Workcount Applciation Specifications

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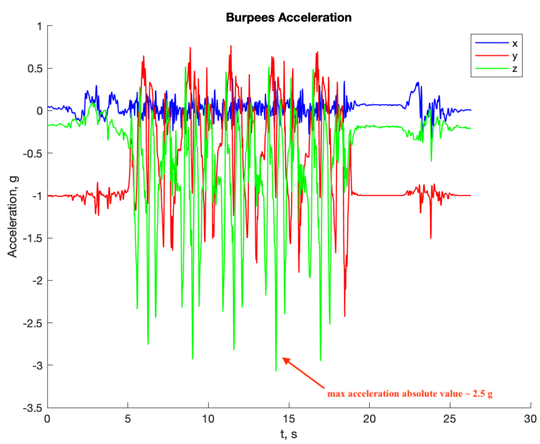
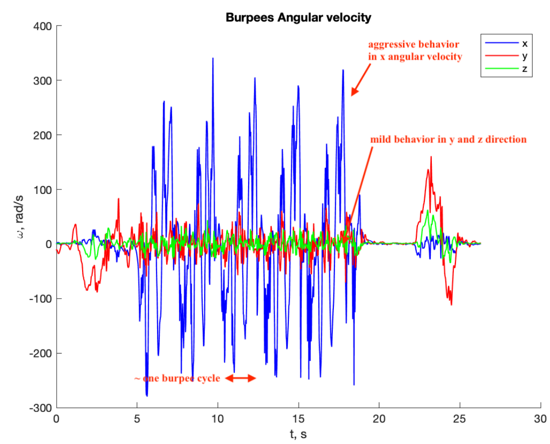
Summary

The ***Workount*** is designed to help people to collect data from their daily workouts. With a gyro and a 3-axis accelerometer installed, the product can do number counts on movements such as burpees, lunges and pushups during a workout series. Ideally, it can distinguish different features from the data and correctly deduce the workout type as well as give the total counts of the workout.

Raw data collection and analysis

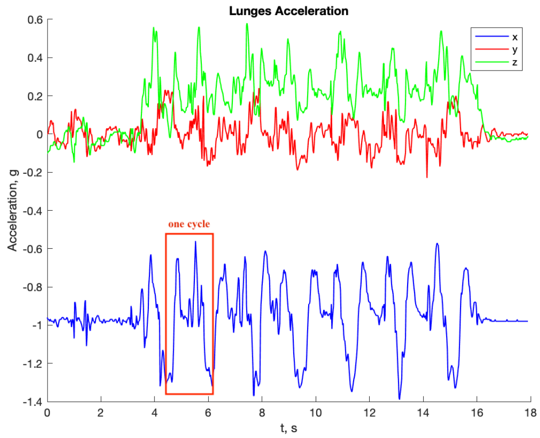
We will analyze three sets of data, for basic workouts - burpees, pushups and lunges. Using PocketLab, the 3-axis accelerations as well as the angular velocities data are collected.

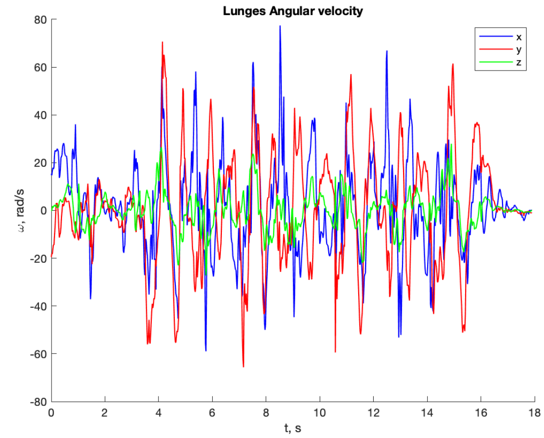




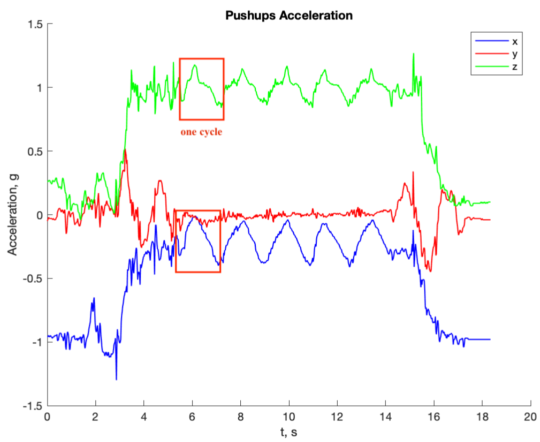
The above data were collected for five burpees. As we can see, the accelerations for the burpees are very aggressive. The z axis has a maximum abusolute value above 2.5g, which is a very distinct feature (compared to other two sets of accelerations). And we can also see that there is maximum angular velocity of around 200 rad/s.

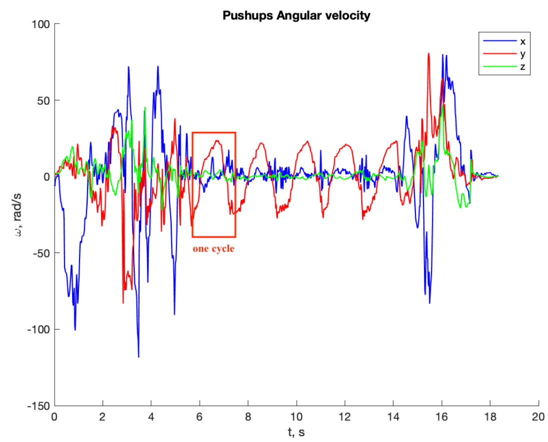
And note that for x axis, it has aggressive behavior in angular velocity while it does not change too much for acceleration. And for y and z axis, while they behave aggressively in acceleration data, they are less aggressive in angular velocity, which is a good way to distinguish the burpees from other motions.





The above data are collected for lunges. The angular velocites for lunges do not have very distinctive patterns. However, we can see distinctive behavior in the acceleration data. We can see distinctive periodic pattern in the x direction.





The above data are collected for five pushups. We can see periodic behaviors in both acceleration and angular velocities, which is a good way to distinguish pushups from other motion.

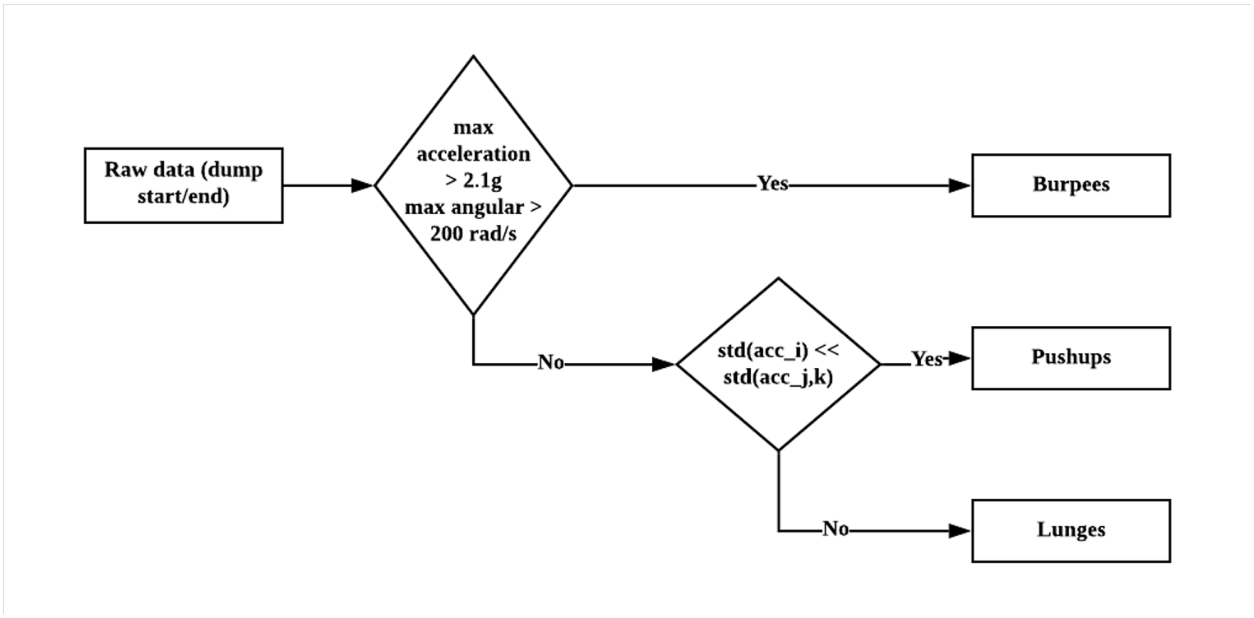
Data processing: methodology

For this application, we need to complete two major tasks:

Categorize motion types

Based on the intial analysis of the raw data, we can easily distinguish burpees from other two motions based on the maximum absolute accleration as well as the maximum absolute angular velocity.

To distinguish pushups from lunges, we can search for periodic behaviors. If periodic behaviors are detected from both accleration and angular velocity, then the motion is pushup. If not, then the motion is lunges. Also, another more "crude" way of distinguish pushups and lunges is to see whether one of the axis has the smallest standard deviation. Since while doing pushups, the body is in a steadier posture, the standard deviation of one of the axis can be comparatively small. We can see from raw data that while doing pushups, the y axis acceleration standard deviation is very small compared to the data of lunges.

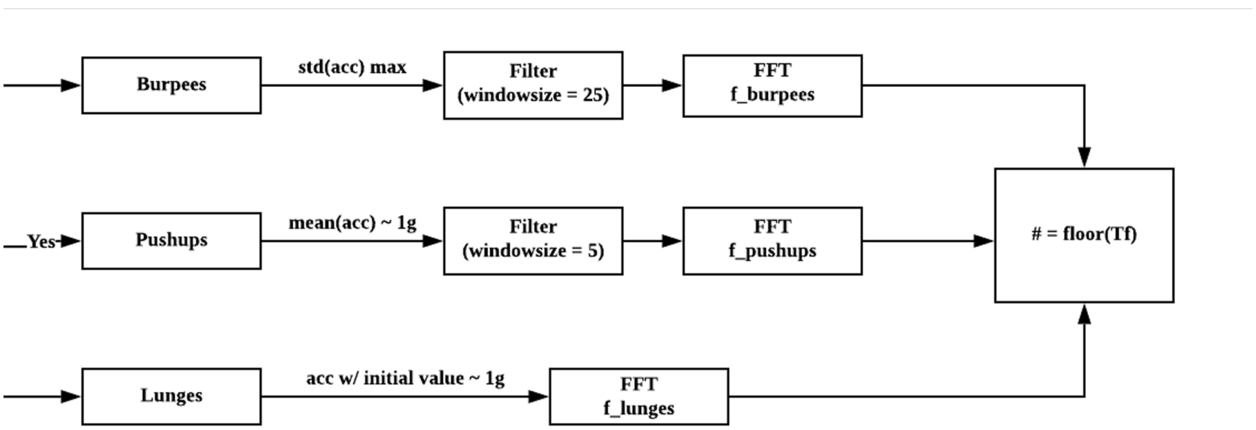


Count cycles

To determine periodic behavior, we can perform FFT to the data to see the primary frequency. If the primary frequency is under 1 Hz, which means that there are periodic behavior which has a period greater then 1 second, then it is highly likely that this frequency represents the motion frequency, which we can use to determine the period T of the motion and then determine the counts of the motion being performed.

Note: we will assume that the data collected (time length) is long such that we can cutoff a few seconds at the start and the end of the data stream while not dirupting the data features.

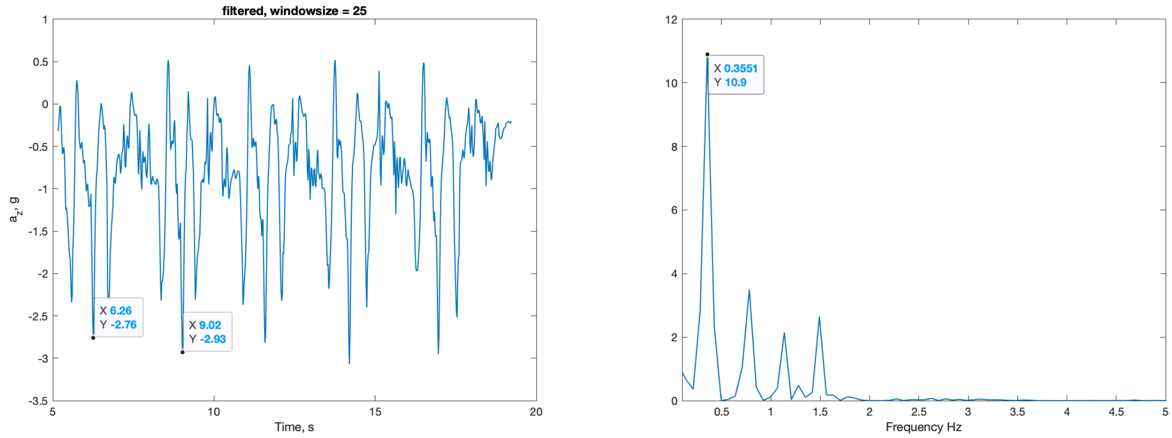
For different motions, we will use different algorithm to count the cycles. However, the basic idea is the same - finding periodic behavior. See the flowchart below.



Data visualization

In this section, we can verify the methodology by applying the procedures above on the sample data we collected to see whether the method is feasible in an ideal situation.

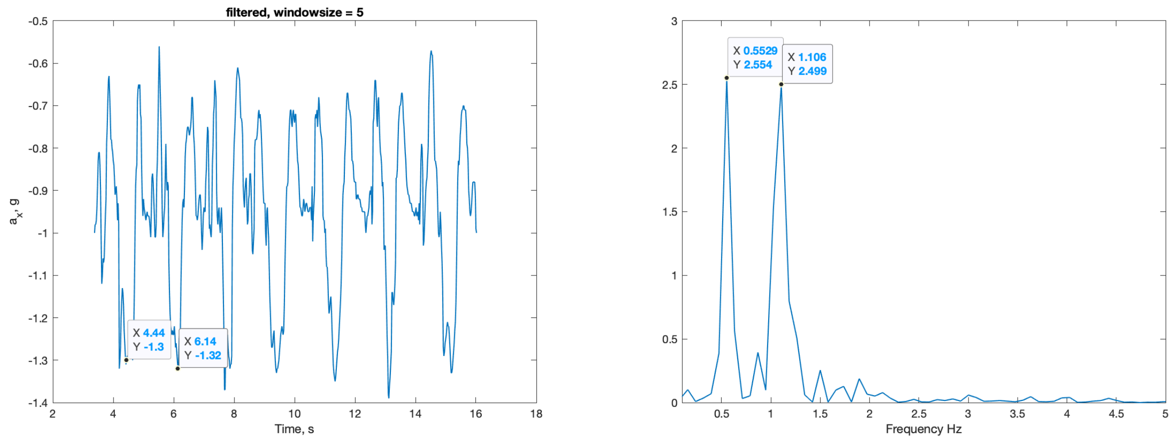
Burpees



The primary frequency is $f_{burpees} = 0.3551\ Hz$ and the time length is $T = 14.1$ s. Therefore, the burpees count is,

$$\#_{burpees} = floor(T f_{burpees}) = 5 \tag{1}$$

Lunges

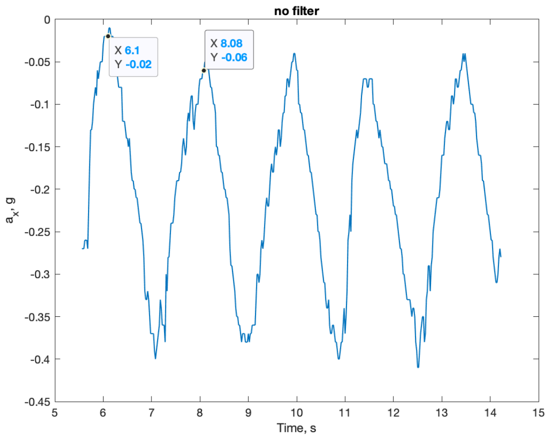


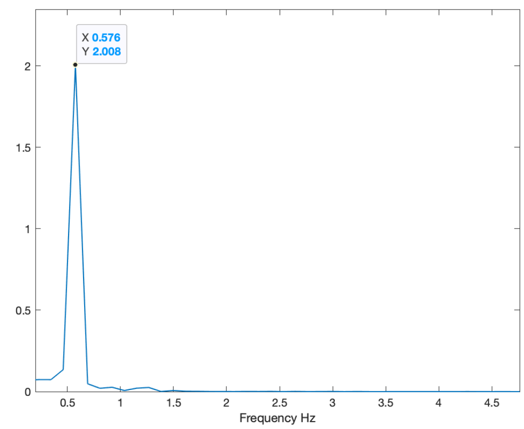
From the FFT diagram, we can see that the primary frequency f_1 and f_2 have a relationship that $f_2 \approx 2f_1$, which is a distinctive feature of lunges as well. So the frequency we are interested in is $f_1 \approx 0.5529\ Hz$. With a $T = 12.7$ s, we have,

$$\#_{lunges} = floor(T f) = 7, \tag{2}$$

which is the exact number of lunges we performed. (ideal situation)

Pushups





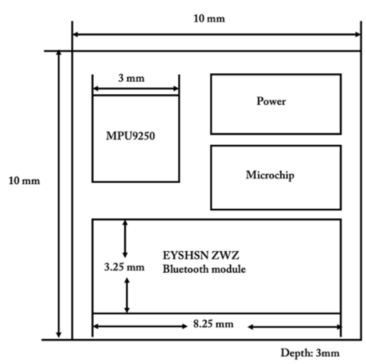
As we can see, pushup motions have only one primary frequency $f_{pushups} = 0.576\ Hz$. With $T = 8.7$ s, we have,

$$\#_{pushups} = floor(T f_{pushups}) = 5 \tag{3}$$

As we can see, from the sample data, the method we used is feasible.

Proposed architecture/System design

Since this is a device recording the acceleration and angular velocity of the body, it is wearable and mounted near the body center. It can be "pinned" to the waist area (preferrably at the back) to ensure that it measures the major movements of the body instead of the limb motion, which can be very different from one person to another.



As we can see from the mechnical design, since the device is very small, it can be easily clamped or pinned onto the waist area.

Datasheet specification

# error	(based on how much data we dumped and data collection duration)
Time length	$T > 1$ min to be conservative

Explanation in **Source of errors** section.

Source of errors

Since the output of the device is simply the workout types and the number of counts, the most important issue to correctly calculate the period of each motion. Therefore, the data stream we collected cannot be too short. Also, since we have dumped some of the start and end of the data stream to conservatively maintain the data features (period, frequency...), it is highly possible that we have dumped useful data so # of count errors depends on how much data we decide to dump. Consequently, the measurement time length is set to be greater than 1 minute.

Also, since different persons have different workout habits and the device is only tested on one person, it is highly likely that the data process procedure should be adjusted based on multiple test subjects.