Edge AI Powered Offline Workout Helper that runs on QIDK

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1. Abstract

Maintaining proper exercise form is critical to achieving fitness goals and preventing injuries. However, many people struggle to perform exercises correctly without the guidance of a personal trainer. This study presents a novel application that leverages pose detection AI to revolutionize the way users approach fitness.

The app uses advanced pose detection algorithms to analyze users' movements during exercises, providing real-time feedback on form, counting repetitions, and offering personalized suggestions for improvement. By combining the precision of AI with user-friendly design, the application aims to make fitness accessible, engaging, and safe for users at all levels.

The proposed system is designed to operate efficiently on a variety of devices, ensuring scalability and accessibility. This innovation has the potential to transform fitness routines by improving accuracy, promoting consistency, and fostering long-term health and wellness outcomes for users.

At the same time, we are also trying to take advantage of the NPU provided by the QIDK (Qualcomm Innovators Development Kit) that Qualcomm has given us.

2. Introduction

Exercise is a cornerstone of a healthy lifestyle, offering numerous benefits such as improved cardiovascular health, improved muscle strength, better mental well-being, and a reduced risk of chronic diseases such as diabetes and obesity. Beyond its physical benefits, regular physical activity is also known to improve mood, reduce stress, and foster a sense of achievement. However, the effectiveness of exercise largely depends on the correct execution of movements, as improper form not only diminishes the efficiency of workouts but also significantly increases the risk of injuries. This challenge is particularly evident among beginners, who may lack the technical knowledge or physical awareness to perform exercises with proper alignment and technique.

For individuals without access to professional guidance, such as personal trainers or structured fitness programs, the risk of injury and ineffective training is further exacerbated. Misalignment in movements, even subtle, can cause cumulative stress on joints and muscles, potentially resulting in long-term damage. Furthermore, incorrect form often reduces workout efficacy, making it difficult for individuals to achieve their fitness goals and leading to demotivation or even discontinuation of their fitness journey.

Over the years, technology has emerged as a promising ally in promoting physical fitness. Wearable fitness trackers and mobile applications have gained widespread popularity for their ability to monitor activity levels and provide basic insights. However, these solutions often fail to ensure safe and effective exercise performance. Wearable devices primarily track heart rate, SpO2, etc., which may not check important parts like posture. The wearable devices that do can be really expensive. Similarly, traditional fitness applications are limited by their static nature, offering pre-recorded videos or generalized instructions that cannot adapt to a user's unique needs or provide real-time feedback. These limitations leave a gap in the market for tools that combine accessibility, precision, and interactivity to improve exercise performance.

This project seeks to bridge this gap by developing an intelligent fitness application powered by advanced pose detection AI. Utilizing computer vision algorithms, the app is capable of identifying key body landmarks, calculating joint angles, and analyzing the alignment of body segments during movement. This real-time analysis enables the app to provide instant feedback on exercise form, detect deviations from optimal posture, and suggest corrective actions to minimize the risk of injury. Additionally, the app tracks workout progress by counting repetitions and providing insights into the user's performance over time. Its personalized suggestions ensure that users receive personalized guidance tailored to their fitness level and goals, offering a virtual alternative to a personal trainer.

The application is designed to function seamlessly on a QIDK but will also support normal phones because, we have added support for CPU and GPU as well. The base algorithms can also be modified to work on laptops and other personal devices, making it accessible to a wide audience without requiring additional hardware. To address concerns about user privacy, all pose data is processed locally on the device, ensuring that sensitive information is neither transmitted nor stored externally. This privacy-centric approach not only protects users but also builds trust in the technology, encouraging broader adoption across diverse demographics.

The implications of this project extend well beyond the fitness industry. By preventing exercise-related injuries, the app has the potential to alleviate the strain on healthcare systems, which often bear the financial burden of treating avoidable injuries. Furthermore, the app's versatility makes it applicable in areas such as rehabilitation, where patients recovering from surgeries or injuries can benefit from guided exercises, and sports training, where athletes can fine-tune their form for optimal performance. It can also serve as a valuable tool in physical education, helping students learn proper exercise techniques from an early age.

This paper outlines the methodologies and technologies employed in the development of the application, including the underlying pose estimation models, feedback generation algorithms, and user interface design. It explores the challenges and considerations involved in creating a system that balances precision, usability, and accessibility while maintaining scalability for a diverse user base. Additionally, the paper discusses the results of user testing and the broader implications of the application on fitness outcomes, user engagement, and societal health.

By introducing a robust, adaptive and intelligent exercise guidance system, this project aims to set a new benchmark in fitness technology. It empowers users to exercise with confidence, achieve their fitness goals safely and effectively, and ultimately leads to a healthier, more active society.

3. Project Overview

The goal of this project is to develop a proof-of-concept pose detection system tailored for specific exercises such as push-ups, squats, and more. One of the key challenges this system addresses is the impact of muscle fatigue and incorrect posture during workouts.

Improper posture can place excessive stress on certain muscles, leading to overuse injuries, while misalignment can cause uneven joint pressure, resulting in wear and tear over time. Additionally, poor posture during dynamic exercises can increase the risk of falls, sprains, or fractures. Beyond physical harm, incorrect form can hinder progress, causing delayed gains that often dishearten individuals pursuing fitness goals.

This app aims to act as an exercise mentor, offering the benefits of a personal trainer from the convenience of home. With fitness becoming increasingly mainstream, particularly in India, the app provides an affordable alternative for individuals worldwide seeking expert guidance without the high costs of a trainer.

Leveraging the Qualcomm Innovators Development Kit (QIDK), the app analyzes gym postures to help users exercise safely. It monitors movements and delivers real-time feedback to correct form, enhancing results while reducing the risk of injuries. Since all computations occur locally on the user's phone, the app functions seamlessly both online and offline, ensuring user privacy by eliminating the need to transmit live video feeds to external servers.

The system calculates body angles to assess posture, cross-referencing them with optimal angles for various exercises. These angles are derived using the MediaPipe TensorFlow Lite model, which has been trained, converted, and quantized into the .dlc format to harness the DSP/NPU capabilities of the QIDK. This optimization ensures efficient, real-time processing for an enhanced user experience.

For yoga poses, the app includes an advanced identifier that guides users through a series of yoga steps. This feature employs a combination of MediaPipe and a Convolutional Neural Network (CNN) classifier to categorize exercises and poses based on body angles, further broadening the app's functionality.

Additionally, a data collection script was utilized to analyze a wide range of exercise images, identifying all possible angles for each activity. Statistical methods were applied to determine the optimal angles for each exercise, which are then compared to live angles captured through the video camera. This approach ensures precise feedback and reinforces the app's role as a comprehensive exercise mentor.

By integrating cutting-edge technology with a user-focused design, this app represents a significant step forward in making fitness safer, more accessible, and effective for users worldwide.

4. Weekly Progress

This is a week-by-week analysis of the steps we took to get to this result and the challenges we faced along the way.

4.1. Week 1

In the initial week, our focus was on understanding the working of the QIDK and the Snapdragon Neural Processing Engine which we needed to use to run the model on the QIDK. We setup the SNPE in all of our laptops and ran several examples through which we were able to familiarize with its working. However, we reached a roadblock early on, as many examples had limitations or were outdated. For example, the Pose Estimation example on the QIDK referenced libraries were not working properly. However, we were able to fix some of the errors and run that. Subsequently, we tested models like YOLO NAS and HRNET to evaluate the QIDK's capabilities and explore potential projects that could leverage its features effectively.

4.2. Week 2

In week 2, we finalized our project topic as "QIDK based Posture Analysis and Rep-Counter for the Gym" which we thought was a really good way to utilize the edge capabilities of the QIDK effectively. We read through research articles regarding pose estimation at this point of time and learned about different pipelines and approaches used by others to develop similar applications.

We set up trial examples using Python on our computers so that we could train and test models easily in the beginning. We tried various models like HRNET, YOLO NAS, Mediapipe and their different versions to find out which model would be best for our specific use case.

After thorough evaluation, we decided to go with Mediapipe Pose Landmark model as it was one of the smallest and efficient enough models provided by Qualcomm AI Hub which could easily run real time analysis on video feed from the camera module. The Mediapipe Pose Landmark also gave us the additional advantage of getting (x,y,z) coordinated with a visibility ratio (confidence) which made it easier for us to calculate angles.

4.3. Week 3

We gathered a dataset of gym images from the internet for analysis and classification. However, some images presented challenges due to poor lighting, which affected the app's performance, and suboptimal viewing angles, which skewed the angle values recorded by the model.

To address these issues, we supplemented the dataset with photos of ourselves performing the exercises. These additional images helped improve the accuracy of the recorded angle values and provided valuable insights into the specific angles we needed to monitor while developing the final app.

The curated angle dataset is available in our GitHub organization repository, linked at the end of this document.

4.3.1. Limitations of the initial dataset:

- Poor camera angles.
- Low-quality images.
- Lack of frontal views.
- Incorrect or skewed angle values.

4.4. Week 4

In the fourth week which also marked our mid-evaluations, we successfully implemented a Python app on our computer which was able to showcase the various features which we were trying to implement on the QIDK. We set up and had models working for push-ups, curls, squats and planks. This was a proof of concept of the different ways we had to interface with the models because it would get harder to test these models once they were converted to tflite and used through a mobile app.

Model training took quite a long time on our computers and we had to use Google Colaboratory to render some of the models.

Now the only part left was to convert this app into an android app which was a huge mountain that we had to climb over the next five weeks.

The code for this can be found in our github organization repositories.

This is the link to our mid-evals presentation: Presentation

4.5. Week 5

In this week, we started our work on the Android app which had its own set of problems. The documentation given by Qualcomm was very difficult to implement the instructions properly, especially the section on running the model. The provided project was outdated, and the pre-trained model supplied did not generate the correct output vector, leading to significant delays. We spent the entire week troubleshooting and trying to get the system to work correctly.

4.6. Week 6

With the foundation in place, we ported the Mediapipe Pose Landmark Model onto the QIDK. This required converting the TensorFlow Lite model into the .dlc format to leverage the QIDK's DSP/NPU for efficient computation.There were compatibility issues between Mediapipe's libraries and the SNPE framework. we also had to fine-tune the model's execution to ensure real-time processing on the QIDK hardware. By the end of the week, we successfully integrated the model and verified its ability to run pose detection in real-time on video input.

4.7. Week 7

In the seventh week, we implemented a feedback mechanism for real-time posture correction. The app was designed to:

- Detect deviations from the optimal posture.
- Provide corrective feedback through audio cues and on-screen prompts (e.g., ”Straighten your back.or .Adjust knee angle”).

The feedback logic was derived from the angle thresholds defined earlier. This required rigorous testing to ensure the system's reliability across various exercises and body types.

4.8. Week 8

In the eighth week, we conducted testing under various conditions:

- Environmental Conditions: Tested the app's performance in diverse lighting and background scenarios.
- User Diversity: Invited participants with different body types to validate the angle thresholds and feedback accuracy.

Based on the test results, we optimized the app for edge-case scenarios, including low-light conditions and overlapping objects in the background.

4.9. Week 9

In the final week we began wrapping up the project making minor changes to improve the quality of the app's UI and started collecting the resources we refered to. We recognized the mistakes we had made along the development procedures and reevaluated the methods we had used during our pipeline.

5. The Final Product

Gymify is a fitness companion designed to help users maintain proper form during exercises, significantly reducing the risk of injuries. By leveraging advanced pose estimation technologies, Gymify ensures real-time analysis of posture, enabling users to perform workouts with correct alignment and efficiency. Additionally, the app features a highly accurate repetition counter, focusing on quality over quantity to maximize workout benefits.

Key Features:

- **Real Time Posture Analysis:**
  - Continuous monitoring of the user's form during exercises using pose estimation models..
  - Provides instant feedback to correct misalignments, ensuring that exercises are performed safely and effectively.
- **Reliable Repetition Counter**
  - Tracks the number of completed reps with a focus on correct posture.
  - Filters out improperly executed reps, promoting better workout habits.
- **User-Friendly Interface:**
  - Intuitive design allowing users to easily navigate through exercise modes.
  - Real-time visual feedback with clearly marked posture corrections and rep counts.
  - Configurable options for various exercises like push-ups, squats, curls, and planks.
- **Offline Capabilities:**
  - Designed to function without constant internet access, ensuring privacy and reliability.
  - All processing is handled locally on the device, leveraging the QIDK's edge computing capabilities.

Applications:

- Personal fitness tracking and improvement.
- Gym environments to assist trainers in monitoring multiple clients.
- Rehabilitation centers to ensure patients maintain proper form during recovery exercises.
- Home fitness setups for individuals seeking guided workout assistance.

While the current version of Gymify focuses on posture analysis and rep-counting for gym exercises, its modular design allows for future expansion.

Future Improvements

Broader Exercise Coverage

1. **Support for Additional Exercises**: Extend the app's capabilities to cover a wider range of workouts, including advanced gym exercises and weightlifting techniques.
2. **Multi-User Tracking**: Incorporate functionality to track multiple users simultaneously, making the app suitable for group fitness classes.
3. **Custom Exercise Plans**: Allow users to design personalized workout routines with real-time guidance and progress tracking.

Software and Algorithm Improvements

1. **Enhanced Posture Detection Algorithms**: Leverage advanced AI techniques for more accurate skeletal tracking and form correction.
2. **Adaptive Feedback System**: Implement a feedback mechanism that adapts to the user's skill level, offering more personalized guidance.

Additional Features

1. **Gamification**: Add elements like badges, leaderboards, and challenges to motivate users and increase engagement.
2. **Integration with Wearables**: Sync with smartwatches or fitness bands to collect additional metrics like heart rate and calories burned during workouts.
3. **Augmented Reality (AR) Integration**: Use AR to project virtual trainers or highlight posture corrections directly in the user's environment.
4. **Social Sharing**: Allow users to share their progress and achievements on social media platforms directly from the app.
5. **Nutritional Recommendations**: Provide diet and hydration tips tailored to the user's workout routine and goals.

6. Editors' Notes

This section summarizes the key experiences, learnings, and outcomes gained by the team throughout the course. It outlines how each member developed both technical and collaborative skills, highlighting the growth achieved through hands-on project work and problem-solving.

6.1. Adithya Kishor

Working on this project has been a remarkable learning experience, helping me grow both technically and in terms of teamwork and communication. Developing a real-world gym posture correction system was both a challenging and rewarding endeavor.

One of my key contributions was building models that could be integrated into the app. I also developed an ONNX pipeline for classification, achieving 90

Additionally, my work on this project played a significant role in helping our team win Megathon 2024. The experience taught me the value of innovation, collaboration, and persistence. It also reinforced my passion for applying technology to solve practical problems. I am proud to have been part of this journey and excited to carry these lessons forward into future endeavors.

6.2. Evan Bijoy

This project has been a great learning experience, helping me grow both technically and in teamwork and communication. As someone who cares about user experience and design, working on a real-world gym posture correction system was an interesting challenge.

One of my significant contributions was designing and building the user interface (UI) dashboard. I focused on creating a simple, intuitive experience for users, abstracting away the technical complexities while ensuring the functionality was easily accessible. This involved not only crafting a visually appealing and user-friendly design but also integrating real-time feedback mechanisms, enabling users to see posture corrections and statistics dynamically. Achieving this balance between simplicity and technical depth was both challenging and fulfilling.

From a technical perspective, this project pushed me to explore areas beyond my initial expertise. I worked closely with motion tracking algorithms and integrated them into the interface, enabling real-time pose analysis. Leveraging tools like Google MediaPipe, I learned to process pose landmarks and apply custom logic to detect and correct gym exercises such as bicep curls. This involved extensive work with geometric calculations to derive angles, measure joint movements, and identify improper form, ensuring feedback was accurate and actionable for users.

When joining IIIT Hyderabad as a Computer Science student, I had never expected I would be exposed to this level of in-depth practical electronics work, not to mention research. Working on this project taught me how design, research, and technology come together to create meaningful solutions. It improved my teamwork and communication skills and reinforced my passion for user-centered design. I am proud to have contributed to the team and am excited to carry these lessons forward.

6.3. UdithKrishna M Nair

This project has been a transformative experience, allowing me to grow as a computer science student and apply my skills to solve real-world problems. Developing a gym posture correction system for Android was both a technical challenge and an opportunity to make a meaningful contribution to the fitness community.

My primary contribution involved developing an Android application that leverages live camera feed integration for real-time inference. A key aspect of this development was deploying deep learning models optimized for execution on Snapdragon NPUs (Neural Processing Units). By utilizing the computational power of Snapdragon NPUs, I was able to achieve significant improvements in processing speed and energy efficiency, enabling the app to perform real-time pose detection and analysis without compromising the user experience.

6.4. Sidharth K

This project has been an opportunity to grow as a computer science student and apply my knowledge to solve real-world problems. Developing a gym posture correction system has been both a technical challenge and a chance to contribute meaningfully to the fitness community.

This project holds a deeply personal significance for me, as I have firsthand experience with the challenges and pain that can arise from incorrect form during gym workouts. My own struggles with improper posture and form during exercises not only led to discomfort but also hindered my progress, making it difficult to achieve my fitness goals. This project became an opportunity to channel those experiences into creating a solution that could help others avoid similar issues.

My primary contribution was in training the model to recognize and analyze various exercises like planks, This involved curating a diverse dataset, training pose detection models using MediaPipe, and fine-tuning them to ensure high accuracy across different users and environments. I developed Python scripts to analyze and provide feedback on proper plank posture and other exercises, leveraging my technical skills to address a real-world challenge in fitness. The scripts are built to analyze real-time pose data using tools like Google MediaPipe, which extract body landmarks for posture assessment. I created algorithms to calculate joint angles, track alignment, and detect deviations from the correct form. For example, while analyzing a plank, the script measures the alignment of the shoulders, hips, and ankles to ensure the user maintains a straight line, providing immediate feedback if the hips sag or the back arches. Achieving a balance between precision and adaptability was a rewarding challenge, as it directly impacted the system's usability and reliability.

7. References

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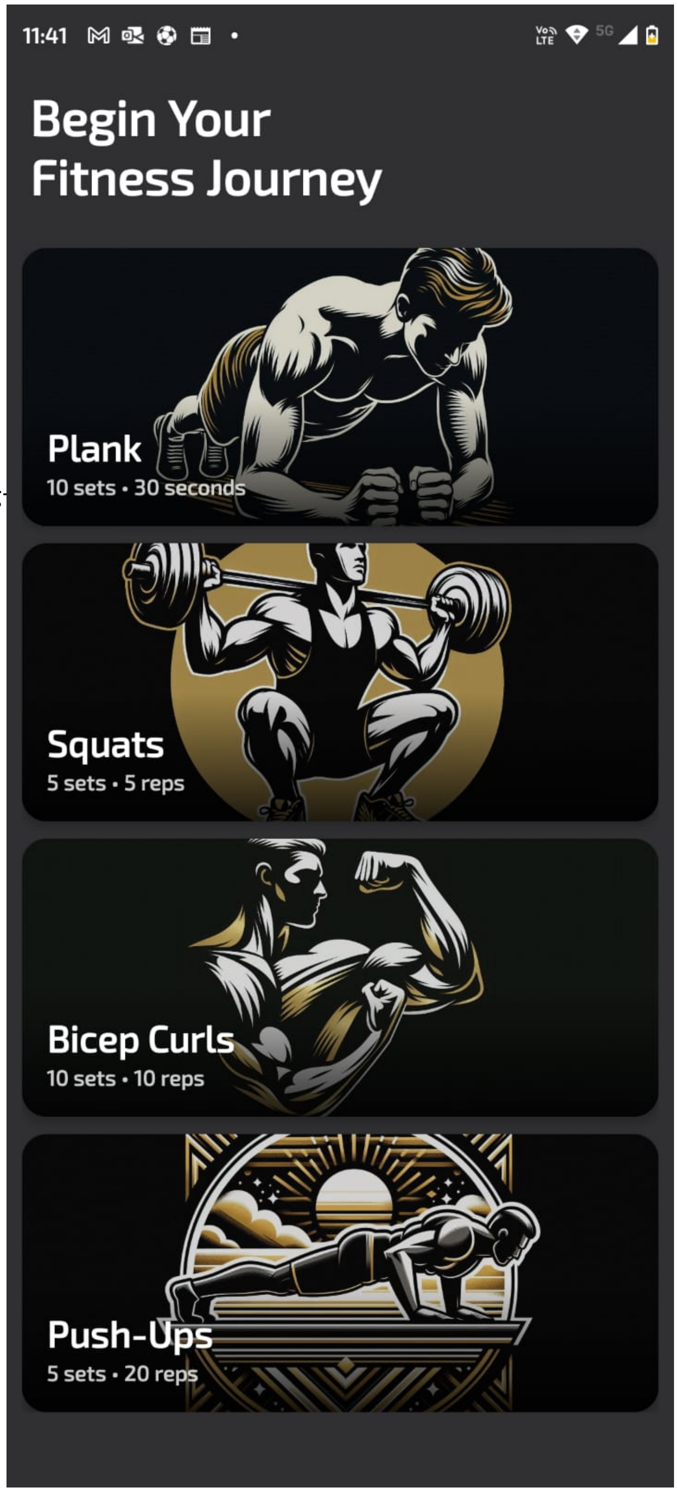

Figura 1: Dash Board