VIRGINIA TECH

Calculation of Field Goal Percentage using Acceleration Data

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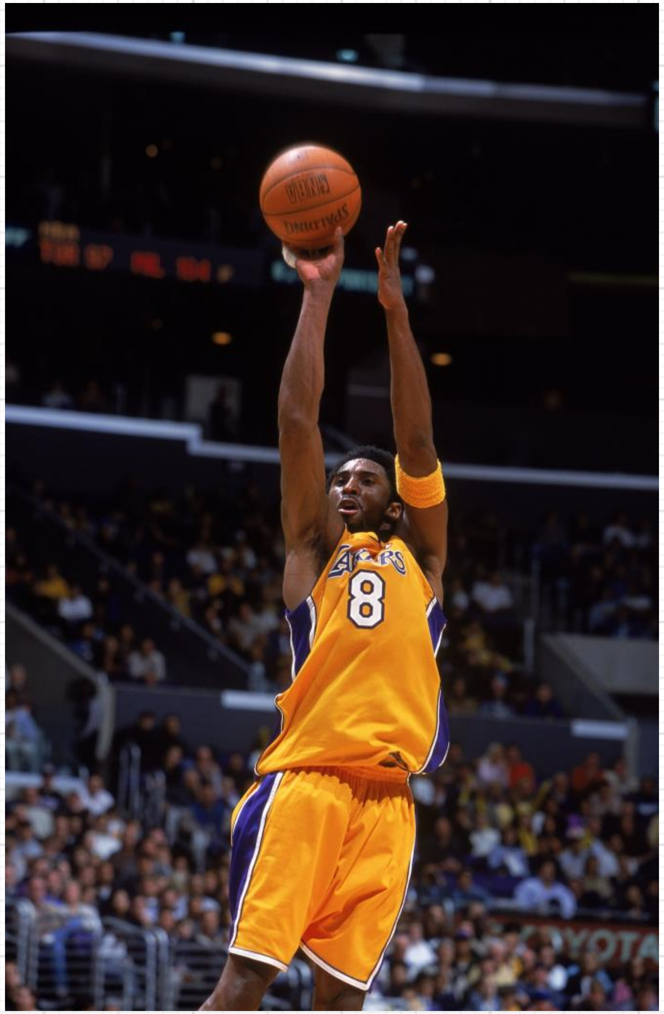
Overview

1. Test Objective, Setup & Procedure
2. Shot Detection
3. Shot Classification

1. Test Objective, Setup & Procedure

The goal of the project is to determine the field goal percentage of a basketball player for a single shooting session

- Objective: create a low cost, simple way to determine FG%
- Allows player to focus on their shooting form rather than counting shots
- After a shooting session, will tell player their field goal percentage
  - FG%(shots made/shots taken)
  - 40% (400/1000)
- Goal: achieve 5% error in FG%



The LSM6DS3 3D digital accelerometer was mounted at the base of the rim in a protective case

- Sample rate: 208 Hz
- Acceleration was measured in 3 directions
  - X = longitudinal
  - Y = lateral
  - Z = vertical
- 10, one minute long shooting sessions were recorded
  - A total of 108 shots were taken
  - Videos were recorded to determine if shots were made or missed
- Hoop characteristics:
  - Chain net
  - Short longitudinal distance to base
  - Small, metal backboard
- Currently not employed in real time

Triaxial accelerometer installed on a hoop, on the underside of the rim

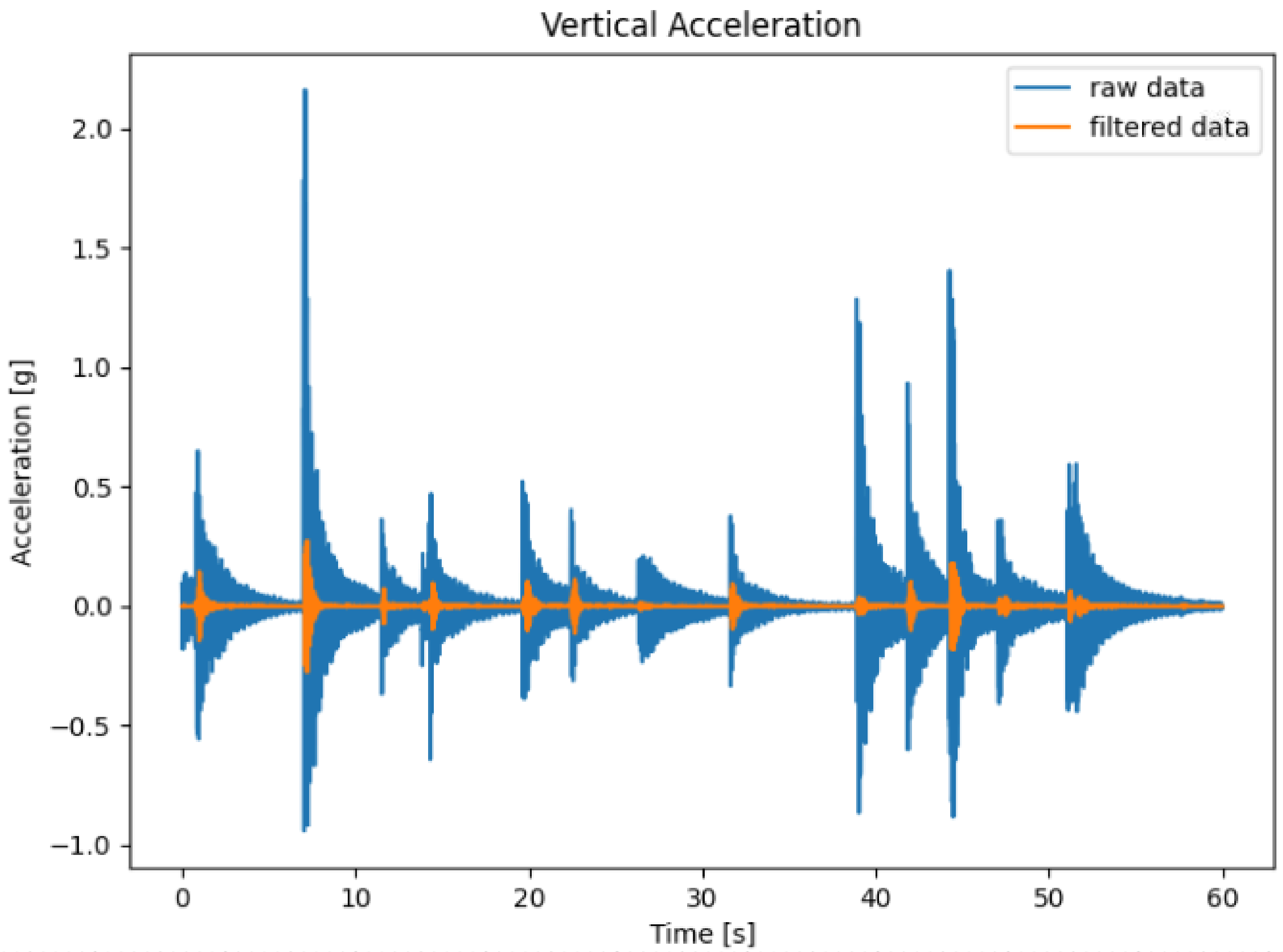
Multiple assumptions were made to facilitate data analysis

- Air balls will not be considered shots
- The system must be installed with prior knowledge of the hoop
  - The filters and thresholds must be adjusted for each hoop
  - Different hoops will have different vibration characteristics depending on materials, height, and other factors
  - Only 1 hoop will be used in analysis

2. Shot Detection

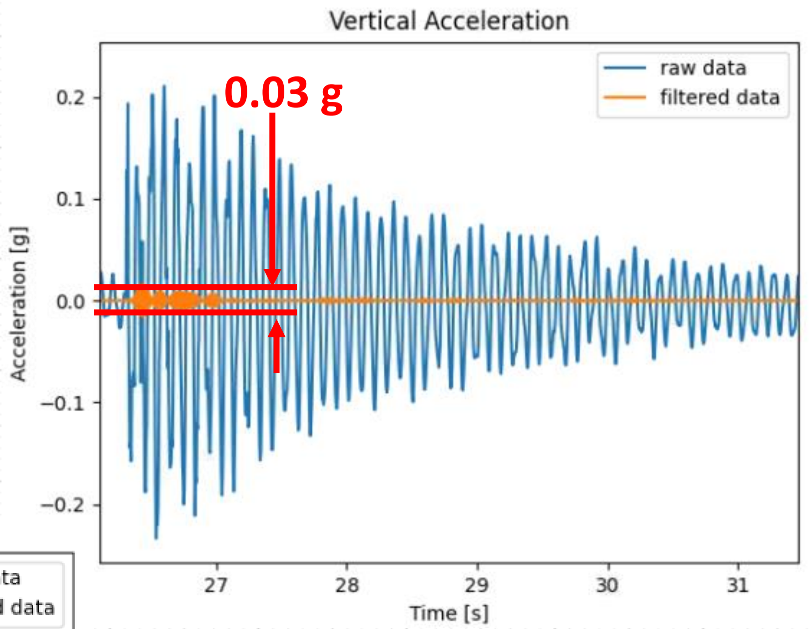
Shot detection was first attempted using the high-pass filtered data

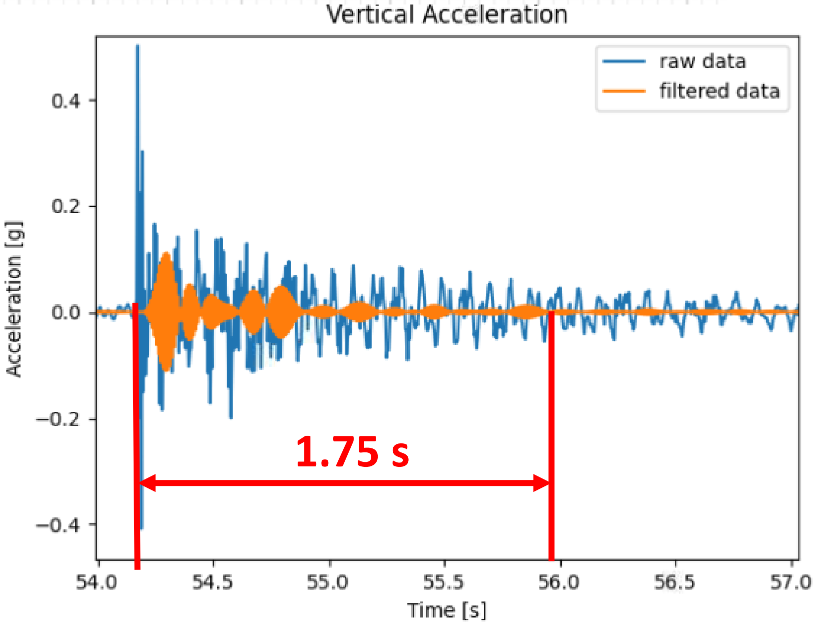
- A high-pass filter was utilized as an edge detector
  - 5th Order Butterworth, break frequency = 99 Hz
- Peak height and the distance between peaks were used to determine when a shot was taken
- If there are errors, missed shots are desired over additional shots



Shot detection was first attempted using the high-pass filtered data

- Small, short signal peaks are difficult to detect



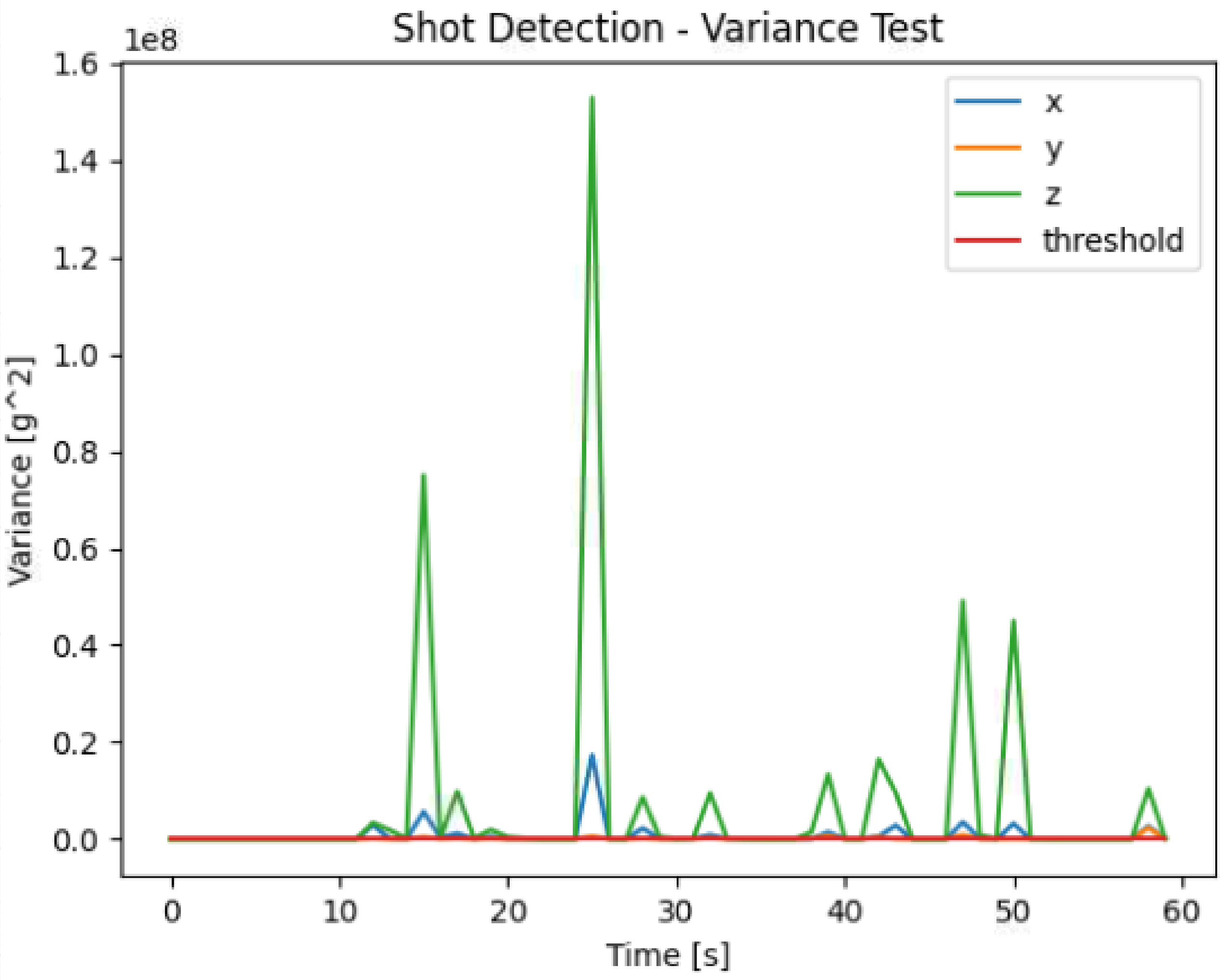


- Long peaks or shots with multiple peaks are difficult to detect only once

- Difficulties using this method:
  - Oscillations in the data make it difficult to create parameters to define shots
  - Shots that induce small vibrations are undetected
  - Shots that attenuate slowly will be detected as two shots rather than one
- Results: **101/108 shots detected correctly**

The number of shots was determined using change in variance event detection techniques

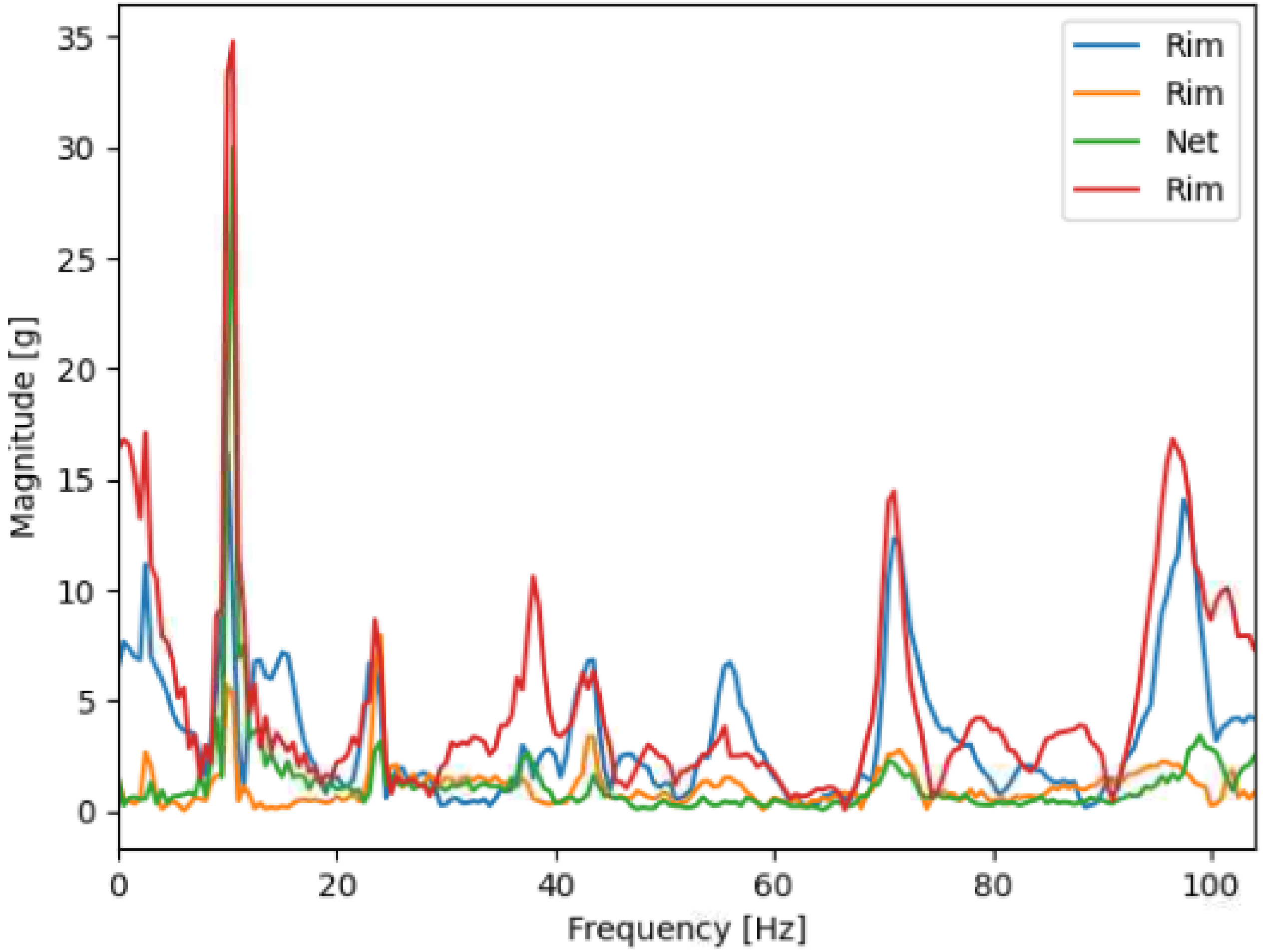
- High-pass filtered data was used for event detection
- Acceleration in all 3 directions was used
  - The direction with the largest number of shots was used
- N = 208 (1 second of data)
- β = 3.0 (1% chance of false detection)
- Results: **107/108 shots detected correctly**
  - The single missed shot was clipped by the end of the data set



3. Shot Classification

The FFT of each detected shot was calculated to determine the frequencies of interest

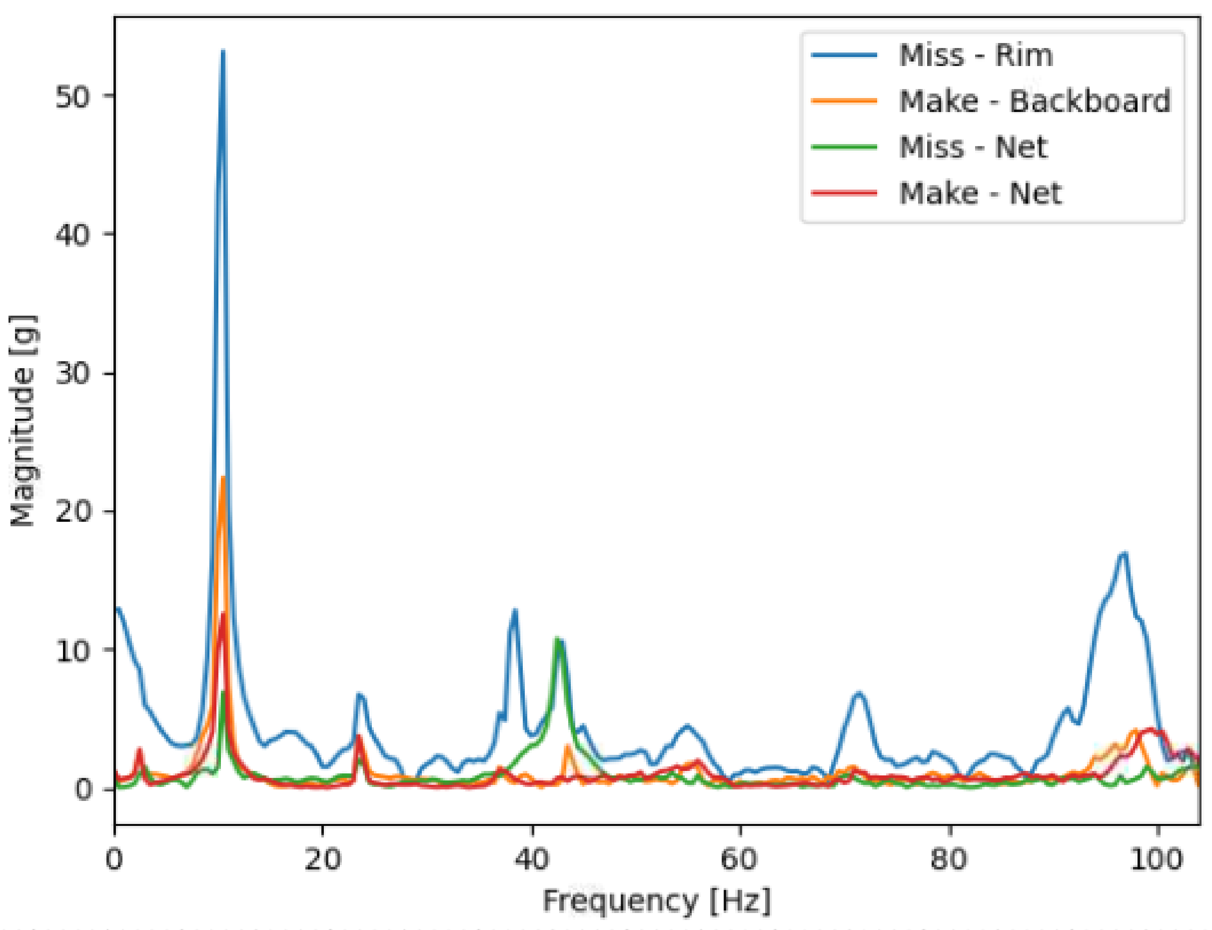
Z-Acceleration FFT comparison of 4 made shots



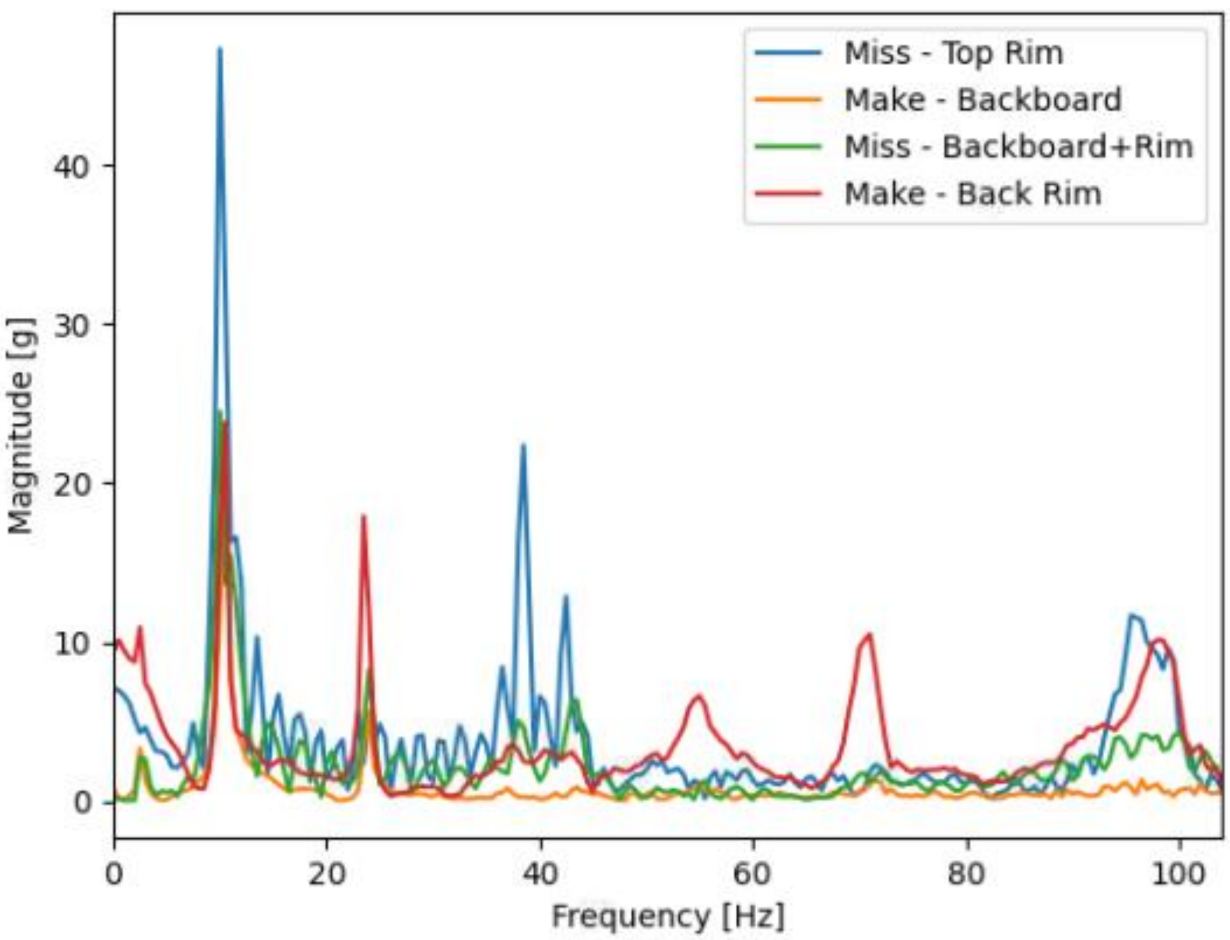
- Unfortunately, the comparison of the FFTs of individual shots were unclear, with many conflicting frequencies and trials
- No specific frequencies of interest for the net could be determined

There are no obvious frequencies of interest that could be isolated to classify shots

Z-Acceleration FFT comparison of 4 shots

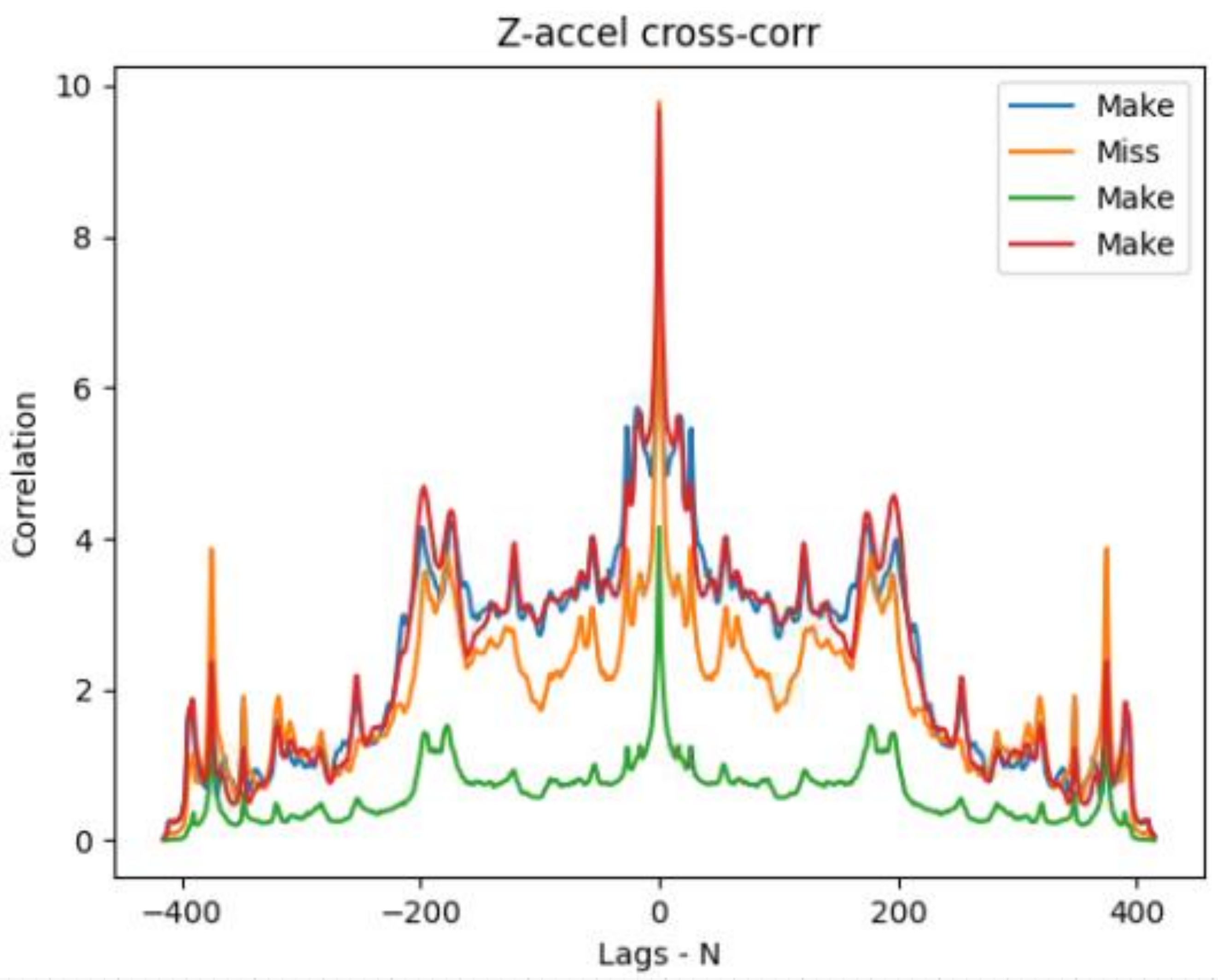


Z-Acceleration FFT comparison of 4 shots

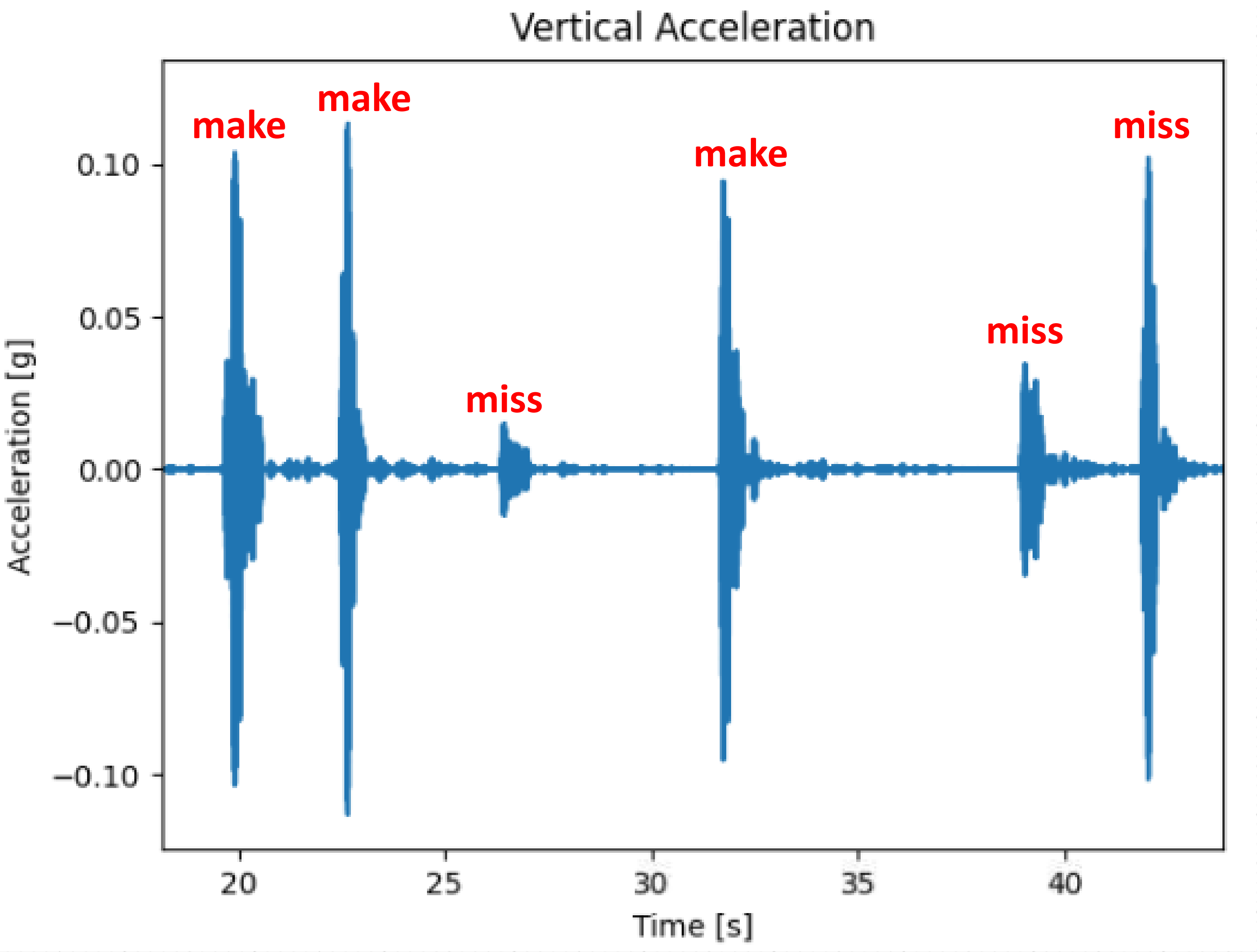


Frequency domain cross-correlation did not provide accurate results for classifying shots

- The acceleration data of a made shot that only hit the net was extracted
- The R0 value was used to classify shots
- The cross-correlation between the known instance of a made shot and other shots did not yield accurate results
    - Dependent on peak locations, width, and magnitude



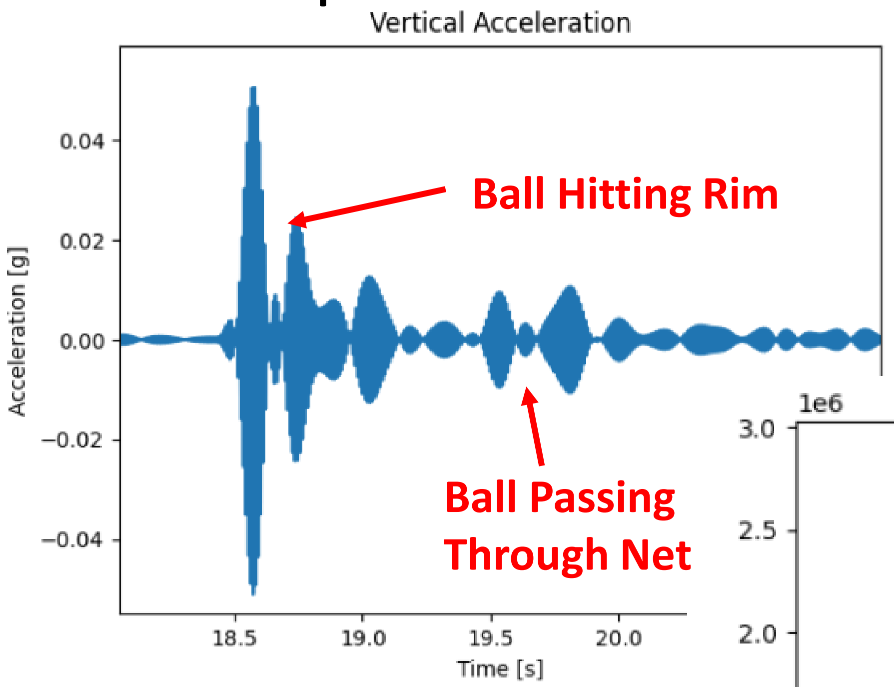
Time domain cross-correlation did not provide accurate results for classifying shots

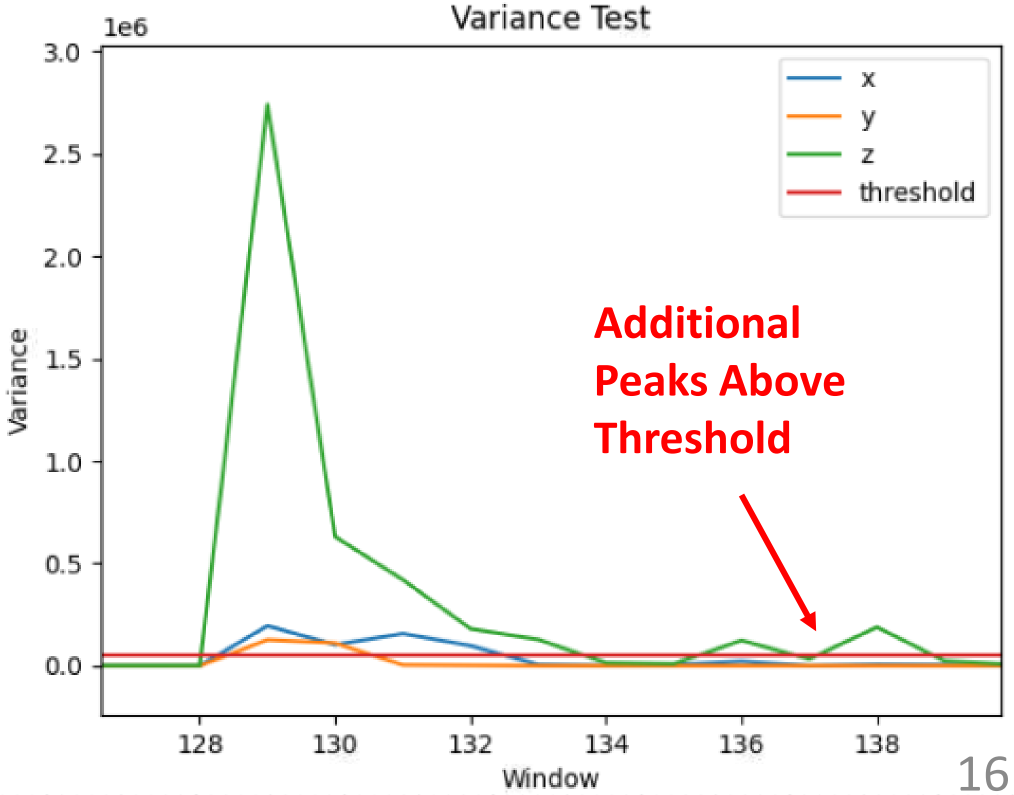


- No frequencies specific to made shots could be isolated with an appropriate filter in the time domain
- The high pass filtered noise dependent more on magnitude of ball contact than location of contact
- There was no specific pattern in the time domain data that would allow for cross-correlation

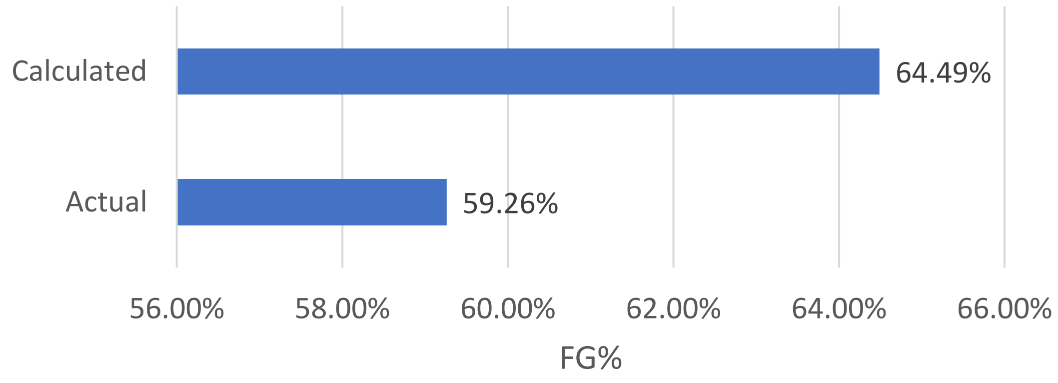
Shots were classified using change in variance event detection techniques

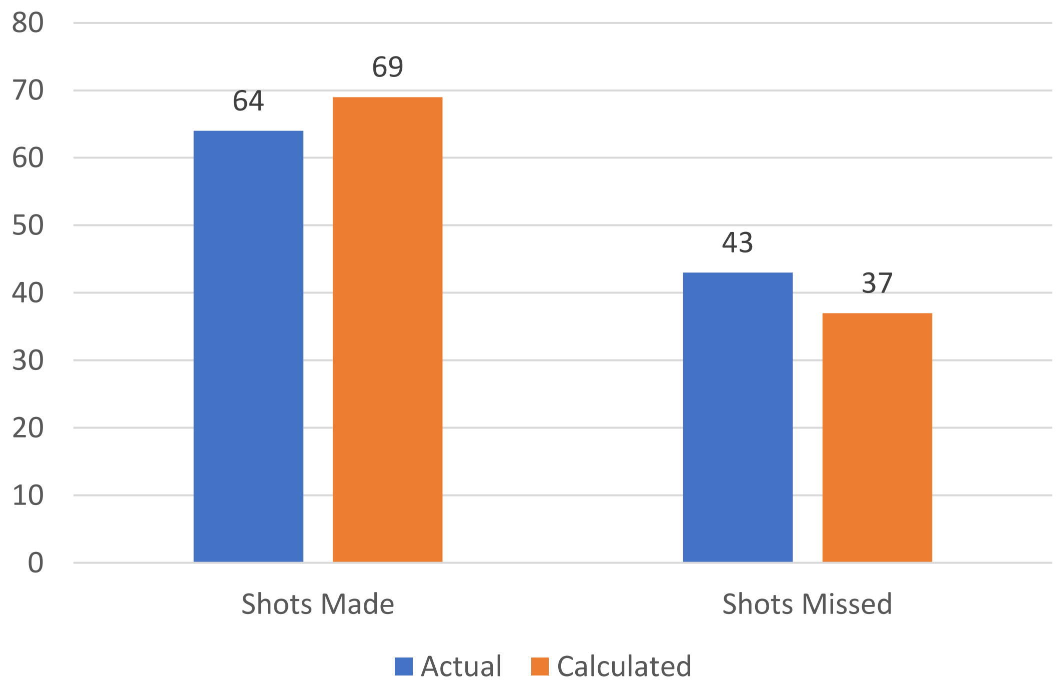
- The variance test was designed to take advantage of the second vibration present in a made shot
  - As the ball bounces off the backboard or rim into the net it will cause a second vibration
  - Error arises when the ball bounces off multiple surfaces and misses or only hits the net
- N = 30, β = 2.0





The calculated FG% is close to the actual value, but the calculation process still has significant error





Percent shots classified correctly = 72.9% (for 107/108 shots detected)

- Percent error made shots = 18.75% (12/64)
- Percent error missed shots = 39.53% (17/43)
- Percent error for FG% = 8.83%
- The FG% is an overestimate
  - It is more likely for a missed shot to be wrongly classified as a made shot than the opposite case

Future work should be done to mitigate error or to classify the locations of shots on the basket

- Gyroscope data can be used to in correspondence with the acceleration data to determine locations of shots on basket
- Adding additional constraints to the classification of shots
- Additional sensors, such as sonar, LiDAR, or cameras can be added to detect and classify shots
- methods can be employed in real time with shot limits or time limits

[1]

- ShotTracker provides real time basketball states using sensors placed around the arena [1]
  - The cost is about $45,000 [1]
  - The goal of future work would be to provide similar performance, but with less complexity and less cost

Questions?

References

[1] J. Young. “Sports tech firm ShotTracker gets backing from Verizon in $11 million financing round.” CNBC. https://www.cnbc.com/2021/01/14/shottracker-gets-backing-from-verizon-in-11-million-financing-round-.html (accessed May 11, 2021)