



DesignNews

Machine Learning Application Design using STM32 MCU's

DAY 3 : Training a Neural Network Part 1

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- If you have technical problems, click “Help” or submit a question asking for assistance.
- Participate in ‘Group Chat’ by maximizing the chat widget in your dock.
- Submit questions for the lecturer using the Q&A widget. They will follow-up after the lecture portion concludes.

Course Sessions

- Introduction to Machine Learning on MCU's
- Capturing, Cleaning and Labeling Data
- **Training a Neural Network Part 1**
- Training a Neural Network Part 2
- Running an Inference on Target

Completed Data Collection Review

DATA ACQUISITION (BENINGO-PROJECT-1)

Training data Test data


 **Did you know?** You can capture data from any de

DATA COLLECTED
7m 30s 

DATA ACQUISITION - TESTING (BENINGO-PROJECT-1)

Training data Test data

 **Did you know?** You can capture data from any d

DATA COLLECTED
3m 19s 

Did you successfully collect your gesture data?

- Yes
- No
- In progress ...

Training a Model Overview

Time Series Parameter Setup

Feature Analysis


Neural Network Design

Training



Model Validation



Deploy


Training a Model – Impulse Design

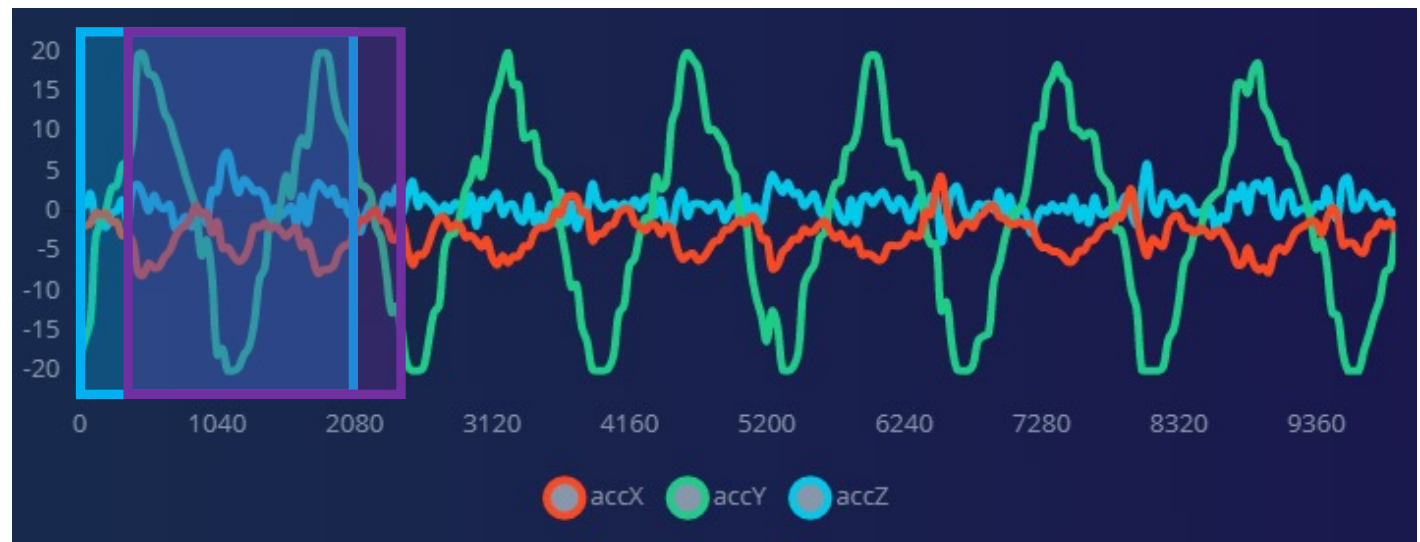

Time series data 

Axes
accX, accY, accZ

Window size 

2000 ms.

Window increase 

80 ms.

Zero-pad data 



Training a Model Impulse Design

Spectral Analysis ⚡

Name

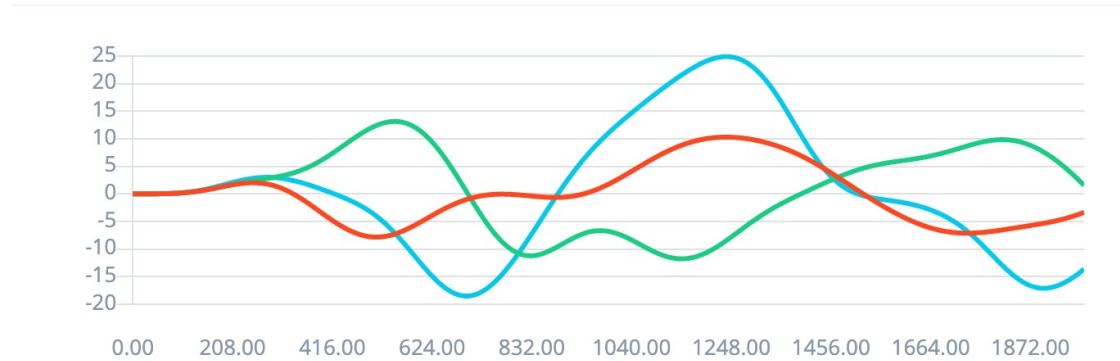
Spectral features

Input axes

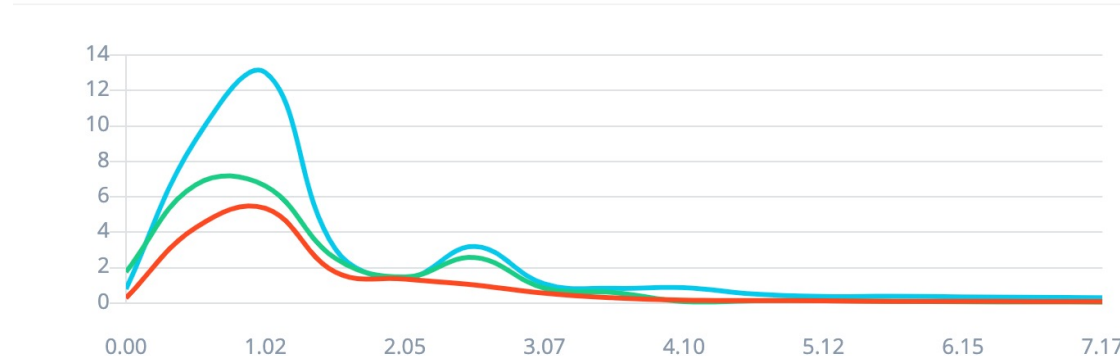
- accX
- accY
- accZ

DSP result

After filter



Frequency domain



What options are available to developers to analyze data features?

- Spectral Analysis
- Spectrogram
- Image Analysis
- All the above
- None of the above

Training a Model Impulse Design

Parameters

Scaling

Scale axes



Filter

Type



Cut-off frequency

Order

Spectral power

FFT length

No. of peaks

Peaks threshold

Power edges

Training a Model Impulse Design

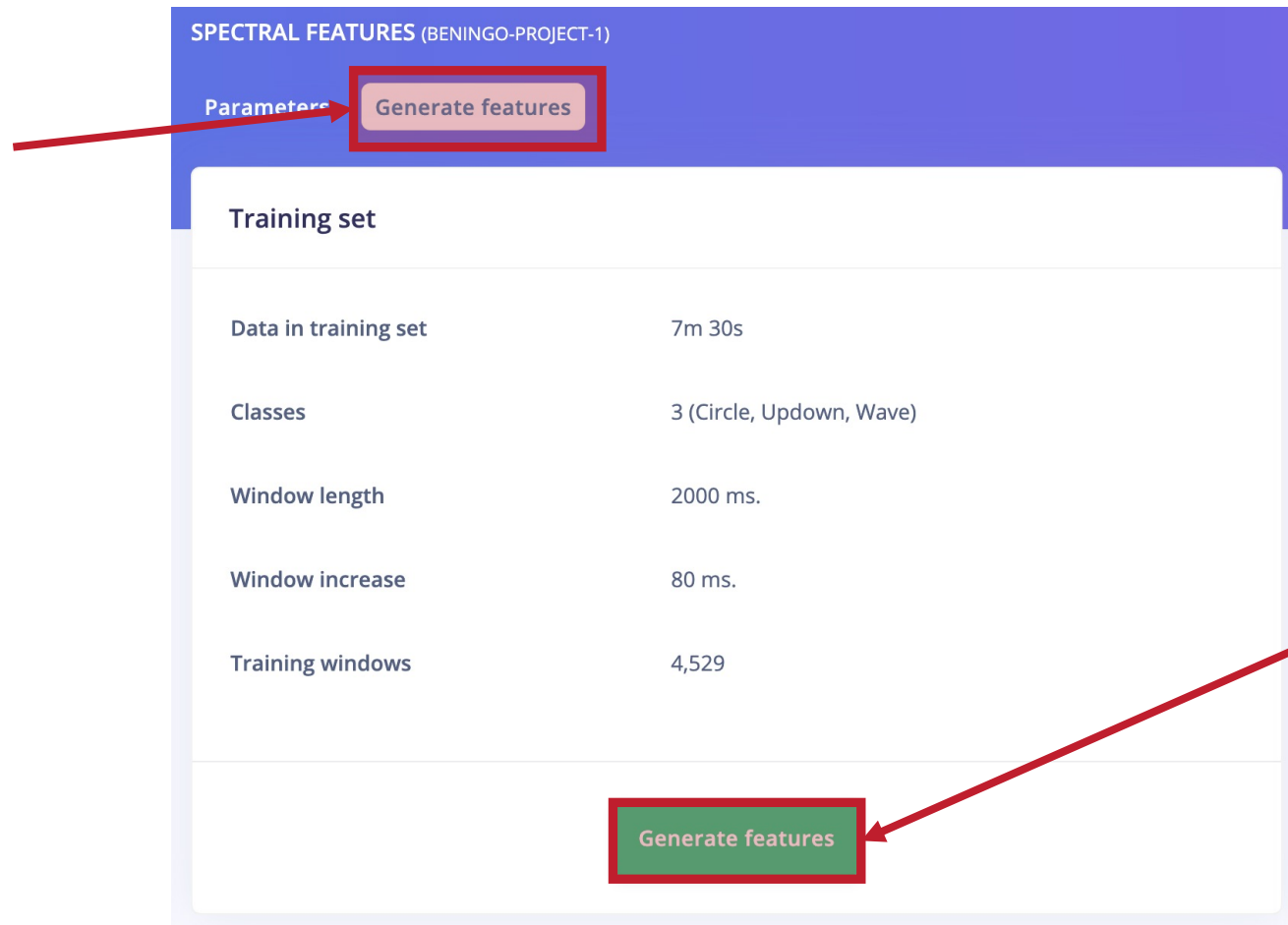
SPECTRAL FEATURES (BENINGO-PROJECT-1)

Parameters **Generate features**

Training set

Data in training set	7m 30s
Classes	3 (Circle, Updown, Wave)
Window length	2000 ms.
Window increase	80 ms.
Training windows	4,529

Generate features



Training a Model – Impulse Design

Feature explorer (4,529 samples)



X Axis

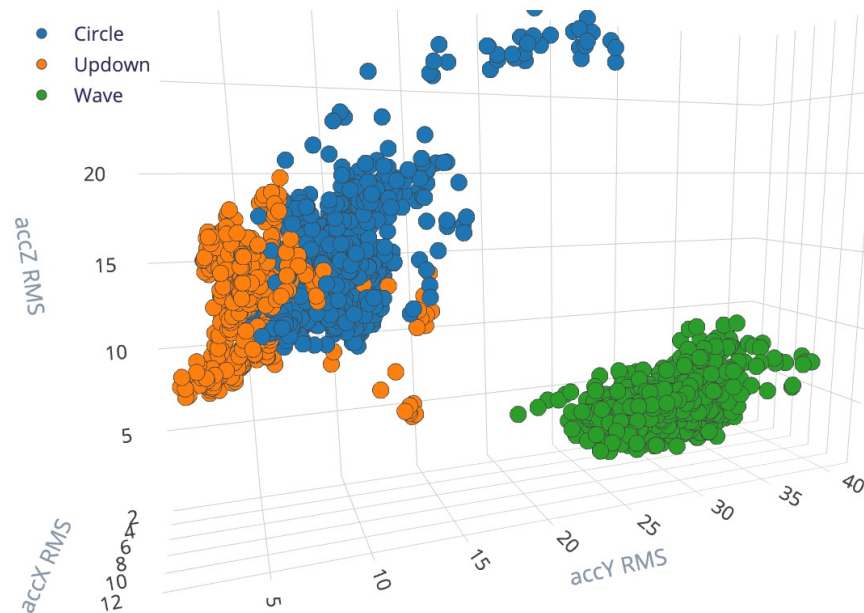
Y Axis

Z Axis

accX RMS

accY RMS

accZ RMS



Training a Model – Impulse Design

Time series data



Axes

accX, accY, accZ

Window size



2000 ms.

Window increase



80 ms.

Zero-pad data



Spectral Analysis



Name

Spectral features

Input axes

accX

accY

accZ



Neural Network (Keras)



Name

NN Classifier

Input features

Spectral features

Output features

3 (Circle, Updown, Wave)



Output features



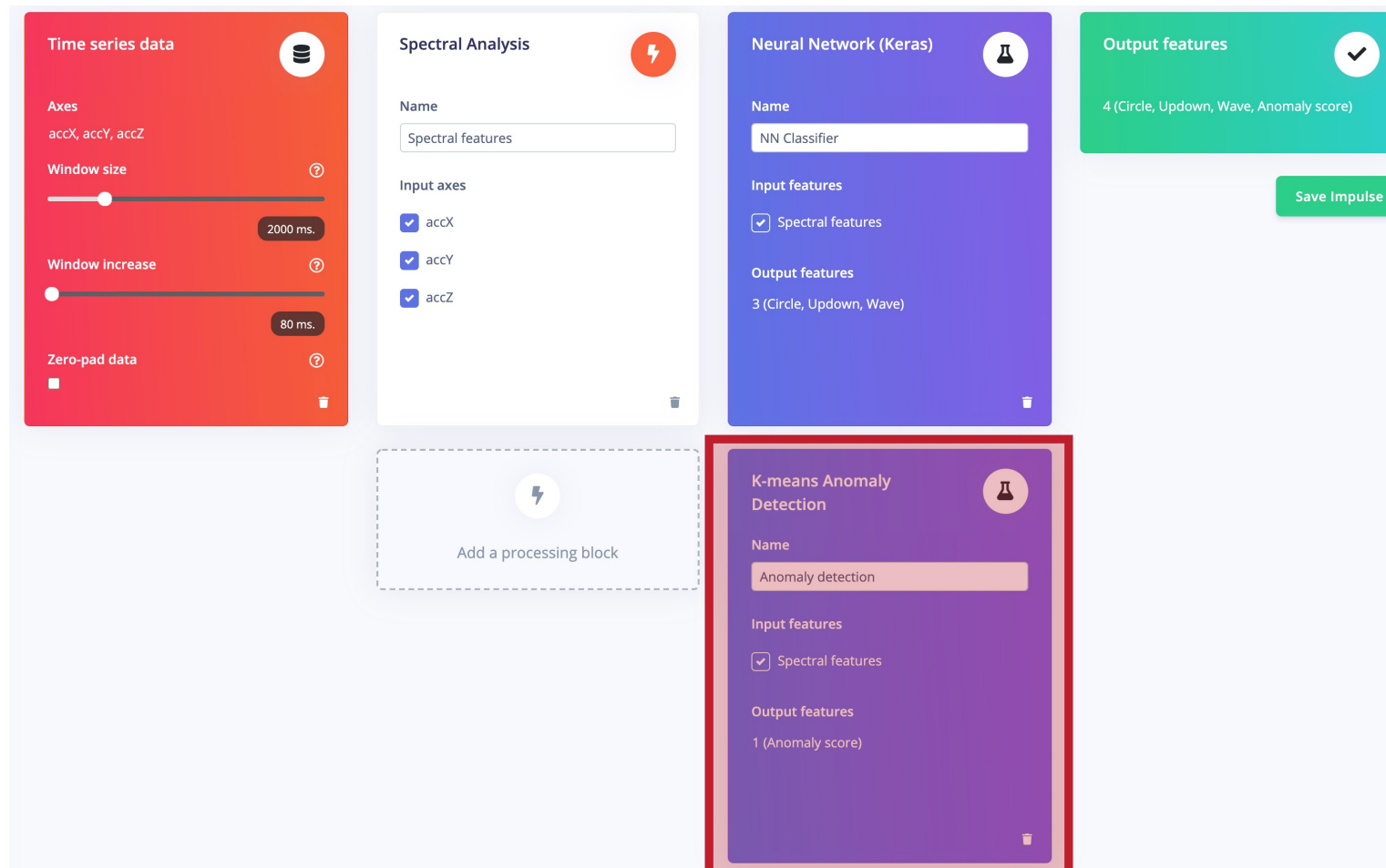
3 (Circle, Updown, Wave)

Save Impulse

What will happen if we present the model with a gesture it has not seen?

- The system will explode
- The classification will be incorrect
- The classification will be reported as unknown
- Other (put your thought in the chat box please)

Training a Model Impulse Design



The screenshot displays a drag-and-drop interface for building a machine learning pipeline. The interface consists of several colored blocks and a central workspace.

- Time series data (Red block):** Contains settings for axes (accX, accY, accZ), window size (2000 ms), window increase (80 ms), and a checkbox for zero-pad data.
- Spectral Analysis (White block):** Name: Spectral features. Input axes: accX, accY, accZ.
- Neural Network (Keras) (Blue block):** Name: NN Classifier. Input features: Spectral features. Output features: 3 (Circle, Updown, Wave).
- Output features (Green block):** 4 (Circle, Updown, Wave, Anomaly score). Includes a "Save Impulse" button.
- K-means Anomaly Detection (Purple block, highlighted with a red border):** Name: Anomaly detection. Input features: Spectral features. Output features: 1 (Anomaly score).
- Workspace:** A dashed box labeled "Add a processing block" with a lightning bolt icon.

Training a Model Impulse Design

Neural Network (Keras)

Name
NN Classifier

Input features
 Spectral features

Output features
3 (Circle, Updown, Wave)

Neural Network settings

Training settings

Number of training cycles	30	100 - 150
Learning rate	0.0005	0.0001
Minimum confidence rating	0.70	0.80

Neural network architecture

- Input layer (33 features)
- Dense layer (20 neurons)
- Dense layer (10 neurons)
- Add an extra layer
- Output layer (3 features)

Start training

Training a Model - Results

Training output

```
114/114 - 1s - loss: 0.0592 - accuracy: 0.9768 - val_loss: 0.0627 - val_accuracy: 0.9801  
Epoch 30/30
```

```
114/114 - 1s - loss: 0.0584 - accuracy: 0.9763 - val_loss: 0.0618 - val_accuracy: 0.9790  
Finished training
```

```
Saving best performing model...
```

```
Converting TensorFlow Lite float32 model...
```

```
Converting TensorFlow Lite int8 quantized model with float32 input and output...
```

```
Converting TensorFlow Lite int8 quantized model with int8 input and output...
```

```
Calculating performance metrics...
```

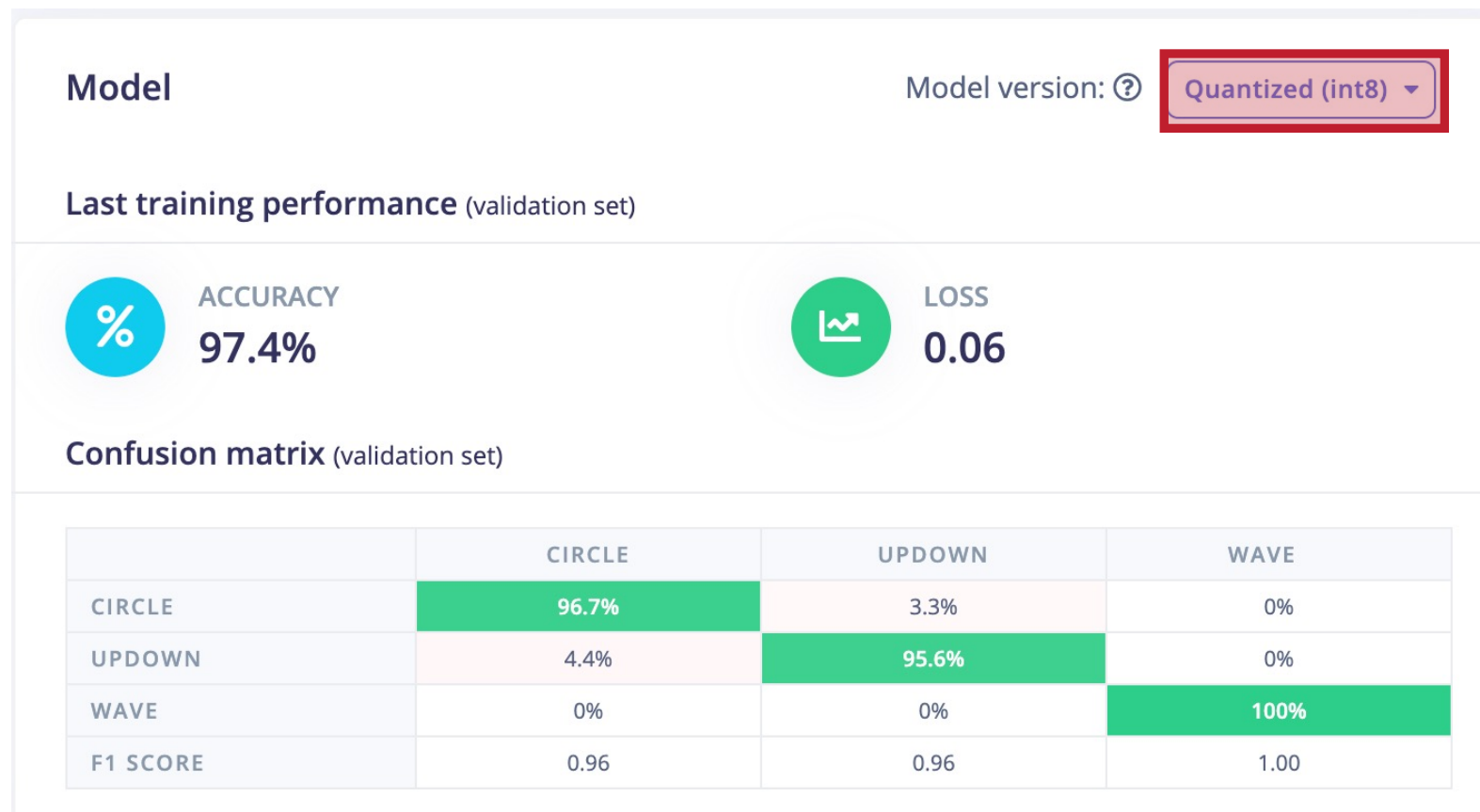
```
Profiling float32 model...
```

```
Profiling int8 model...
```

```
Model training complete
```

```
Job completed
```

Training a Model - Results



Training a Model - Results

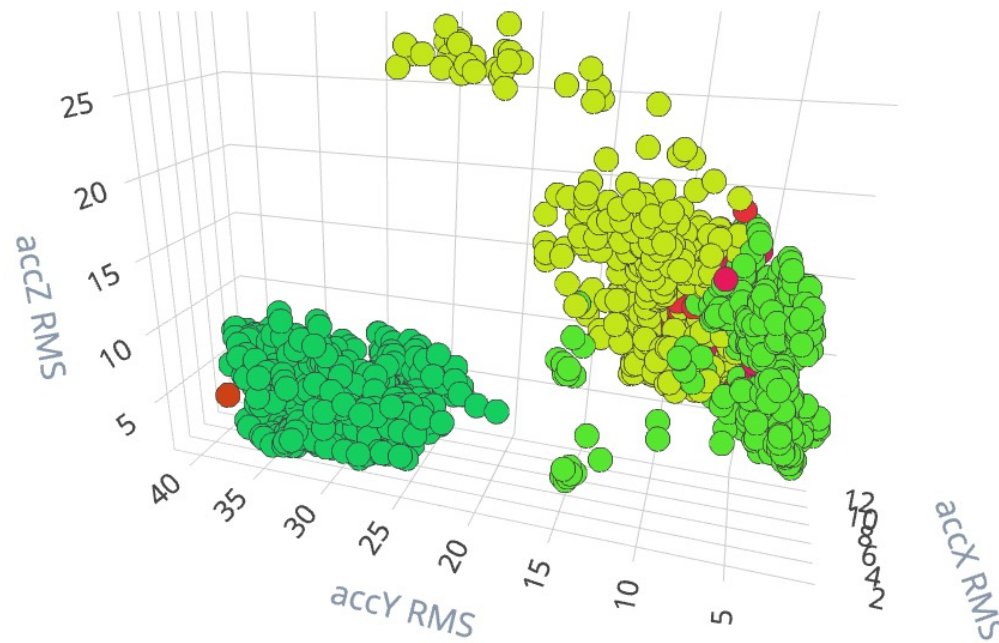
Feature explorer (full training set) ?

accX RMS

accY RMS

accZ RMS

- Circle - correct
- Updown - correct
- Wave - correct
- Circle - incorrect
- Updown - incorrect
- Wave - incorrect



How do you feel about these results? Are they ...

- Good
- Okay
- horrendous
- Other (put your though in the chat box please)

Adding Anomaly Detection

Impulse design

Create impulse

Spectral features

NN Classifier

Anomaly detection



Axes

Select all axes

- accX RMS ★
- accX Peak 1 Freq
- accX Peak 1 Height
- accX Peak 2 Freq
- accX Peak 2 Height
- accX Peak 3 Freq
- accX Peak 3 Height
- accX Spectral Power 0.1 - 0.5
- accX Spectral Power 0.5 - 1.0
- accX Spectral Power 1.0 - 2.0
- accX Spectral Power 2.0 - 5.0
- accY RMS ★
- accY Spectral Power 0.1 - 0.5
- accY Spectral Power 0.5 - 1.0
- accY Spectral Power 1.0 - 2.0
- accY Spectral Power 2.0 - 5.0
- accZ RMS ★
- accZ Peak 1 Freq
- accZ Peak 1 Height
- accZ Peak 2 Freq
- accZ Peak 2 Height
- accZ Peak 3 Freq
- accZ Peak 3 Height
- accZ Spectral Power 0.1 - 0.5

Adding Anomaly Detection

Anomaly explorer (4,529 samples)



Live Classification Testing

Classify new data

Device ?

Sensor

Sample length (ms.)

Frequency

Classification result

Summary

Name

Expected outcome

CATEGORY

COUNT

Circle

0

Updown

0

Wave

100

uncertain

0

anomaly

0

Model Testing

Test data

[Classify all](#)

Set the 'expected outcome' for each sample to the desired outcome to automatically score the impulse.

Model Testing Results

Validation results

ACCURACY
95.88%



	CIRCLE	UPDOWN	WAVE	ANOMALY	UNCERTAIN
CIRCLE	87.6%	6.6%	0%	0%	5.8%
UPDOWN	0%	100%	0%	0%	0%
WAVE	0%	0%	100%	0%	0%
ANOMALY	-	-	-	-	-

Model Testing Results

Feature explorer [?](#)

accX RMS



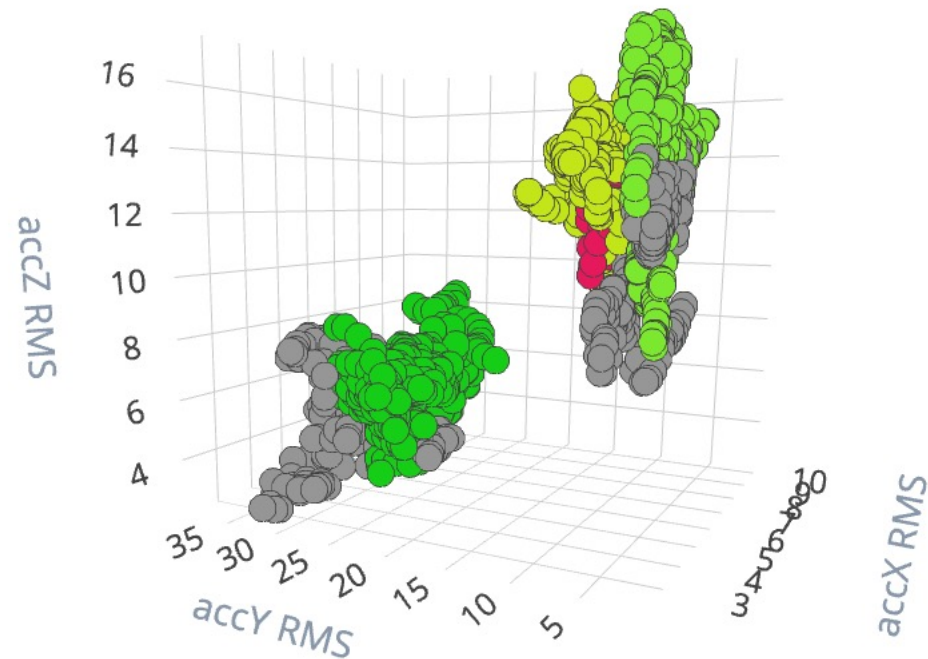
accY RMS



accZ RMS



- Circle - correct
- Updown - correct
- Wave - correct
- Circle - incorrect
- testing



Thank you for attending

Please consider the resources below:

- www.beningo.com
 - Blog, White Papers, Courses
 - Embedded Bytes Newsletter
 - <http://bit.ly/1BAHYXm>



From www.beningo.com under

- Blog > CEC – Machine Learning Application Design using STM32 MCUs



Thank You

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