Analysis and recognition of CrossFit movements from data from inertial sensors

One page review

1 Introduction and Objectives

This project, in partnership with the French company **Bravvo**, aims to simplify an athlete-support app by removing the need for manual input on the Apple Watch. The goal is to automate exercise tracking without requiring users to count reps, enter data, or control sessions manually.

To this end, we developed and evaluated algorithms with two main objectives:

1. **Classify** twelve types of exercises using 3-axis acceleration and absolute altitude data.
2. **Count** repetitions for each identified exercise.

The final goal is to ensure smooth, end-to-end workout tracking—detecting both activity and rest periods while accurately counting reps.

2 Data acquisition

The dataset was collected from three individuals, each performing the twelve exercises once while wearing an Apple Watch that recorded 3-axis acceleration at 100Hz. One person also performed a WOD (Workout of the Day), a circuit of three exercises repeated twice without rest. The expected number of repetitions and the WOD exercise order were provided separately. Figure 1 shows sample push-up data (10 reps), with measurement index on the x-axis and acceleration (in g) on the y-axis.

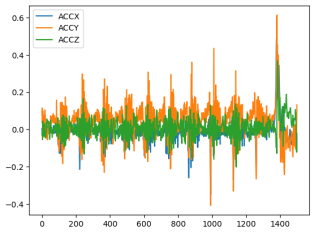

Figure 1: Example of acceleration data captured during pushups.

3 Methodology

Basic statistics were used to compare exercises and athletes, identify relevant data parts, and guide method selection.

3.1 Counting repetitions

The implemented repetition counting process consists of three steps:

1. **3-axis low pass filter**: smooths raw acceleration data by removing high-frequency noise.
2. **PCA**: reduces the filtered data to its main component for simplification.
3. **Basic thresholding**: counts repetitions by detecting signal crossings over a set threshold.

3.2 Classification on the WOD

The WOD classification involves three steps:

1. **Windowing and labeling**: segmenting the data and assigning exercise labels.
2. **Feature extraction**: computing relevant linear and non-linear features from each window.
3. **Using a Random forest algorithm** (n=100): A classifier is trained on the labelised data in order to try it on the WOD.

4 Results

4.1 Counting repetitions

Exercise	RMSE	Exercise	RMSE
Box jump	0	Power snatch	0.58
Burpee	0.75	Pushups	2.16
Deadlift	0.816	Strict pull up	1
Double unders	10.89	Thruster	0
Front squat	0.57	Toes to bar	8.34
Power clean	0.87	Wall ball	4.655

Table 1: Exercise values

The repetition counting method relies on peak detection, which can struggle with irregular or noisy acceleration curves. As a result, it may fail on certain exercises or vary between athletes. For example, the wall ball exercise gave incorrect results only for one athlete.

4.2 Classification on the WOD

Clear differences are found between exercises. Push-ups detection seems lacking compared to the rest. This can be explained by the differences between the training data and the test data. In order to have better results, the model needs to be trained on a wider variety of pushups.

Exercise	Accuracy	Exercise	Accuracy
Push ups 1	0.94	Box jump 2	0.96
Power clean 1	0.79	Push ups 3	0.34
Box jump 1	0.95	Box jump 3	1
Push ups 2	0.34	Power clean 3	0.71
Power clean 2	0.82		

Table 2: Accuracy by exercise (split view)

Possible global improvements: use rotational acceleration data aswell, detect break times in workouts.