Track4

IoT

Internet de las Cosas

Machine Learning

Sound Classification Intro & Hands-On

Prof. Stalin Arciniegas
smarciniegas@pucesi.edu.ec

PUCE Ibarra- Pontificia Universidad Católica del Ecuador Ibarra

PUCE

IBARRA

Vision

Sound

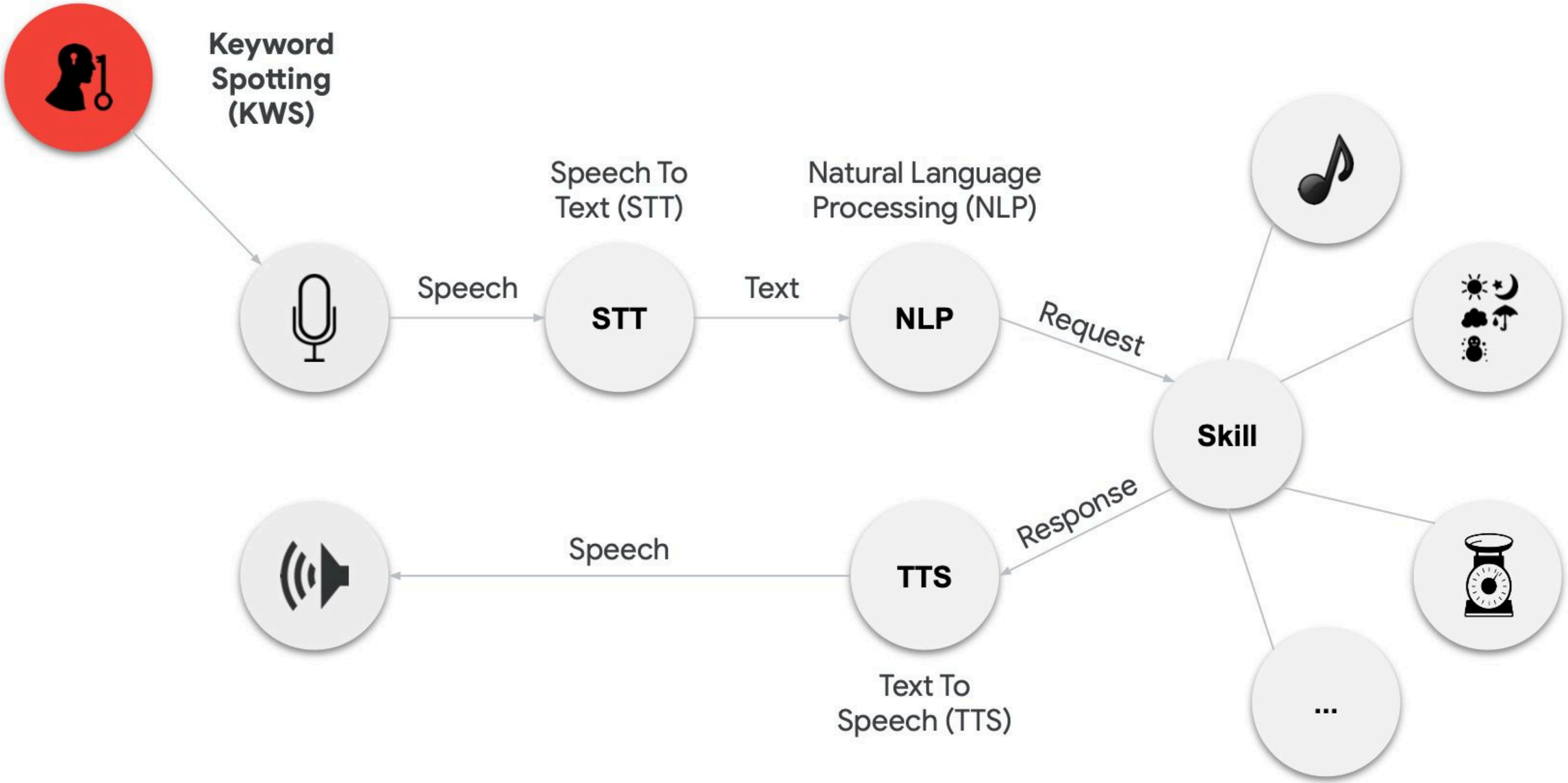
Vibration

KWS (KeyWord Spotting) Introduction

Keyword Spotting

Alexa

Hi, Stalin


Keyword Spotting (KWS)
Speech To Text (STT)
Natural Language Processing (NLP)
Speech
STT
Text
NLP
Request
Skill
Response
Speech
TTS
Text To Speech (TTS)
...

KeyWord Spotting (KWS) - Inference

Obtains an input

Pre-Process

Runs model

Post-Processes

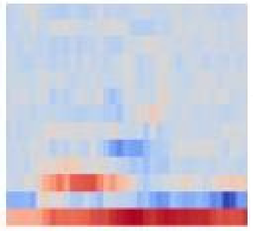
Make things happen

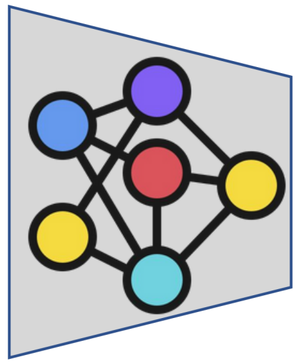
Digital Mic

16KHz / 16 bits
Sample: [1s]

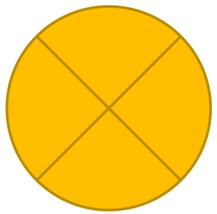
MFCC Feature Converter

Output: Image
[49, 40, 1]

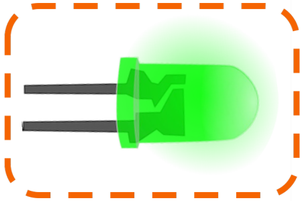




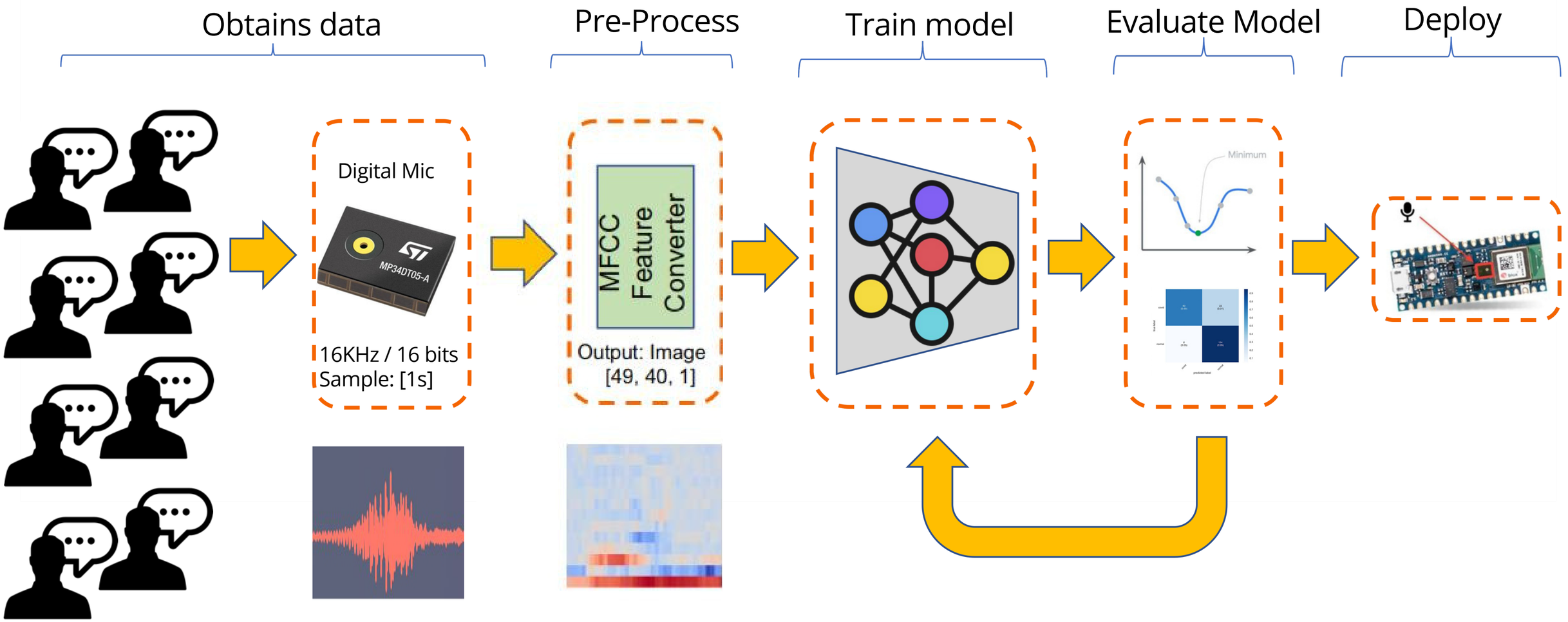
Output Dim [1, 4]
- Prob 'Silence'
- Prob 'Unknown'
- Prob 'Yes'
- Prob 'No'

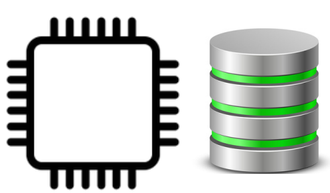


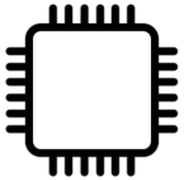
If Probability of YES is greater than 80%
Take actions



KeyWord Spotting (KWS) – Create Model (Training)





Data Engineering

Model Engineering

Model Deployment

Product Analytics

Collect Data → Preprocess Data → Design a Model → Train a Model → Evaluate Optimize → Convert Model → Deploy Model → Make Inferences

TensorFlow

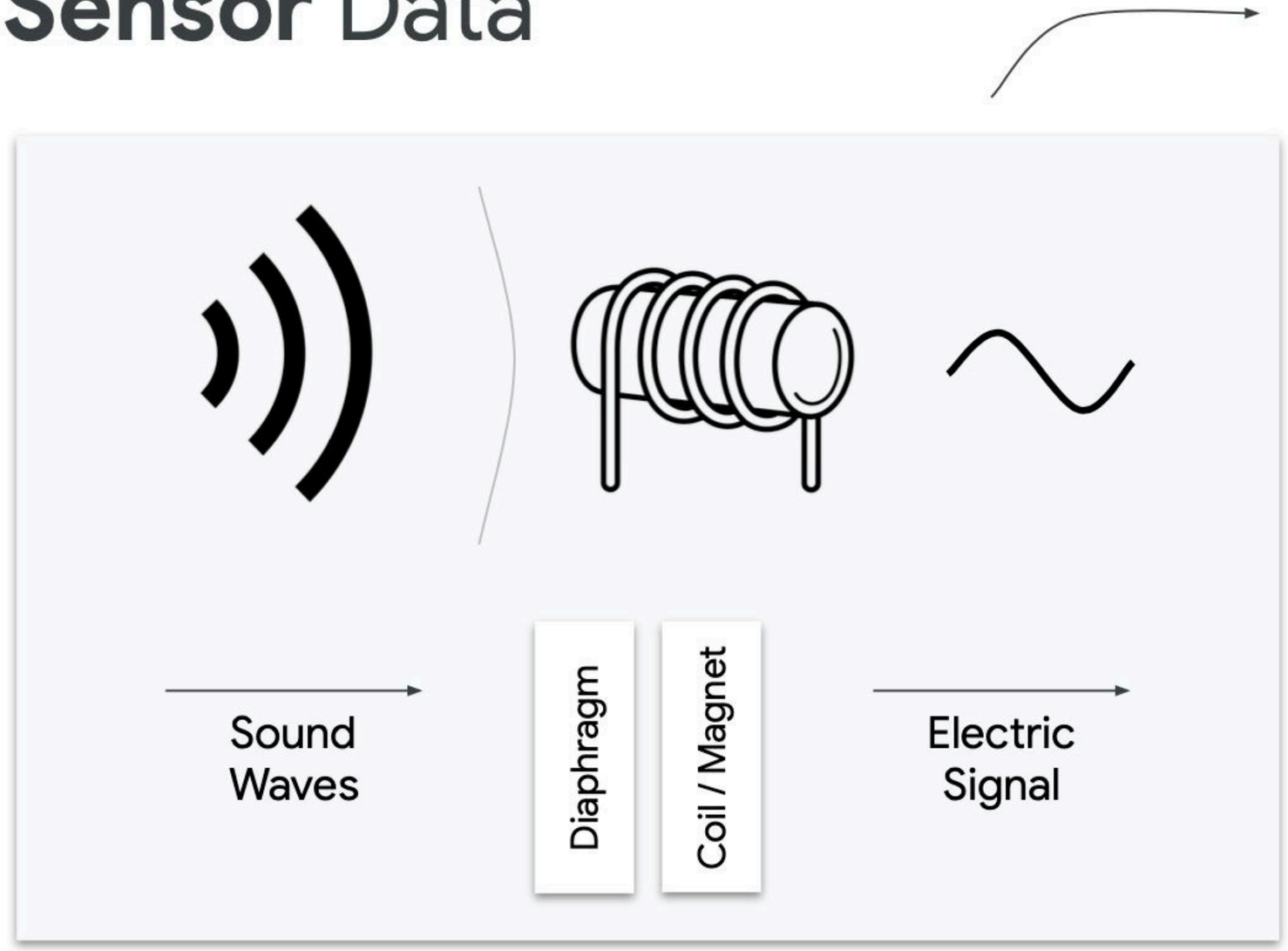
TensorFlow Lite

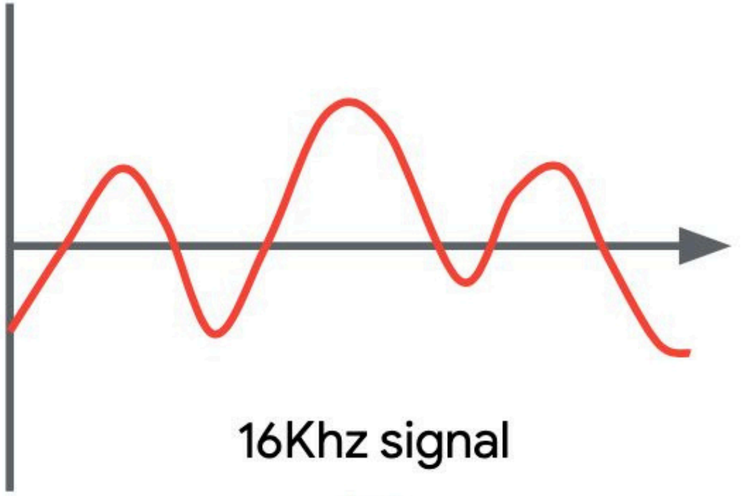
TensorFlow Lite Micro

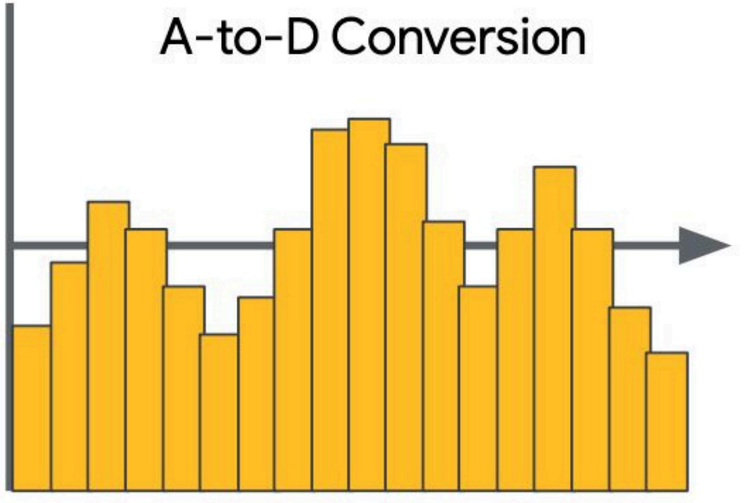

Collect Data
Preprocess Data
Design a Model
Train a Model
Evaluate Optimize
Convert Model
Deploy Model
Make Inferences
TensorFlow
TensorFlow Lite
TensorFlow Lite Micro


EDGE IMPULSE

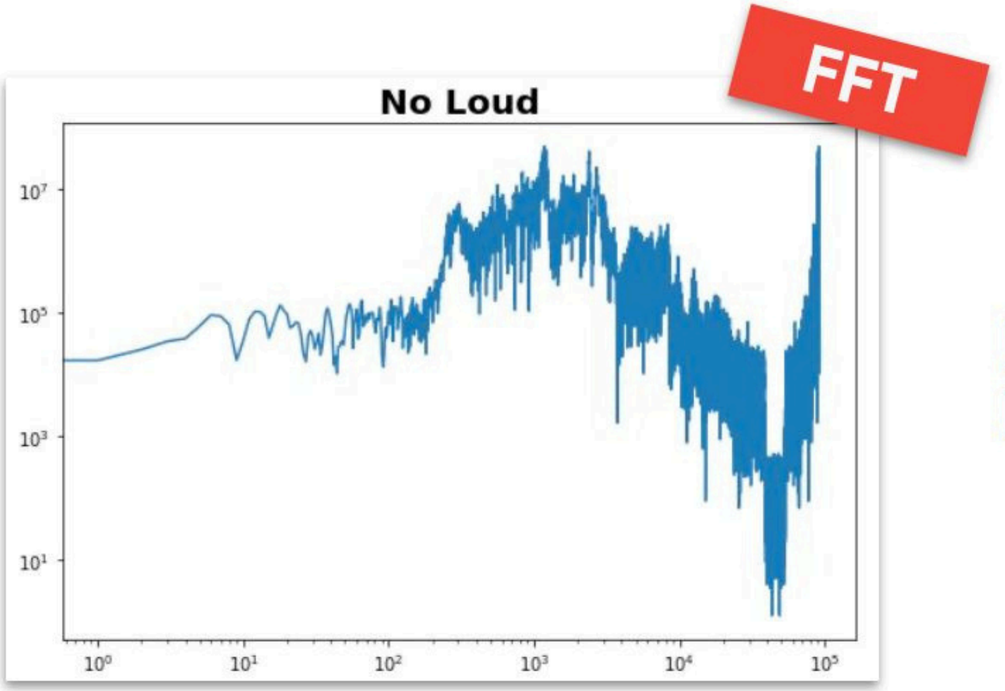
Sensor Data

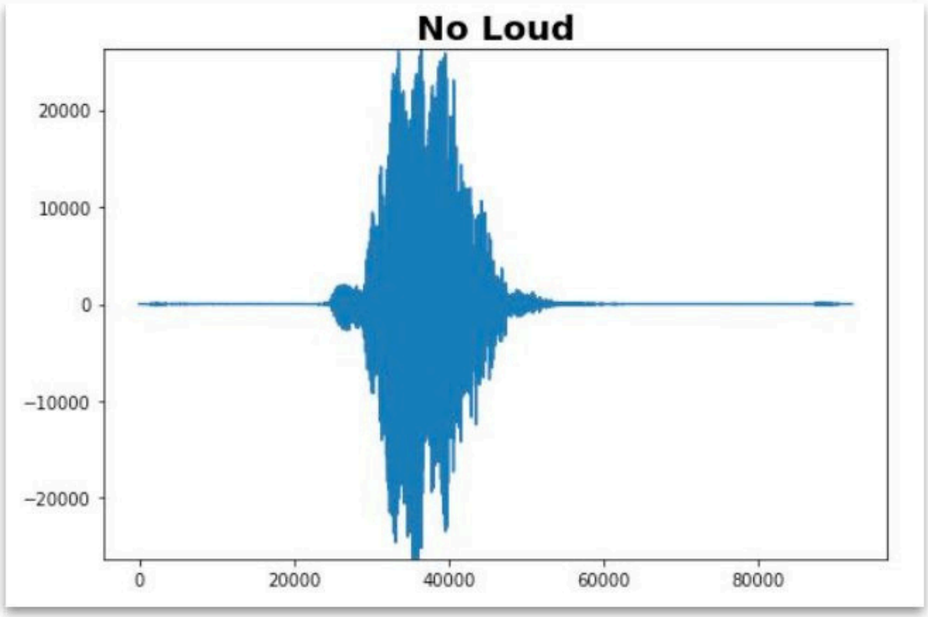

Sound
Waves
Diaphragm
Coil / Magnet
Electric
Signal


16Khz signal


A-to-D Conversion

Signal **Components**?

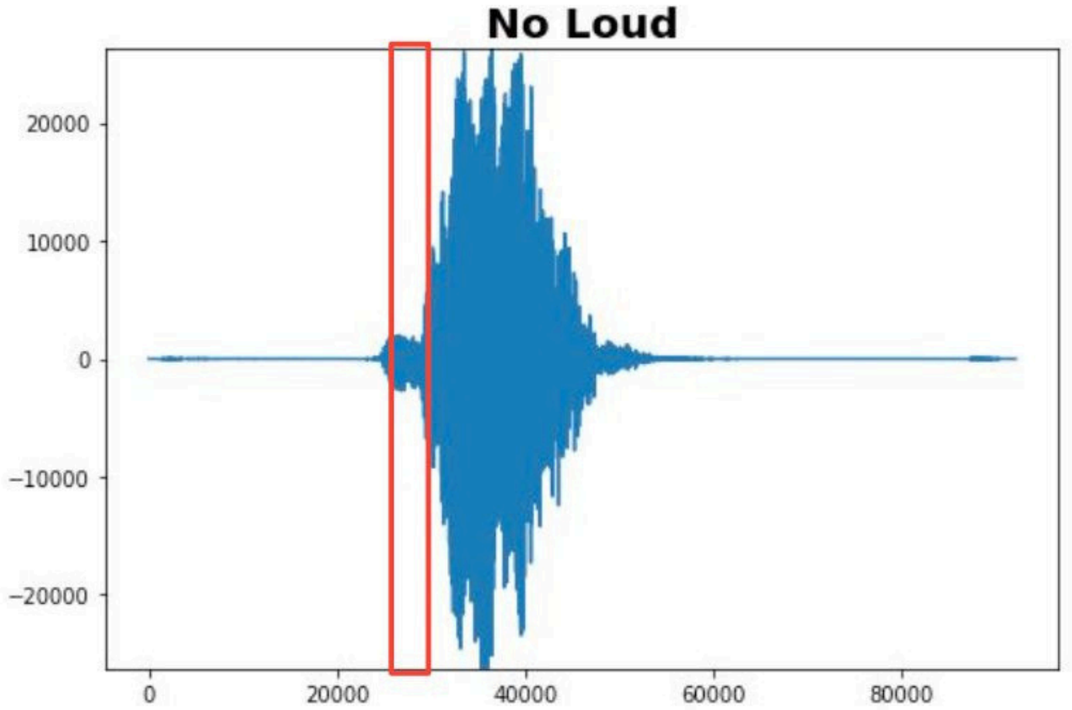




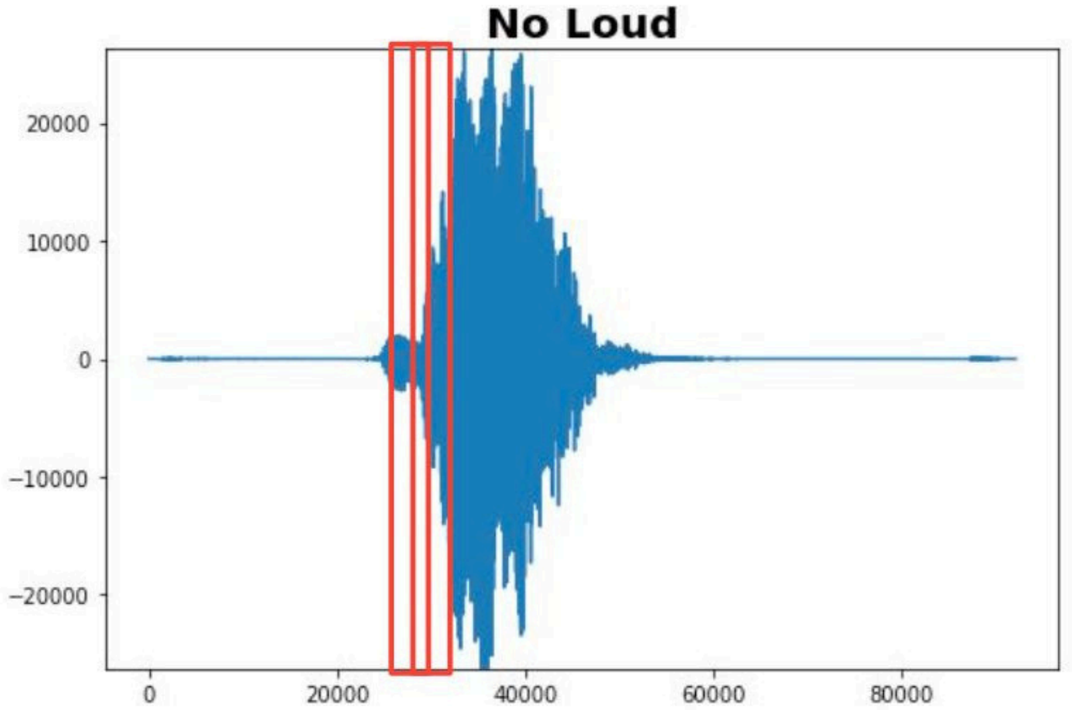
Frequency

Time

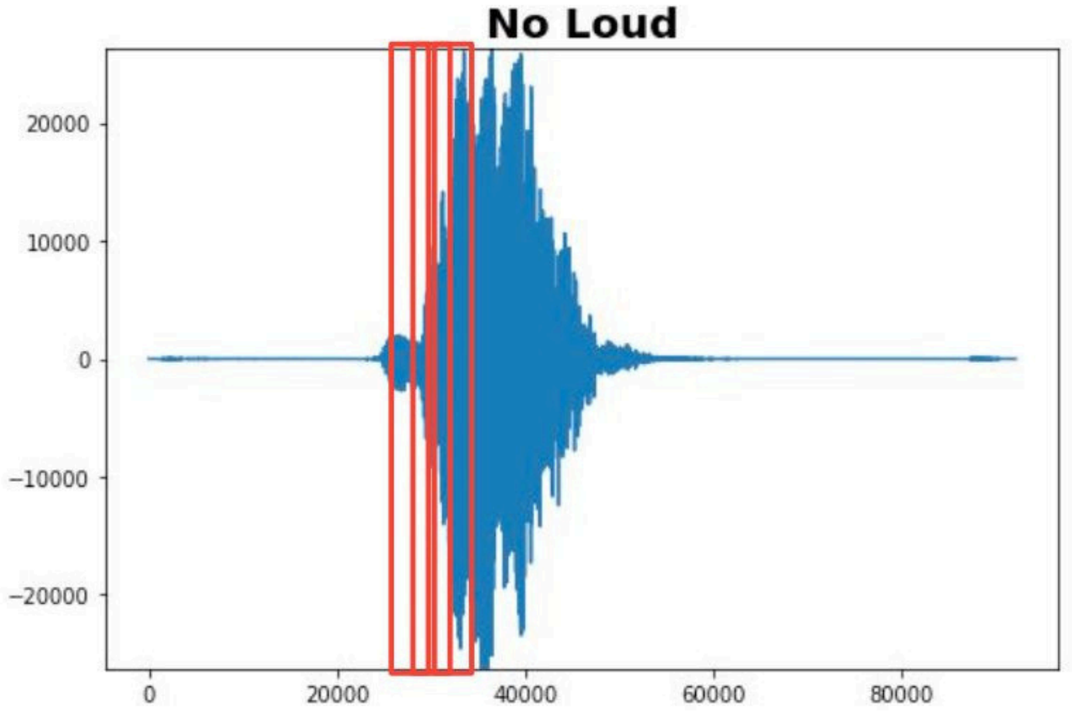
Data Preprocessing



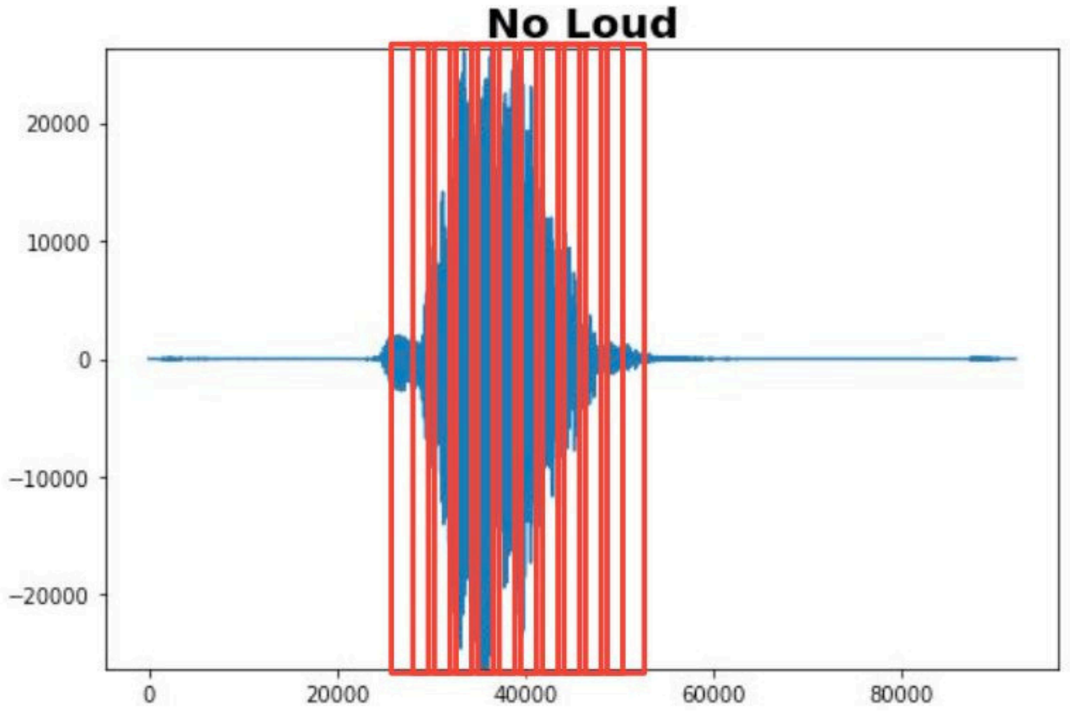
Data Preprocessing

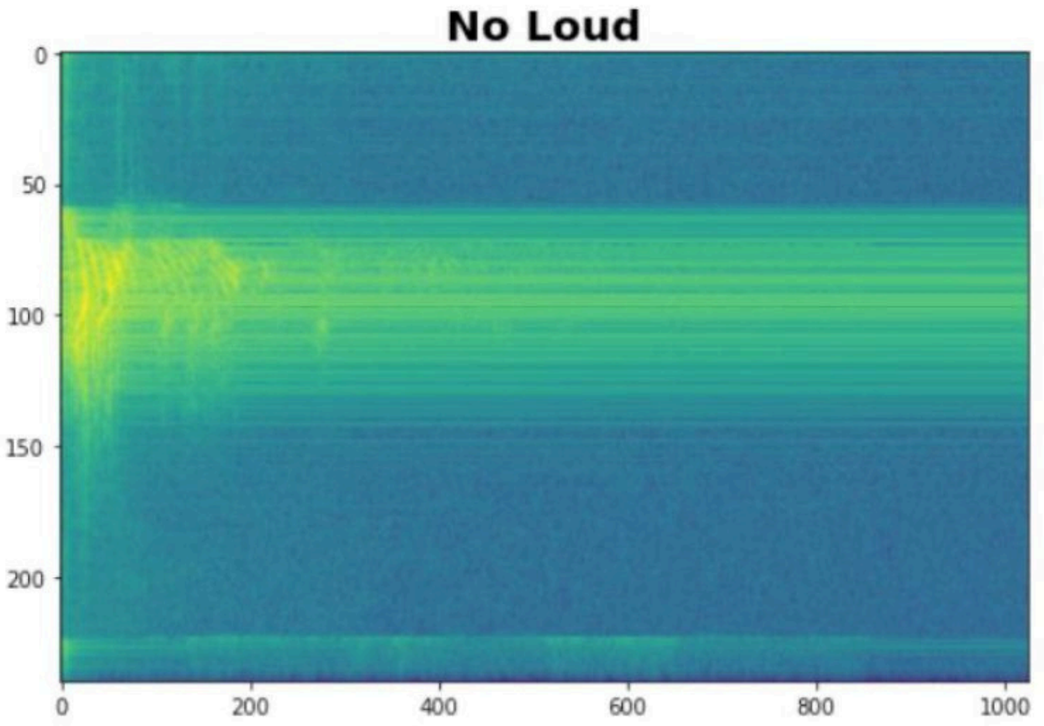


Data Preprocessing

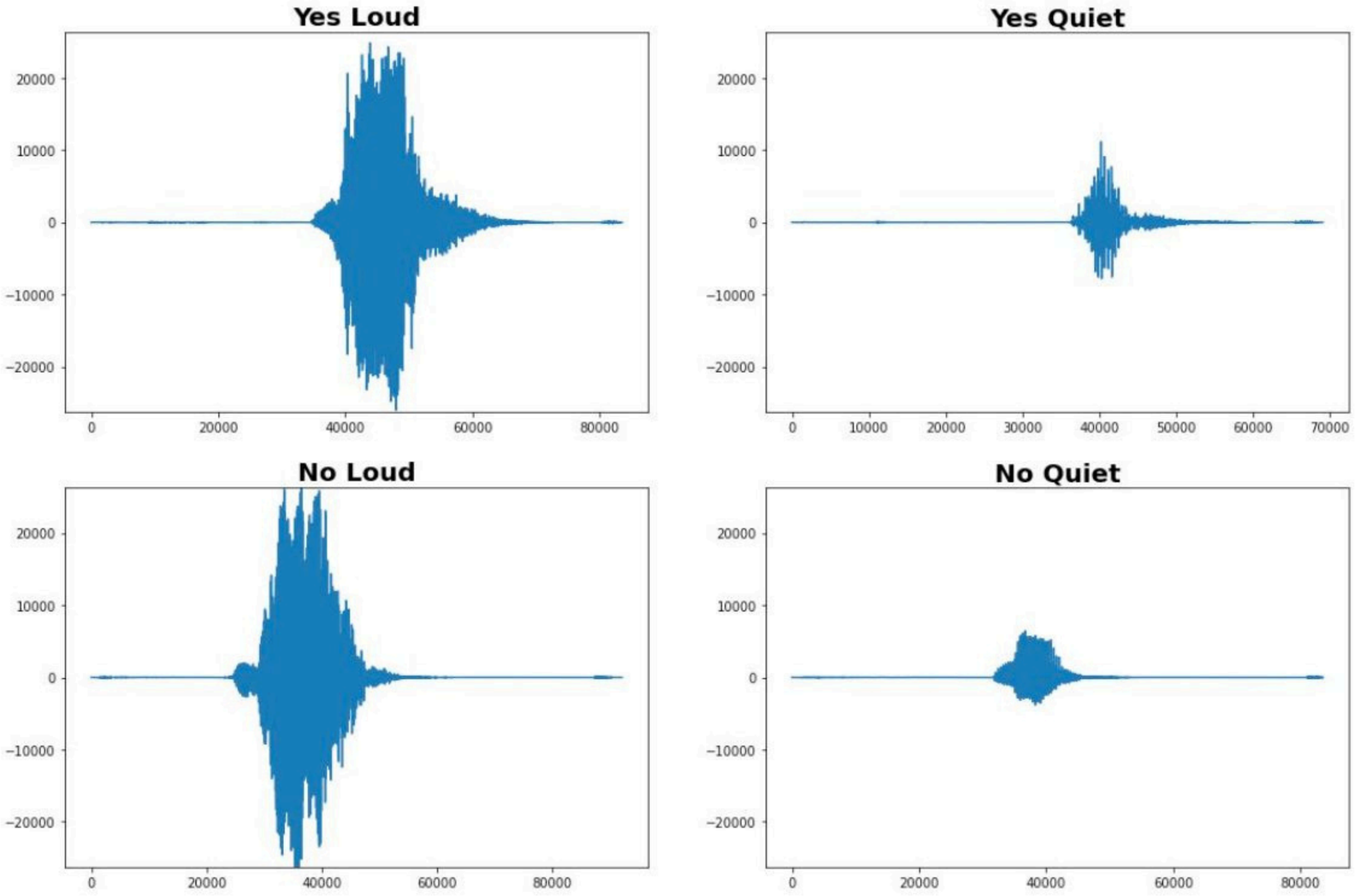


Data Preprocessing: **Spectrograms**

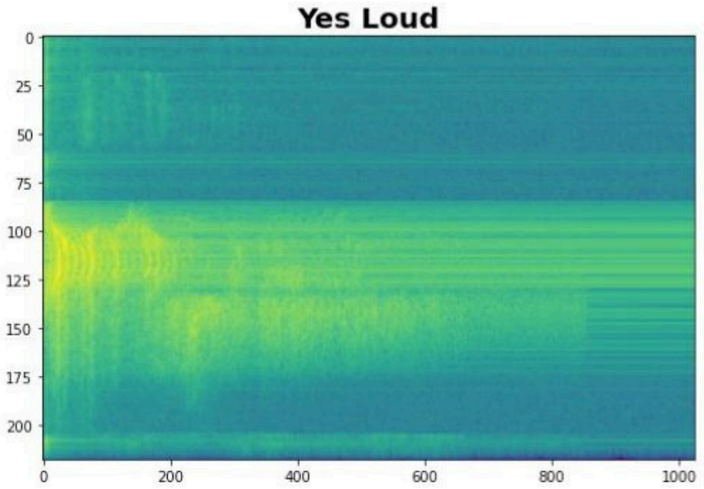


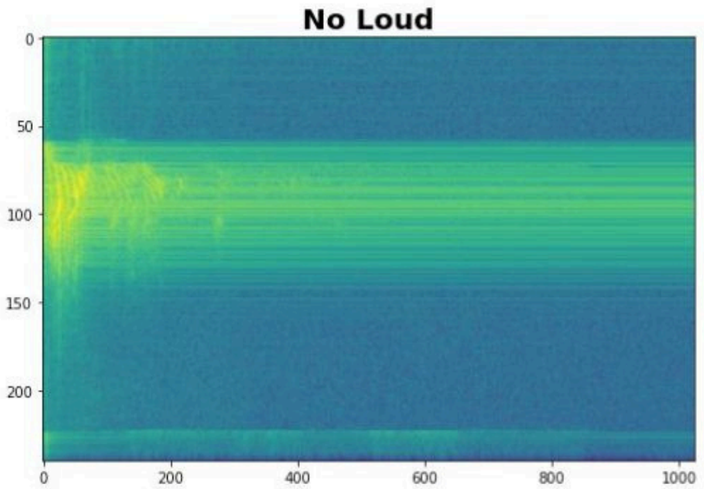


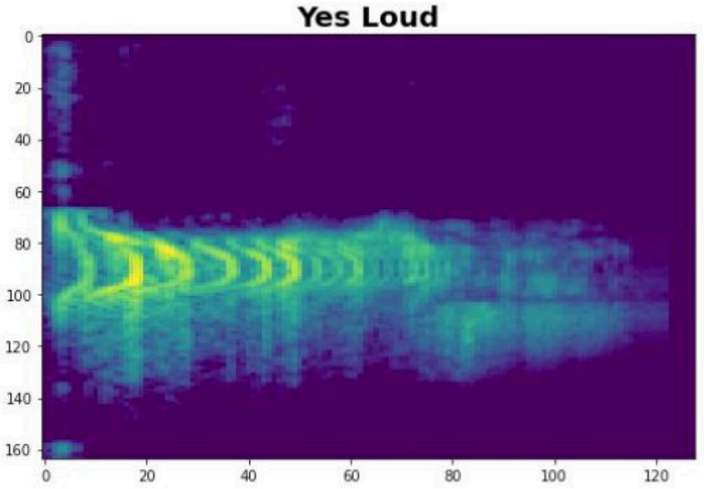
Data Preprocessing: **Spectrograms**

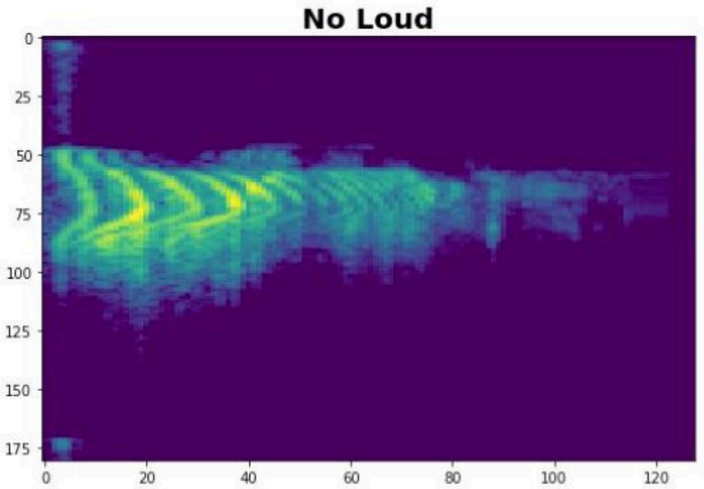


Spectrograms v. MFCCs

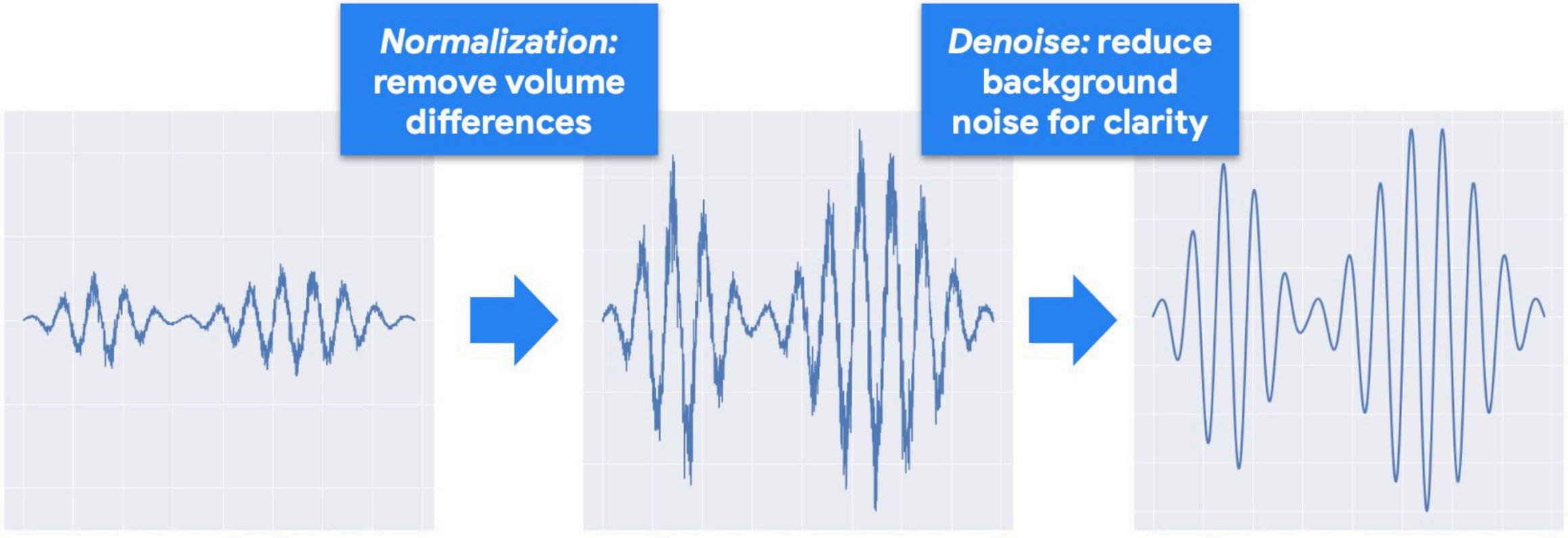








Additional **Feature Engineering**



KWS
Keyword Spotting Project 1

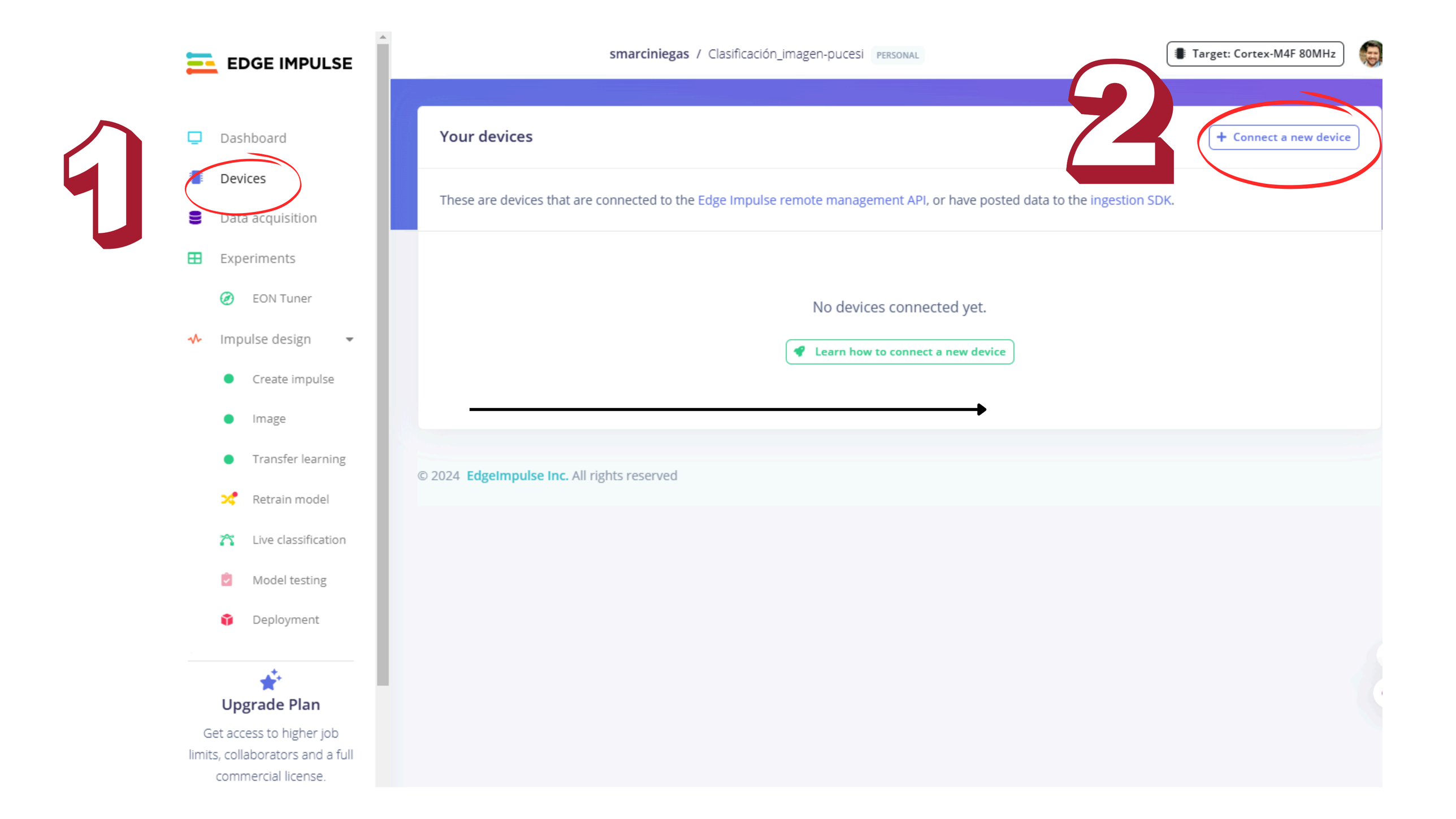
- Dataset

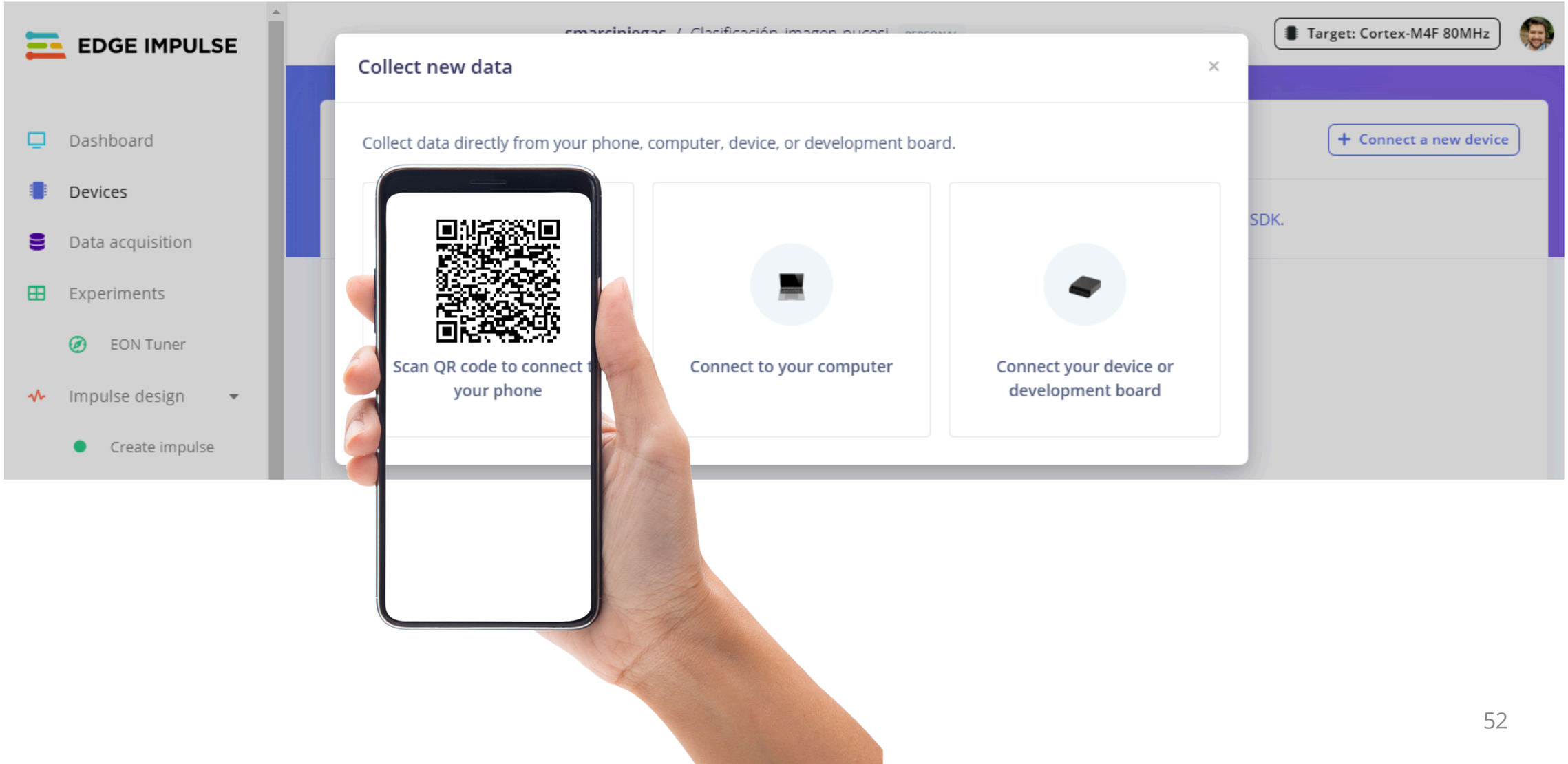
https://docs.edgeimpulse.com/docs/pre-built-datasets/keyword-spotting

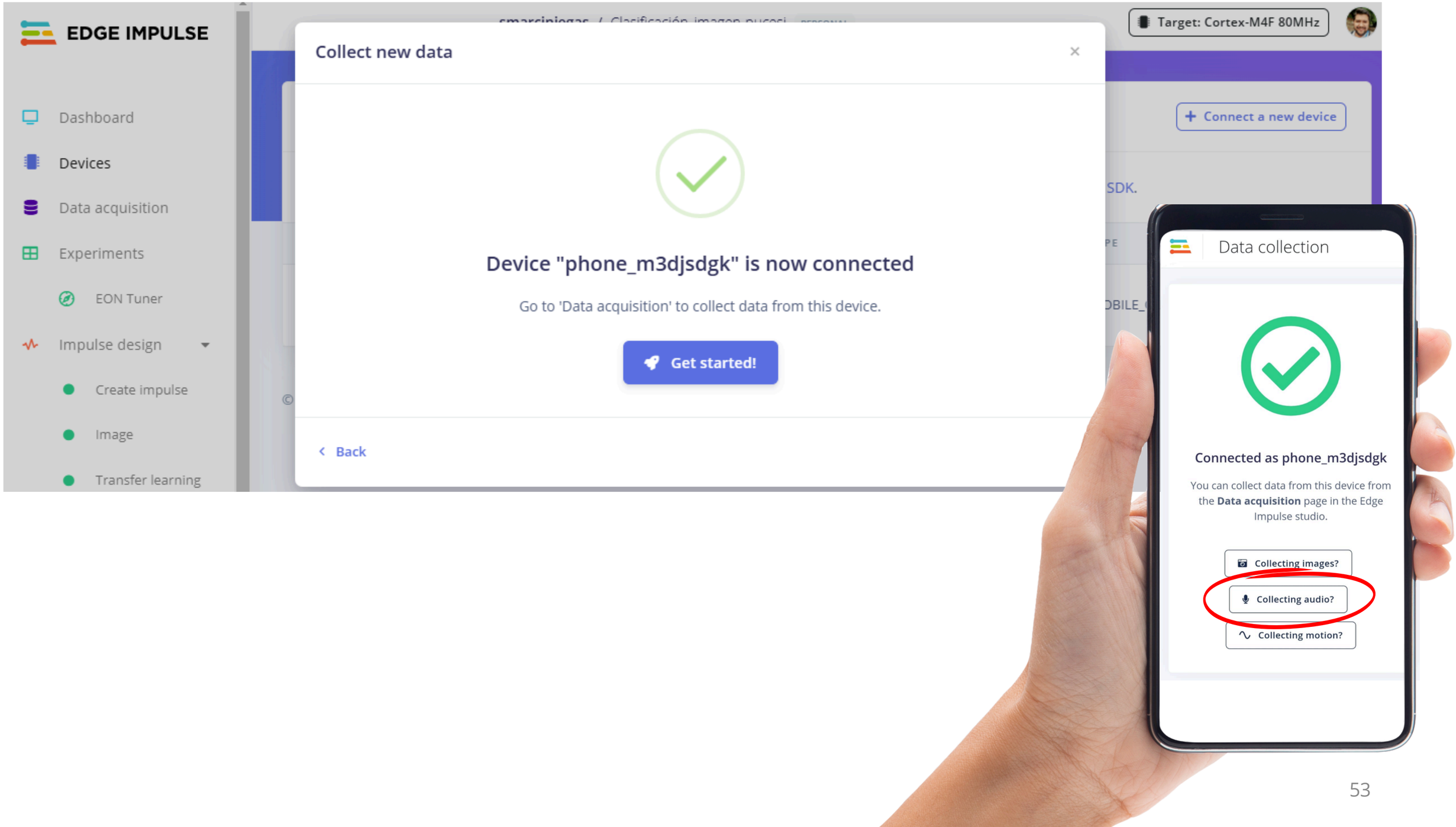
- First keyword: YES
- Second keyword: NO
- BACKGROUND
- NOISE

- EI Project

https://studio.edgeimpulse.com/studio/309308


EDGE IMPULSE
Dashboard
Devices
Data acquisition
Experiments
EON Tuner
Impulse design
Create impulse
Image
Transfer learning
Retrain model
Live classification
Model testing
Deployment
Upgrade Plan
Get access to higher job limits, collaborators and a full commercial license.
smarciniegas / Clasificación_imagen-pucesi
PERSONAL
Target: Cortex-M4F 80MHz
1
2
Your devices
Connect a new device
These are devices that are connected to the Edge Impulse remote management API, or have posted data to the ingestion SDK.
No devices connected yet.
Learn how to connect a new device
© 2024 EdgeImpulse Inc. All rights reserved


EDGE IMPULSE
Dashboard
Devices
Data acquisition
Experiments
EON Tuner
Impulse design
Create impulse
Target: Cortex-M4F 80MHz
Collect new data
Collect data directly from your phone, computer, device, or development board.
Scan QR code to connect t
your phone
Connect to your computer
Connect your device or
development board
+ Connect a new device
SDK.


EDGE IMPULSE
Dashboard
Devices
Data acquisition
Experiments
EON Tuner
Impulse design
Create impulse
Image
Transfer learning
Target: Cortex-M4F 80MHz
Connect a new device
Collect new data
Device "phone_m3djsdgk" is now connected
Go to 'Data acquisition' to collect data from this device.
Get started!
Back
Data collection
Connected as phone_m3djsdgk
You can collect data from this device from the Data acquisition page in the Edge Impulse studio.
Collecting images?
Collecting audio?
Collecting motion?

Data collection

Connected as phone_m3djsdgk

You can collect data from this device from the **Data acquisition** page in the Edge Impulse studio.

Collecting images?

Collecting audio?

Collecting motion?

Data collection

Permission required

Give access to the microphone

Data collection

Label: yes

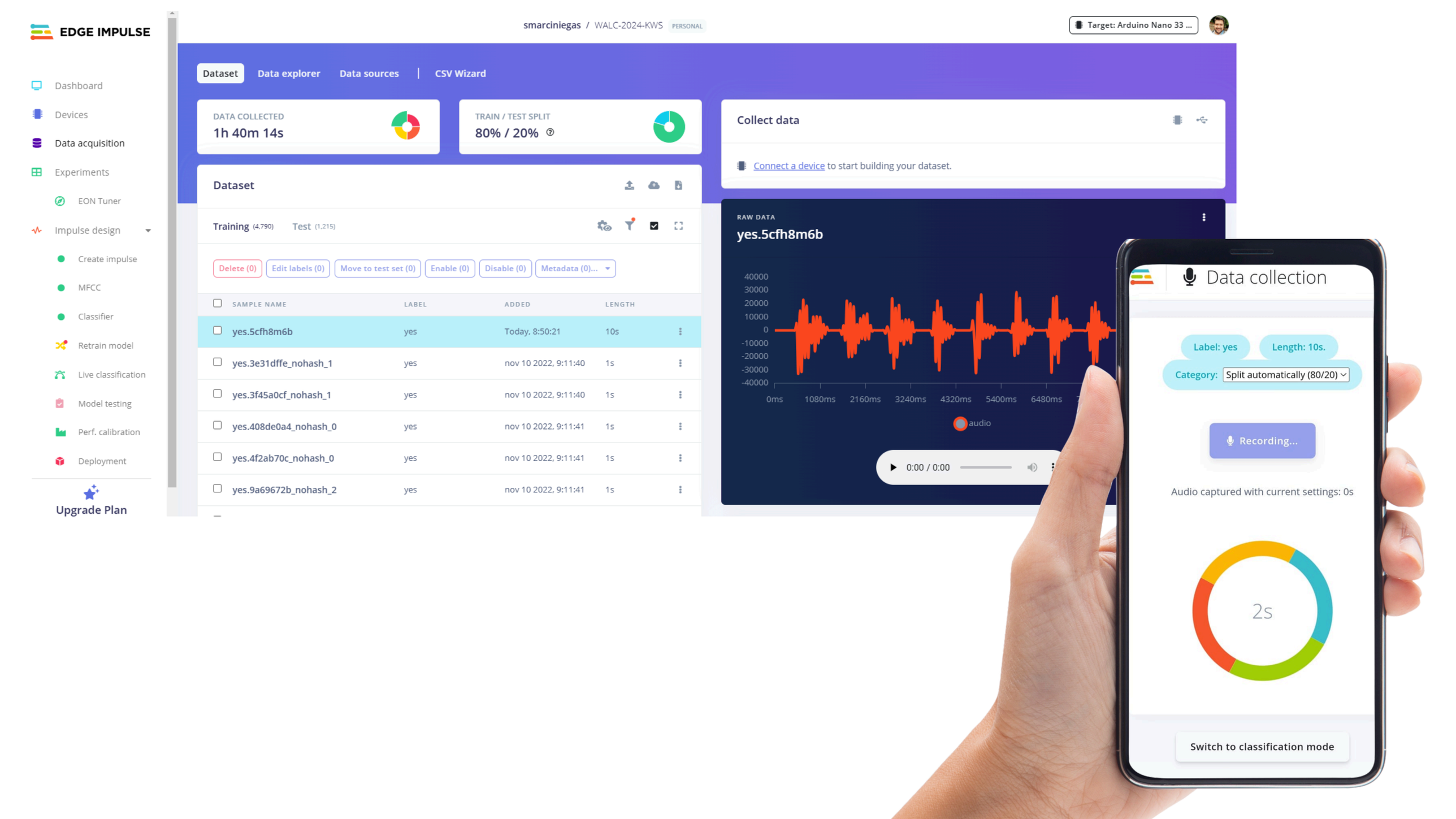
Length: 1s.

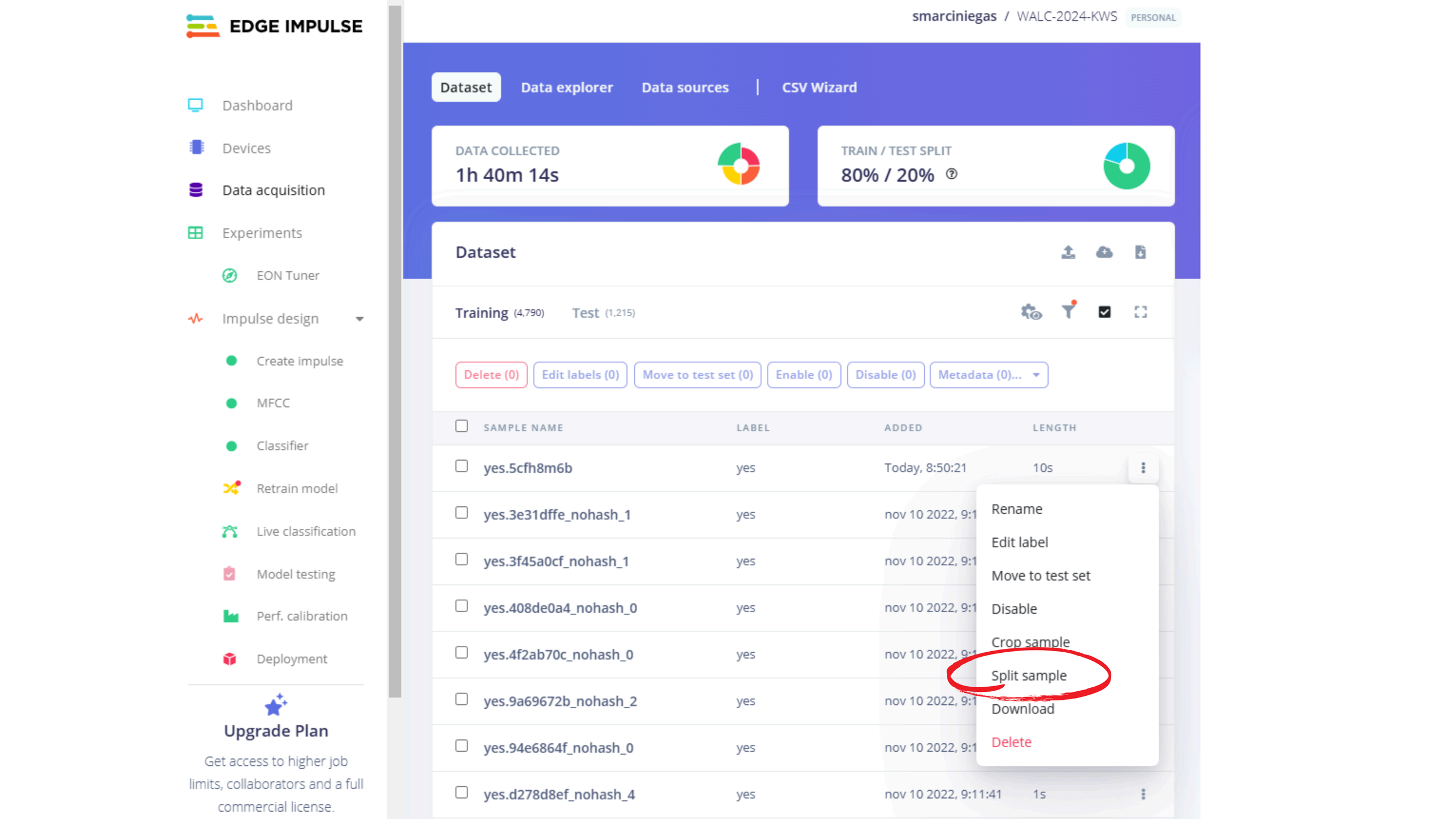
Category: Split automatically (80/20)

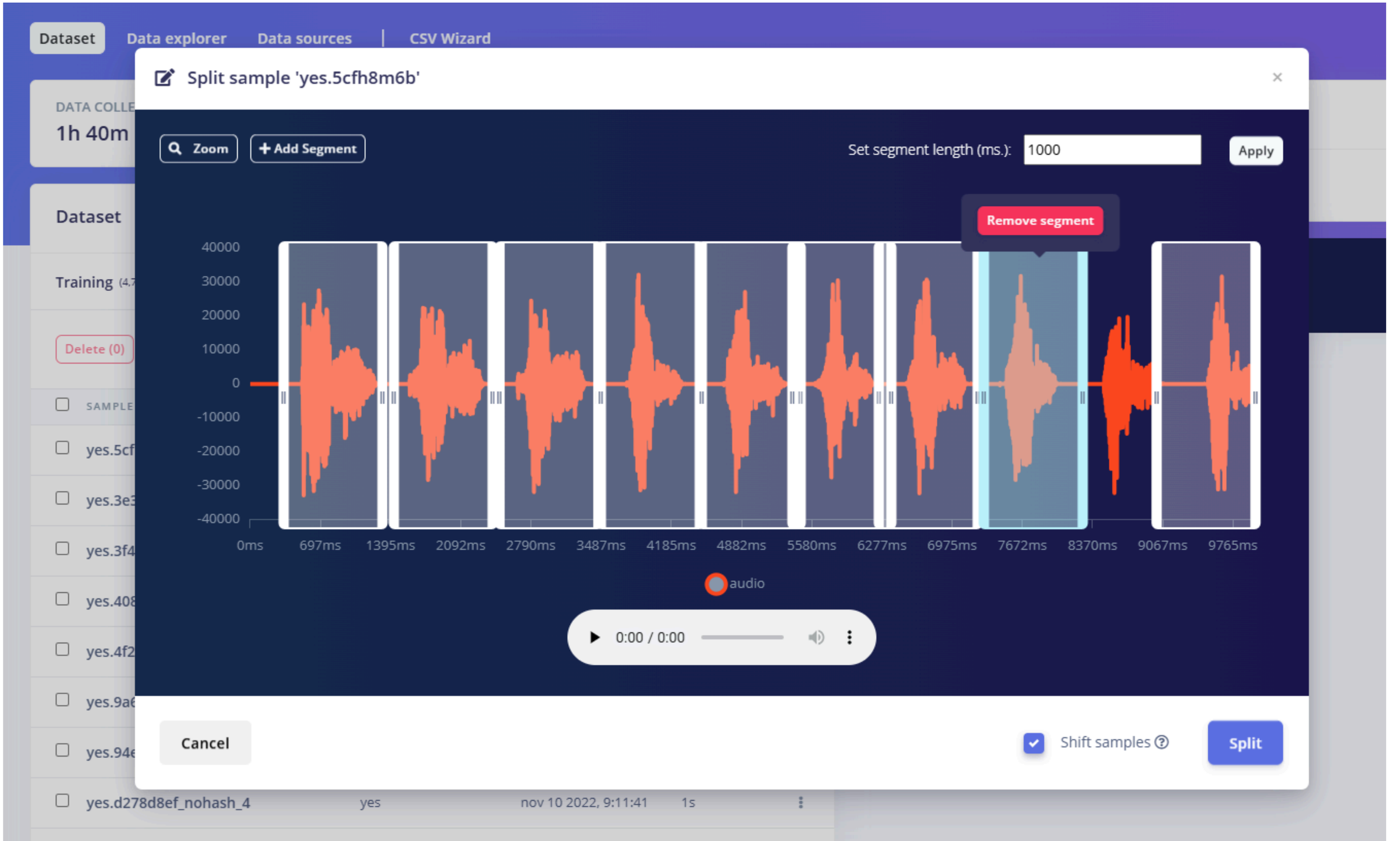
Start recording

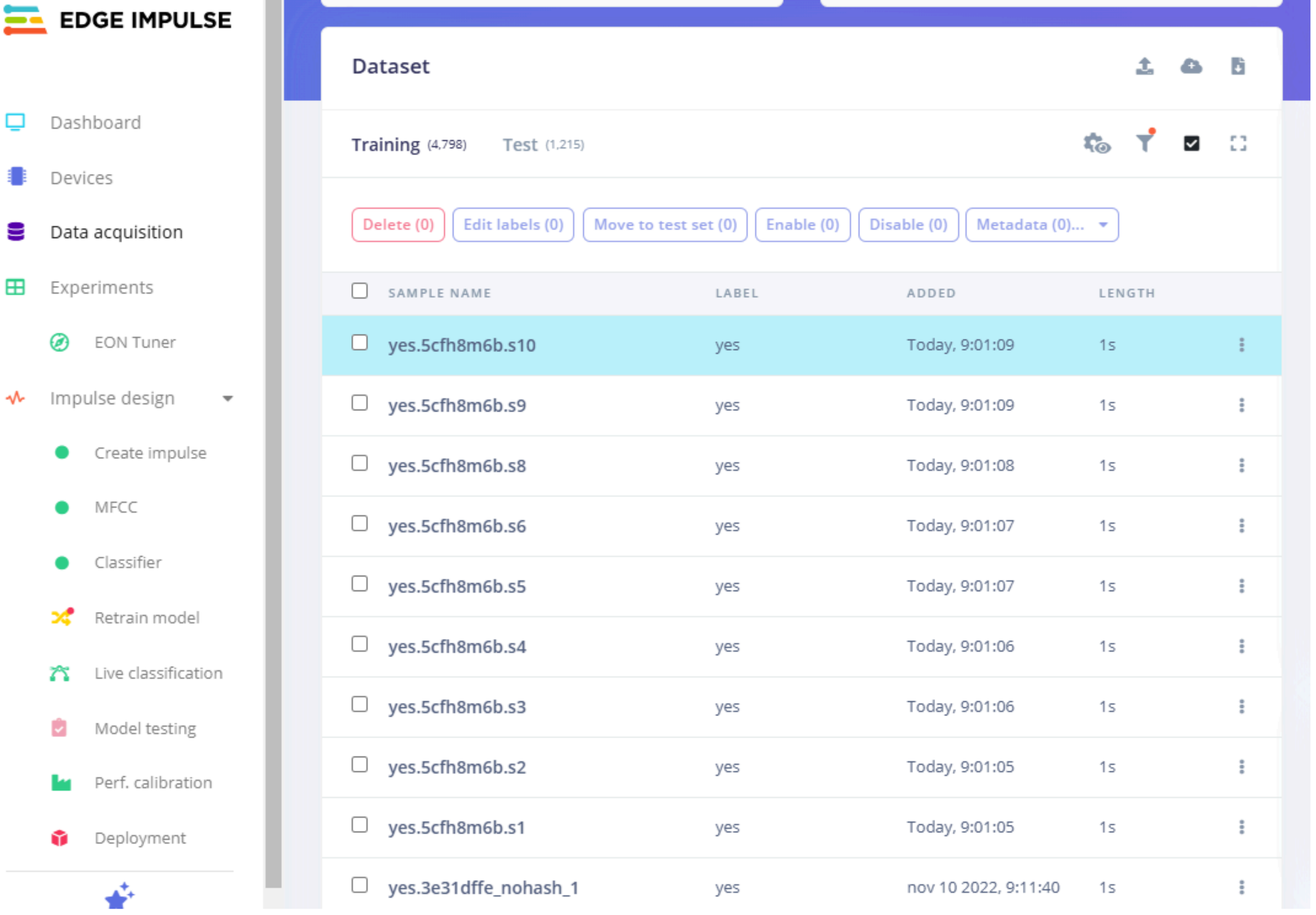
Audio captured with current settings: 0s

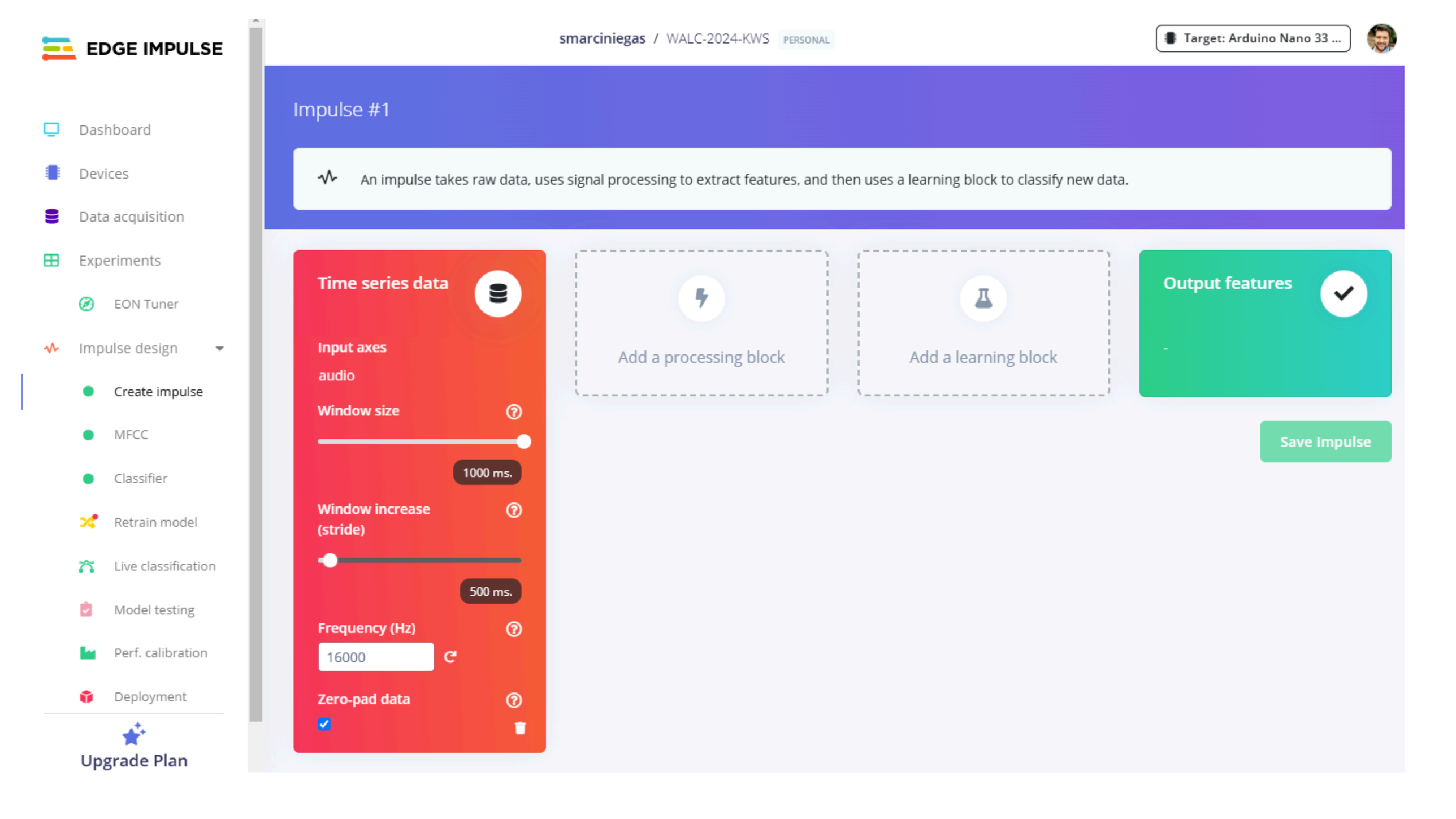
Switch to classification mode

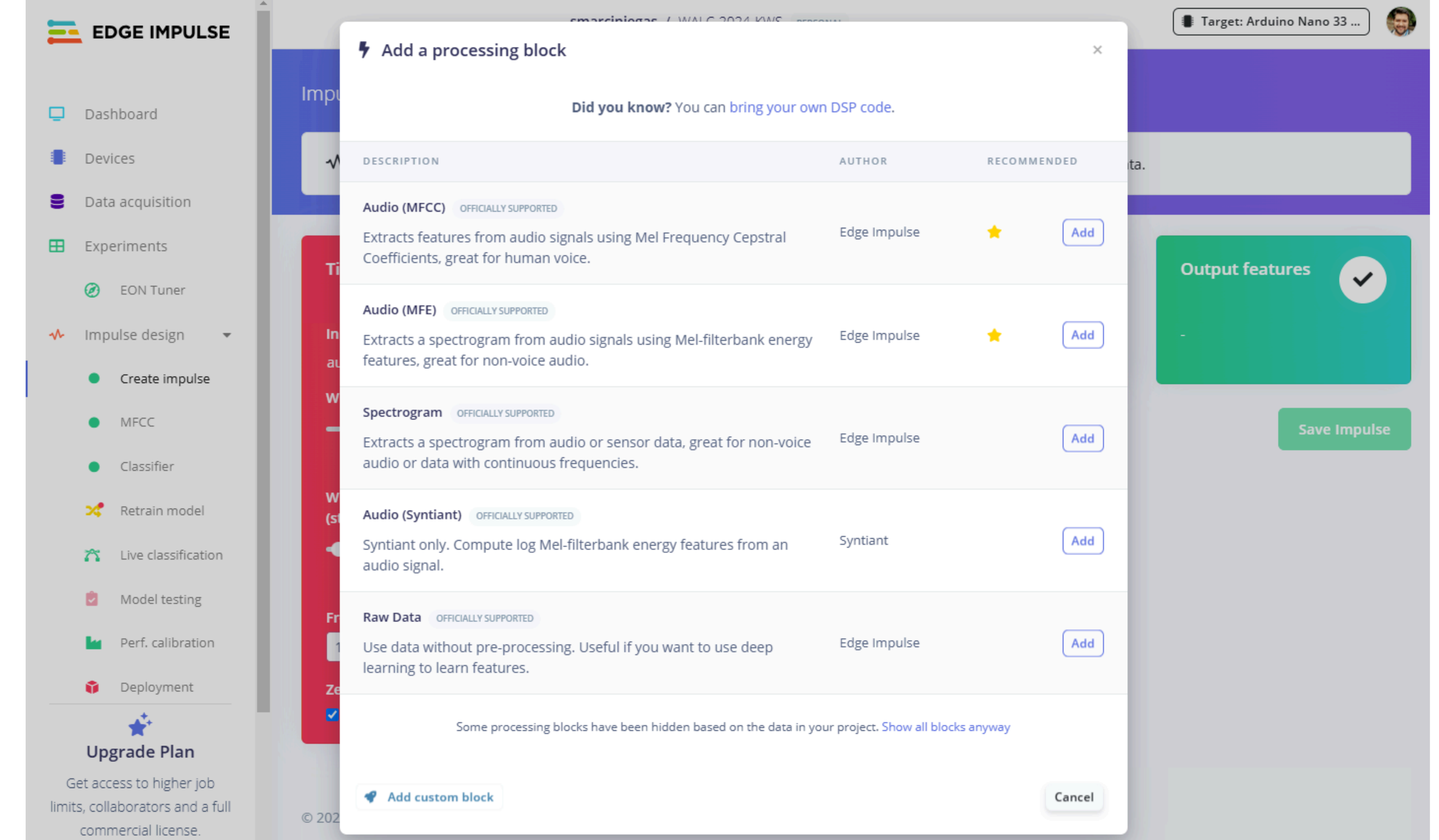

EDGE IMPULSE
smarciniegas / WALC-2024-KWS PERSONAL
Target: Arduino Nano 33 ...
Dashboard
Devices
Data acquisition
Experiments
EON Tuner
Impulse design
Create impulse
MFCC
Classifier
Retrain model
Live classification
Model testing
Perf. calibration
Deployment
Upgrade Plan
Dataset
Data explorer
Data sources
CSV Wizard
DATA COLLECTED
1h 40m 14s
TRAIN / TEST SPLIT
80% / 20%
Collect data
Connect a device to start building your dataset.
Dataset
Training (4.790)
Test (1,215)
Delete (0)
Edit labels (0)
Move to test set (0)
Enable (0)
Disable (0)
Metadata (0)...
SAMPLE NAME
LABEL
ADDED
LENGTH
yes.5cfh8m6b yes Today, 8:50:21 10s
yes.3e31dffe_nohash_1 yes nov 10 2022, 9:11:40 1s
yes.3f45a0cf_nohash_1 yes nov 10 2022, 9:11:40 1s
yes.408de0a4_nohash_0 yes nov 10 2022, 9:11:41 1s
yes.4f2ab70c_nohash_0 yes nov 10 2022, 9:11:41 1s
yes.9a69672b_nohash_2 yes nov 10 2022, 9:11:41 1s
RAW DATA
yes.5cfh8m6b
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
0ms
1080ms
2160ms
3240ms
4320ms
5400ms
6480ms
audio
0:00 / 0:00
Data collection
Label: yes
Length: 10s.
Category: Split automatically (80/20)
Recording...
Audio captured with current settings: 0s
2s
Switch to classification mode


EDGE IMPULSE
smarciniegas / WALC-2024-KWS PERSONAL
Dashboard
Devices
Data acquisition
Experiments
EON Tuner
Impulse design
Create impulse
MFCC
Classifier
Retrain model
Live classification
Model testing
Perf. calibration
Deployment
Upgrade Plan
Get access to higher job limits, collaborators and a full commercial license.
Dataset
Data explorer
Data sources
CSV Wizard
DATA COLLECTED
1h 40m 14s
TRAIN / TEST SPLIT
80% / 20%
Dataset
Training (4,790)
Test (1,215)
Delete (0)
Edit labels (0)
Move to test set (0)
Enable (0)
Disable (0)
Metadata (0)...
SAMPLE NAME
LABEL
ADDED
LENGTH
yes.5cfh8m6b
yes
Today, 8:50:21
10s
yes.3e31dffe_nohash_1
yes.3f45a0cf_nohash_1
yes.408de0a4_nohash_0
yes.4f2ab70c_nohash_0
yes.9a69672b_nohash_2
yes.94e6864f_nohash_0
yes.d278d8ef_nohash_4
nov 10 2022, 9:11:41
1s
Rename
Edit label
Move to test set
Disable
Crop sample
Split sample
Download
Delete

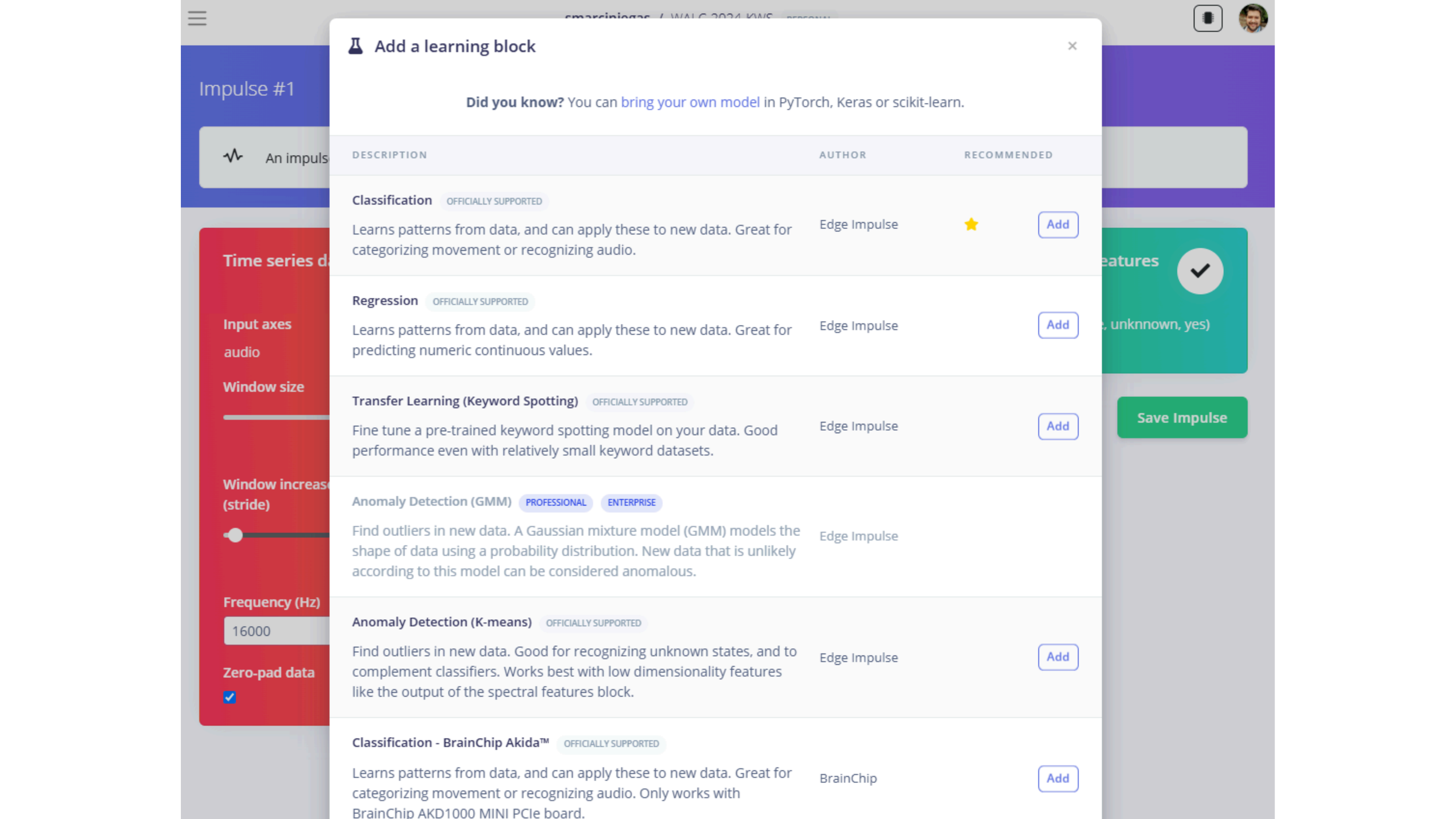

Dataset
Data explorer
Data sources
CSV Wizard
Split sample 'yes.5cfh8m6b'
Zoom
+ Add Segment
Set segment length (ms.):
1000
Apply
Remove segment
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
0ms
697ms
1395ms
2092ms
2790ms
3487ms
4185ms
4882ms
5580ms
6277ms
6975ms
7672ms
8370ms
9067ms
9765ms
audio
0:00 / 0:00
Cancel
Shift samples
Split
DATA COLLE
1h 40m
Dataset
Training
Delete (0)
SAMPLE
yes.5cf
yes.3e3
yes.3f4
yes.408
yes.4f2
yes.9a6
yes.94e
yes.d278d8ef_nohash_4
yes
nov 10 2022, 9:11:41
1s


EDGE IMPULSE
Dashboard
Devices
Data acquisition
Experiments
EON Tuner
Impulse design
Create impulse
MFCC
Classifier
Retrain model
Live classification
Model testing
Perf. calibration
Deployment
Dataset
Training (4,798)
Test (1,215)
Delete (0)
Edit labels (0)
Move to test set (0)
Enable (0)
Disable (0)
Metadata (0)...
SAMPLE NAME
LABEL
ADDED
LENGTH
yes.5cfh8m6b.s10 yes Today, 9:01:09 1s
yes.5cfh8m6b.s9 yes Today, 9:01:09 1s
yes.5cfh8m6b.s8 yes Today, 9:01:08 1s
yes.5cfh8m6b.s6 yes Today, 9:01:07 1s
yes.5cfh8m6b.s5 yes Today, 9:01:07 1s
yes.5cfh8m6b.s4 yes Today, 9:01:06 1s
yes.5cfh8m6b.s3 yes Today, 9:01:06 1s
yes.5cfh8m6b.s2 yes Today, 9:01:05 1s
yes.5cfh8m6b.s1 yes Today, 9:01:05 1s
yes.3e31dffe_nohash_1 yes nov 10 2022, 9:11:40 1s

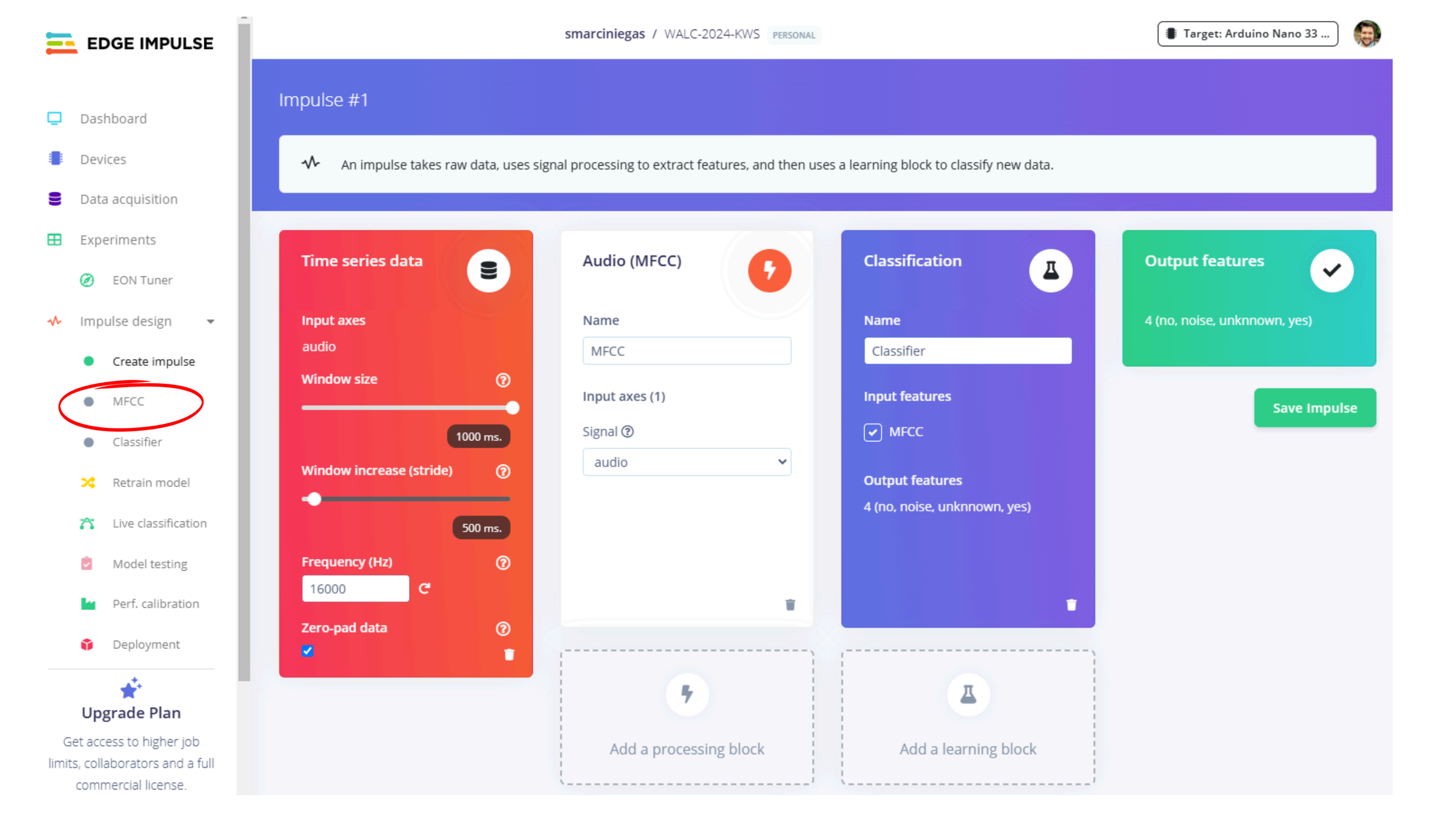

EDGE IMPULSE
smarciniegas / WALC-2024-KWS PERSONAL
Target: Arduino Nano 33 ...
Dashboard
Devices
Data acquisition
Experiments
EON Tuner
Impulse design
Create impulse
MFCC
Classifier
Retrain model
Live classification
Model testing
Perf. calibration
Deployment
Upgrade Plan
Impulse #1
An impulse takes raw data, uses signal processing to extract features, and then uses a learning block to classify new data.
Time series data
Input axes
audio
Window size
1000 ms.
Window increase (stride)
500 ms.
Frequency (Hz)
16000
Zero-pad data
Add a processing block
Add a learning block
Output features
-
Save Impulse


EDGE IMPULSE
Dashboard
Devices
Data acquisition
Experiments
EON Tuner
Impulse design
Create impulse
MFCC
Classifier
Retrain model
Live classification
Model testing
Perf. calibration
Deployment
Upgrade Plan
Get access to higher job limits, collaborators and a full commercial license.
Target: Arduino Nano 33 ...
Add a processing block
Did you know? You can bring your own DSP code.
DESCRIPTION
AUTHOR
RECOMMENDED
Audio (MFCC) OFFICIALLY SUPPORTED
Extracts features from audio signals using Mel Frequency Cepstral Coefficients, great for human voice.
Edge Impulse
Add
Audio (MFE) OFFICIALLY SUPPORTED
Extracts a spectrogram from audio signals using Mel-filterbank energy features, great for non-voice audio.
Edge Impulse
Add
Spectrogram OFFICIALLY SUPPORTED
Extracts a spectrogram from audio or sensor data, great for non-voice audio or data with continuous frequencies.
Edge Impulse
Add
Audio (Syntiant) OFFICIALLY SUPPORTED
Syntiant only. Compute log Mel-filterbank energy features from an audio signal.
Syntiant
Add
Raw Data OFFICIALLY SUPPORTED
Use data without pre-processing. Useful if you want to use deep learning to learn features.
Edge Impulse
Add
Some processing blocks have been hidden based on the data in your project. Show all blocks anyway
Add custom block
Cancel
Output features
Save Impulse

Método	Descripción	Autor	Uso
Audio (MFCC)	Extrae características de señales de audio usando coeficientes cepstrales de frecuencia Mel; genial para voz humana.	Edge Impulse	Análisis de voz humana
Audio (MFE)	Extrae un espectrograma de señales de audio usando características Mel-filterbank; genial para audio no vocal.	Edge Impulse	Análisis de audio no vocal
Spectrogram	Extrae un espectrograma de datos de audio o sensor; genial para audio no vocal o datos con frecuencias continuas.	Edge Impulse	Análisis de audio general
Audio (Syntiant)	Solo Syntiant. Calcula características Mel-filterbank logarítmicas de una señal de audio.	Syntiant	Procesamiento eficiente en dispositivos Syntiant
Raw Data	Usa datos sin preprocesar; útil si se desea usar aprendizaje profundo para aprender características.	Edge Impulse	Aprendizaje profundo


Impulse #1
An impuls
Time series d
Input axes
audio
Window size
Window increas
(stride)
Frequency (Hz)
16000
Zero-pad data
eatures
, unknnown, yes)
Save Impulse
Add a learning block
Did you know? You can bring your own model in PyTorch, Keras or scikit-learn.
DESCRIPTION
AUTHOR
RECOMMENDED
Classification OFFICIALLY SUPPORTED
Learns patterns from data, and can apply these to new data. Great for categorizing movement or recognizing audio.
Edge Impulse
Add
Regression OFFICIALLY SUPPORTED
Learns patterns from data, and can apply these to new data. Great for predicting numeric continuous values.
Edge Impulse
Add
Transfer Learning (Keyword Spotting) OFFICIALLY SUPPORTED
Fine tune a pre-trained keyword spotting model on your data. Good performance even with relatively small keyword datasets.
Edge Impulse
Add
Anomaly Detection (GMM) PROFESSIONAL ENTERPRISE
Find outliers in new data. A Gaussian mixture model (GMM) models the shape of data using a probability distribution. New data that is unlikely according to this model can be considered anomalous.
Edge Impulse
Anomaly Detection (K-means) OFFICIALLY SUPPORTED
Find outliers in new data. Good for recognizing unknown states, and to complement classifiers. Works best with low dimensionality features like the output of the spectral features block.
Edge Impulse
Add
Classification - BrainChip Akida™ OFFICIALLY SUPPORTED
Learns patterns from data, and can apply these to new data. Great for categorizing movement or recognizing audio. Only works with BrainChip AKD1000 MINI PCIe board.
BrainChip
Add

Método	Descripción	Autor	Uso
Classification	Aprende patrones de los datos y puede aplicarlos a nuevos datos. Genial para categorizar movimiento o reconocer audio.	Edge Impulse	Clasificación de movimiento/audio
Regression	Aprende patrones de los datos y puede aplicarlos a nuevos datos. Genial para predecir valores numéricos continuos.	Edge Impulse	Predicción de valores numéricos continuos
Transfer Learning (Keyword Spotting)	Ajusta un modelo pre-entrenado de detección de palabras clave en tus datos. Buen rendimiento incluso con conjuntos de datos pequeños.	Edge Impulse	Detección de palabras clave
Anomaly Detection (GMM)	Encuentra valores atípicos en nuevos datos. El modelado GMM define la forma de los datos usando distribución de probabilidad.	Edge Impulse	Detección de anomalías empleando GMM
Anomaly Detection (K-means)	Encuentra valores atípicos en nuevos datos. Bueno para reconocer estados desconocidos y complementar clasificadores.	Edge Impulse	Detección de anomalías empleando K-means
Classification - BrainChip Akida™	Aprende patrones de los datos y puede aplicarlos a nuevos datos. Solo funciona con la placa BrainChip AKD1000 MINI PCIe.	BrainChip	Clasificación de movimiento/audio

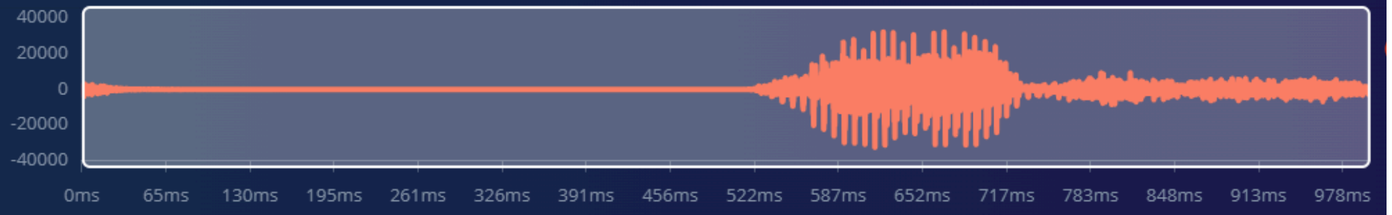

EDGE IMPULSE
smarciniegas / WALC-2024-KWS PERSONAL
Target: Arduino Nano 33 ...
Dashboard
Devices
Data acquisition
Experiments
EON Tuner
Impulse design
Create impulse
MFCC
Classifier
Retrain model
Live classification
Model testing
Perf. calibration
Deployment
Upgrade Plan
Get access to higher job limits, collaborators and a full commercial license.
Impulse #1
An impulse takes raw data, uses signal processing to extract features, and then uses a learning block to classify new data.
Time series data
Input axes
audio
Window size
1000 ms.
Window increase (stride)
500 ms.
Frequency (Hz)
16000
Zero-pad data
Audio (MFCC)
Name
MFCC
Input axes (1)
Signal
audio
Classification
Name
Classifier
Input features
MFCC
Output features
4 (no, noise, unknnown, yes)
Output features
4 (no, noise, unknnown, yes)
Save Impulse
Add a processing block
Add a learning block

Parameters Generate features

Raw data

Show: All labels

yes.5cfh8m6b.s1



0:00 / 0:01

Raw features

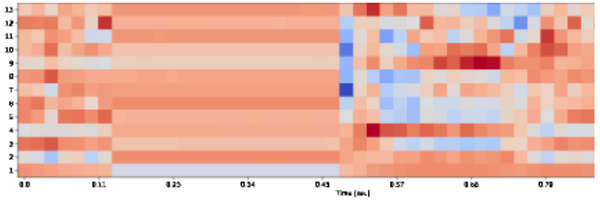
632, -737, -83, 1223, -1593, 804, 320, -824, 682, -8,…

Label

yes

DSP result

Cepstral Coefficients



Processed features

0.7850, -0.9685, 1.2699, -1.1111, 0.9605, 0.9659, -0.0791, 0.761

Parameters

Autotune parameters

Mel Frequency Cepstral Coefficients

Number of coefficients	13
Frame length	0.02
Frame stride	0.02
Filter number	32
FFT length	256
Normalization window size	101
Low frequency	0

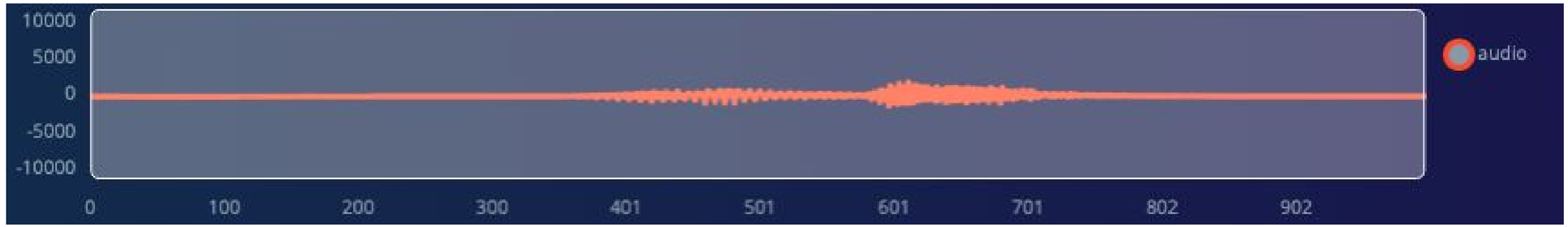
On-device performance

PROCESSING TIME
266 ms.

PEAK RAM USAG
15 KB

Mel Frequency Cepstral Coefficients	-	Son coeficientes que representan el espectro de sonido de manera similar a cómo el oído humano percibe el sonido. Fundamentales en reconocimiento de voz y análisis de audio.
Number of coefficients	13	• Determina la cantidad de coeficientes MFCC a extraer • Es un valor estándar en la industria • Balance entre detalle y eficiencia computacional
Frame length	0.02	• Duración de cada segmento de audio en segundos (20ms) • Define el tamaño de la "ventana" de análisis • Determina la resolución temporal del análisis
Frame stride	0.02	• Intervalo entre el inicio de frames consecutivos • Al ser igual al frame length, indica que no hay solapamiento • Afecta a la continuidad del análisis
Filter number	32	• Cantidad de filtros en el banco de filtros Mel • Determina la resolución en frecuencia • Valor común para un buen equilibrio entre precisión y eficiencia
FFT length	256	• Tamaño de la Transformada Rápida de Fourier • Define la resolución frecuencial • Adecuado para aplicaciones de voz estándar
Normalization window size	101	• Tamaño de la ventana para normalización • Ayuda a equilibrar variaciones en amplitud • Mejora la robustez del análisis
Low frequency	0	• Frecuencia mínima a analizar • Comienza desde 0 Hz • Incluye todo el rango de frecuencias bajas
High frequency	Click to set	• Frecuencia máxima a analizar • Valor ajustable según necesidades • Define el límite superior del análisis
Pre-emphasis Coefficient	0.98	• Amplifica las frecuencias altas • Valor estándar en la industria • Mejora el análisis de consonantes

Raw data



1 second of Sound raw data

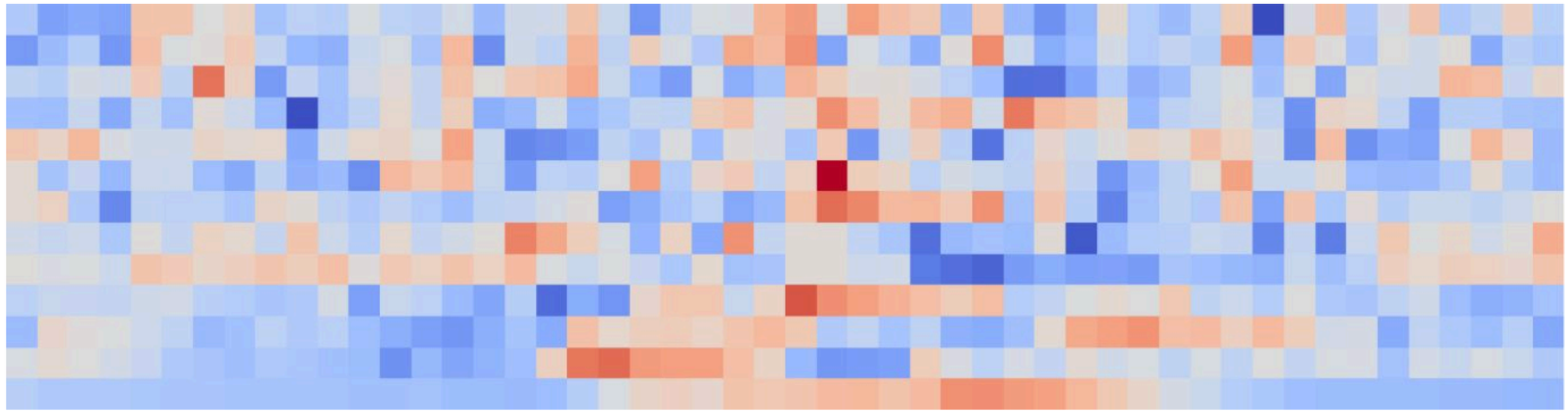
Mel Frequency Cepstral Coefficients

Number of coefficients 13

Frame length 0.02

MFCC

13 Coef.



Slots = 1/ 0.02 = 50

Dim = 13 x 50 = 650

50 slots

Dashboard
Devices
Data acquisition
Experiments
EON Tuner
Impulse design
Create impulse
MFCC
Classifier
Retrain model
Live classification
Model testing
Perf. calibration
Deployment

Parameters | Generate features

Training set

Data in training set	1h 19m 58s
Classes	4 (no, noise, unknnown, yes)
Training windows	4,798

Generate features

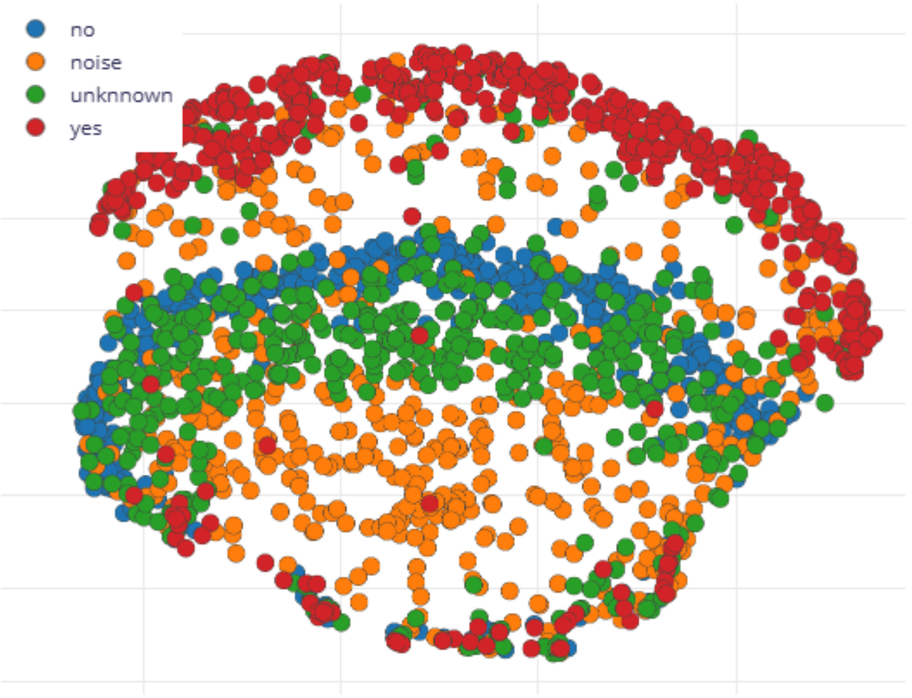
Feature generation output

(0)

```
Job started
Reducing dimensions for visualizations...
UMAP( verbose=True)
Wed Nov 13 14:30:02 2024 Construct fuzzy simplicial set
Wed Nov 13 14:30:05 2024 Finding Nearest Neighbors
Wed Nov 13 14:30:07 2024 Finished Nearest Neighbor Search
Wed Nov 13 14:30:08 2024 Construct embedding
Epochs completed: 100% 500/500 [00:04<00:00, 109.03it/s]
Wed Nov 13 14:30:14 2024 Finished embedding
Writing output files...
Writing output files OK
Reducing dimensions for visualizations OK (took 12033ms.)

Job completed (success)
```

Feature explorer



On-device performance

PROCESSING TIME
266 ms.

PEAK RAM USAGE
15 KB

- Dashboard
- Devices
- Data acquisition
- Experiments
- EON Tuner
- Impulse design
  - Create impulse
  - MFCC
  - Classifier
  - Retrain model
  - Live classification
  - Model testing
  - Perf. calibration
  - Deployment

Upgrade Plan

Get access to higher job limits, collaborators and a full commercial license.

View plans

Learning rate: 0.005

Training processor: CPU

Advanced training settings

Audio training options

Data augmentation

Neural network architecture

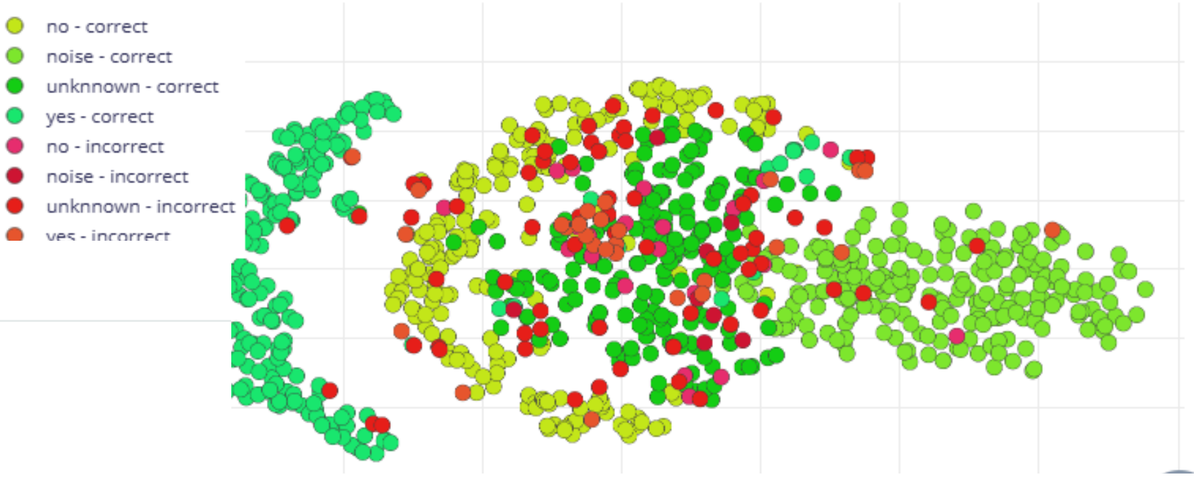
Architecture presets: 1D Convolutional (Default) | 2D Convolutional

- Input layer (650 features)
- Reshape layer (13 columns)
- 1D conv / pool layer (8 neurons, 3 kernel size, 1 layer)
- Dropout (rate 0.25)
- 1D conv / pool layer (16 neurons, 3 kernel size, 1 layer)
- Dropout (rate 0.25)
- Flatten layer
- Add an extra layer
- Output layer (4 classes)

Capa	Tipo	Función
Input Layer	Capa de Entrada	• Recibe los datos de entrada con 650 características • Define la dimensionalidad inicial de los datos • Sirve como punto de entrada para el procesamiento
Reshape Layer	Capa de Reshape	• Reorganiza los datos en 13 columnas • Prepara los datos para el procesamiento convolucional • Optimiza la estructura de datos para las siguientes capas
1ª Conv/Pool	Capa Convolucional 1D	• Procesa los datos con 8 neuronas y kernel size 3 • Extrae características de bajo nivel • Realiza la primera etapa de procesamiento convolucional
1º Dropout	Capa de Dropout	• Desactiva aleatoriamente el 25% de las neuronas • Previene el sobreajuste • Mejora la generalización del modelo
2ª Conv/Pool	Capa Convolucional 1D	• Procesa con 16 neuronas y kernel size 3 • Extrae características de alto nivel • Realiza la segunda etapa de procesamiento convolucional
2º Dropout	Capa de Dropout	• Desactiva aleatoriamente el 25% de las neuronas • Previene el sobreajuste • Mantiene la regularización del modelo
Flatten	Capa de Aplanamiento	• Convierte datos multidimensionales a unidimensionales • Prepara los datos para la capa de salida • Facilita la clasificación final
Output Layer	Capa de Salida	• Realiza la clasificación final en 4 clases • Produce las probabilidades para cada clase • Genera la predicción final del modelo

METRIC	VALUE
Area under ROC Curve	0.99
Weighted average Precision	0.92
Weighted average Recall	0.92
Weighted average F1 score	0.92

Data explorer (full training set)



Last training performance (validation set)

ACCURACY
92.0%

LOSS
0,28

Confusion matrix (validation set)

	NO	NOISE	UNKNNOWN	YES
NO	**95.9%**	1.4%	2.7%	0%
NOISE	0.4%	**95.6%**	3.9%	0%
UNKNNOWN	7.5%	5.6%	**84.0%**	3.0%
YES	2.9%	1.2%	2.1%	**93.8%**
F1 SCORE	0.92	0.93	0.88	0.95

EDGE IMPULSE

- Dashboard
- Devices
- Data acquisition
- Experiments
- EON Tuner
- Impulse design
- Create impulse
- Image
- Transfer learning
- Retrain model
- Live classification
- Model testing
- Deployment
- Versioning

Upgrade Plan

Get access to higher job limits, collaborators and a full commercial license.

View plans

Configure your deployment

You can deploy your impulse to any device. This makes the model run without an interr with minimal power consumption. Read more.

Search deployment options

DEFAULT DEPLOYMENT

Arduino library

An Arduino library with examples that runs on most Arm-based Arduino d

MODEL OPTIMIZATIONS

Model optimizations can increase on-device performance but may reduce accuracy

EON™ Compiler

Same accuracy, 17% less RAM, 15% less ROM.

Quantized (int8)

Selected ✓

	IMAGE	TRANSFER LEARNING	TOTAL
LATENCY	7 ms.	1061 ms.	**1068 ms.**
RAM	4,0K	334,6K	**334,6K**
FLASH	-	585,3K	-
ACCURACY			-

Unoptimized (float32)

Select

	IMAGE	TRANSFER LEARNING	TOTAL
LATENCY	7 ms.	1462 ms.	**1469 ms.**
RAM	4,0K	893,7K	**893,7K**
FLASH	-	1,6M	-

Run this model

Scan QR code or launch in browser to test your prototype

Launch in browser

Track4

IoT

Internet de las Cosas

Machine Learning

Thanks