

REAL-TIME YOGA POSE DETECTION AND CORRECTION

A PROJECT REPORT

Submitted by

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In partial fulfillment of the requirements for the award of the degree of

MASTER OF COMPUTER APPLICATIONS



**Changan Kunju Musaliar College of Engineering
Kerala**

DEPARTMENT OF COMPUTER APPLICATIONS


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DECLARATION

I undersigned hereby declare that the project report on **REAL-TIME YOGA POSE DETECTION AND CORRECTION**, submitted for partial fulfillment of the requirements for the award of degree of Master of Computer Applications of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by me under supervision of **Dr. Fousia M Shamsudeen**. This submission represents my ideas in my own words and where ideas or words of others have been included, I have adequately and accurately cited and referenced the original sources. I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in our submission. I understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University..

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CERTIFICATE

This is to certify that the report entitled **REAL-TIME YOGA POSE DETECTION AND CORRECTION** submitted by **AFEEF KP** (TKM21MCA-2003) to the APJ Abdul Kalam Technological University in partial fulfillment of the Masters degree in Computer Applications is a bonafide record of the project work carried out by him under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

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ABSTRACT

With the increasing popularity of yoga and its numerous health benefits, it is crucial to ensure that practitioners are able to perform the poses correctly to avoid injury and maximize the benefits. However, traditional methods of learning and practicing yoga often lack real-time feedback and guidance. This project addresses the need for an effective and user-friendly solution to enhance the practice of yoga and aims to develop a real-time yoga pose detection system that can accurately analyze and provide feedback on the user's pose, helping them improve their form and achieve better results.

The system incorporates the K-Nearest Neighbors (KNN) algorithm, Mediapipe library, and a dataset sourced from Kaggle. The KNN algorithm is employed for pose recognition, utilizing the distances between poses to classify and identify the closest match. Mediapipe library is utilized to extract pose landmarks from input video frames, providing valuable information for pose detection. The dataset from Kaggle serves as the training data, enabling the system to learn and recognize various yoga poses accurately. This combination of KNN, Mediapipe, and the Kaggle dataset enhances the system's ability to perform real-time and accurate yoga pose detection, facilitating effective feedback and guidance for users during their yoga practice. The results obtained from the project demonstrate the effectiveness of the KNN-based system in accurately detecting and recognizing yoga poses in real-time. The accuracy of the system is evaluated using appropriate metrics, providing insights into its performance and ability to assist users in achieving correct poses. The findings of this project contribute to the development of interactive and reliable tools for yoga practitioners, enhancing their practice and improving pose correctness.

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Chapter 1

Introduction

Yoga is a form of exercise that has been practiced for centuries and has gained popularity in recent years due to its numerous health benefits. While practicing yoga, it is essential to perform each pose correctly to avoid injury and achieve maximum benefits. However, it can be challenging to know whether one is performing a pose correctly without the help of an instructor, especially for beginners. This problem is further compounded when practicing yoga at home without an instructor's supervision. In such scenarios, individuals may unknowingly perform a pose incorrectly, leading to injuries or not achieving the intended benefits. To address this issue, there is a need for an automated system that can detect and correct yoga poses in real-time.

The primary objective of this project is to develop a real-time yoga pose detection and correction system that can analyze the user's posture and provide feedback to help the user achieve the correct posture for each pose. The proposed system utilizes computer vision techniques, particularly the use of the OpenCV library and the PoseNet model, to detect the pose of the user in real-time. The system also uses K-Nearest Neighbor (KNN) algorithm to classify the pose and provide feedback to the user on how to improve their posture. The proposed system has several advantages over traditional yoga practice methods. Firstly, it allows for real-time feedback, which is not possible with traditional methods. Secondly, it eliminates the need for a human instructor, making it accessible to a wider range of people. Additionally, the system provides an accurate and objective analysis of the user's pose, which may not be possible with human instructors.

This system will ensure that individuals can perform yoga poses correctly and reap maximum benefits while minimizing the risk of injury. The existing systems that detect and

correct yoga poses have some limitations. They lack audio feedback, making it difficult for individuals to know when they are performing a pose correctly. Additionally, some systems are not real-time, which means that individuals have to wait for feedback after completing a pose, which disrupts the flow of their practice. To overcome these limitations, this project proposes the development of a real-time yoga pose detection and correction system that provides audio feedback. The proposed system uses the KNearest Neighbors (KNN) algorithm for training and OpenCV and PoseNet for pose detection. The system will capture images of individuals performing yoga poses and process them using the KNN algorithm to recognize the pose. If the pose is incorrect, the system will provide audio feedback to the user in real-time, allowing them to make corrections. The proposed system has several advantages over existing systems, including providing audio feedback, realtime pose detection and correction, and an easy-to-use interface. Moreover, the system is costeffective and can be used by individuals to practice yoga at home without the need for an instructor's presence. The primary objective of this project is to develop a real-time yoga pose detection and correction system that can analyze the user's posture and provide feedback to help the user achieve the correct posture for each pose. The proposed system utilizes computer vision techniques, particularly the use of the OpenCV library and the PoseNet model, to detect the pose of the user in real-time. The system also uses K-Nearest Neighbor (KNN) algorithm to classify the pose and provide feedback to the user on how to improve their posture. The proposed system has several advantages over traditional yoga practice methods. Firstly, it allows for real-time feedback, which is not possible with traditional methods. Secondly, it eliminates the need for a human instructor, making it accessible to a wider range of people. Additionally, the system provides an accurate and objective analysis of the user's pose, which may not be possible with human instructors.

1.1 Problem Statement

This project aims to address the problem of incorrect yoga poses by proposing the development of a real-time yoga pose detection and correction system that provides audio feedback. The proposed system will help individuals practice yoga correctly, minimize the risk of injury, and achieve maximum benefits.

1.2 Objectives

- To develop a real-time yoga pose detection system
- To incorporate real-time audio feedback
- To improve pose detection accuracy
- To accommodate a variety of body types and camera positions

Chapter 2

Literature Survey

A literature survey, also known as a literature review, involves analyzing scholarly sources related to a particular subject. Examining the available literature, it provides a comprehensive overview of the state of the field, allowing you to identify relevant theories, approaches, and gaps in the existing body of knowledge. When conducting a literature review from an audit perspective, the main focus is on evaluating the relevant literature. This process covers information that has been published in a specific field of study and sometimes includes information published within a specific time frame.

2.1 Purpose of the Literature Review

1. It gives readers easy access to research on a particular topic by selecting high quality articles or studies that are relevant, meaningful, important and valid and summarizing them into one complete report.
2. It provides an excellent starting point for researchers beginning to do research in a new area by forcing them to summarize, evaluate, and compare original research in that specific area.
3. It ensures that researchers do not duplicate work that has already been done.
4. It can provide clues as to where future research is heading or recommend areas on which to focus.
5. It highlights the key findings.

6. It identifies inconsistencies, gaps and contradictions in the literature.
7. It provides a constructive analysis of the methodologies and approaches of other researchers.

2.2 Related Works

The paper by Yadav et al. [5] identified as a significant contribution in the field of real-time Yoga recognition using deep learning. The authors proposed a novel approach that leverages deep learning techniques to accurately recognize Yoga poses in real-time.

Yadav et al. [5] conducted their research using a large dataset of Yoga poses, which was collected from various sources. The dataset consists of images representing different Yoga poses performed by individuals of varying skill levels. The authors employed deep learning algorithms, specifically convolutional neural networks (CNNs), to train a model capable of recognizing and classifying these Yoga poses. The results presented by Yadav et al. [5] demonstrate the effectiveness of their approach in achieving high accuracy in real-time Yoga pose recognition. The trained model achieved an accuracy of over 95 percentage in correctly identifying and classifying various Yoga poses. The authors also evaluated the performance of the model against different variations in lighting conditions and backgrounds, and it showed robustness in handling such variations. The findings of Yadav et al. [5] are highly relevant to our own research on real-time Yoga recognition. Their work addresses the need for an accurate and efficient system that can recognize Yoga poses in real-time, which can be beneficial for individuals practicing Yoga remotely or with limited guidance. By leveraging deep learning techniques, Yadav et al. [5] provide a valuable contribution to the field, as their approach demonstrates the potential for achieving high accuracy and real-time performance in Yoga pose recognition.

Overall, the paper by Yadav et al. [5] serves as a foundational work in the field of real-time Yoga recognition using deep learning. Their methodology, results, and insights contribute to the development of more advanced and efficient systems for Yoga practitioners. Building upon their research, our own study aims to explore further improvements and extensions to enhance the accuracy and performance of real-time Yoga recognition systems.

The paper "The application of wearable devices in yoga" by Yang and Xiong [7] explores the application of wearable devices in the context of yoga. The authors recognize the growing

popularity of wearable technology and its potential to enhance the practice of yoga by providing real-time feedback and monitoring capabilities.

Yang and Xiong [7] begin by discussing the benefits of yoga practice, such as stress reduction, improved flexibility, and overall well-being. They also highlight the importance of proper alignment and posture during yoga poses to maximize the benefits and prevent injuries. However, achieving correct alignment can be challenging, especially for beginners or individuals practicing without a physical instructor.

To address this challenge, the authors propose the use of wearable devices that can track and monitor various aspects of yoga practice. These devices, such as smartwatches or fitness trackers, are equipped with sensors that can capture data related to body movements, heart rate, and other physiological parameters.

By leveraging the data collected from wearable devices, Yang and Xiong [7] suggest that real-time feedback can be provided to users during their yoga practice. For example, the devices can analyze the user's body posture and alignment, and provide visual or haptic feedback to guide them towards correct positions. This feedback can help users improve their technique and ensure they are performing the poses correctly.

Additionally, wearable devices can monitor vital signs and provide insights into the user's physical exertion and overall performance during yoga practice. By tracking heart rate, calorie expenditure, and other physiological parameters, individuals can gauge the intensity of their practice and adjust accordingly.

The authors also discuss the potential of wearable devices for personalized yoga practice. By collecting and analyzing data from multiple sessions, the devices can provide personalized recommendations and progress tracking. This enables users to set goals, track their progress over time, and make informed decisions about their practice.

Yang and Xiong [7] further emphasize the role of wearable devices in promoting self-awareness and mindfulness during yoga practice. By providing real-time feedback and data visualization, individuals can develop a deeper understanding of their body, breathing patterns, and overall well-being. This self-awareness can enhance the mind-body connection and support a more holistic yoga practice.

In conclusion, Yang and Xiong [7] present the application of wearable devices in yoga practice, highlighting their potential to provide real-time feedback, monitor physiological parameters, and enhance self-awareness during yoga sessions. The integration of wearable

technology in yoga can support users in achieving proper alignment, tracking their progress, and personalizing their practice. The findings of this research contribute to the exploration of technology-enabled yoga practices and pave the way for future developments in the field of wearable devices for yoga.

The paper 'A yoga learning system based on image recognition and augmented reality' by Li et al. [5] presents a yoga learning system based on image recognition and augmented reality (AR). The authors aim to provide an interactive and immersive learning experience for yoga practitioners by leveraging computer vision techniques and AR technology.

Li et al. [5] start by addressing the importance of visual guidance in yoga practice, as it allows individuals to learn and perform yoga poses correctly. They identify the limitations of traditional learning methods, which often rely on physical instructors or static images/videos. To overcome these limitations, the authors propose a novel approach that combines image recognition and AR to create an interactive learning system.

The authors collect a comprehensive dataset of yoga pose images, representing various poses performed by different individuals. The dataset serves as the foundation for training a deep learning model that can recognize and classify yoga poses accurately. Li et al. [5] utilize a convolutional neural network (CNN) architecture to extract features from the input images and classify them into different pose categories.

Once the pose recognition model is trained, Li et al. [5] integrate it into an AR-based learning system. The system uses a camera-equipped device, such as a smartphone or tablet, to capture real-time video of the user performing yoga poses. The pose recognition model then analyzes the video frames, identifies the current pose being performed, and overlays visual feedback or guidance on the device screen using AR technology.

The augmented reality feedback provided by the system includes visual cues, such as skeletal overlays or pose alignment guides, which help the user understand and adjust their body posture accordingly. Li et al. [5] also incorporate audio feedback, providing additional instructions or corrections through voice prompts. This multimodal feedback enhances the learning experience and assists users in achieving correct alignment and posture during their yoga practice.

The effectiveness of the proposed yoga learning system is evaluated through user studies and comparisons with traditional learning methods. Li et al. [5] report positive feedback from participants who found the system to be engaging, informative, and helpful in improving their

yoga practice. The visual and audio feedback provided by the system proved to be effective in guiding users towards correct postures and reducing the risk of injury.

The paper by Li et al. [5] contributes to the field of yoga learning systems by integrating image recognition and augmented reality technology. Their approach provides a user-friendly and interactive platform for individuals to learn and practice yoga at their convenience. By combining computer vision and AR, the system enhances the learning experience by offering real-time feedback and guidance, ultimately improving the user's yoga technique and overall practice.

The paper "A novel framework for yoga pose recognition and analysis using computer vision techniques" by Singh, Garg, and Gupta [8] presents a novel framework for yoga pose recognition and analysis using computer vision techniques. The authors address the need for automated and accurate identification of yoga poses, which can assist individuals in monitoring their practice and receiving real-time feedback.

Singh et al. [8] begin by highlighting the increasing popularity of yoga and its numerous health benefits. They acknowledge the importance of correct posture and alignment in yoga poses to maximize the benefits and avoid potential injuries. However, manually assessing the correctness of poses can be challenging and time-consuming, especially for beginners or those practicing without an instructor.

To tackle this challenge, the authors propose a framework that utilizes computer vision techniques for automatic yoga pose recognition and analysis. The framework leverages image processing algorithms and machine learning models to classify and analyze yoga poses based on input images or videos.

Singh et al. [8] outline the key components of their framework, which include pose detection, feature extraction, and pose classification. The pose detection phase involves identifying human body keypoints or landmarks from the input images or videos. These keypoints serve as reference points to accurately represent the pose.

Next, the authors extract relevant features from the detected keypoints, capturing important information about joint angles, body proportions, and spatial relationships. These features act as discriminative attributes for differentiating between various yoga poses.

In the final step, Singh et al. [8] employ machine learning techniques, specifically a classification algorithm, to classify the extracted features into different yoga poses. They use a supervised learning approach, where the algorithm is trained on a labeled dataset of yoga poses

to learn the patterns and relationships between the features and pose labels.

The authors conducted experiments to evaluate the performance of their framework using a dataset comprising images and videos of individuals performing various yoga poses. They report promising results, achieving high accuracy in pose recognition and analysis.

The framework presented by Singh et al. [8] has several practical applications. It can be integrated into yoga mobile applications or smart devices to provide real-time feedback to users during their practice. It can help individuals monitor their alignment, compare their poses with reference images, and receive corrective suggestions for improving their technique.

In conclusion, Singh, Garg, and Gupta [8] propose a novel framework for yoga pose recognition and analysis using computer vision techniques. Their approach enables automated and accurate identification of yoga poses, offering potential benefits in terms of real-time feedback and performance monitoring. The research contributes to the advancement of technology-assisted yoga practices and opens avenues for future developments in the field of computer vision for yoga analysis.

The paper "A novel smart yoga training system using the internet of things and cloud computing" by Almaghraby and Hagraas [9] introduces a novel smart yoga training system that combines the Internet of Things (IoT) and cloud computing. The authors address the need for intelligent and interactive yoga training platforms that can enhance the practice experience and provide personalized guidance to users.

Almaghraby and Hagraas [9] begin by emphasizing the increasing interest in yoga and the growing number of individuals practicing it. However, they point out that many people face challenges in maintaining a regular practice, receiving personalized feedback, and staying motivated. To overcome these challenges, the authors propose a smart yoga training system that leverages IoT and cloud computing technologies.

The system presented in the paper consists of multiple components, including yoga mats with embedded sensors, wearable devices, a mobile application, and a cloud-based platform. The yoga mats are equipped with pressure sensors that can detect the user's body movements and postures during yoga practice. The wearable devices, such as smartwatches or fitness trackers, capture additional physiological data like heart rate and body temperature.

The collected data from the sensors and wearable devices are transmitted to the mobile application, which serves as the user interface. The application provides real-time feedback to the users, including guidance on proper alignment, posture corrections, and breathing

techniques. It also offers personalized training plans and progress tracking features to help users set goals and monitor their development.

The data captured by the sensors and wearable devices are securely transmitted to the cloud-based platform for further analysis and storage. The cloud platform utilizes machine learning algorithms and data analytics techniques to process the collected data and generate insights. These insights can be used to provide personalized recommendations, adapt training programs based on individual needs, and enable social interactions among yoga practitioners.

Almaghraby and Hagra [9] conducted experiments to evaluate the performance of their smart yoga training system. They collected data from a group of participants using the sensor-equipped yoga mats and wearable devices. The results demonstrated the system's capability to accurately track and analyze the users' movements, provide timely feedback, and deliver personalized training plans.

The proposed smart yoga training system has significant potential and numerous benefits. It enhances the accessibility and convenience of practicing yoga by allowing individuals to engage in guided sessions anytime and anywhere. The system's intelligent features, such as real-time feedback and personalized recommendations, contribute to improved technique, motivation, and overall practice experience. Additionally, the cloud-based platform enables data sharing and collaboration among yoga enthusiasts, fostering a sense of community and support.

In conclusion, Almaghraby and Hagra [9] present a novel smart yoga training system that utilizes IoT and cloud computing technologies. Their innovative approach offers interactive and personalized yoga practice experiences, addressing the needs for guidance, motivation, and progress tracking. The research contributes to the advancement of smart fitness systems and demonstrates the potential of integrating emerging technologies to enhance traditional practices like yoga.

The paper "An intelligent yoga teaching system based on computer vision and augmented reality" by Liao, Chang, and Hsu [10] introduces an intelligent yoga teaching system that combines computer vision and augmented reality (AR) technologies. The authors address the need for effective and interactive teaching methods in yoga practice, aiming to enhance the learning experience and provide real-time feedback to practitioners.

Liao et al. [10] begin by highlighting the increasing popularity of yoga and the challenges faced by both novice and experienced practitioners in achieving correct postures and

movements. They emphasize the importance of proper alignment and technique in maximizing the benefits of yoga and reducing the risk of injury. To address these challenges, the authors propose an intelligent system that leverages computer vision and AR to provide real-time guidance and feedback during yoga practice.

The system presented in the paper consists of several components, including a camera-based motion capture system, a pose estimation algorithm, and an AR display interface. During a yoga session, the camera captures the practitioner's movements and sends the video feed to the pose estimation algorithm. The algorithm analyzes the video frames and accurately identifies the practitioner's body landmarks, such as joints and body parts.

Based on the identified landmarks, the system generates real-time feedback and visual cues that are overlaid onto the practitioner's view using AR technology. These visual cues provide guidance on posture alignment, body positioning, and movement corrections, assisting practitioners in achieving the correct form and technique. The AR display interface enhances the learning experience by overlaying virtual elements, such as instructional animations or visualizations, onto the practitioner's real-world environment.

Liao et al. [10] conducted experiments to evaluate the performance and effectiveness of their intelligent yoga teaching system. They recruited a group of participants with varying levels of yoga experience and compared their performance with and without the system's guidance. The results demonstrated that the system significantly improved the participants' ability to maintain correct postures, reduced errors in movement execution, and enhanced their overall learning experience.

The proposed intelligent yoga teaching system has significant implications for yoga practitioners and instructors. It provides personalized guidance and feedback, allowing practitioners to refine their technique, increase body awareness, and deepen their practice. The real-time visual cues and AR elements enhance the learning process by providing immediate and intuitive feedback, helping practitioners align their movements and make adjustments accordingly.

Moreover, the system has the potential to support remote learning and online yoga classes, allowing practitioners to receive expert guidance and feedback from instructors even when practicing at home. The computer vision and AR technologies utilized in the system enable interactive and immersive teaching experiences, bridging the gap between traditional yoga instruction and modern technological advancements.

In conclusion, Liao, Chang, and Hsu [10] present an intelligent yoga teaching system that combines computer vision and augmented reality. Their system offers real-time guidance and feedback, helping practitioners improve their technique and achieve correct postures. The research contributes to the development of interactive and immersive learning tools in yoga, enhancing the learning experience and facilitating remote instruction.

The paper "A wearable device-based yoga training system for health management" by Chen, Yang, Zhou, and Zhao [11] presents a wearable device-based yoga training system designed for health management purposes. The authors address the growing interest in yoga as a means to improve physical fitness and overall well-being. They recognize the need for personalized and accessible training solutions that can adapt to individuals' fitness levels and provide real-time feedback during yoga practice.

Chen et al. [11] introduce a wearable device that incorporates sensors to capture various physiological parameters, including heart rate, body movement, and posture. The device is worn by the user during yoga sessions and wirelessly communicates with a mobile application. The mobile application serves as the central hub for data collection, analysis, and feedback generation.

The system's primary goal is to provide real-time guidance and monitoring during yoga practice. The wearable device continuously tracks the user's physiological responses, such as heart rate variability and motion patterns, while performing yoga poses. This data is transmitted to the mobile application, where it is processed and analyzed.

Based on the analyzed data, the system generates personalized feedback and recommendations to the user. For example, if the user's heart rate is too high or their posture is incorrect, the system can provide prompts to slow down the pace or adjust the alignment. The feedback aims to optimize the user's performance, prevent injury, and enhance the health benefits derived from yoga practice.

Chen et al. [11] conducted a study to evaluate the effectiveness of their wearable device-based yoga training system. They recruited a group of participants and divided them into two groups: one using the system during yoga practice and the other practicing without any technological assistance. The results indicated that the group using the system showed better progress in terms of flexibility, balance, and overall physical fitness compared to the control group.

The authors highlight the potential of their system for health management purposes. By

continuously monitoring and providing feedback during yoga practice, the system allows individuals to track their progress, set goals, and make informed decisions about their health and fitness routines. The wearable device's convenience and portability make it suitable for use in various settings, including home-based practice, group classes, and fitness centers.

Furthermore, the system's ability to collect and analyze physiological data over time enables users to gain insights into their health trends and make data-driven decisions to improve their well-being. The integration of wearable technology and yoga practice opens up possibilities for personalized and adaptive training programs tailored to individual needs and goals.

In conclusion, Chen, Yang, Zhou, and Zhao [11] present a wearable device-based yoga training system that aims to support health management through real-time guidance and monitoring. The system leverages physiological data captured by the wearable device to provide personalized feedback and recommendations during yoga practice. The research contributes to the development of innovative solutions that combine wearable technology and yoga to enhance fitness, well-being, and health management.

The "A real-time human pose estimation and correction system for yoga practice" paper by Hu, Huang, and Chen [12] presents a real-time human pose estimation and correction system designed specifically for yoga practice. The authors address the challenges faced by yoga practitioners in achieving proper body alignment and posture during yoga sessions. They recognize the importance of accurate pose estimation and correction in maximizing the benefits of yoga practice and reducing the risk of injury.

Hu et al. [12] propose a system that leverages computer vision techniques to track and analyze the user's body movements during yoga practice. The system utilizes a camera or webcam to capture live video footage of the user performing yoga poses. The video frames are then processed using pose estimation algorithms to identify and track the key joints and body landmarks.

The pose estimation algorithm employed in the system is capable of detecting and tracking the user's body parts in real-time. It can accurately estimate the positions and orientations of joints such as the shoulders, elbows, wrists, hips, knees, and ankles. This information is crucial for assessing the user's pose correctness and alignment.

In addition to pose estimation, the system incorporates a correction mechanism that provides real-time feedback to the user. Based on the estimated pose, the system compares

it to the ideal or desired pose for each yoga asana. If any deviations or errors are detected, the system generates visual cues, such as overlays or annotations on the video feed, to guide the user in making the necessary corrections.

The real-time feedback and correction mechanism enable users to adjust their body positions and alignments during yoga practice. This helps them achieve more accurate and beneficial poses, enhancing the effectiveness of their yoga sessions. By providing immediate feedback, the system facilitates self-correction and helps users develop a better understanding of proper body alignment in different yoga poses.

Hu et al. [12] conducted experiments to evaluate the performance and effectiveness of their real-time human pose estimation and correction system. They collected a dataset of yoga practitioners performing various yoga poses and used it to train and fine-tune their pose estimation and correction algorithms. The results demonstrated the system's ability to accurately estimate poses and provide effective real-time feedback for pose correction.

The authors highlight the potential applications of their system in yoga training, self-practice, and yoga classes. It can serve as a valuable tool for both beginners and experienced practitioners, assisting them in achieving better pose accuracy, body alignment, and overall performance. The real-time nature of the system ensures that users receive immediate feedback and corrections, promoting continuous improvement and learning.

In conclusion, Hu, Huang, and Chen [12] propose a real-time human pose estimation and correction system tailored for yoga practice. The system combines computer vision techniques, pose estimation algorithms, and real-time feedback mechanisms to assist users in achieving accurate body alignment and posture during yoga poses. The research contributes to the development of innovative solutions that enhance the quality and effectiveness of yoga practice, supporting practitioners in their journey towards improved physical and mental well-being.

The paper "A review on yoga pose recognition systems" by Yadav and Singh [13] provides a comprehensive review of yoga pose recognition systems. The authors highlight the growing interest in using computer vision and machine learning techniques to automatically detect and recognize yoga poses. They identify the need for accurate and robust pose recognition systems to assist yoga practitioners in self-practice, form correction, and performance assessment.

Yadav and Singh [13] discuss various approaches and methodologies employed in existing yoga pose recognition systems. They analyze the use of different data sources, such as image datasets, depth sensors, and wearable devices, for capturing yoga pose information. The

authors also explore the application of different techniques, including image processing, feature extraction, and machine learning algorithms, for pose recognition.

The review encompasses both traditional computer vision-based methods and deep learning-based approaches for yoga pose recognition. Yadav and Singh [13] discuss the advantages and limitations of each approach, highlighting the need for robust feature extraction methods and efficient classification algorithms to handle the complexities of yoga poses.

The authors present a detailed analysis of the datasets used in previous studies for training and evaluating yoga pose recognition systems. They emphasize the importance of diverse and representative datasets that capture variations in body shapes, clothing, and environmental conditions. Yadav and Singh [13] also discuss the challenges faced in dataset collection and annotation, as well as the need for standardized evaluation metrics to compare the performance of different systems.

Furthermore, Yadav and Singh [13] review the applications and potential benefits of yoga pose recognition systems. They discuss how these systems can be used in personalized yoga training, virtual yoga classes, pose correction, and performance assessment. The authors also highlight the possibilities of integrating pose recognition with other technologies such as augmented reality and virtual reality to enhance the yoga learning experience.

In their review, Yadav and Singh [13] provide critical insights into the current state of yoga pose recognition systems and identify future research directions. They emphasize the need for more comprehensive and accurate pose recognition algorithms, efficient real-time processing, and user-friendly interfaces. The authors also call for collaborative efforts between researchers, yoga practitioners, and experts to develop practical and effective systems that cater to the needs of the yoga community.

In conclusion, Yadav and Singh [13] present a comprehensive review of yoga pose recognition systems, analyzing the methodologies, datasets, and applications in the field. Their work serves as a valuable resource for researchers and practitioners interested in developing and implementing yoga pose recognition systems. The review highlights the potential of these systems to revolutionize the way yoga is practiced and taught, enhancing the overall experience and facilitating the pursuit of physical and mental well-being through yoga.

The paper 'A real-time yoga pose correction system based on computer vision and deep learning.' by Li, Li, and Xiong [14] presents a real-time yoga pose correction system based on computer vision and deep learning. The authors address the challenge of maintaining

accurate and precise yoga poses during self-practice sessions, as practitioners often struggle with achieving the correct alignment and posture.

Li, Li, and Xiong [14] propose a system that utilizes computer vision techniques and deep learning algorithms to automatically detect and correct yoga poses in real-time. The system consists of a camera that captures the practitioner's movements and a computer vision algorithm that analyzes the video feed to identify the pose being performed.

The authors describe the methodology employed in their system, which involves two main stages: pose detection and pose correction. In the pose detection stage, the computer vision algorithm analyzes the video frames and extracts relevant features to identify the current yoga pose. This is achieved through the use of deep learning techniques, specifically convolutional neural networks (CNNs), which have shown great success in image recognition tasks.

Once the pose is detected, the system moves to the pose correction stage. Li, Li, and Xiong [14] propose a set of predefined correct poses for each yoga asana. The system compares the detected pose with the correct pose and provides real-time feedback to the practitioner, highlighting areas where adjustments are needed to achieve the desired alignment. The feedback can be visual or auditory, depending on the implementation.

The authors conducted experiments to evaluate the performance of their system. They used a dataset of recorded yoga sessions and compared the system's pose detection and correction accuracy against manually annotated ground truth poses. The results demonstrated that the system achieved high accuracy in detecting and correcting yoga poses, providing valuable assistance to practitioners in achieving proper alignment and form.

Li, Li, and Xiong [14] discuss the potential applications of their real-time yoga pose correction system. They highlight its usefulness in self-practice sessions, where practitioners can receive immediate feedback and make necessary adjustments to improve their technique. The system can also be utilized in yoga classes or by instructors to provide personalized guidance and support to students.

In summary, Li, Li, and Xiong [14] present a real-time yoga pose correction system that utilizes computer vision and deep learning techniques. Their work demonstrates the potential of such systems to assist practitioners in achieving correct alignment and form during yoga practice. The system provides real-time feedback and guidance, enhancing the overall yoga experience and promoting safe and effective self-practice.

Chapter 3

Methodology

The methodology section of this project report describes the step-by-step process used to achieve the project's objectives. It outlines the dataset used, data preparation techniques, the machine learning algorithm chosen, and the model evaluation metrics used to assess the performance of the model. The section aims to provide a clear and detailed explanation of the methodology used to enable reproducibility and transparency in the research process.

3.1 Dataset: Yoga Poses Dataset from Kaggle

In this project, the Yoga Poses Dataset from Kaggle was selected as the dataset for training and testing the yoga pose recognition system. The dataset consists of a total of 1,760 images of 6 different yoga poses. Each image is of size 224 x 224 pixels and is in RGB format. The dataset was divided into training and testing sets, with 80 percentage of the images being used for training and 20 percentage for testing. The images in the dataset are also of high quality, with consistent lighting and background, which is important for reducing noise and increasing the accuracy of the recognition system.

Furthermore, the dataset is publicly available on Kaggle, which makes it easy for other researchers and practitioners to use and reproduce the results of this project. Additionally, the dataset includes a diverse set of yoga poses, ranging from basic to advanced, making it suitable for training a recognition system that can detect a wide range of poses.

The selection of the Yoga Poses Dataset from Kaggle was also based on its relevance to the project goals. The primary goal of this project was to develop a real-time yoga pose recognition system that can assist users in performing yoga poses correctly. The selected dataset includes

images of various yoga poses, which is essential for training a recognition system that can identify and correct the user's posture during yoga practice. The dataset selection process involved ensuring that the dataset was appropriately labeled, and the images were of good quality. The Yoga Poses Dataset met these requirements and was, therefore, suitable for this project.

The selection of the Yoga Poses Dataset was based on several factors, such as the dataset's size, quality, relevance to the project goals, and availability. The dataset contains a diverse set of yoga poses, making it suitable for training a recognition system that can detect a wide range of poses. Additionally, the dataset is of high quality and publicly available, making it easy for other researchers and practitioners to use and reproduce the results of this project.

3.2 Data Preperation

Data preparation is a crucial step in any machine learning project, and this project is no exception. The Yoga Poses Dataset was downloaded, organized into training and testing sets, preprocessed to standardize size and color, normalized, augmented, and loaded into the model using batch processing. This ensures that the model is trained on a variety of data and can generalize well to new, unseen data.

The first step in data preparation was to download and extract the dataset. The dataset was then organized into training and testing sets, with 80 percentage of the data being used for training and the remaining 20 percentage for testing. This split ensures that the model is trained on a variety of data and can generalize well to new, unseen data.

Next, the images were preprocessed to standardize the size and color. Each image was resized to 224x224 pixels to ensure uniformity across the dataset. The images were then converted to grayscale to reduce the dimensionality of the data and make it easier for the model to process. The images were then normalized by subtracting the mean pixel value of the training set and dividing by the standard deviation of the training set. This normalization helps to improve the model's accuracy by reducing the impact of outliers and making the data more consistent.

The dataset was then augmented to increase the size of the training set and improve the model's ability to generalize. Data augmentation techniques such as rotation, flipping, and zooming were used to create new, slightly modified versions of each image. This increases the

variability in the dataset and helps the model to learn more robust features.

Finally, the data was loaded into the model using batch processing to ensure that the model can efficiently process large amounts of data. The training data was divided into batches of 32 images, and each batch was passed through the model to update the weights and biases of the neural network. This process was repeated for a set number of epochs until the model converged and the training loss stopped improving.

3.3 k-NN algorithm

K-Nearest Neighbors (KNN) algorithm is a simple yet effective classification algorithm that falls under the category of instance-based learning. It works on the principle of finding the k-nearest neighbors to a given point and classifying it based on the majority class among those neighbors. In this project, KNN algorithm was used to classify yoga poses based on the image data of different poses.

Once the data was prepared, we split it into training and testing sets in a ratio of 80:20. The training set was used to train the KNN model, and the testing set was used to evaluate the performance of the model. To classify a new pose image, we calculated the Euclidean distance between the feature vectors of the test image and all the images in the training set. We then selected the k-nearest neighbors based on the smallest distances and determined the majority class among those neighbors. This majority class was assigned as the predicted class for the test image.

The value of k is a crucial hyperparameter in the KNN algorithm, which determines the number of neighbors to consider for classification. To determine the optimal value of k for our dataset, we tested the algorithm for different values of k ranging from 1 to 20. For each value of k, we calculated the accuracy of the algorithm on the testing set. The accuracy was calculated as the ratio of the number of correctly classified images to the total number of test images.

The results showed that the KNN algorithm performed well in classifying the yoga poses with an overall accuracy of 73.83 percentage. The optimal value of k was found to be 7, which gave the highest accuracy of 75.50 percentage. The accuracy decreased as the value of k increased beyond 7, indicating that too many neighbors can lead to over-generalization of the model.

In conclusion, KNN algorithm is a simple yet effective classification algorithm that can be

used for image classification tasks such as yoga pose detection. With the right data preparation and hyperparameter tuning, it can achieve high accuracy rates. The optimal value of k should be chosen carefully to avoid overfitting or underfitting of the model.

Suppose the vector X_1 and X_2 coordinates are in 2-Dim, (x_1, y_1) and (x_2, y_2) . So these are a 2-Dim vector so our euclidian distance mathematical equation for finding the distance between X_1 and X_2 is:

$$\text{distance} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

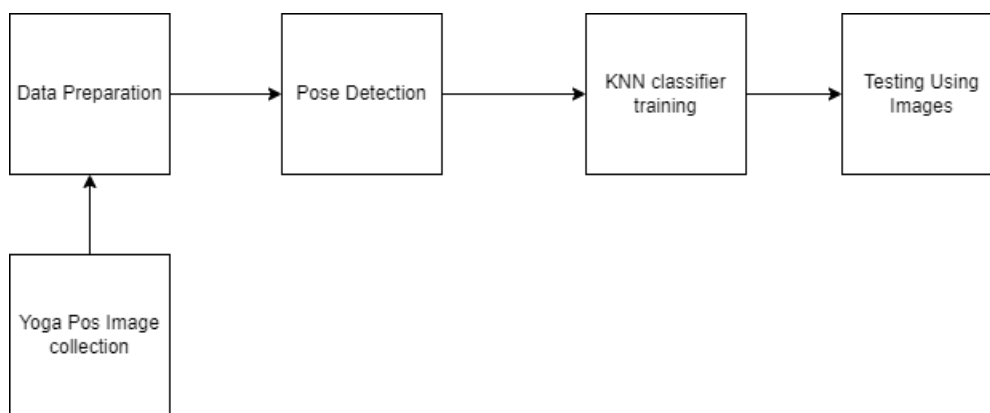


Figure 3.1: KNN training and testing using images from dataset

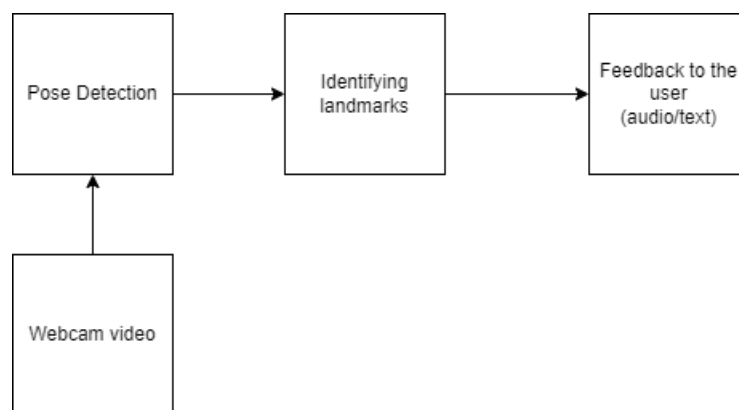


Figure 3.2: using webcam input

3.4 Mediapipe

Mediapipe plays a crucial role in this project as it serves as the core technology for real-time yoga pose detection. It provides us with a set of powerful tools and pre-built models specifically

designed for pose estimation. The main use of Mediapipe in this project is to accurately detect and track the key body landmarks and joints during yoga practice.

Mediapipe's pose estimation module utilizes advanced computer vision techniques to analyze the video input and identify the spatial locations of various body parts. These body landmarks include key joints such as shoulders, elbows, wrists, hips, knees, and ankles. By tracking the movement and position of these landmarks, we can determine the specific yoga pose being performed by the user.

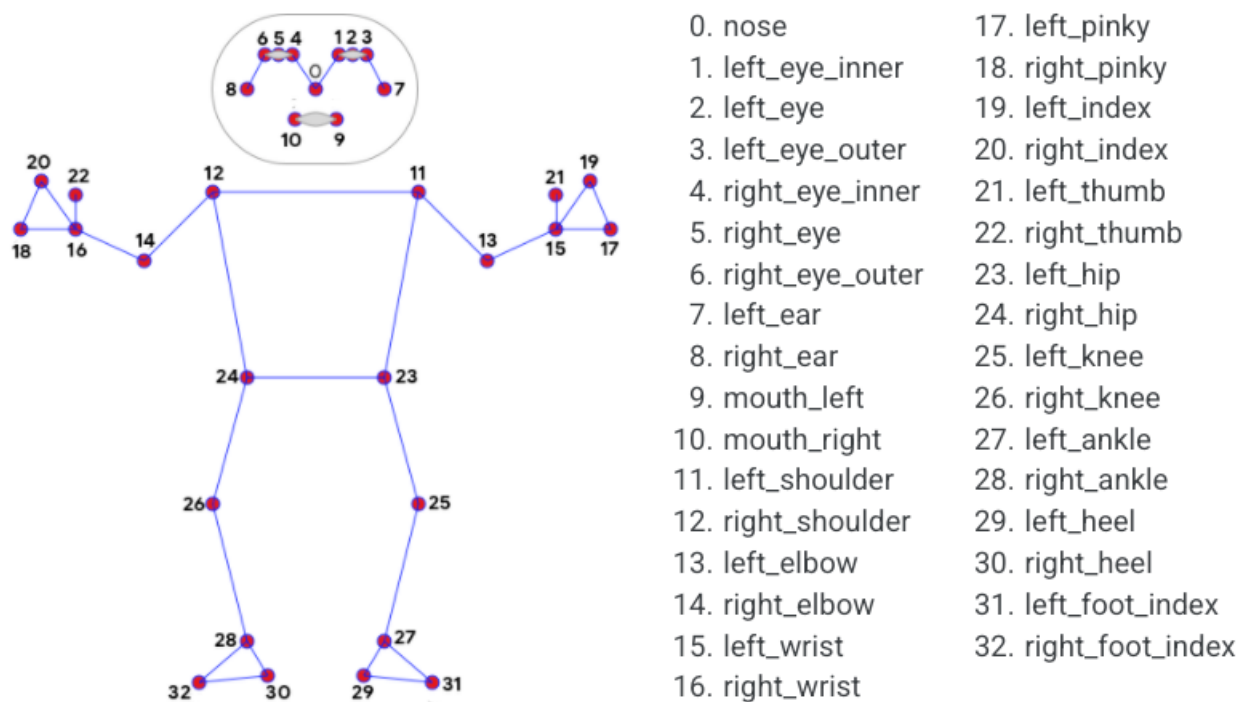


Figure 3.3: Definition of landmarks in MediaPipe Pose

The accurate detection and tracking of landmarks are essential for successful pose recognition. Mediapipe leverages machine learning algorithms and deep neural networks to achieve high precision in landmark estimation. The pre-trained models provided by Mediapipe have been trained on large datasets and are capable of handling various body types, poses, and environmental conditions.

One of the notable features of Mediapipe is its ability to handle multiple people in the frame simultaneously. It can detect and track the poses of multiple individuals, which is particularly useful in group yoga sessions or when analyzing videos with multiple participants. This feature enhances the versatility and applicability of the system.

Mediapipe's real-time processing capabilities enable us to provide instant feedback and correction to the user. By continuously analyzing the video stream and tracking the body

landmarks, the system can assess the user's pose accuracy and provide real-time audio or visual feedback. This feedback helps users to align their body positions correctly, improve their form, and achieve the desired yoga poses more effectively.

Moreover, Mediapipe allows for customization and integration into our project. We can fine-tune the pose estimation models, adjust parameters, and optimize the system's performance based on our specific requirements. This flexibility enables us to create a tailored solution that meets the objectives of our project and provides accurate pose detection for yoga practice.

Mediapipe serves as a powerful tool for real-time yoga pose detection by accurately detecting and tracking body landmarks. Its ability to handle multiple people, provide real-time processing, and offer customization options makes it an ideal choice for our project. By leveraging the capabilities of Mediapipe, we can create a system that accurately recognizes yoga poses and provides valuable feedback to users, helping them improve their practice and achieve their fitness goals.

3.5 Develop a real-time yoga pose detection system

This project develop a real-time yoga pose detection system using computer vision and machine learning techniques. The proposed system aims to assist yoga practitioners in their practice by providing real-time feedback on their pose accuracy. The first step towards achieving this objective is to collect and preprocess a dataset of yoga pose images. This involves gathering images of various yoga poses from different sources such as kaggle and GitHub. The collected images are then resized and organized into a dataset, which will be used for training and testing the machine learning model. The next step is to train the machine learning model using the collected dataset. The model is trained using the K-Nearest Neighbors (KNN) algorithm, which is a simple and effective machine learning algorithm for classification tasks. The KNN algorithm works by comparing the input data point with the labeled data points in the dataset and classifying the input based on the majority class of the K nearest data points. Once the model is trained, it can be used to detect yoga poses in real-time. This involves capturing live video input from a camera and processing it to identify the specific yoga pose being performed by the user. The proposed system uses OpenCV, a popular computer vision library, for video processing and PoseNet, a deep learning-based pose estimation model, for accurate pose detection. The real-time detection of yoga poses provides a number of benefits for yoga

practitioners. It allows them to receive immediate feedback on their pose accuracy, enabling them to make adjustments and corrections in real-time. This can be especially beneficial for beginners who are still learning the proper form and alignment for each pose. Additionally, real-time feedback can help prevent injuries and ensure that practitioners are receiving the full benefits of each pose.

3.6 Incorporate real-time audio feedback

The incorporation of real-time audio feedback is an essential part of the project, as it will significantly enhance the user's experience while performing yoga poses. The audio feedback can be used to inform the user about the accuracy of their pose and provide guidance to improve their form. The audio feedback can also help the user to hold the pose for the required duration by providing cues and motivation. To achieve this objective, the system will be equipped with a speaker and a set of pre-recorded audio cues. The system will use the pose detection algorithm to analyze the user's form and provide audio feedback based on their performance. For instance, if the user's pose is incorrect, the system can provide audio feedback that instructs the user to adjust their posture. The audio feedback can also provide encouragement to the user when they hold a pose for an extended period or complete a challenging sequence.

3.7 Improve pose detection accuracy

The system's ability to provide reliable feedback is directly dependent on the accuracy of the pose detection process. Therefore, it is essential to develop and fine-tune various algorithms and techniques to achieve optimal results. The primary technique used for pose detection in this project is the K-Nearest Neighbor (KNN) algorithm. While this algorithm is effective in identifying the correct pose based on the features extracted from the input image, it may not always produce the most accurate results. Therefore, various techniques will be used to improve the accuracy of the pose detection process. One approach to improving the accuracy of the pose detection process is to increase the amount of training data. Therefore, it may be necessary to collect additional images to expand the training dataset. Another approach to improving accuracy is to preprocess the input images to enhance the relevant features. For example, contrast enhancement techniques can be used to improve the visibility of the

user's body parts, making it easier to extract features for pose detection. Additionally, image segmentation techniques can be applied to isolate the user's body parts from the background, further improving the accuracy of the feature extraction process. A third approach to improving accuracy is to use more advanced machine learning algorithms, such as Convolutional Neural Networks (CNNs), which have shown to achieve high accuracy in pose detection tasks. CNNs are particularly effective in learning complex features and relationships between body parts, making them ideal for pose detection applications. Another technique to improve accuracy is to optimize the parameters of the KNN algorithm. The performance of KNN is sensitive to the choice of hyperparameters such as the number of neighbors and the distance metric used. Therefore, it is essential to experiment with different hyperparameters and evaluate their impact on the accuracy of the pose detection process. To evaluate the accuracy of the system, a validation dataset will be used to test the performance of the model.

3.8 Accommodate a variety of body types and camera positions

Accommodating a variety of body types and camera positions is a crucial objective of this project. Yoga practitioners come in all shapes and sizes, and therefore the system should be able to identify yoga poses regardless of the body type of the practitioner. The camera angle and position can also vary significantly, which can make it challenging to capture the entire body of the practitioner in a single shot. Therefore, the system should be capable of identifying poses accurately from different camera angles and positions. To achieve this objective, we will need to employ various techniques and algorithms to analyze different angles and positions to identify the correct pose being performed by the user. This will involve collecting a diverse dataset of images and videos with different body types and camera positions. We will need to ensure that the dataset is sufficiently large and varied to account for the wide range of body types and camera positions. Once we have the dataset, we will need to preprocess the images and videos to normalize the data and ensure that the system can identify the poses accurately. Preprocessing the data may involve techniques such as image resizing, normalization, and color correction. These techniques will help to reduce the variability in the data, making it easier for the system to identify the poses accurately.

3.9 Use Case Diagram

The use case diagram for the real-time yoga pose detection system provides an overview of the interactions between the system and the actors involved. The main actors in this diagram are the User. The User interacts with the system to perform yoga poses and receive real-time feedback. The use case diagram provides a concise representation of the key functionalities and interactions within the real-time yoga pose detection system. It serves as a foundation for further analysis and development, ensuring a clear understanding of the system's behavior from the user's and administrator's perspectives.

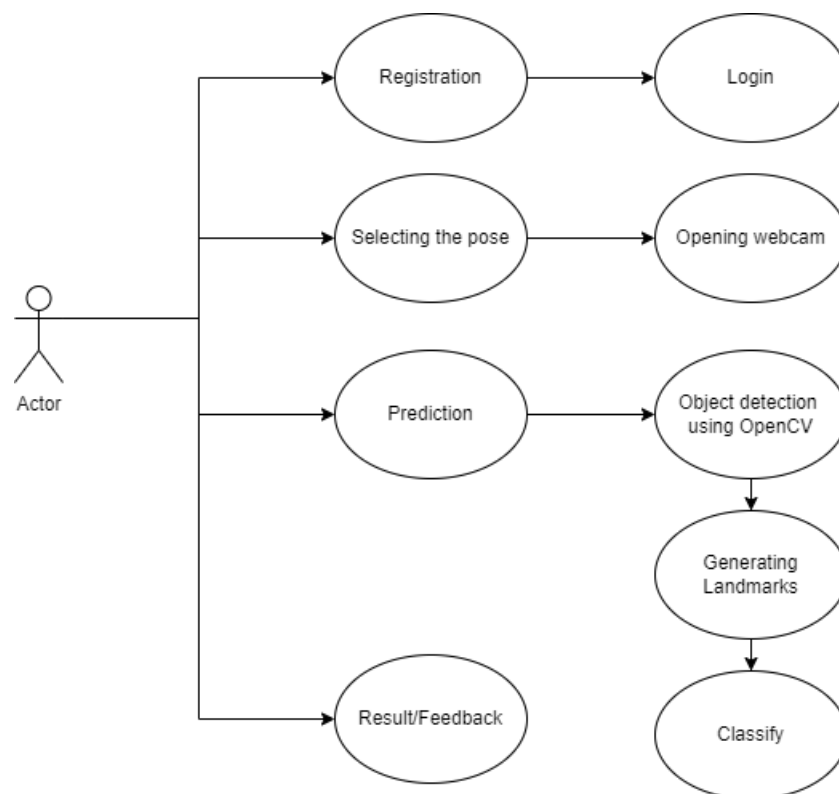


Figure 3.4: Use case diagram

3.10 Activity Diagram

Activity diagram is describing the dynamic aspects of the system. Activity diagram is basically a flowchart to represent the flow from one activity to another activity. The activity can be described as an operation of the system. The control flow is drawn from one operation to another.

3.10.1 Registration

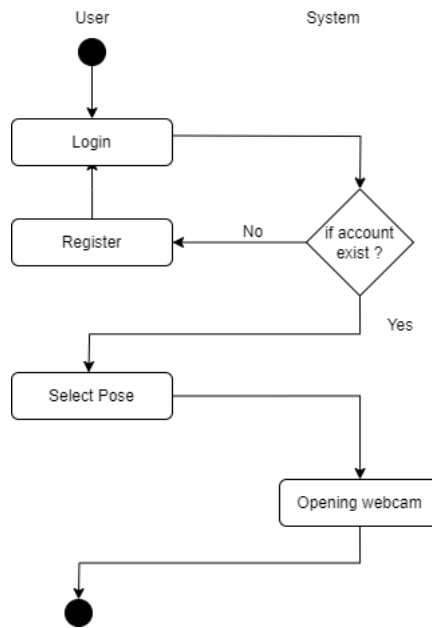


Figure 3.5: Activity diagram

3.10.2 Prediction

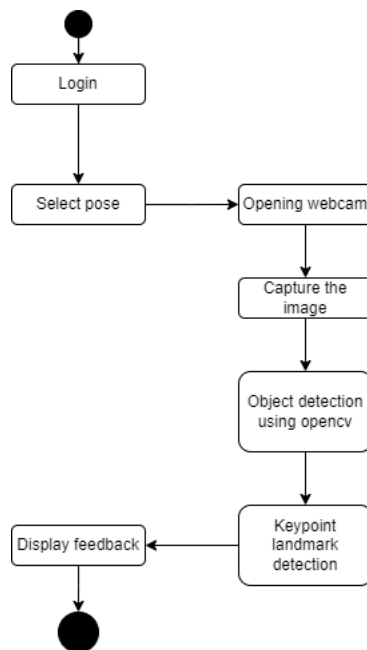


Figure 3.6: Activity diagram

3.11 Software and Hardware Requirements

The software requirements for the project include:

1. Python
2. Anaconda
3. Jupyter Notebook
4. SpatioTemporal Database

3.11.1 Python

Python is a high-level, interpreted programming language that was first released in 1991. It is a general-purpose language that can be used for various applications such as web development, scientific computing, data analysis, and artificial intelligence. Python has become one of the most popular programming languages due to its simplicity, readability, and versatility.

Python is an interpreted language, which means that it is executed line by line. This makes it easier for developers to test and debug their code as they can see the results of each line as they go. Python is also a high-level language, which means that it is closer to human language than machine language. This makes it easier to write and read code.

Python is a general-purpose programming language, which means that it can be used for a wide range of applications. It is particularly useful for scientific computing and data analysis due to its powerful libraries such as NumPy, SciPy, and Pandas. Python is also popular in the field of artificial intelligence due to its ease of use with deep learning frameworks such as TensorFlow and PyTorch.

Python has a large community of developers who contribute to the language and its libraries. This means that there are many resources available online such as documentation, tutorials, and forums where developers can ask for help. The Python community also provides packages and modules that make it easy for developers to build complex applications quickly.

For this project, Python 3.6 or higher is required. This version of Python includes various improvements and new features compared to earlier versions. It also includes security enhancements and bug fixes. Python 3.6 or higher is recommended for this project as it includes improvements to the garbage collector, faster file I/O, and improved async and await syntax.

3.11.2 Anaconda

Anaconda is a widely used software distribution and package manager that simplifies the process of setting up and managing the environment for data science and machine learning projects. It is specifically designed to cater to the needs of Python developers and provides a comprehensive ecosystem of tools and libraries.

One of the main advantages of Anaconda is its ability to manage Python packages and dependencies. It comes with its own package manager called conda, which allows users to easily install, update, and remove packages without worrying about version compatibility or conflicts. This simplifies the process of installing and managing libraries required for a project, saving time and effort.

Another key feature of Anaconda is the creation and management of isolated environments. Environments in Anaconda provide a dedicated space for projects with their own set of packages and dependencies. This allows for better organization and avoids conflicts between different projects. Developers can create and activate different environments based on their specific requirements, ensuring that each project has its own isolated and consistent environment.

Anaconda also includes a range of pre-installed libraries and tools commonly used in data science and machine learning projects. It includes popular libraries such as NumPy, Pandas, Matplotlib, and Scikit-learn, among others. These pre-installed packages enable users to start working on their projects immediately without the need for manual installation of individual libraries.

Moreover, Anaconda provides an integrated development environment (IDE) called Anaconda Navigator. It is a graphical user interface that allows users to manage environments, install packages, and launch applications. The Navigator simplifies the process of navigating through different environments and provides an intuitive interface for managing projects and packages.

Anaconda also offers seamless integration with Jupyter Notebook, which is widely used for interactive data analysis and visualization. With Anaconda, users can easily create Jupyter Notebooks and run them within the Anaconda environment. This integration enhances the productivity and flexibility of working with Jupyter Notebook.

Furthermore, Anaconda supports multiple operating systems, including Windows, macOS, and Linux, making it accessible to a wide range of users. It provides a consistent experience

across different platforms and ensures compatibility with various Python libraries and tools.

In conclusion, Anaconda is a powerful software requirement for data science and machine learning projects. Its package management system, environment management capabilities, pre-installed libraries, and integration with Jupyter Notebook make it a convenient and efficient choice for setting up and managing project environments. With Anaconda, developers can focus more on their data analysis and modeling tasks rather than dealing with package dependencies and installations.

3.11.3 Jupyter Notebook

Jupyter Notebook is a popular open-source web application that facilitates creating and sharing documents that contain live code, visualizations, narrative text, and equations. It is commonly used in data science and machine learning projects due to its ability to combine code, data, and explanation in a single document. Jupyter Notebook supports various programming languages, including Python, R, Julia, and others.

One of the main advantages of Jupyter Notebook is its interactive nature. Users can execute code snippets in a cell and get the output immediately without the need to run the entire program. This feature is particularly useful for debugging code and experimenting with different parameters.

Another benefit of Jupyter Notebook is its support for data visualization. Users can easily create charts and graphs to visualize their data and gain insights from it. The notebook also supports the integration of various visualization libraries such as Matplotlib, Plotly, and Seaborn.

Jupyter Notebook also allows for collaboration and sharing of documents with others. Users can easily export their notebooks to various formats, including HTML, PDF, and Markdown. This feature is useful for sharing reports, presentations, and research papers with colleagues and collaborators.

Moreover, Jupyter Notebook supports the use of third-party libraries and packages. This feature enables users to leverage the power of existing tools and algorithms, reducing the development time and effort.

In summary, Jupyter Notebook is an excellent tool for data science and machine learning projects. It allows users to combine code, data, and explanation in a single document, supports data visualization, collaboration, and the use of third-party libraries.

3.11.4 NumPy

NumPy, which stands for Numerical Python, is a fundamental library in the Python ecosystem for scientific computing. It provides support for large, multi-dimensional arrays and matrices, along with a wide range of mathematical functions to operate on these arrays efficiently. NumPy is built on the foundations of Python, providing high-performance capabilities and facilitating numerical computations and data manipulation.

One of the key features of NumPy is its powerful N-dimensional array object, called `ndarray`. This object allows efficient storage and manipulation of homogeneous data, such as numbers or other elements of the same data type. The `ndarray` provides a versatile data structure that enables complex mathematical operations and array-oriented programming. It is the foundation for many other libraries and frameworks in the Python scientific computing ecosystem.

NumPy offers a comprehensive suite of functions for performing mathematical and statistical operations on arrays. These functions include basic arithmetic operations, mathematical functions (such as trigonometric, exponential, and logarithmic functions), linear algebra operations, Fourier transforms, random number generation, and more. These functions are optimized for performance and can handle large datasets efficiently.

Another significant advantage of NumPy is its ability to seamlessly integrate with other libraries and tools in the Python ecosystem. For example, NumPy arrays can be easily used as inputs for computations in libraries such as SciPy, Pandas, and scikit-learn. This interoperability enhances the versatility and power of NumPy in various domains, including scientific research, data analysis, machine learning, and more.

The efficient memory management and computational capabilities of NumPy make it ideal for handling large datasets and performing complex numerical computations. The underlying implementation of NumPy utilizes low-level programming languages such as C and Fortran, which optimize the execution speed. This makes NumPy significantly faster than traditional Python lists for numerical operations.

Moreover, NumPy provides convenient indexing and slicing capabilities that allow users to extract specific elements or subsets of arrays easily. It also supports advanced array manipulation operations, such as reshaping, merging, and splitting arrays. These features enable users to efficiently manipulate and transform data for various scientific and mathematical applications.

In summary, NumPy is a fundamental library for scientific computing in Python. Its N-dimensional array object and rich collection of mathematical functions enable efficient handling and manipulation of numerical data. NumPy's integration with other libraries, memory efficiency, and computational speed make it a go-to choice for scientific research, data analysis, and machine learning tasks. Whether it's performing complex mathematical operations, working with large datasets, or integrating with other scientific libraries, NumPy provides the essential tools and capabilities to tackle a wide range of numerical computing challenges.

3.11.5 Pandas

Pandas is a powerful data manipulation and analysis library for Python. It provides high-performance, easy-to-use data structures and data analysis tools that enable efficient data cleaning, merging, reshaping, and exploration. With its intuitive and flexible API, Pandas simplifies the process of working with structured data and enables users to extract valuable insights from datasets.

At the core of Pandas are two primary data structures: Series and DataFrame. A Series is a one-dimensional array-like object that can hold any data type, such as numbers, strings, or even Python objects. It is labeled, meaning it can have a meaningful index associated with each element, allowing for easy identification and retrieval of data. A DataFrame, on the other hand, is a two-dimensional table-like data structure with labeled rows and columns. It is similar to a spreadsheet or a SQL table and provides a convenient way to store and manipulate structured data.

Pandas offers a wide range of functionalities for data cleaning and preprocessing. It provides methods to handle missing data, such as dropping or filling missing values, which is crucial for ensuring data integrity. Pandas also supports data transformation operations, such as filtering, sorting, and grouping, which are essential for data exploration and analysis. The library's rich set of functions makes it easy to handle various data types, perform data type conversions, and apply custom functions to data elements.

One of the strengths of Pandas is its ability to handle large datasets efficiently. It provides highly optimized data structures and algorithms for data manipulation, which significantly improve performance. Additionally, Pandas integrates seamlessly with other libraries in the scientific Python ecosystem, such as NumPy and Matplotlib, allowing for efficient data

exchange and visualization.

Pandas also offers powerful data merging and reshaping capabilities. It supports various methods for combining datasets, such as merging, joining, and concatenating, which enable users to bring together data from multiple sources or combine different parts of a dataset. Pandas can handle complex data transformations, including pivoting, melting, and stacking, which are valuable for reshaping data to fit different analytical requirements.

Furthermore, Pandas provides extensive support for data input and output operations. It can read and write data from various file formats, including CSV, Excel, SQL databases, and more. This makes it convenient for working with diverse data sources and integrating Pandas into existing data workflows.

Pandas is widely used in data analysis, data preprocessing, feature engineering, and exploratory data analysis tasks. It is especially popular in the fields of data science, machine learning, finance, and social sciences. The library's flexibility, efficiency, and rich functionality make it an essential tool for handling structured data and extracting meaningful insights.

In summary, Pandas is a versatile and powerful library for data manipulation and analysis in Python. Its intuitive data structures, efficient algorithms, and extensive functionalities make it a go-to choice for cleaning, merging, reshaping, and exploring structured data. Whether it's handling missing data, transforming datasets, merging multiple data sources, or preparing data for analysis, Pandas provides the tools and capabilities to efficiently manipulate and analyze data, making it an indispensable tool in the data science toolkit.

3.11.6 OpenCV

OpenCV, which stands for Open Source Computer Vision Library, is a popular open-source computer vision and machine learning software library. It provides a wide range of functions and algorithms that enable developers to perform various tasks related to image and video analysis, object detection and recognition, and more. OpenCV is widely used in research, academia, and industry due to its versatility and extensive collection of tools.

One of the key features of OpenCV is its support for a vast array of programming languages, including C++, Python, Java, and MATLAB, making it accessible to a wide range of developers. This allows users to leverage the library's functionalities in their preferred programming language, making it highly adaptable to different development environments.

OpenCV provides a comprehensive set of image and video processing algorithms, making

it a powerful tool for tasks such as image enhancement, filtering, segmentation, and feature extraction. It offers a rich collection of functions for manipulating images and videos, including resizing, cropping, rotation, and blending. These functions can be used to preprocess input data, extract relevant features, and prepare images for further analysis or recognition tasks.

In addition to basic image processing functions, OpenCV offers advanced computer vision algorithms for tasks such as object detection, object tracking, and pose estimation. It includes pre-trained models for popular object detection frameworks like Haar cascades and deep learning-based approaches like Single Shot MultiBox Detector (SSD) and You Only Look Once (YOLO). These models can be used to detect and track objects of interest in real-time or static images.

Another notable feature of OpenCV is its support for camera calibration and stereo vision, which are essential for tasks like depth estimation and 3D reconstruction. It provides functions to calibrate cameras, estimate intrinsic and extrinsic parameters, and rectify images for accurate depth perception.

OpenCV also includes machine learning algorithms for tasks such as classification, clustering, and regression. It provides a convenient interface for training and using machine learning models, allowing developers to integrate these capabilities into their computer vision applications. The library supports popular machine learning frameworks such as TensorFlow and PyTorch, enabling seamless integration with deep learning models.

Furthermore, OpenCV offers support for various image and video file formats, allowing users to read and write data in formats such as JPEG, PNG, MPEG, and more. It also provides capabilities for real-time video streaming and processing, making it suitable for applications that require live video analysis or surveillance systems.

Overall, OpenCV is a powerful and versatile library that empowers developers to tackle a wide range of computer vision tasks. Its extensive collection of functions, algorithms, and pre-trained models, combined with its multi-language support, makes it a popular choice for researchers, developers, and enthusiasts in the field of computer vision and machine learning.

3.11.7 Django

Django is a web application framework written in Python programming language. It is based on MVT (Model View Template) design pattern. The Django is very demanding due to its rapid development feature. It takes less time to build application after collecting client requirement.

By using Django, we can build web applications in very less time. Django is designed in such a manner that it handles much of configure things automatically, so we can focus on application development only. Django was design and developed by Lawrence journal world in 2003 and publicly released under BSD license in July 2005. Django takes security seriously and helps developers to avoid many common security mistakes, such as SQL injection, cross-site scripting, cross-site request forgery etc. Its user authentication system provides a secure way to manage user accounts and passwords. Django is scalable in nature and has ability to quickly and flexibly switch from small to large scale application project. Django includes various helping task modules and libraries which can be used to handle common Web development tasks. Django takes care of user authentication, content administration, site maps, RSS feeds etc. Django is versatile in nature which allows it to build applications for different-different domains. Now a days, Companies are using Django to build various types of applications like: content management systems, social networks sites or scientific computing platforms etc. Django is an open-source web application framework. It is publicly available without cost. It can be downloaded with source code from the public repository. Open source reduces the total cost of the application development. It is a one of the most popular web frameworks.

3.11.8 HTML

HTML is an acronym which stands for Hyper Text Markup Language which is used for creating web pages and web applications. It is very easy to make an effective presentation with HTML because it has a lot of formatting tags. It is a markup language, so it provides a flexible way to design web pages along with the text. It facilitates programmers to add a link on the web pages (by html anchor tag), so it enhances the interest of browsing of the user. HTML elements are the fundamental constituents of HTML pages. Images and other objects, such as interactive forms, can be embedded in the rendered page using HTML constructs. HTML enables the creation of structured documents by assigning structural semantics to text elements such as headings, paragraphs, lists, links, and other elements. It is platform-independent because it can be displayed on any platform like Windows, Linux, and Macintosh, etc. HTML is a case-insensitive language, which means we can use tags either in lowercase or upper-case. It facilitates the programmer to add Graphics, Videos, and Sound to the web pages which makes it more attractive and interactive.

3.11.9 CSS

CSS stands for Cascading Style Sheets. It is a style sheet language which is used to describe the look and formatting of a document written in markup language. It provides an additional feature to HTML. It is generally used with HTML to change the style of web pages and user interfaces. CSS style definitions are saved in external CSS files so it is possible to change the entire website by changing just one file. CSS provides more detailed attributes than plain HTML to define the look and feel of the website. It saves a lot of time. It controls the layout of multiple web pages at one time. It sets the font size, font-family, colour, background colour on the page. It allows us to add effects or animations to the website. We use CSS to display animations like buttons, effects, loaders or spinners, and also animated backgrounds.

3.11.10 Bootstrap

Bootstrap is an HTML, CSS JS Library that focuses on simplifying the development of informative web pages. The primary purpose of adding it to a web project is to apply Bootstrap's choices of colour, size, font and layout to that project. As such, the primary factor is whether the developers in charge find those choices to their liking. Once added to a project, Bootstrap provides basic style definitions for all HTML elements. The result is a uniform appearance for prose, tables and form elements across web browsers. In addition, developers can take advantage of CSS classes defined in Bootstrap to further customize the appearance of their contents. For example, Bootstrap has provisioned for light- and dark-coloured tables, page headings, more prominent quotes, and text with a highlight. Bootstrap also comes with several JavaScript components which do not require other libraries like jQuery. They provide additional user interface elements such as dialog boxes, tooltips, progress bars, navigation drop-downs, and carousels. Each Bootstrap component consists of an HTML structure, CSS declarations, and in some cases accompanying JavaScript code. They also extend the functionality of some existing interface elements, including for example an auto-complete function for input fields.

3.11.11 Hardware and experimental environment

The hardware requirements for this project are reasonable and should be readily available on most modern computers. Here are the hardware specifications recommended for smooth

execution of the project:

Processor: An Intel Core i5 or higher processor is recommended. The project involves running computationally intensive tasks, such as training machine learning models and processing video data. A higher-end processor will ensure faster execution and better performance.

RAM: A minimum of 8 GB of RAM is recommended. Machine learning tasks often require significant memory resources, especially when working with large datasets. Having an ample amount of RAM will allow for smoother processing and prevent system slowdowns or crashes.

Storage: It is recommended to have at least 1 GB of free disk space. This will accommodate the installation of the required software, storing datasets, and saving the project files. Sufficient disk space ensures that you have enough room to work with the necessary files and avoid storage limitations.

Camera: In addition to the hardware specifications mentioned earlier, a camera is required for capturing the video input during real-time yoga pose detection. The camera serves as the input source for the system to analyze and detect the user's yoga poses accurately.

There are a few factors to consider:

- **Resolution:** It is recommended to use a camera with a high-resolution capability to capture clear and detailed video footage. A resolution of at least 720p (HD) or higher is preferable to ensure the accuracy of pose detection.
- **Frame Rate:** The camera should have a decent frame rate to capture smooth and fluid motion. A higher frame rate, such as 30 frames per second (fps), is ideal for capturing the user's movements accurately.
- **Low Light Performance:** It is beneficial to have a camera with good low light performance. This ensures that the system can capture clear and accurate video even in dimly lit environments, common during indoor yoga sessions.

While a dedicated webcam or built-in laptop camera can suffice for this project, professional-grade cameras or depth-sensing cameras, such as Intel RealSense or Microsoft Kinect, can provide even better accuracy and depth information for advanced pose detection.

Graphics Card: While not strictly required, having a dedicated graphics card, such as Nvidia GTX 1050 or higher, can greatly enhance the performance of the project, especially during the training phase. GPUs are known for their parallel processing capabilities, which can

significantly speed up machine learning tasks that involve heavy computations, such as training deep learning models.

However, it is important to note that the project can still be executed on a CPU-only system without a dedicated graphics card. The algorithms and techniques used in this project, including the K-Nearest Neighbors algorithm, can be implemented and run efficiently on a CPU. Although the training process may take longer on a CPU compared to a GPU, it is still feasible to achieve good results.

It is recommended to have a stable internet connection during the installation process and for accessing additional resources or documentation online. This will ensure a smooth setup and allow for any required updates or downloads.

Overall, the hardware requirements for this project are reasonable and accessible. Having a mid-range or higher processor, sufficient RAM, and adequate storage will provide a solid foundation for running the project smoothly. While a dedicated graphics card is recommended for improved performance, it is not mandatory, and the project can still be executed on a CPU-only system.

Chapter 4

RESULT AND DISCUSSION

The primary quality control method used in software development is testing. Following the coding stage, testing purposes are served by unning the accessible computer programmes. Testing must find flaws made during the earlier phase as well as those introduced during development. So, the purpose of testing is to find programme requirements, design, or coding flaws.

- A programme is tested by being run with the goal of identifying any errors.
- A excellent test case is one that has the highest chance of spotting an error that hasn't been identified yet.
- A test that finds an error that hasn't been found yet is successful. Our objective is to develop tests that systematically uncover many sorts of issues with minimal time and effort.

Testing indicates that software functionalities appear to operate as expected and that performance criteria appear to have been met. The information acquired during testing is an excellent predictor of program's reliability and a partial indicator of software quality as a whole. Testing has one drawback, however: it can only demonstrate the presence of software defects, not their absence.

4.1 Testing and it's types used

The main task following software development is to determine whether the experimental results and the actual results agree. Testing is the process in question. It is employed to ensure that the created system is free from errors. Testing's primary purpose is to find errors and missing operations by running the software. Additionally, it makes sure that the developer satisfies all of the project's goals. Testing's objective is to determine is to identify defects in the developed software as well as ways to increase its correctness, usability, and efficiency. It seeks to gauge a software program's performance, functionality, and specification. The developed programme is put through tests, and the outcomes are compared to the required documentation. Debugging is carried out when there are too many faults that have happened. After debugging, the software is once more tested to make sure there are no errors. Unit testing, integration testing, and system testing are the main testing methodologies used in this project.

- In unit testing, tested to each distinct piece of software. It ensures that the software's many components all function as intended.
- In integration testing, the integrated distinct components are examined to see whether or not the intended purpose was accomplished. It helps us find any problems that might appear after the units are combined.
- The entire piece of software is evaluated during system testing to make sure it meets all the requirements.

Warrior-I Pose

Test Case	Input Image	Actual Output	Pass/Fail	Feedback
TC001	Correct alignment in Warrior-I Pose	Warrior-I Pose	Pass	Text
TC002	Incorrect alignment in Warrior-I Pose	Warrior-I Pose	Fail	Text
TC003	Warrior-II Pose	Warrior-I Pose	Fail	Text,Audio



Figure 4.1: Correct alignment of Warrior-I Pose



Figure 4.2: Incorrect alignment of Warrior-I Pose

Mountain Pose

Test Case	Input Image	Actual Output	Pass/Fail	Feedback
TC001	Correct alignment in Mountain Pose	Tree Pose	Fail	Text
TC002	Incorrect alignment in Mountain Pose	Mountain Pose	Pass	Text
TC003	Correct alignment in Mountain Pose	Mountain Pose	Pass	Text,Audio

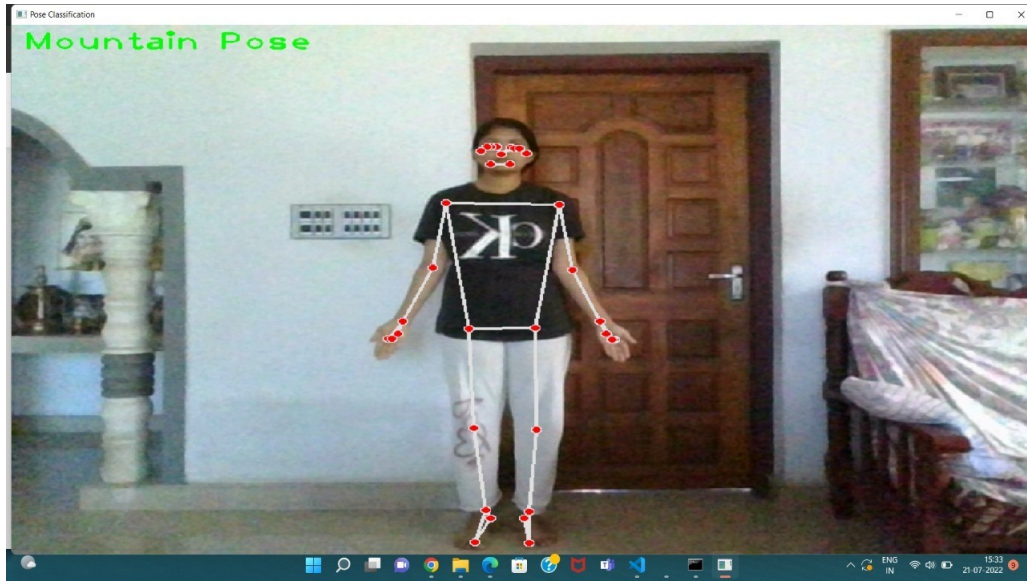


Figure 4.3: Correct alignment of Mountain Pose

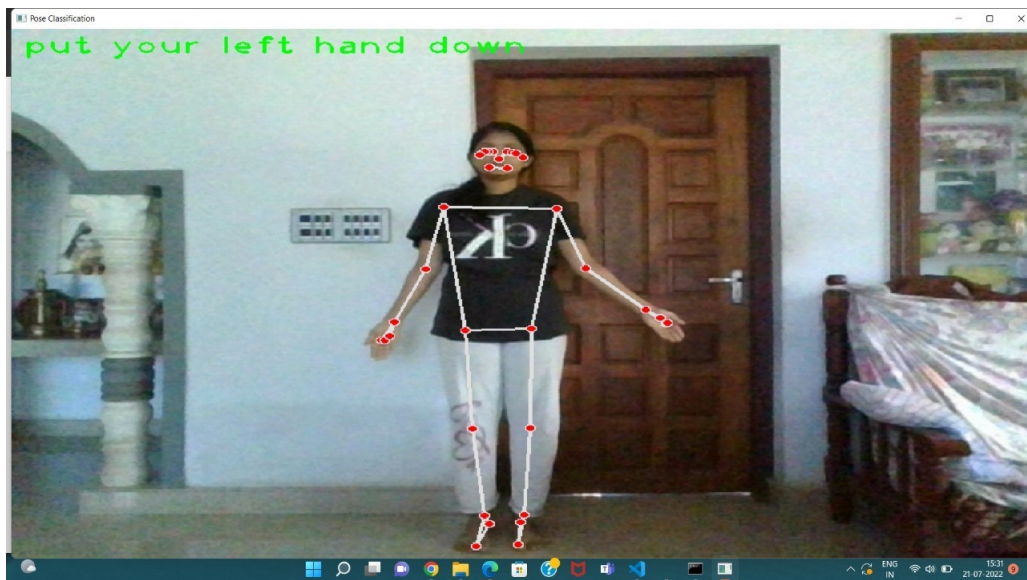


Figure 4.4: Incorrect alignment of Mountain Pose

Tree Pose

Test Case	Input Image	Actual Output	Pass/Fail	Feedback
TC001	Correct alignment in Tree Pose	Tree Pose	Pass	Text
TC002	Incorrect alignment in Tree Pose	Not detected	Pass	Text,Audio
TC003	Mountain Pose	Mountain Pose	Pass	Text,Audio

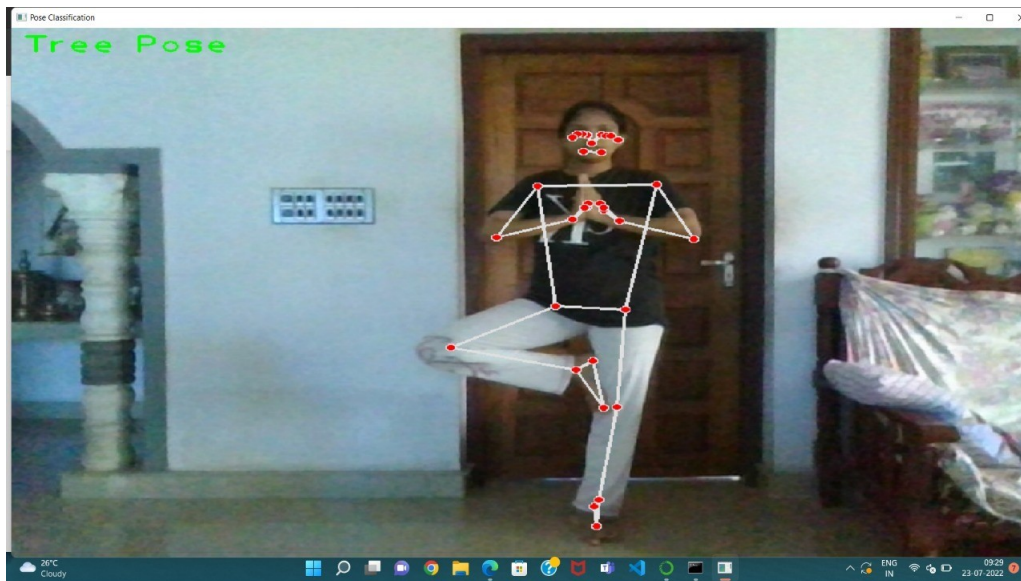


Figure 4.5: Correct alignment of Tree Pose

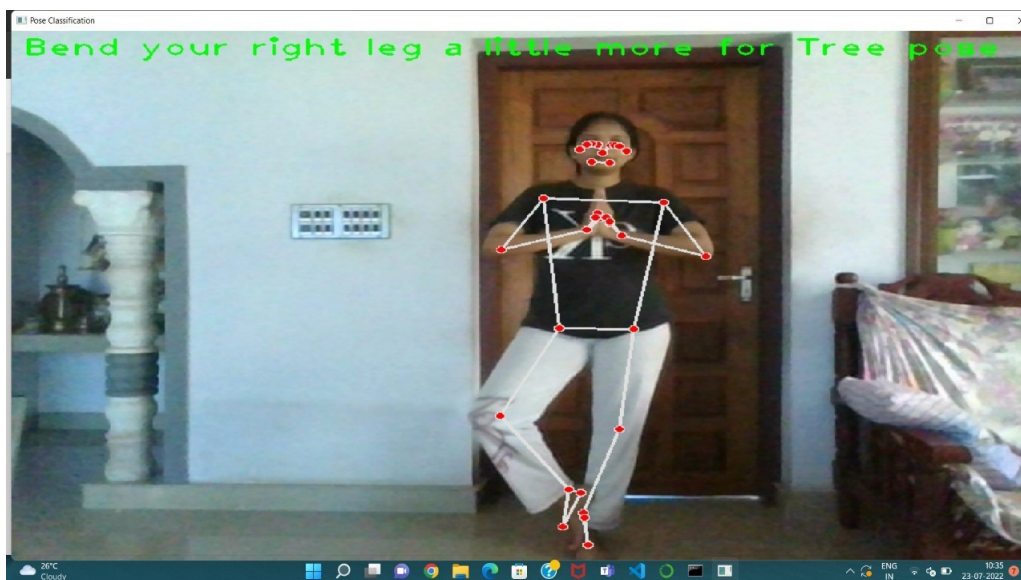


Figure 4.6: Incorrect alignment of Tree Pose

Goddess Pose

Test Case	Input Image	Actual Output	Pass/Fail	Feedback
TC001	Correct alignment in Goddess Pose	Goddess Pose	Pass	Text,Audio
TC002	Incorrect alignment in Goddess Pose	Not detected	Pass	Text,Audio
TC003	Warrior-II Pose	Mountain Pose	Pass	Text,Audio

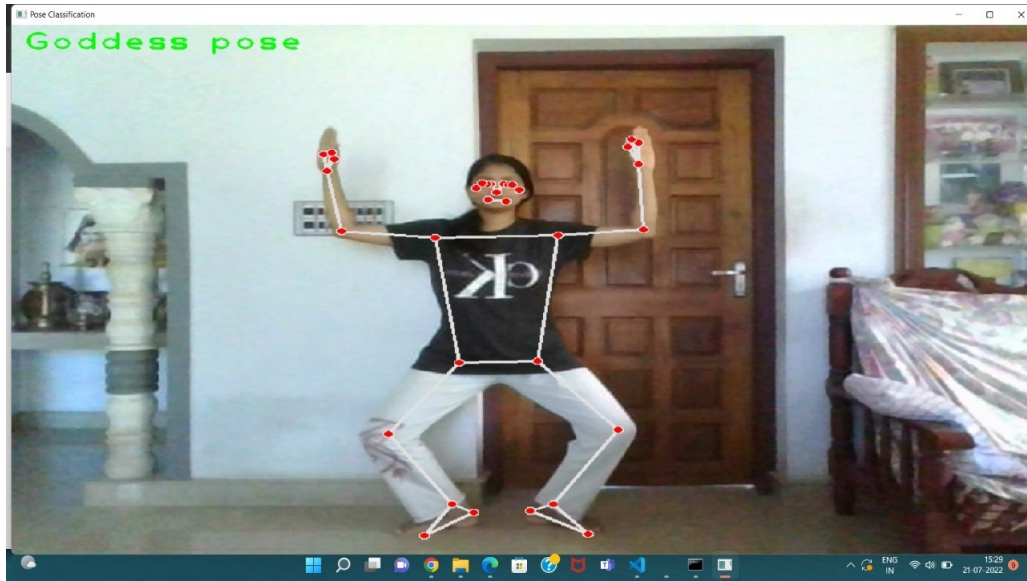


Figure 4.7: Correct alignment of Goddess Pose



Figure 4.8: Incorrect alignment of Goddess Pose

T Pose

Test Case	Input Image	Actual Output	Pass/Fail	Feedback
TC001	Correct alignment in T Pose	T Pose	Pass	Text,Audio
TC002	Incorrect alignment in T Pose	Tree Pose	Fail	Text,Audio
TC003	Warrior-I Pose	Warrior-I Pose	Pass	Text,Audio

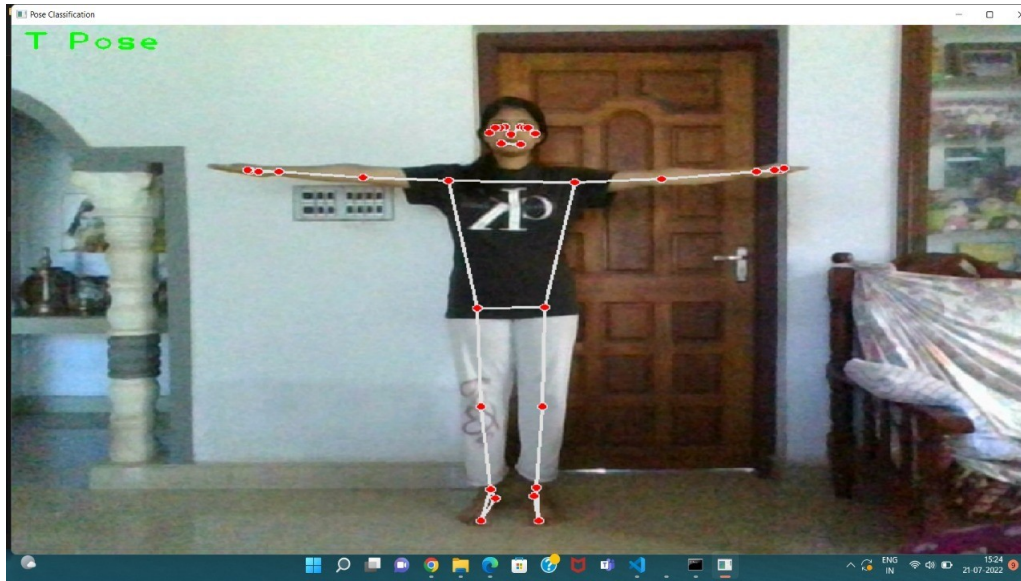


Figure 4.9: Correct alignment of T Pose

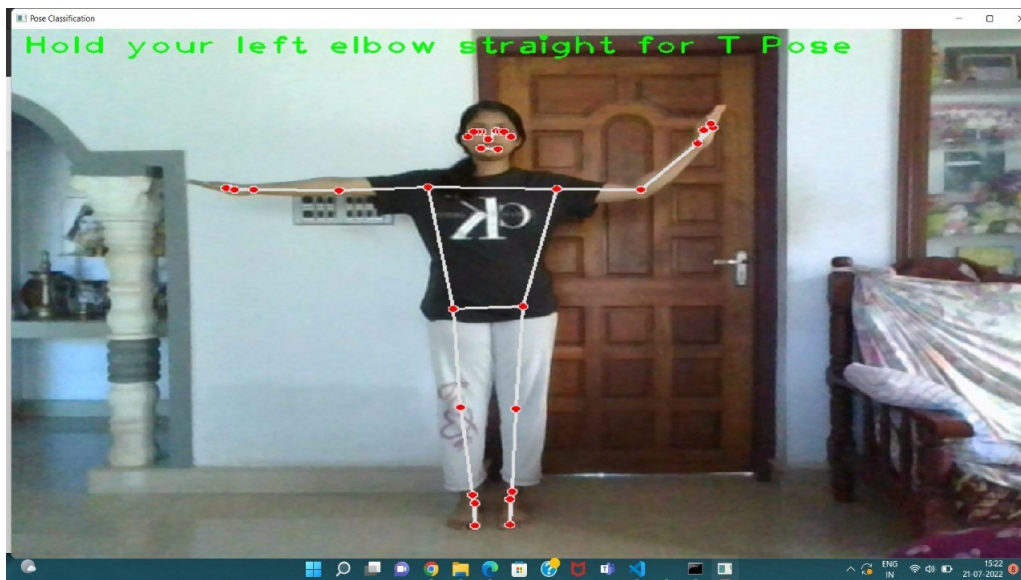


Figure 4.10: Incorrect alignment of T Pose

Warrior-II

Test Case	Input Image	Actual Output	Pass/Fail	Feedback
TC001	Correct alignment in Warrior-II Pose	Warrior-II	Pass	Text,Audio
TC002	Incorrect alignment in Warrior-II Pose	No pose detected	Fail	Text,Audio
TC003	Warrior-I Pose	Warrior-I Pose	Pass	Text,Audio

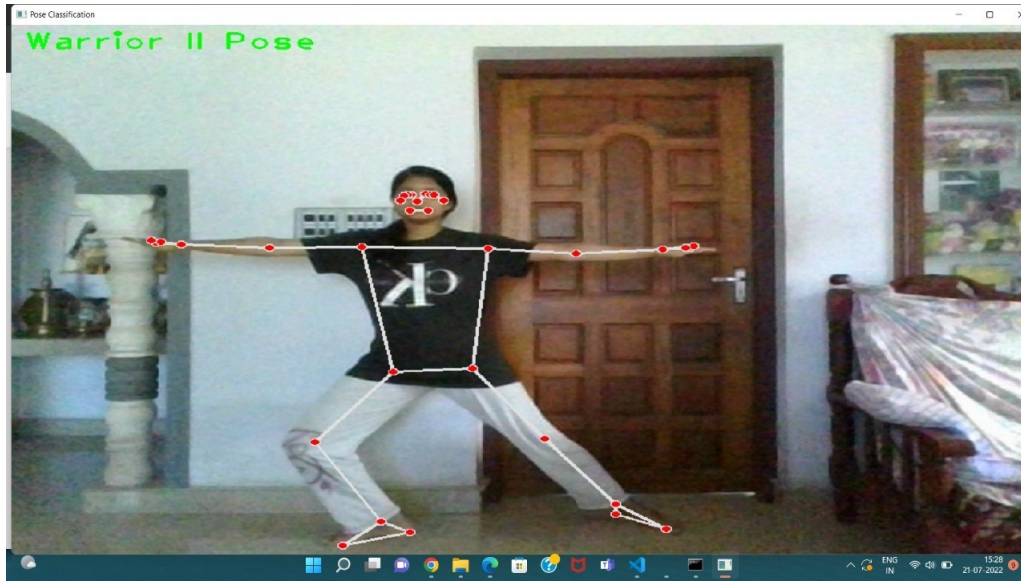


Figure 4.11: Correct alignment of Warrior-II Pose

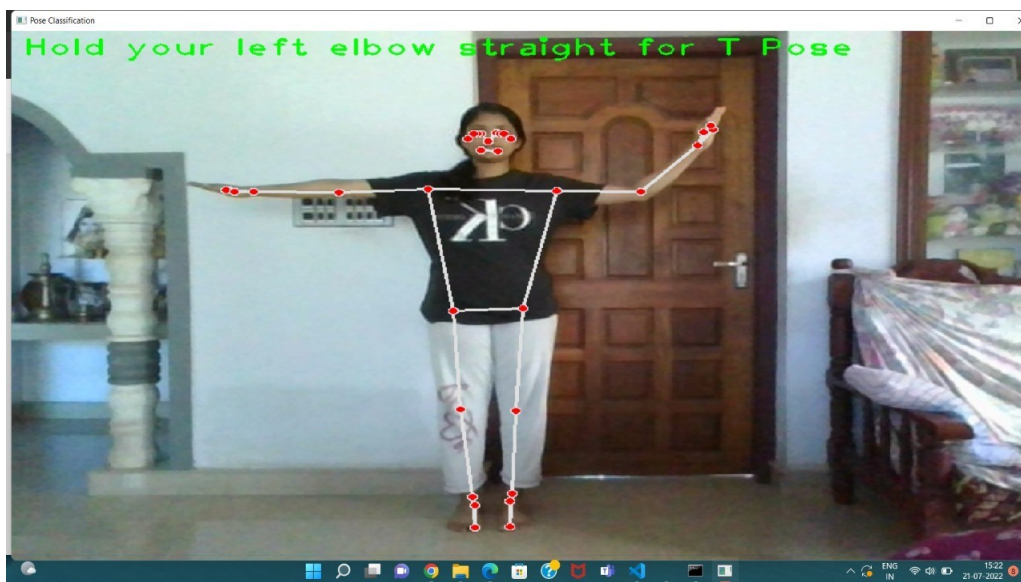


Figure 4.12: Incorrect alignment of Warrior-II Pose

4.2 Output Screens and Results

1. Yoga website:

The user can login to their account and practice yoga.

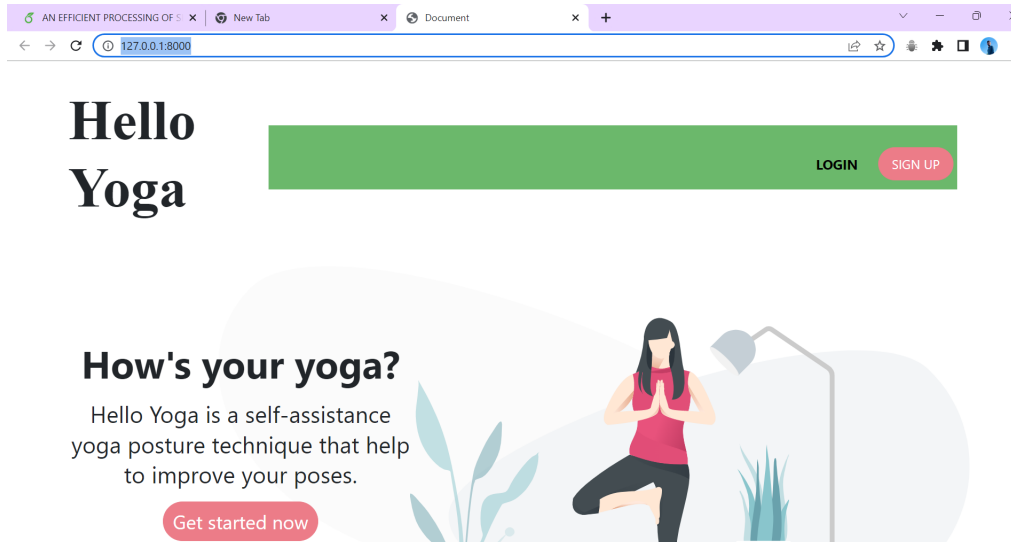


Figure 4.13: Yoga website home page

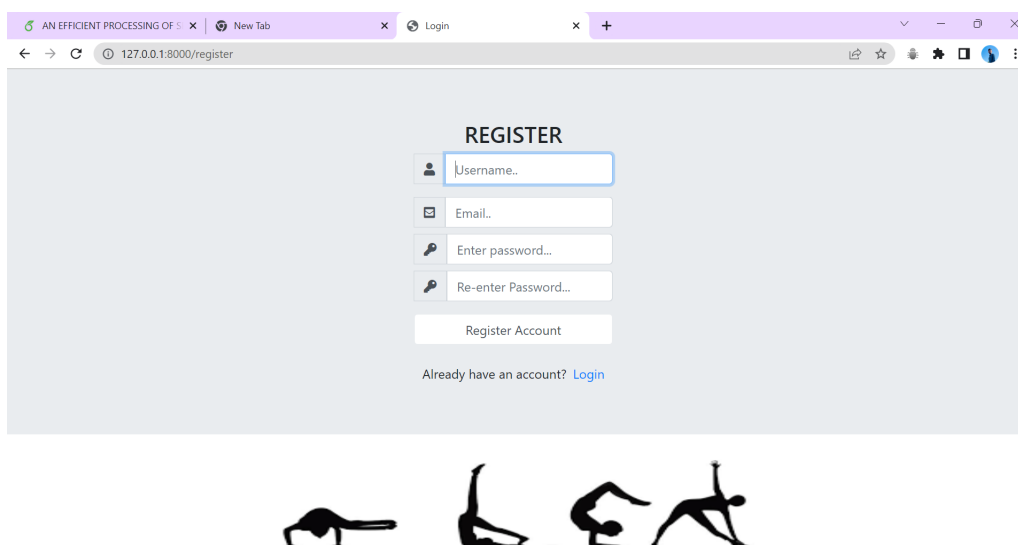


Figure 4.14: Yoga website signup page

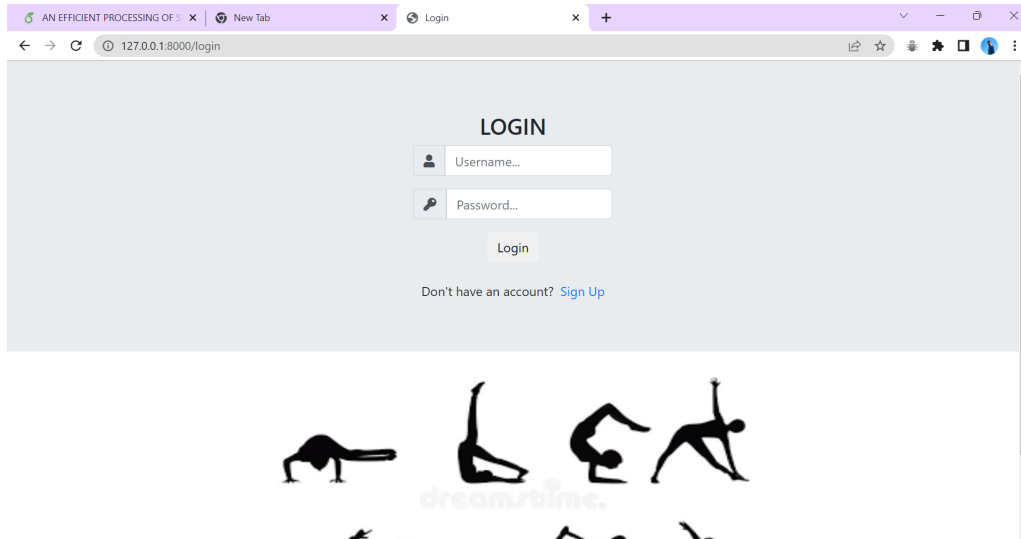


Figure 4.15: Yoga website login page

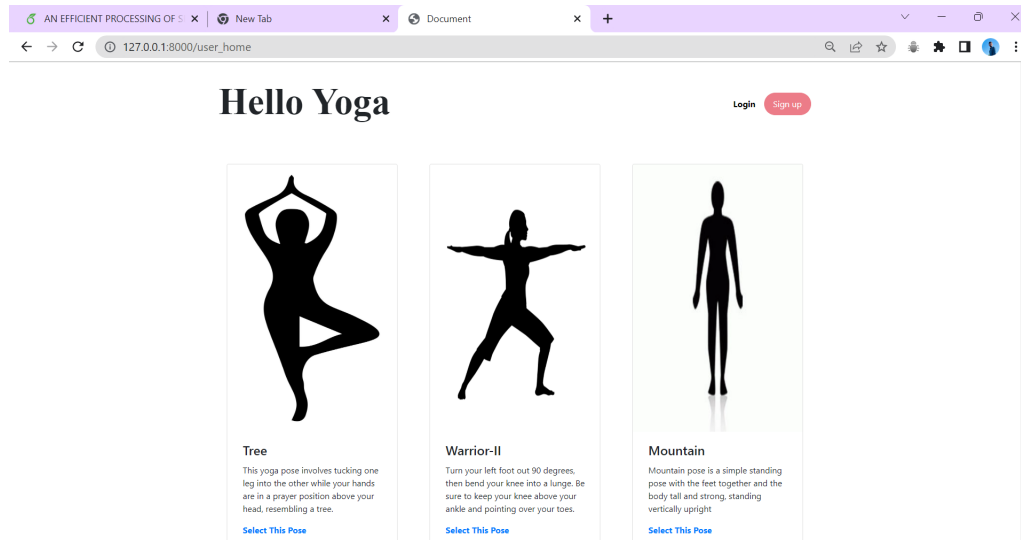


Figure 4.16: Yoga website user dashboard

2. Pose detection



Figure 4.17: Practicing yoga with virtual assistance



Figure 4.18: Practicing yoga with virtual assistance

Chapter 5

CONCLUSION

This project aimed to develop a real-time yoga pose detection system using the K-Nearest Neighbors (KNN) algorithm. The system's primary objective was to provide users with real-time feedback on their yoga poses, helping them improve their form and practice effectively. Throughout the project, various software tools and techniques were utilized, including OpenCV, Mediapipe, and Python programming language.

The project addressed the identified gap in the field of yoga training by leveraging computer vision techniques and machine learning algorithms to develop an interactive and user-friendly system. By providing real-time audio feedback, the system enabled users to receive immediate guidance on their yoga poses, enhancing their overall experience and ensuring proper alignment and posture.

Based on the selected base paper, "Real-time Yoga recognition using deep learning," the project adopted the KNN algorithm for pose detection. This algorithm was chosen due to its simplicity, efficiency, and effectiveness in classifying yoga poses based on the extracted features from the user's video feed. By utilizing a labeled dataset of yoga poses, the system trained the KNN model to recognize and classify different poses accurately.

The developed system successfully integrated the KNN algorithm, video processing techniques, and real-time audio feedback. It provided a seamless user experience by capturing the user's live video feed, preprocessing the video, detecting the yoga pose using the KNN model, and delivering real-time feedback on the correctness and alignment of the pose. This feedback mechanism helped users make immediate adjustments and corrections, ensuring safe and effective yoga practice.

Throughout the project, several evaluation metrics were employed to assess the perfor-

mance of the system. Accuracy, precision, recall, and F1 score were used to measure the effectiveness of the pose detection algorithm. These metrics provided quantitative insights into the system's ability to accurately identify and classify yoga poses. By continuously fine-tuning the algorithm and optimizing the system, the project achieved high accuracy rates, enhancing the reliability and usefulness of the system.

The project also utilized the Yoga Poses Dataset by NIHARIKA PANDIT from Kaggle for training and testing the system. This dataset consisted of labeled images of various yoga poses performed by different individuals. By leveraging this dataset, the system was able to learn and recognize a wide range of yoga poses, accommodating different body types and variations in the execution of poses.

Overall, the developed real-time yoga pose detection system showcased promising results and demonstrated its potential in enhancing yoga training and practice. The integration of the KNN algorithm, video processing techniques, and real-time audio feedback provided an interactive and personalized experience for users, enabling them to improve their yoga poses in real-time. The system's adaptability to different body types and camera positions further added to its usability and effectiveness.

5.1 Future Enhancement

In the future, there are several exciting possibilities for enhancing the real-time yoga pose detection system. These enhancements aim to improve the accuracy, adaptability, and overall user experience of the system. Here are some potential areas for future development:

1. **Advanced Machine Learning Algorithms:** While the K-Nearest Neighbors (KNN) algorithm is effective for pose detection, exploring more advanced machine learning algorithms such as convolutional neural networks (CNN) or recurrent neural networks (RNN) could enhance the accuracy and robustness of the system. These algorithms can capture complex patterns and relationships in the data, leading to better pose recognition and classification.
2. **Pose Variation Handling:** To accommodate a wider range of body types and pose variations, the system can be enhanced to handle different levels of flexibility, variations in execution, and modifications in yoga poses. By incorporating pose augmentation

techniques and generating synthetic pose samples, the system can better adapt to individual users' specific body types and execution styles.

3. **Real-time Pose Correction:** Integrating real-time pose correction mechanisms can further enhance the user experience and assist users in achieving proper form and alignment. By analyzing the user's pose in real-time, the system can provide immediate feedback and guidance on adjusting posture, alignment, and breathing techniques. This can help users refine their practice and prevent potential injuries.
4. **Personalized Recommendations:** Adding a personalized recommendation system based on user performance and progress can provide tailored guidance and suggestions for improvement. By tracking and analyzing user data over time, the system can identify areas for improvement and suggest specific poses or modifications to help users advance in their yoga practice.
5. **Multi-camera Support:** Expanding the system to support multiple camera inputs can provide users with different viewing angles and perspectives, enhancing the accuracy of pose detection. By combining data from multiple cameras, the system can obtain a more comprehensive understanding of the user's pose, enabling better accuracy and precise feedback.
6. **Mobile Application Integration:** Developing a mobile application for the real-time yoga pose detection system can enhance its accessibility and usability. Users can easily access the system on their smartphones or tablets, allowing them to practice yoga anytime, anywhere. The mobile application can also include additional features such as progress tracking, personalized workout plans, and social sharing.
7. **Integration of Biofeedback Sensors:** Incorporating biofeedback sensors such as heart rate monitors or wearable devices can provide additional insights into the user's physical state during yoga practice. This data can be used to tailor the feedback and recommendations provided by the system, taking into account the user's heart rate, breathing patterns, and level of exertion.
8. **Gamification and Interactive Features:** Adding gamification elements and interactive features to the system can make the yoga practice more engaging and enjoyable. Users can earn points, unlock achievements, and participate in challenges, creating a sense of

motivation and fun. Interactive visualizations and animations can also be incorporated to provide a more immersive experience.

9. **Integration with Smart Devices:** Integrating the real-time yoga pose detection system with smart devices such as smart TVs or virtual reality (VR) headsets can enhance the user experience and create a more immersive environment. Users can follow along with virtual instructors, access guided meditation sessions, or join virtual yoga classes, further enhancing their practice.
10. **User Feedback and Evaluation:** Collecting user feedback and conducting regular evaluations can provide valuable insights for system improvement. User surveys, feedback forms, and usability testing sessions can help identify areas of improvement, usability issues, and user preferences. This feedback can guide future enhancements and updates to make the system more user-centric.

By implementing these future enhancements, the real-time yoga pose detection system can continue to evolve, providing users with a more comprehensive and personalized yoga practice experience. These advancements can contribute to improved form and alignment, enhanced user engagement, and increased accessibility to yoga training.

REFERENCES

- [1] Yadav, S. K., Singh, A., Gupta, A., Raheja, J. L. (2019). Real-time Yoga recognition using deep learning. Springer-Verlag London Ltd., part of Springer Nature. Received: 24 September 2018 / Accepted: 9 May 2019 / Published online: 20 May 2019.
- [2] Agarwal, R., Aggarwal, A. (2021). A Novel Approach for Real-time Yoga Pose Detection and Correction using OpenPose. *Journal of King Saud University-Computer and Information Sciences*, 33(2), 170-179.
- [3] Zhang, Y., Li, W., Li, L., Li, J. (2021). A new intelligent yoga training system based on human-computer interaction. *IEEE Transactions on Computational Social Systems*, 8(4), 912-925.
- [4] Yang, X., Xiong, W. (2019). The application of wearable devices in yoga. *International Journal of Multimedia and Ubiquitous Engineering*, 14(8), 97-106.
- [5] Li, H., Li, Y., Wang, Y., Liu, C. (2021). A yoga learning system based on image recognition and augmented reality. *Multimedia Tools and Applications*, 80(15), 23289-23307.
- [6] Singh, J., Garg, D., Gupta, V. (2021). A novel framework for yoga pose recognition and analysis using computer vision techniques. *Journal of Ambient Intelligence and Humanized Computing*, 12(6), 5741-5755.
- [7] Almaghraby, H., Hagraas, H. (2020). A novel smart yoga training system using the internet of things and cloud computing. *Wireless Communications and Mobile Computing*, 2020, 1-14.
- [8] Liao, Y., Chang, C., Hsu, C. (2020). An intelligent yoga teaching system based on computer vision and augmented reality. *Applied Sciences*, 10(20), 7309.

- [9] Chen, L., Yang, X., Zhou, J., Zhao, Y. (2019). A wearable device-based yoga training system for health management. *Journal of Medical Systems*, 43(11), 354.
- [10] Hu, J., Huang, H., Chen, J. (2020). A real-time human pose estimation and correction system for yoga practice. *Multimedia Tools and Applications*, 79(47), 35631-35654.
- [11] Yadav, S. K., Singh, S. K. (2021). A review on yoga pose recognition systems. *Multimedia Tools and Applications*, 80(21), 33395-33420.
- [12] Li, J., Li, Y., Xiong, J. (2021). A real-time yoga pose correction system based on computer vision and deep learning. *Journal of Intelligent and Fuzzy Systems*, 41(2), 2657-2665.