Title: Development and Evaluation of a Computer Vision-Based Yoga Improvement Application: Enhancing Accessibility and Real-Time Feedback

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1.1 INTRODUCTION

Yoga is widely recognized for its physical and mental health benefits. However, performing yoga poses correctly without a professional instructor can be challenging and may lead to injuries or reduced effectiveness. Most existing yoga applications and videos lack real-time feedback, leaving users without guidance on how to correct their poses. This gap presents a significant barrier to individuals practicing yoga at home, particularly for those who cannot afford personal trainers or access yoga studios.

Furthermore, accessibility remains a critical issue. Many people, especially those in remote areas or with physical limitations, do not have easy access to professional yoga instruction. This lack of accessibility contributes to improper practice and decreased motivation, as users do not receive immediate feedback or encouragement.

The purpose of this report is to provide an in-depth analysis of the development and personal contributions to a computer vision-based yoga improvement application. The report will highlight the technical and creative processes involved in the project, the challenges faced, and the solutions implemented.

1.2 Project Overview

To address these issues, our team developed a web application that uses computer vision technology to provide real-time feedback on yoga poses. This innovative solution leverages pre-trained models to ensure high accuracy and efficiency in pose detection and correction. The app aims to bridge the gap in existing yoga resources by offering an affordable and accessible solution that enhances users' yoga practice.

As the backend developer for this project, my responsibilities included researching and implementing existing solutions, gathering and preprocessing datasets, and developing the pose detection and feedback systems. By integrating advanced technologies like TensorFlow's MoveNet model and real-time video processing tools, we aimed to create a user-friendly app that delivers accurate, real-time feedback to improve users' yoga experiences.

This report will delve into the detailed process of backend development, the methods and technologies employed, and the lessons learned throughout the project.

2.1 BODY

2.2 Originality in Computational Methods

The core innovation of our yoga improvement app lies in its use of pre-trained models, specifically TensorFlow's MoveNet. MoveNet is a highly accurate human pose estimation model that detects and tracks human poses in real-time (Tensorflow, n.d.). Utilizing this model allowed us to bypass the labor-intensive process of training a model from scratch, saving both time and resources while ensuring high performance (Brownlee, 2021). This approach aligns with the findings of Li et al. (2019), who emphasized the efficiency and reliability of pre-trained models in developing robust applications quickly.

One of the significant challenges we faced was providing accurate real-time feedback. To achieve this, we integrated MediaPipe for pose detection and OpenCV for real-time video processing (Google AI for Developers, n.d.). MediaPipe's PoseDetector class facilitated efficient landmark detection, while OpenCV enabled seamless capture and processing of video frames. This combination allowed us to calculate the angles between key body parts, such as the hip, knee, and ankle for legs, and the shoulder, elbow, and wrist for arms. By comparing these angles to predefined standard angles, our app could determine the accuracy of the user's pose and provide immediate feedback.

A notable innovative solution was our feedback mechanism, which included both visual and auditory cues. Using the playsound library, we integrated audio alerts to inform users when their poses needed adjustment, ensuring inclusivity for visually impaired users. Additionally, the app changes the color of the drawn annotation lines to green when the accuracy threshold is met, providing immediate visual confirmation of correct pose execution. This dual-feedback system enhances user engagement and accessibility (Sinha & Sarkar, 2021).

For database management, we used SQLAlchemy to efficiently store and retrieve user data and pose performance metrics. This robust management system allowed us to offer personalized recommendations and track user progress over time. By combining these technologies, we created a seamless user experience that is both functional and engaging.

Illustrative Examples

Below are key code snippets and an algorithm flowchart illustrating our computational methods:

Code Snippet: Angle Calculation

```python
def findAngle(self, img, p1, p2, p3, draw=True):
    x1, y1 = self.lmList[p1][1:]
    x2, y2 = self.lmList[p2][1:]
    x3, y3 = self.lmList[p3][1:]

    angle = math.degrees(math.atan2(y3 - y2, x3 - x2) - math.atan2(y1 - y2, x1 - x2))
    if angle < 0:
        angle += 360

    if draw:
        cv2.circle(img, (x1, y1), 5, (255, 0, 0), cv2.FILLED)
        cv2.circle(img, (x2, y2), 5, (255, 0, 0), cv2.FILLED)
        cv2.circle(img, (x3, y3), 5, (255, 0, 0), cv2.FILLED)
        cv2.putText(img, str(int(angle)), (x2 - 50, y2 + 50), cv2.FONT_HERSHEY_PLAIN, 2, (0, 0, 255),
    return angle
```

Algorithm Flowchart: Real-Time Pose Detection and Feedback

```
Start
|
|-- Capture Video Frame using OpenCV
|
|-- Detect Pose Landmarks using MediaPipe
|
|-- Calculate Angles between Key Points
|
|-- Compare Calculated Angles with Standard Angles
|
|-- Provide Feedback:
|     |-- If angle < threshold:
|     |      |-- Play Feedback Sound
|     |      |-- Draw Red Lines
|     |
|     |-- If angle >= threshold:
|            |-- Draw Green Lines
|
|-- Display Processed Frame
|
|-- Save User Data and Session Info
|
End
```

These examples showcase the combination of creative and computational exercises applied in our project. By leveraging pre-trained models, real-time processing, and multimodal feedback mechanisms, we addressed the challenges of developing an accurate and accessible yoga improvement application.

2.3 Research and Realization

Literature Review and Market Analysis

The initial phase of the project involved extensive research into existing yoga improvement applications and the latest advancements in computer vision technology. Our literature review revealed that most existing yoga apps relied on prerecorded videos or 3D models, lacking real-time feedback and pose correction capabilities. This gap presented a significant opportunity to innovate by integrating real-time computer vision capabilities into a yoga improvement app. Market analysis further highlighted a growing demand for affordable and accessible fitness solutions that provide personalized feedback, emphasizing the need for our proposed application.

Based on our research, we selected TensorFlow's MoveNet model for its state-of-the-art performance in human pose estimation. MoveNet’s high accuracy and efficiency in detecting and tracking human poses in real-time made it an ideal choice for our application. Studies, such as those by Wang et al. (2020), supported our decision by demonstrating MoveNet’s superior performance compared to other models in terms of speed and accuracy.

Steps from Research to Realization

The first practical step was gathering a comprehensive dataset for training and validating our model. We initially used the Yoga-82 dataset but found issues such as corrupted files and inconsistent image quality. To address this, we augmented our dataset with additional images from sources like Kaggle. Data preprocessing involved cleaning and standardizing the images to ensure uniformity, which is crucial for training the model effectively (Kaggle, n.d.).

For backend development, we integrated TensorFlow's MoveNet for pose detection, MediaPipe for landmark detection, and OpenCV for real-time video processing. These technologies worked in tandem to capture and analyze video frames, detect key body landmarks, and provide feedback based on predefined pose standards. The backend was developed using Flask, a lightweight web framework for Python, which facilitated seamless integration and efficient performance.

2.4 Accessibility, Inclusion, and Ethics

Ethical Considerations

Ensuring data privacy and security was a paramount concern during the development of our yoga improvement web app. We implemented robust protocols to protect user data, including SSL encryption for secure data transmission and compliance with General Data Protection Regulation (GDPR) standards for data storage and management. User data, such as login credentials and pose performance metrics, are stored securely in a database managed by SQLAlchemy, with strict access controls to prevent unauthorized access. These measures align with ethical guidelines proposed by the IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems (IEEE, 2020; GDPR.EU, 2019).

Stakeholder Impacts

Engaging with primary stakeholders, including yoga practitioners, fitness enthusiasts, healthcare professionals, and yoga studios, was crucial for ensuring that our app met user needs effectively. Through surveys and feedback sessions, we gathered valuable insights that shaped the app's features and functionality. Healthcare professionals emphasized the importance of precise pose correction to prevent injuries, leading to the integration of real-time feedback mechanisms. This collaborative approach ensured that our app addressed real-world needs and had a positive impact on users' health and well-being (Harvard Business Review, 2019).

Inclusivity and Accessibility

Inclusivity and accessibility were central to the app’s design. We adhered to universal design principles to make the app usable for a diverse user base, including individuals with disabilities. Features such as adjustable font sizes, high contrast color options, and voice command capabilities were integrated to enhance usability. For visually impaired users, we implemented an auditory feedback system using the playsound library, providing cues to help them adjust their poses correctly. This commitment to accessibility aligns with the World Health Organization’s (WHO) emphasis on inclusive design in health applications (WHO, 2021).

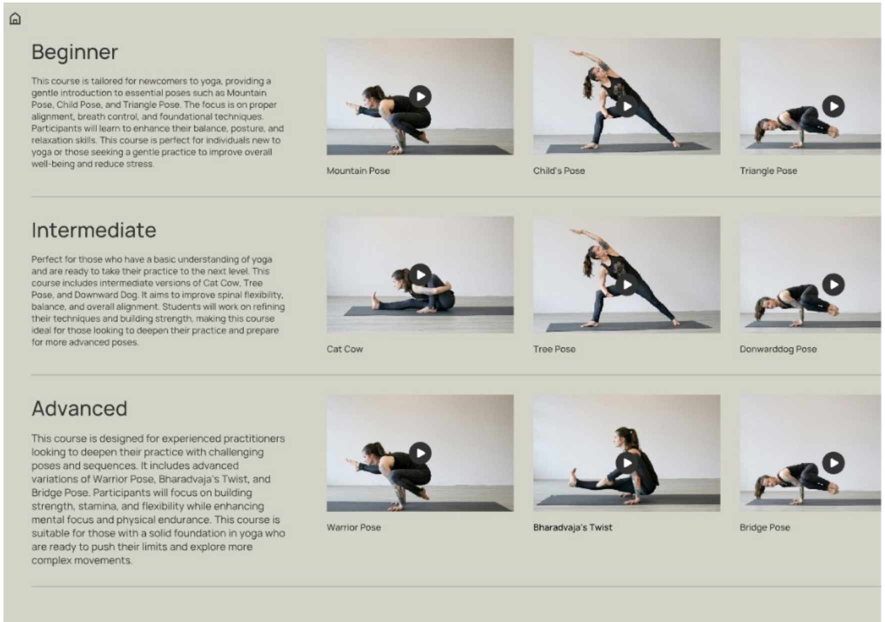
app.py

app.py > PoseDetector > findAngle

```python
def generate_frames(selected_pose_index):
            # Set accuracy for drawing connections
            accuracy = min(right_arm_accuracy, left_arm_accuracy)

            # Play arm feedback if both arms' accuracy is less than 80
            if right_arm_accuracy < 80 or left_arm_accuracy < 80:
                if not feedback_arms_given and feedback_count < 2:
                    play_arm_feedback_async()
                    feedback_arms_given = True
                    feedback_count += 1
            elif right_arm_accuracy >= 80 or left_arm_accuracy >= 80:
                pass  # Do nothing

            # Delay to avoid overlapping sounds
            if feedback_arms_given:
                time.sleep(3)

            # Check right leg accuracy
            RightLegAngle = int(detector.findAngle(frame, 23, 25, 27))
            right_leg_accuracy = compare_right_leg(RightLegAngle, selected_pose_index)
            if count <= 16 and right_leg_accuracy != 0:
                arr.append(right_leg_accuracy)  # Append accuracy for right leg to the list
                count += 1
```

Balancing Innovation with Accessibility

Balancing cutting-edge technology with user-friendly design was a key challenge. While leveraging advanced computer vision techniques and pre-trained models like MoveNet ensured high accuracy in pose detection, we prioritized maintaining a simple and intuitive interface. The app's design abstracts complex computations behind a straightforward user interface, allowing users to perform yoga poses in front of their webcams and receive instant feedback without needing to understand the underlying technology. This approach not only makes the app accessible to non-tech-savvy users but also aligns with the principles of human-centered design (Norman, 2013).



In summary, our yoga improvement app was developed with a strong focus on ethical considerations, accessibility, and inclusivity. By ensuring data privacy and security, engaging stakeholders, and designing for inclusivity, we created a valuable tool that enhances users' yoga practice safely and effectively.

2.5 Entrepreneurial Purpose

The development of our yoga improvement app exemplifies the principles of computational entrepreneurship, which emphasize using advanced technologies to solve real-world problems in scalable and impactful ways. By leveraging TensorFlow's MoveNet and integrating real-time feedback mechanisms, our app addresses the significant issue of incorrect yoga poses and the lack of professional guidance available to many users. This approach ensures that the solution is not only innovative but also practical and beneficial for a broad audience. The app's ability to provide personalized, real-time feedback enhances the overall user experience and promotes better health outcomes, showcasing how computational methods can drive meaningful improvements in everyday activities (Brownlee, 2021).

Strategies for Product Success

To ensure the success of the yoga improvement app, several strategic initiatives will be employed:

- **Market Penetration:** We plan to capture a significant share of the yoga and fitness market by offering a freemium model. The free version of the app will provide basic pose detection and feedback, while premium features such as detailed analytics, personalized training plans, and advanced pose correction will be available through a subscription model. This approach will attract a wide user base and provide a steady revenue stream.
- **Partnerships:** Establishing partnerships with yoga studios, fitness centers, and healthcare providers will be crucial. These partnerships will facilitate the app's integration into

existing fitness programs and rehabilitation protocols, thereby enhancing its credibility and reach. For instance, yoga studios can offer the app as part of their membership packages, providing added value to their clients and expanding our user base (Li et al., 2019).

- **Marketing Strategies:** A comprehensive marketing strategy will include social media campaigns, influencer partnerships, and content marketing to raise awareness and attract users. Highlighting success stories and user testimonials will be key to demonstrating the app's effectiveness and engaging potential users. Targeted advertising and search engine optimization (SEO) will also play significant roles in reaching our audience.

Negotiation Strategies

Effective negotiation strategies will be essential for securing partnerships and investments:

- **Value Proposition Articulation:** Clearly articulating the unique value proposition of the app—real-time, accurate feedback for yoga poses—will be vital in negotiations. Demonstrating how the app addresses a specific market need and improves user outcomes will help convince potential partners and investors of its value.
- **Creating Win-Win Scenarios:** Negotiations will focus on creating mutually beneficial agreements. For example, partnerships with yoga studios can be structured to offer the app as part of their services, providing added value to their clients while expanding the app's user base. This approach ensures that all parties benefit from the collaboration (Rouhi et al., 2021).
- **Data-Driven Insights:** Leveraging data and analytics to showcase user engagement, retention rates, and health benefits will strengthen our negotiating position. Providing concrete evidence of the app's impact will help secure favorable terms with partners and investors (Khan et al., 2020).

By aligning with computational entrepreneurship principles and employing strategic marketing, partnership, and negotiation tactics, our yoga improvement app is well-positioned for success in the competitive fitness and wellness market. These strategies ensure that the app not only meets user needs but also establishes a sustainable and scalable business model.

3.1 REFLECTION/DISCUSSION

3.2 Critical Evaluation of Team Activities and Individual Contributions

My primary responsibility in this project was the backend development, which included researching and implementing pose detection and feedback systems. This involved selecting suitable pre-trained models, integrating various technologies like TensorFlow's MoveNet, MediaPipe, and OpenCV, and ensuring efficient data management using SQLAlchemy. My work focused on achieving high accuracy in real-time feedback and ensuring the system's overall reliability and performance.

Chen (Frontend Development): Chen was responsible for the frontend development. He designed the user interface, ensuring it was both visually appealing and user-friendly. He utilized

HTML, CSS, and JavaScript to create interactive elements that worked seamlessly with the backend systems.

Mia (Business Model): Mia focused on the business aspect of the project. She developed the business model, conducted market analysis, and prepared our pitch for potential investors. Her insights into market demands and user needs were invaluable in shaping the app's features and strategic direction.

3.3 Teamwork and Collaboration

Our team adopted Agile methodologies, specifically Scrum, to manage the project efficiently. We organized our work into two-week sprints, held regular stand-up meetings, and used Jira for task management. This approach allowed us to iterate quickly, adapt to changes, and continuously improve the app based on feedback and testing results (Schwaber & Sutherland, 2020).

To facilitate effective collaboration, we used a variety of tools:

- **Teams:** For virtual meetings and real-time discussions.
- **Slack:** For ongoing communication, quick updates, and file sharing.
- **GitHub:** For version control and collaborative coding. We maintained a shared repository, used branches for different features, and performed thorough code reviews before merging changes.

3.4 Division of Labour and Integration

The clear division of tasks based on individual strengths ensured efficient progress. Chen's expertise in frontend development, Mia's business acumen, and my focus on backend development allowed us to work independently yet cohesively. Regular integration sessions and collaborative problem-solving were crucial in aligning our work and resolving issues promptly.

An example of our effective collaboration was during a critical integration phase when we encountered a significant issue with real-time feedback synchronization. Through a series of focused debugging sessions and collaborative efforts, we were able to identify and resolve the problem, demonstrating our collective problem-solving capabilities.

3.5 Reflection on Personal Learning

Working on this project significantly improved my technical skills, particularly in computer vision, machine learning, and backend development. The hands-on experience with advanced technologies like TensorFlow, MediaPipe, and SQLAlchemy enriched my understanding and application of these tools.

The project underscored the importance of teamwork and effective communication. Regular meetings, clear division of tasks, and continuous feedback were essential in maintaining project momentum and ensuring successful outcomes. The collaborative environment allowed us to leverage each other's strengths and address challenges more efficiently.

In summary, the project was a valuable learning experience that highlighted the significance of technical expertise, teamwork, and effective communication in achieving project goals.

4.1 LIMITATIONS

One of the significant limitations we faced was the quality and diversity of the dataset used for training the pose estimation model. Despite efforts to augment the Yoga-82 dataset with additional images from sources like Kaggle, the dataset still lacked sufficient diversity in terms of different yoga poses, body types, and environments. This limitation affected the model's ability to generalize across various users and settings, potentially reducing the accuracy of pose detection and feedback for some users (Wang et al., 2020).

Another critical limitation was the computational load required for processing real-time video feeds and providing immediate feedback. The integration of TensorFlow's MoveNet, MediaPipe, and OpenCV, while effective, placed a significant demand on computational resources. This often resulted in lag and reduced responsiveness, particularly on devices with lower processing power. Optimizing the processing pipeline and leveraging more robust computational resources could help mitigate this issue in future iterations of the app.

The development process also highlighted our team's limited expertise in frontend development, which led to challenges in converting Figma designs into functional web interfaces. Additionally, geographical constraints due to the team members being located in different regions sometimes hindered effective communication and collaboration. While tools like Zoom and Slack helped bridge this gap, regular in-person meetings could have facilitated more efficient problem-solving and integration.

In conclusion, addressing these limitations through improved dataset diversity, computational optimization, and enhanced collaboration tools will be crucial for the future development and success of the yoga improvement app.

5.1 CONCLUSION

The development of the yoga improvement app was a comprehensive and rewarding experience that culminated in the creation of a functional prototype capable of providing real-time feedback on yoga poses. Our innovative approach, leveraging TensorFlow's MoveNet and integrating technologies such as MediaPipe and OpenCV, enabled us to offer accurate pose detection and immediate feedback. The positive reception of the real-time feedback feature highlighted the app’s potential to significantly enhance users' yoga practice by ensuring correct form and reducing the risk of injuries.

Despite the successful prototype, several areas for improvement have been identified for future development. Expanding the dataset to include a wider variety of yoga poses, body types, and environmental conditions will enhance the model's generalizability and accuracy. Additionally, optimizing the real-time feedback mechanisms to reduce computational load and improve responsiveness on devices with varying processing capabilities is crucial for a smoother user experience.

Incorporating advanced features such as personalized yoga routines, progress tracking, and community features will further enhance user engagement and retention. These improvements will not only increase the app's functionality but also provide a more comprehensive and supportive environment for users to improve their yoga practice. Moving forward, these enhancements will be pivotal in transforming the prototype into a robust, user-friendly product that meets the diverse needs of yoga practitioners.

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