SciTinyML

Scientific use of machine learning on low power devices
Regional Workshop - Africa

Supervised Learning and Motion Classification

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Machine Learning

Supervised learning

Task-driven

- Regression
- Classification
- Object detection

Unsupervised learning

Data-driven

- Clustering
- Segmentation
- Anomaly detection

Reinforcement learning

Learn from experience

- Robotics
- Games
- Recommender systems

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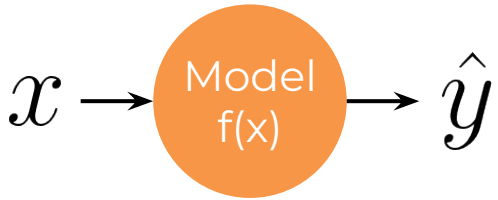
Supervised Learning

Training data:

$$(x_0, y_0)$$
$$(x_1, y_1)$$
$$(x_2, y_2)$$
$$\vdots$$



Training: automatically update the model parameters so that loss function is minimized

Goal:

$$f(x_n) = \hat{y_n}$$

where

$$\hat{y_n} = y_n$$

Loss function:

$$L(\hat{y_n}, y_n)$$

Inference: using the trained machine learning model to make predictions with new, unseen data

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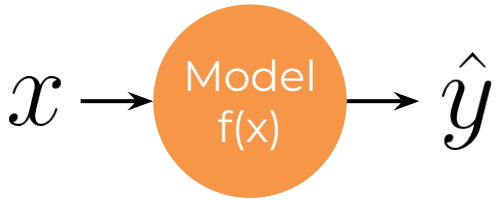
Supervised Learning

Training data:

$$(x_0, y_0)$$
$$(x_1, y_1)$$
$$(x_2, y_2)$$
$$\vdots$$



Labels (y_n) are known for training data

Goal:

$$f(x_n) = \hat{y_n}$$

where

$$\hat{y_n} = y_n$$

Loss function:

$$L(\hat{y_n}, y_n)$$

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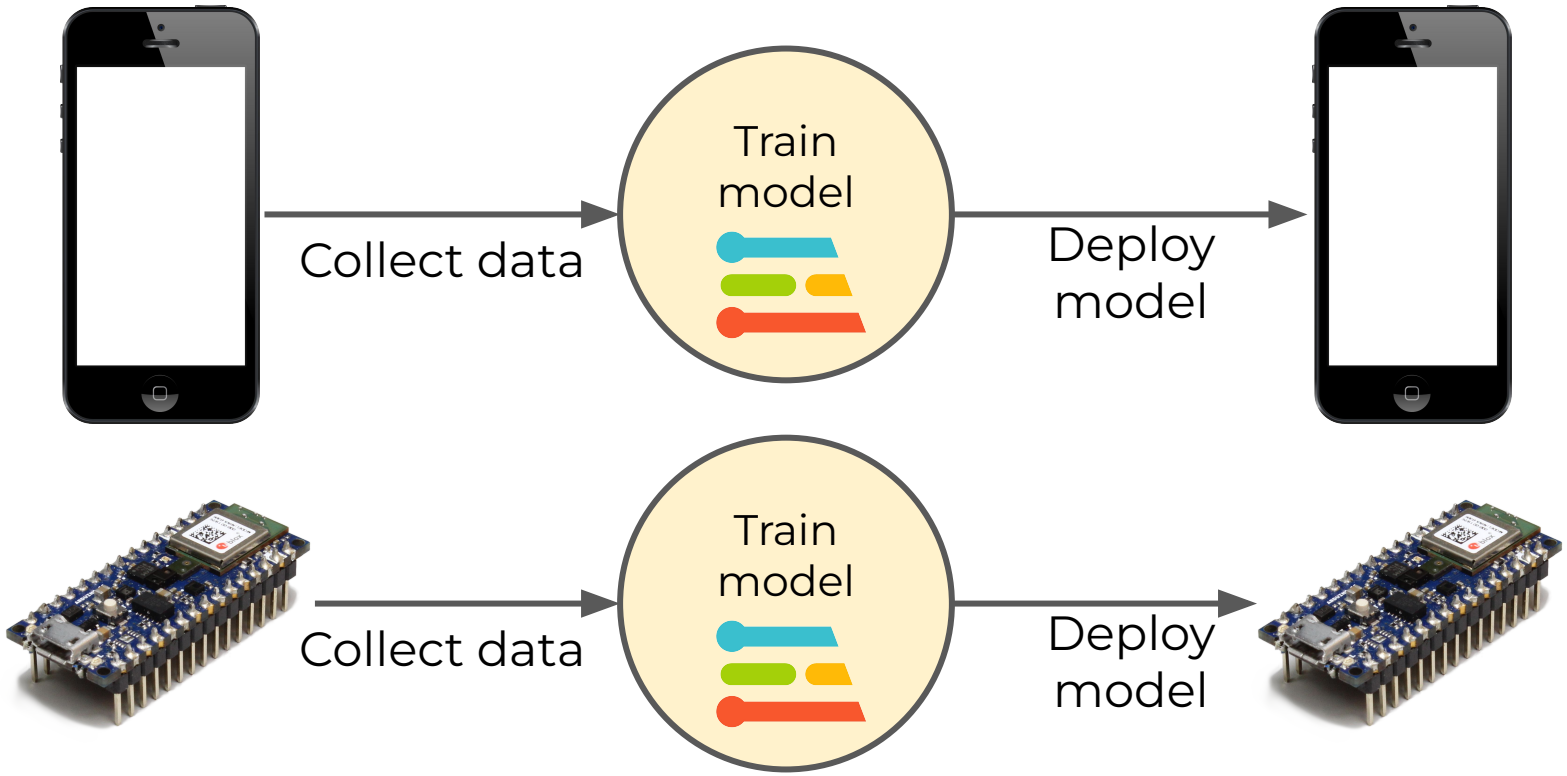
Workflow



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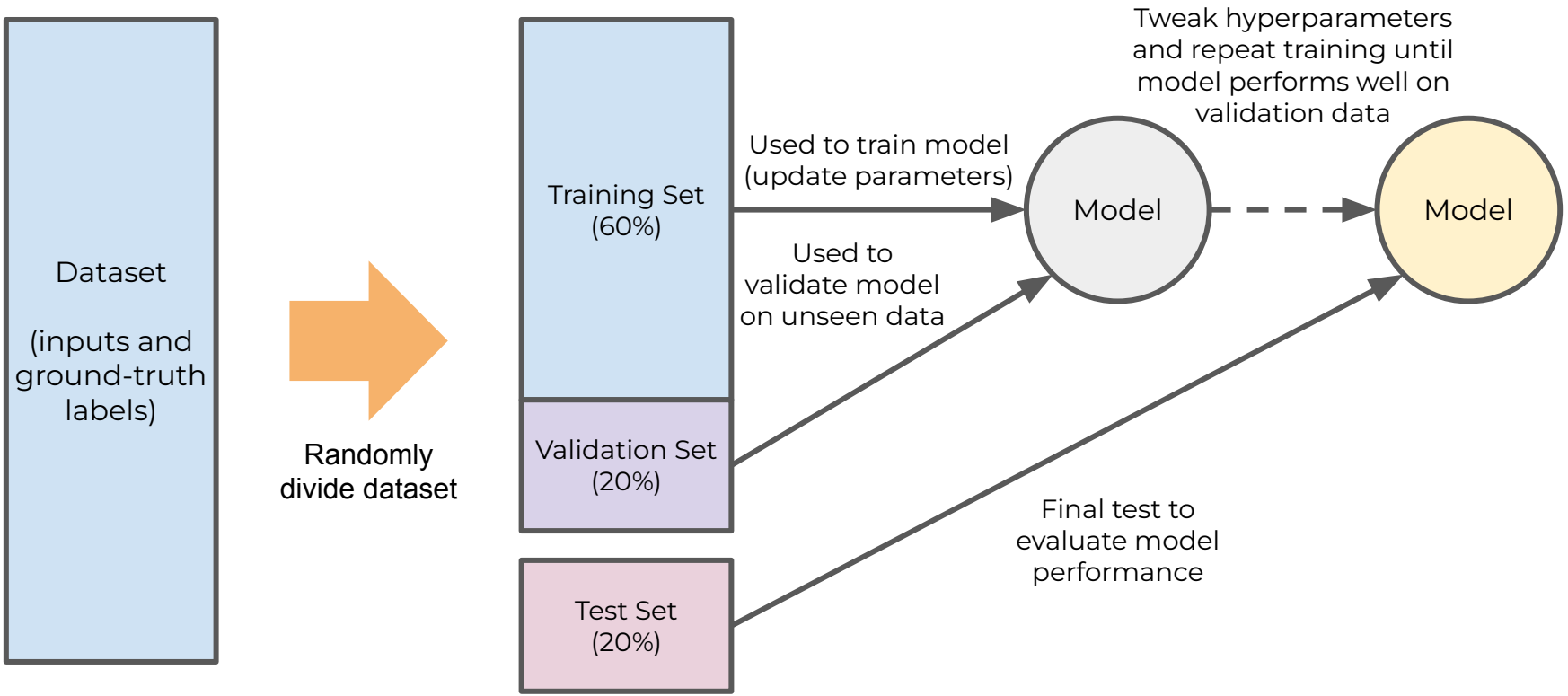
Holdout Method



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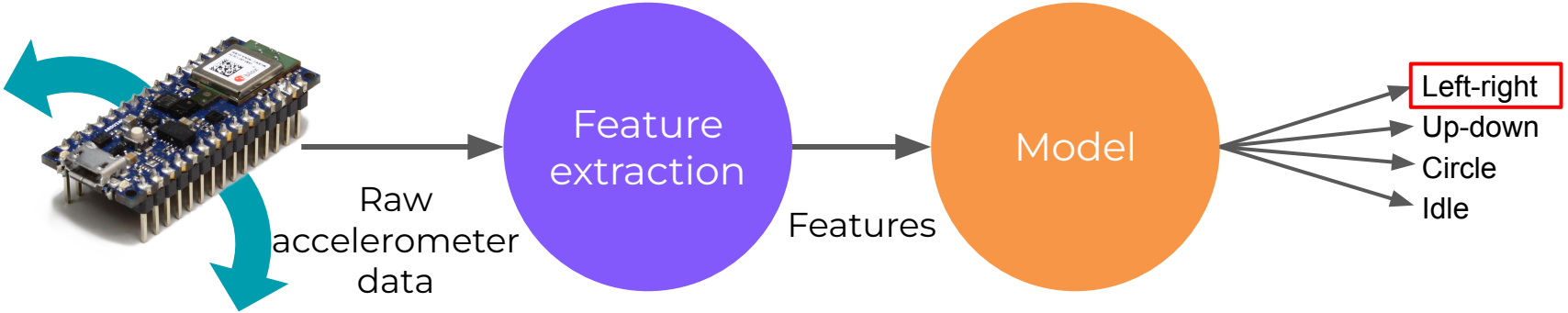
Motion Classification



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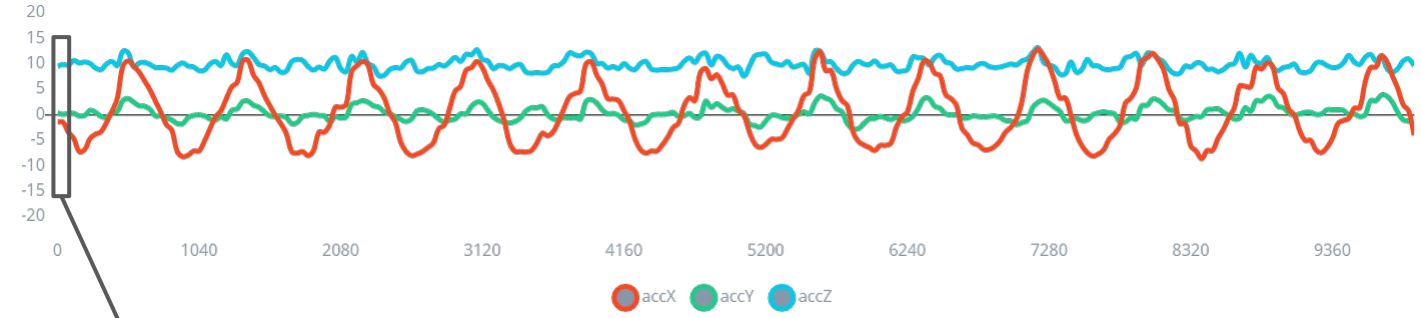
Feature Example



Acceleration (m/s^2)

x	-1.4
y	0.4
z	9.6

Model

- Left-right
- Up-down
- Circle
- Idle

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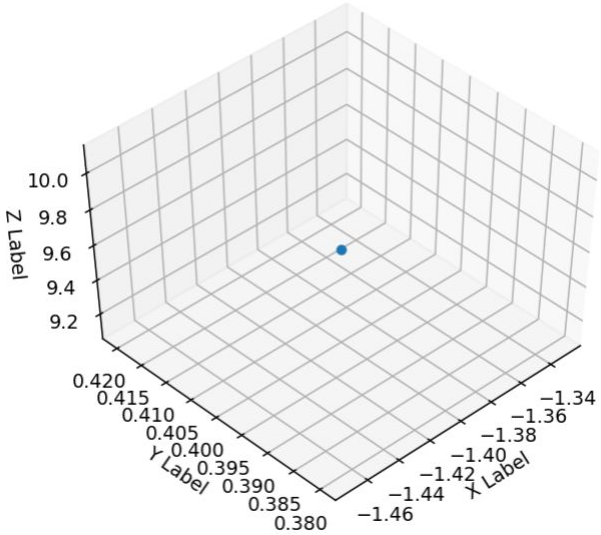
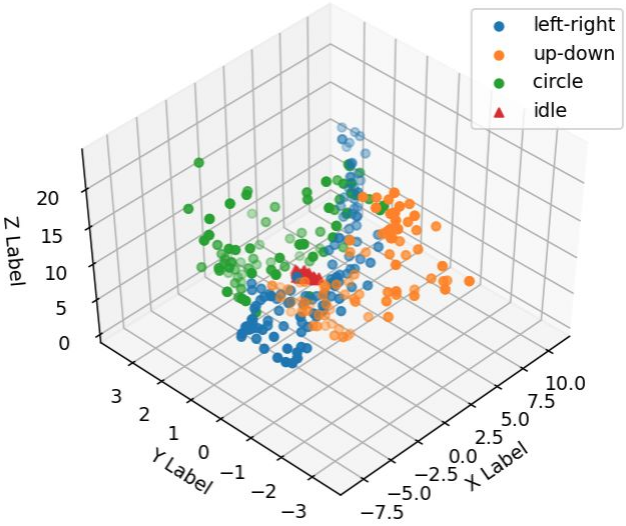
1 (x, y, z) accelerometer point from “left-right” sample



Many (x, y, z) accelerometer points from all classes



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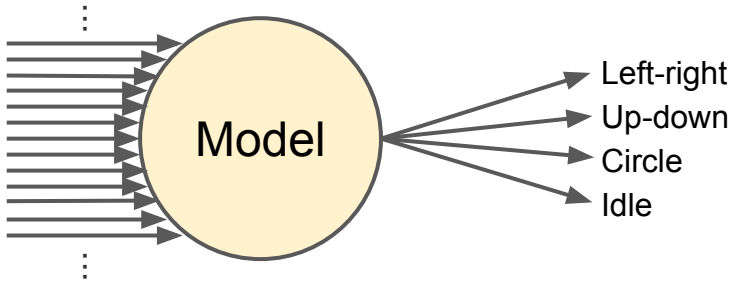
Feature Example

Acceleration (m/s^2)

x	-1.4	-1.4	-2.8	-3.4	-4.0	...
y	0.4	0.4	0.1	0.2	0.3	...
z	9.6	9.6	9.9	9.7	9.8	...

125 samples for each axis



375 total inputs to the model!

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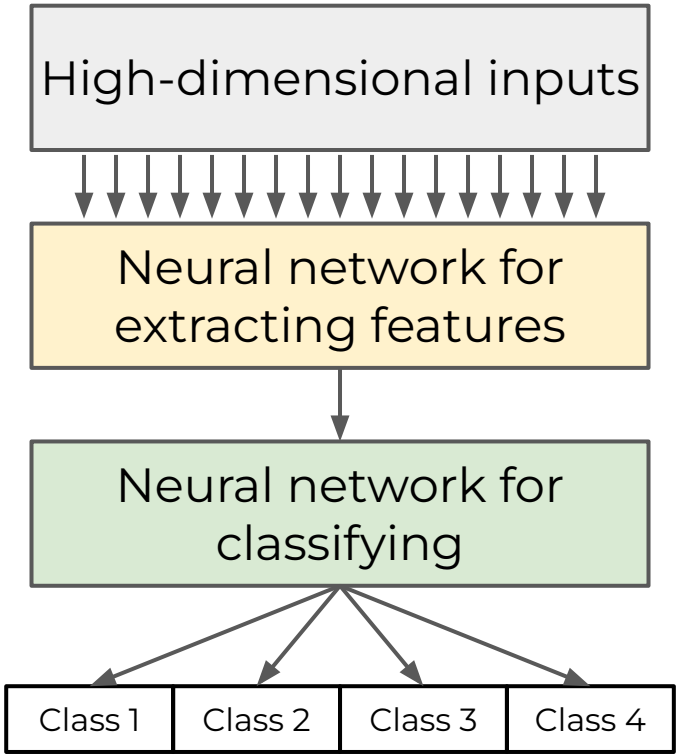
Problems with deep learning

1. Computational complexity
2. Requires lots of training data



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Feature Example

Acceleration (m/s^2)

x	-1.4	-1.4	-2.8	-3.4	-4.0	…
y	0.4	0.4	0.1	0.2	0.3	…
z	9.6	9.6	9.9	9.7	9.8	…

375 raw values

Feature extraction: Calculate RMS for each axis

x_{RMS} = 5.7 m/s^2 (RMS)

y_{RMS} = 1.2 m/s^2 (RMS)

z_{RMS} = 9.9 m/s^2 (RMS)

3 model input values

Model

- Left-right
- Up-down
- Circle
- Idle

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X Axis

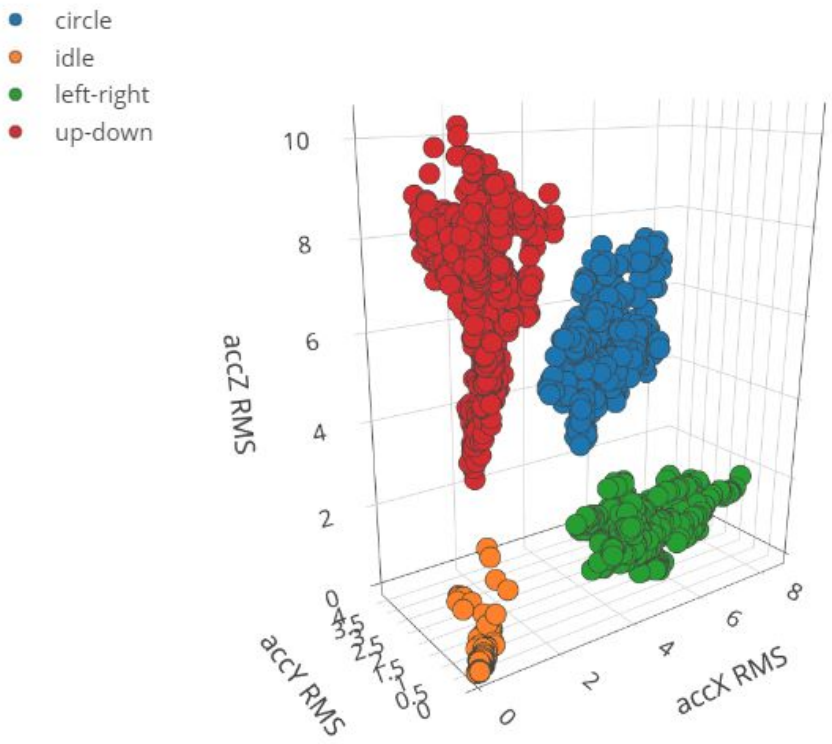
accX RMS

Y Axis

accY RMS

Z Axis

accZ RMS



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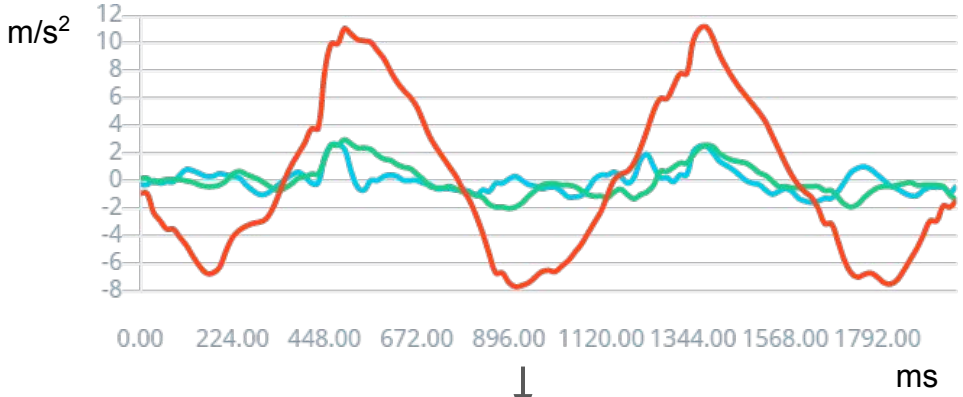
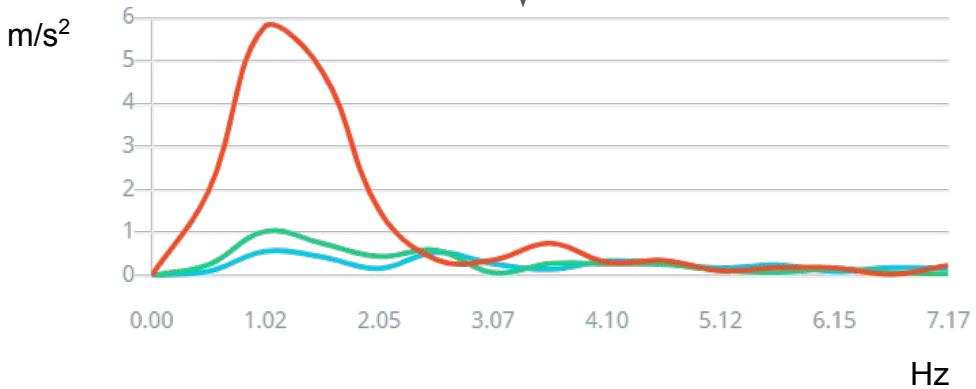


Time domain

Feature extraction:
FFT



Frequency domain

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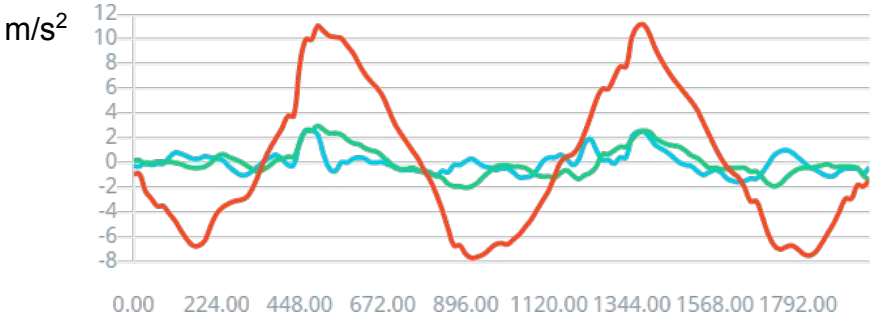
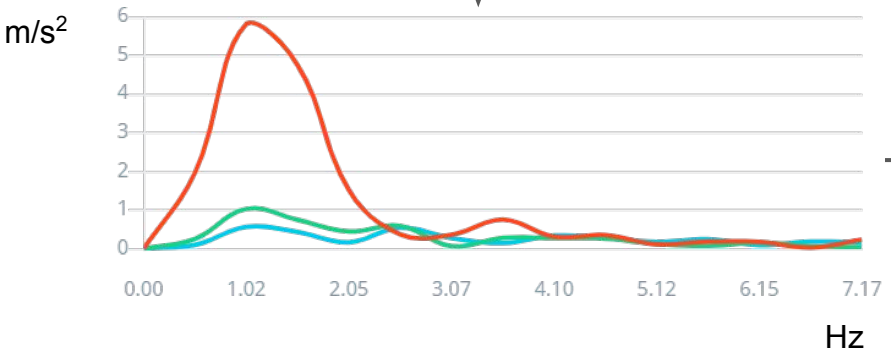
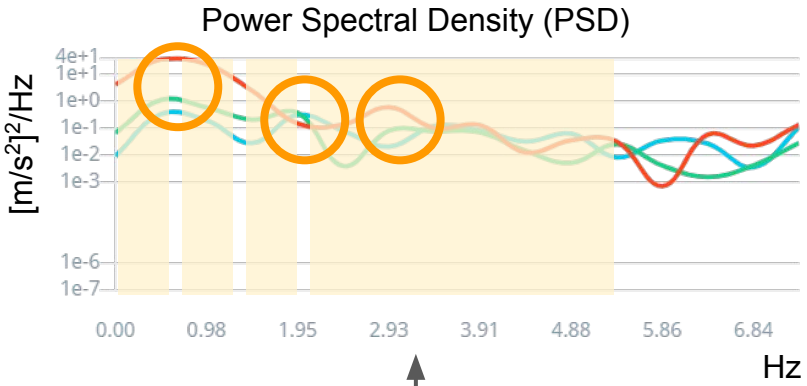


Feature extraction: FFT



Feature extraction: PSD



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Feature Example

Acceleration (m/s^2)

x	-1.4	-1.4	-2.8	-3.4	-4.0	…
y	0.4	0.4	0.1	0.2	0.3	…
z	9.6	9.6	9.9	9.7	9.8	…

375 raw values

"DSP Block"

Feature extraction: RMS and Power Spectral Density (PSD)

11 features per axis: RMS, 3x peak amplitudes from PSD, 3x peak frequencies from PSD, 4x spectral bins

33x features

Model

- Left-right
- Up-down
- Circle
- Idle

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Feature Example

Acceleration (m/s^2)

x	-6.8	-5.6	-4.6	-4.1	-3.8	…
y	-0.1	0.2	0.7	0.9	0.7	…
z	10.4	10.3	10.2	10.1	9.6	…

375 raw values

"DSP Block"

Feature extraction: RMS and Power Spectral Density (PSD)

11 features per axis: RMS, 3x peak amplitudes from PSD, 3x peak frequencies from PSD, 4x spectral bins

33x features

Model

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- Circle
- Idle

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