# Real-Time Detection of Repetitive Movements using Smartphone Cameras

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## 1 Research Objective

We propose to leverage smartphone-based cameras to detect repetitive movements, conducted during physical workouts, in real-time. Using object detection methods in an athletic environment can prove to reinforce health records and individual physical fitness; while helping to combat fitness-related injuries. These enhancements have become more of a necessity as the number of people who participate in physical activities increases [6]. **This research directly aligns with NASA's mission and fits within the scope of the Human Exploration and Operations Mission Directorate.** The proposed research maintains continuity between exercising within the constraints of earth gravity as well as in the weightlessness of orbit. With tether-like restraints and webcams, astronauts in the International Space Station (ISS) could potentially utilize our system to keep physically fit; while refraining from injuries and misinterpretation of athletic progress.

## 2 Introduction

Until recent years, athletes have relied on themselves, and those around them, to assess the correctness of their movements and log their progress. However, this practice leaves room for error and can potentially lead to overload or form related injuries. Personal trainers and coaches can aid such assessment but are often costly and are not guaranteed to help amateur fitness enthusiasts. An automated approach to monitoring exercise movements can help athletes improve their form, prevent injuries, and efficiently track their progress. Such a technique would not only reduce the number of injuries caused by improper form but could also accelerate performance.

Existing systems require additional equipment such as wearable inertial sensors, chargers, and mesh casings [5]. However, these additional sensors are expensive, and

can add to the user's cognitive load by forcing them to remember to carry and charge an additional device. Our proposal consists of a smartphone camera-based application that monitors exercise movements and computes performance metrics in real-time. Our system attempts to bridge the gap between usability and cost by being tailored towards the needs of the user. It provides exercise analysis using only the user's smartphone and is a low-cost scalable solution for users to track their physical activity in any setting.

# 3 Investigation

Figure 1 shows the logical flow of the proposed solution. Our prototype will be built on the Android operating system. An application will utilize the smartphone's camera and process live video feed. As incoming frames are captured and displayed to the user through OpenCV (a computer vision API) [3], an object detection classifier trained through TensorFlow Lite (a machine learning API) [4] will detect workout equipment in the camera's view.

The athletic equipment, i.e., a barbell, is then detected in subsequent frames and its positions are recorded. Multiple bar positions exhibit peaks and troughs in a series of data and are crucial to identifying repetitions [6]. Troughs, or local minima, appear as the user begins to raise the barbell and peaks, or local maxima, appear as the user starts to lower the barbell. A pair of troughs and a single peak are used to represent a repetition. The time between the first trough and the peak represents the user's lifting duration; while the distance between these two identifiers represents the user's lifting range of motion (ROM). On the other hand, the time and distance between the peak and the second trough are used to represent the users lowering duration and ROM respectively. Then, using the metrics generated for ROM and duration, we can calculate how fast the user was lifting or lowering the workout equipment.

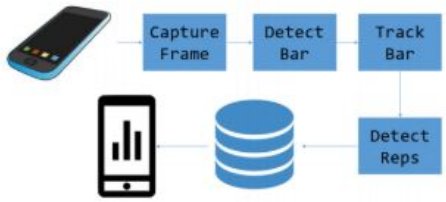


Figure 1: System Overview

Additionally, we propose to use pose estimation frameworks [2] to accurately determine the user's posture and provide feedback on their form. As users perform repetitions, the model tracks the positions of their hands, shoulders, and elbows [1]. These positions are then evaluated to determine the correctness of the user's movements by calculating a difference in the locations of these joints on both sides of the users body. A percent value representing this information can help us detect not only incorrect form, but also symmetry between motion conducted by the user's arm.

All metrics related to each rep, including ROM, duration, and velocity are then added to each workout and stored in an online database as well as the phone's storage. The computed values are then queried and the application displays the users athletic

history through a workout-wise graphical representation. Over time, multiple workout summaries will serve as a progress report, giving the user insight into their physical progression in an attempt to account for all development and help prevent any injuries.

# 4 Conclusion and Future Work

This application is a cost-effective, scalable solution that relies on commercial off-the-shelf smartphones to allow users to gather and visualize workout analytics. In hopes of furthering fitness tracking, preventing injury, and aiding in physical development at a lower cost, this application allows the user to access all of their movements, along with a detailed analysis of the workout down to each repetition.

In the near future, after refining the data analytics and detection algorithm, we aim to extend the system to a wider range of workouts for the user to record and analyze. Our application will eventually give the user the ability to share a selected session and its analysis as well as their progress over a specified amount of time through social media platforms. Eventually, the application will incorporate voice assistants that provide audio feedback to the user, much like a personal trainer, in order to correct form related issues in real-time. We hope to see our application being used not only by athletes, but also in physical therapy. Improving such an application could help users enhance their performance over time and potentially prevent patients from enduring any further pain.

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