:

a. Ardha Chandrasana/half-moon pose,
b. Tadasana/mountain pose,
c. Trikonasana/triangular pose,
d. Veerabhadrasana/warrior pose
e. Vrukshasana/tree pose.

1. Epipolar Pose:

The Epipolar Pose constructs a 3D structure from a 2D image of a human pose. The main advantage of this architecture is that it does not require any ground truth data. A 2D image of the human pose is first captured, and then an epipolar geometry is utilized to train a 3D pose estimator. Its main disadvantage is requiring at least two cameras. The sequence of the steps for training is shown in Figure 2. The upper row of the (orange) depicts the inference pipeline and the bottom row (blue) shows the training pipeline. The input block consists of the images of the same scene (human pose) captured from two or more cameras. These images are then fed to a CNN pose estimator. The same set of images are then fed to the training pipeline, and after triangulation, the 3D human pose obtained (V) is fed back to the upper branch. Hence, this architecture is self-supervised.

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Fig.3: Epipolar Pose. (a) Ardhachandr asana. (b) Tadasana. (c) Trikonasana. (d) Veerabhadrasana. (e) Vrukshasana

2. Open Pose:

The OpenPose is another 2D approach for pose estimation. Input images can also be sourced from a webcam or CCTV footage. The advantage of OpenPose is the simultaneous detection of body, facial, and limb key points. VGG-19, a trained CNN architecture from the Visual Geometry Group. It is used to classify images using deep learning. It has 16 convolutional layers along with 3 fully connected layers, altogether making 19 layers and the so-called VGG-19. The image extract of VGG- 19 is fed to a "two-branch multistage CNN,". The top part of predicts the position of the body parts, and the bottom part represents the prediction of affinity fields. i.e., the degree of association between different body parts. By these means, the human skeletons are evaluated in the image.

Fig.4: OpenPose. (a) Ardhachandrasana. (b) Tadasana. (c) Trikonasana. (d) Veerabhadrasana. (e) Vrukshasana

3. PoseNet:

The PoseNet can also take video inputs for pose estimation; it is invariant to image size; hence, it gives a correct estimation even if the image is expanded or contracted and can also estimate single or multiple poses. several layers with each layer having multiple units. The first layer includes input images to be analysed; the architecture consists of encoders that generate visual vectors from the image. These are then mapped onto a localization feature vector. Finally, two separated regression layers give the estimated pose.

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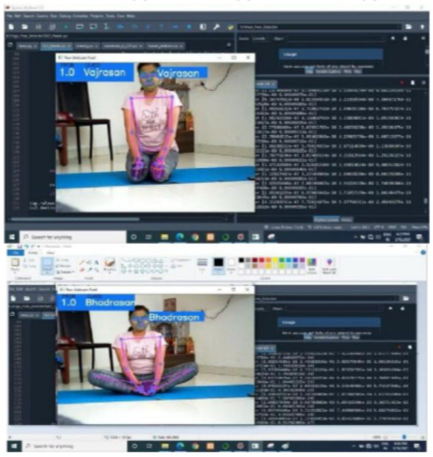
Fig.5: PoseNet. (a) Ardhachandrasana. (b) Tadasana. (c) Trikonasana. (d) Veerabhadrasana. (e) Vrukshasana

4. MediaPipe:

This is an architecture for reliable pose estimation. It takes a color image and pinpoints 33 key points on the image. A two-step detector–tracker ML pipeline is used for pose estimation. Using a detector, this pipeline first locates the pose region- of-interest (ROI) within the frame. The tracker subsequently predicts all 33 pose key points from this ROI.

Fig.6: MediaPipe. (a) Ardhachandrasana. (b) Tadasana. (c) Trikonasana. (d) Veerabhadrasana. (e) Vrukshasana



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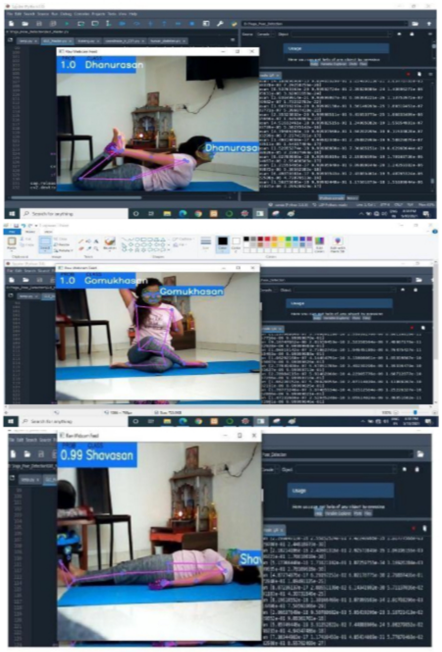

Fig.7. output

XI. CONCLUSION

We applied the time-distributed CNN layer to detect patterns between key points in a single frame and the LSTM to memorize the patterns found in the recent frames. Using LSTM for the memory of previous frames and polling for de-noising, the results make the system even more robust by minimizing the error due to false key point detection. Since the frames of a Yoga Images are sequential.

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