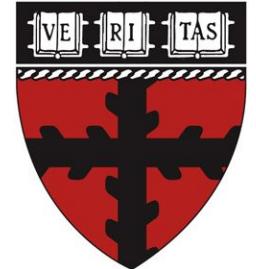




Topics in Applied Machine Learning: A Hands-on Approach – MS12 (Audio)

Marcelo José Rovai and José Alberto Ferreira Filho
UNIFEI - Universidade Federal de Itajubá, Brazil

Flávio Calmon and Lucas Monteiro Paes
Harvard University, USA



Sound



Vibration



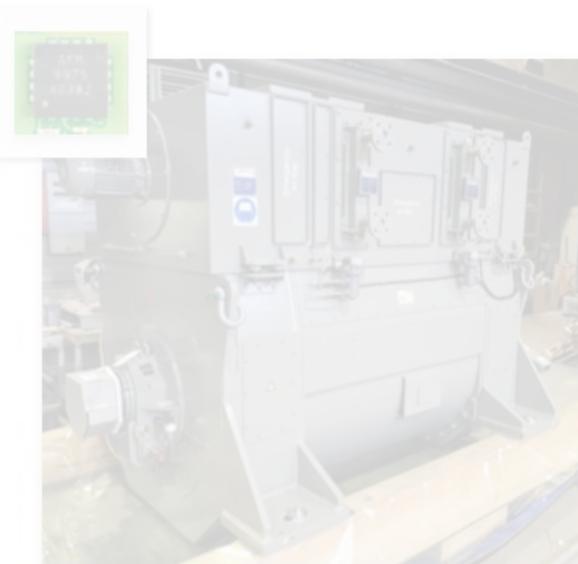
Vision



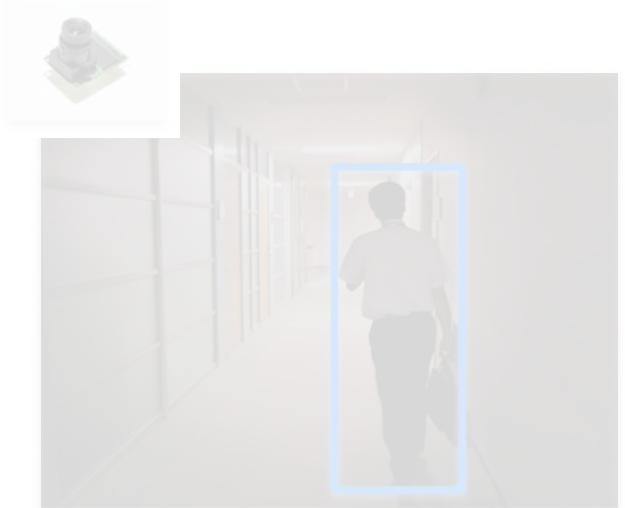
Sound



Vibration



Vision



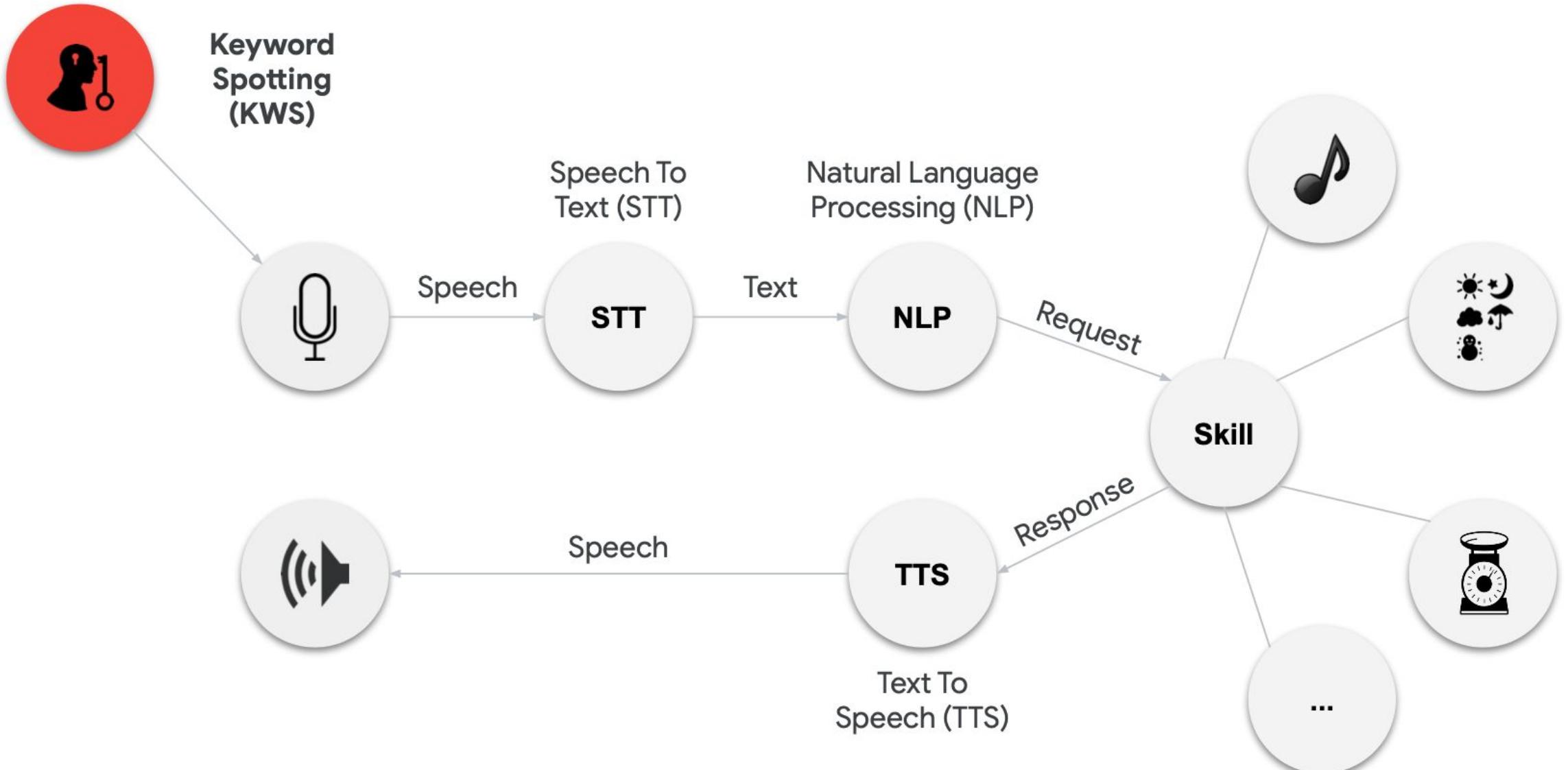
KWS (KeyWord Spotting) Introduction

Personal Assistant

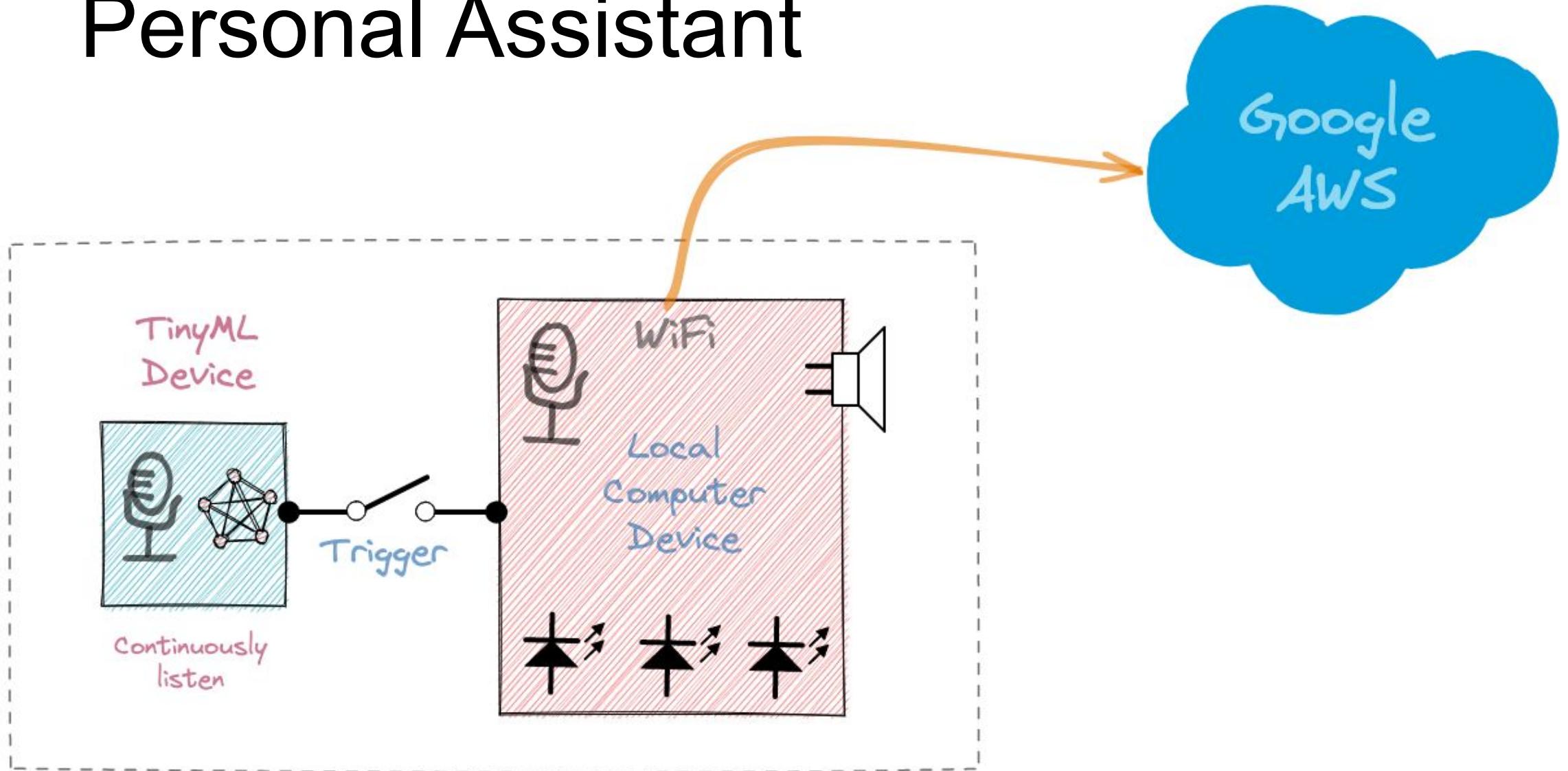


Keyword Spotting v. General Speech Recognition

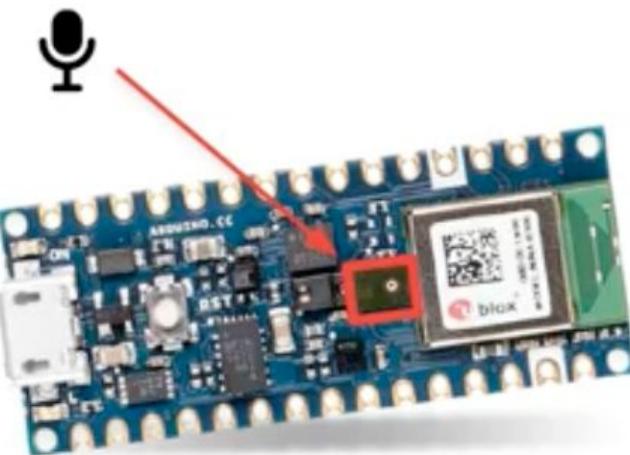
- **Keyword spotting** is one of the most successful examples of **TinyML**
 - Low-power, continuous, on-device
 - Common Voice SWTS^{*} expands keyword spotting to more languages
 - * Single Word Target Segment
- **General ASR**^{*} still requires **larger, power-hungry models**
 - But it can run on mobile devices (offline dictation on smartphones)
 - * Automatic Speech Recognition



Personal Assistant



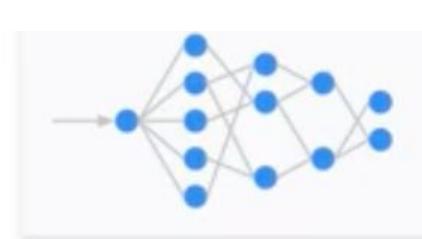
“Cascade” Detection: multi-stage model



- 1 Continuously listen on the microcontroller

2

- Process the data with **TinyML** at the edge



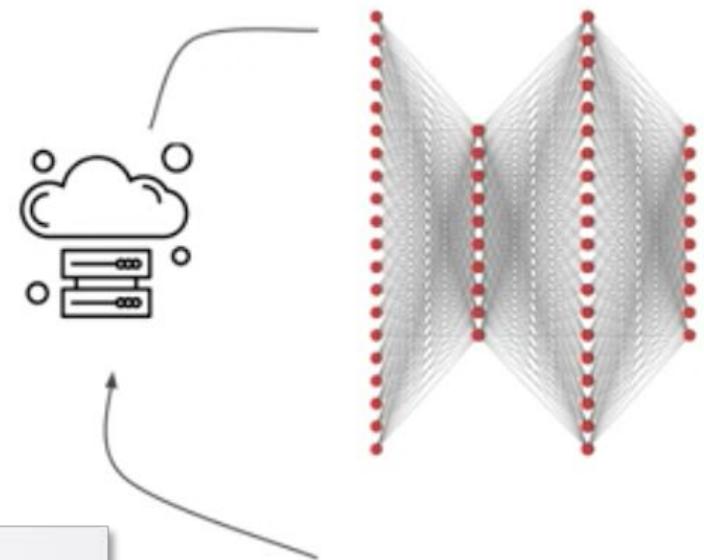
3

- Process on a secondary larger model on a larger local device



5

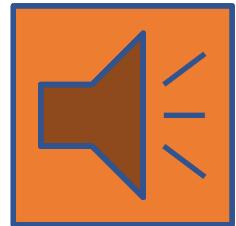
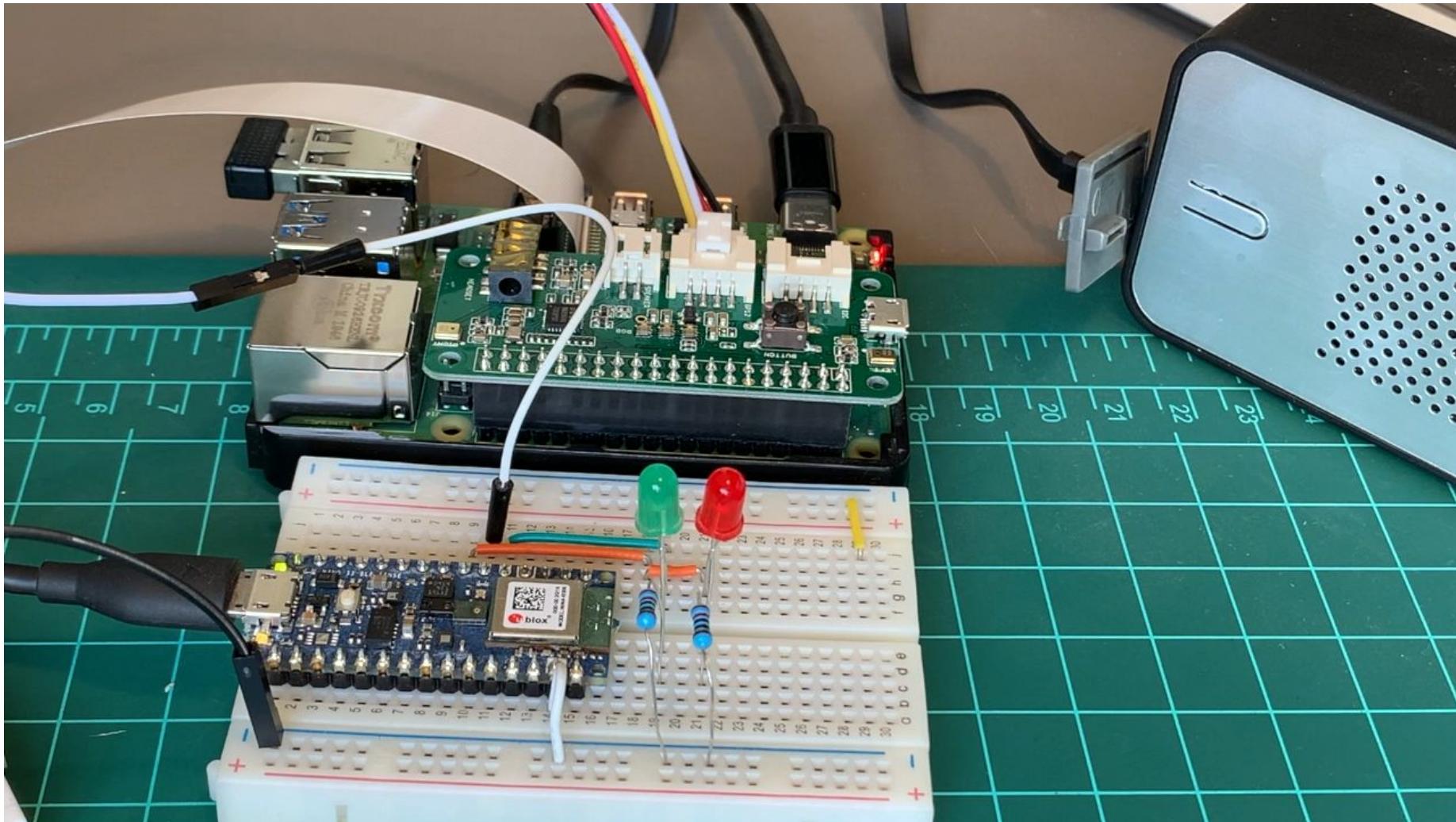
- Process the full speech data with a large model in the cloud



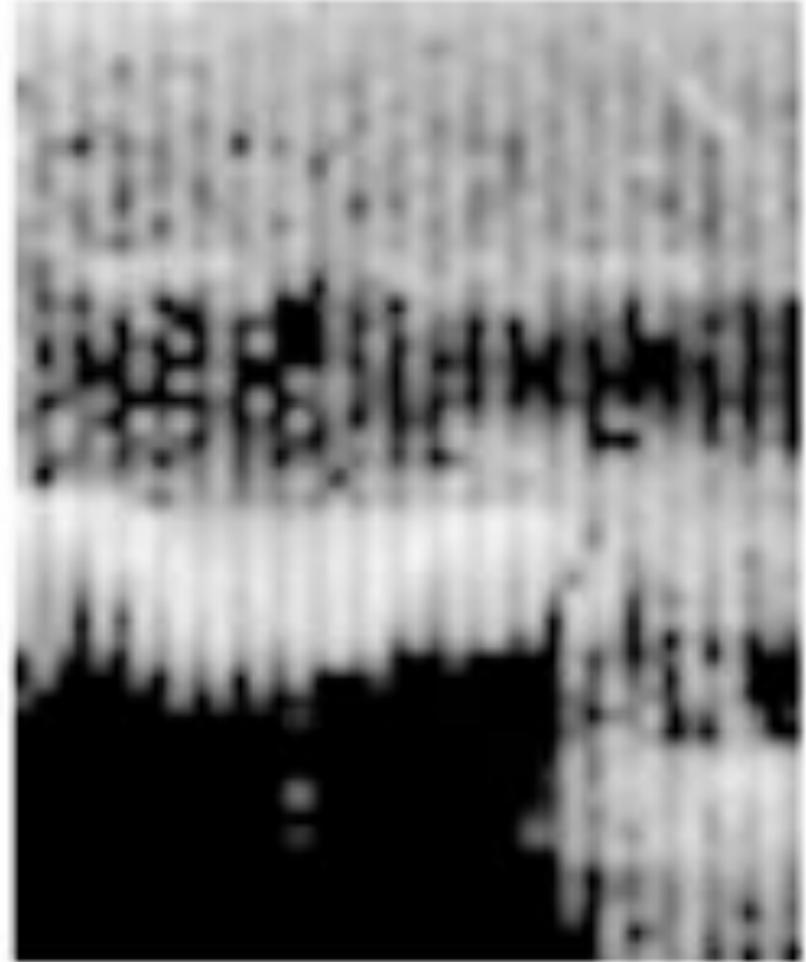
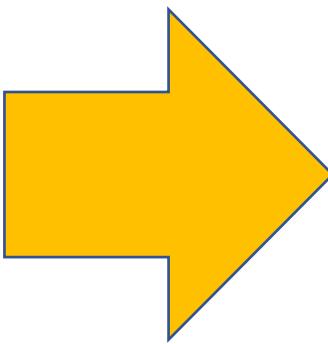
4

- Send the data to the cloud when triggered

KeyWord Spotting (KWS)



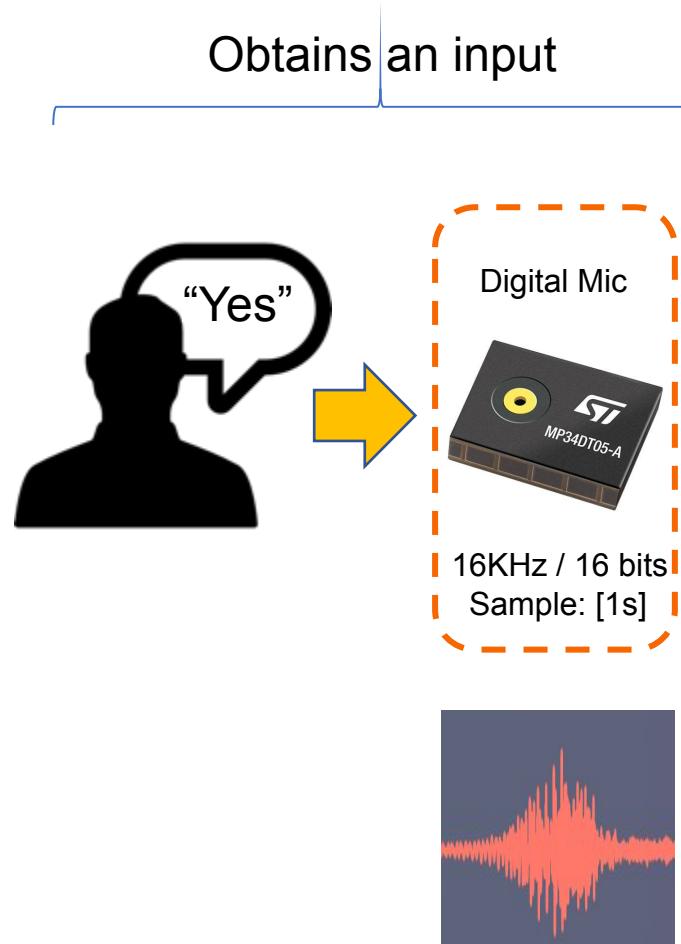
<https://mijrobot.org/2021/01/27/building-an-intelligent-voice-assistant-from-scratch/>



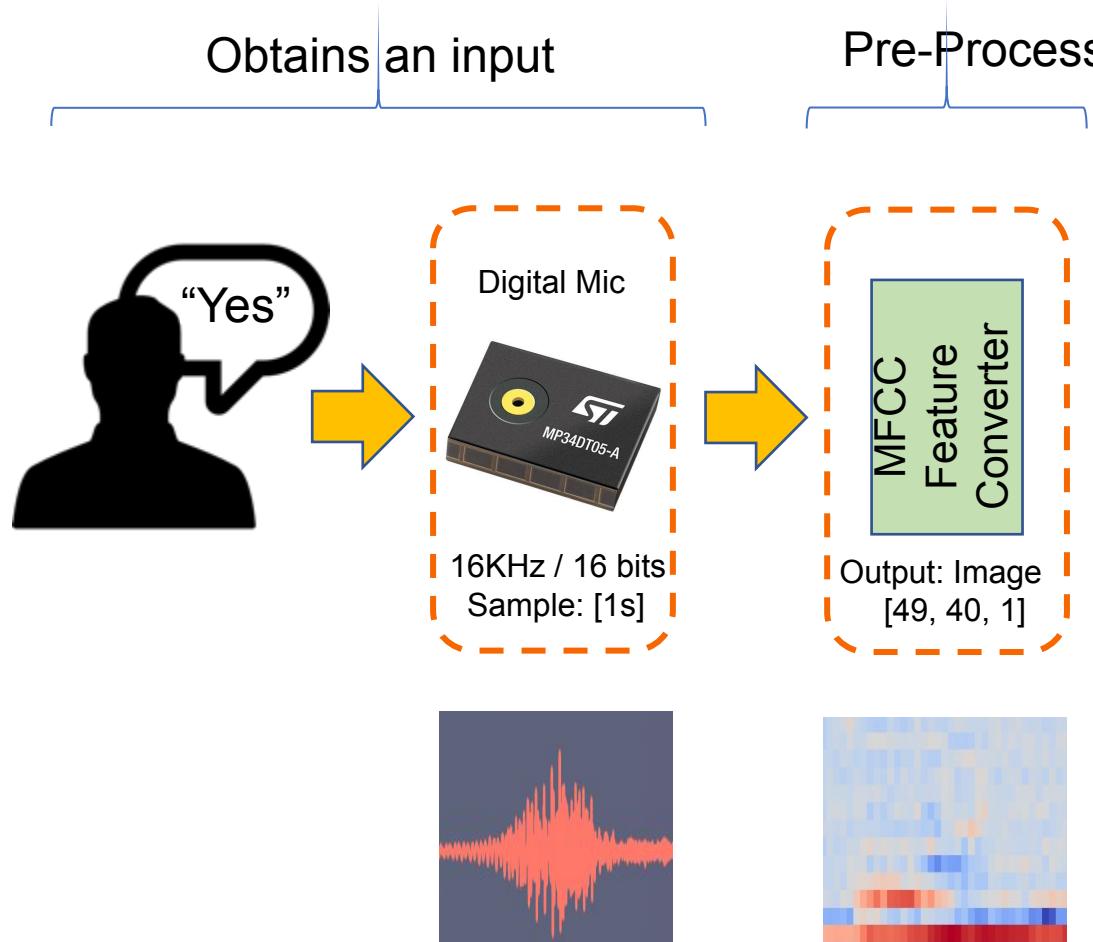
Sound

Image

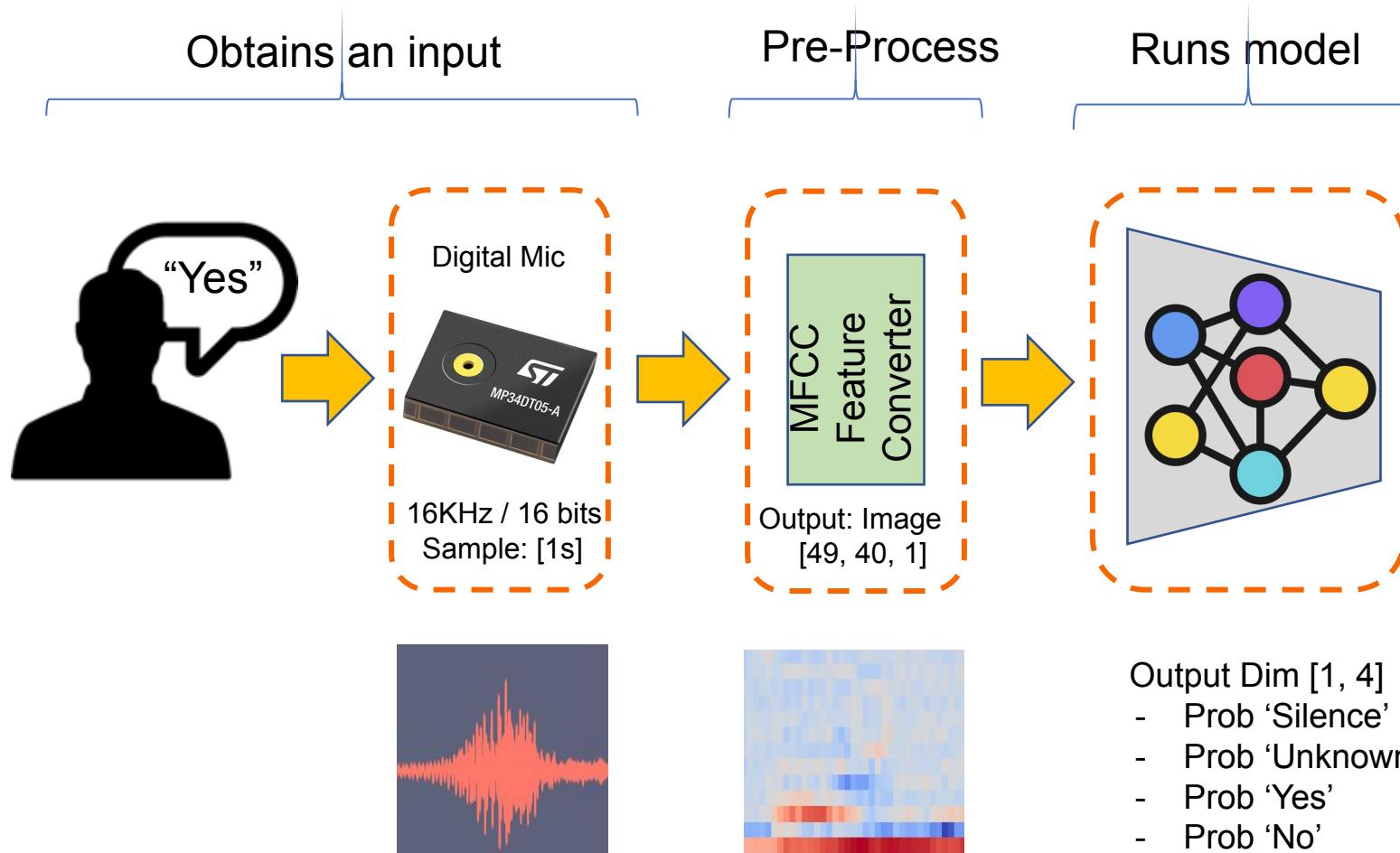
KeyWord Spotting (KWS) - Inference



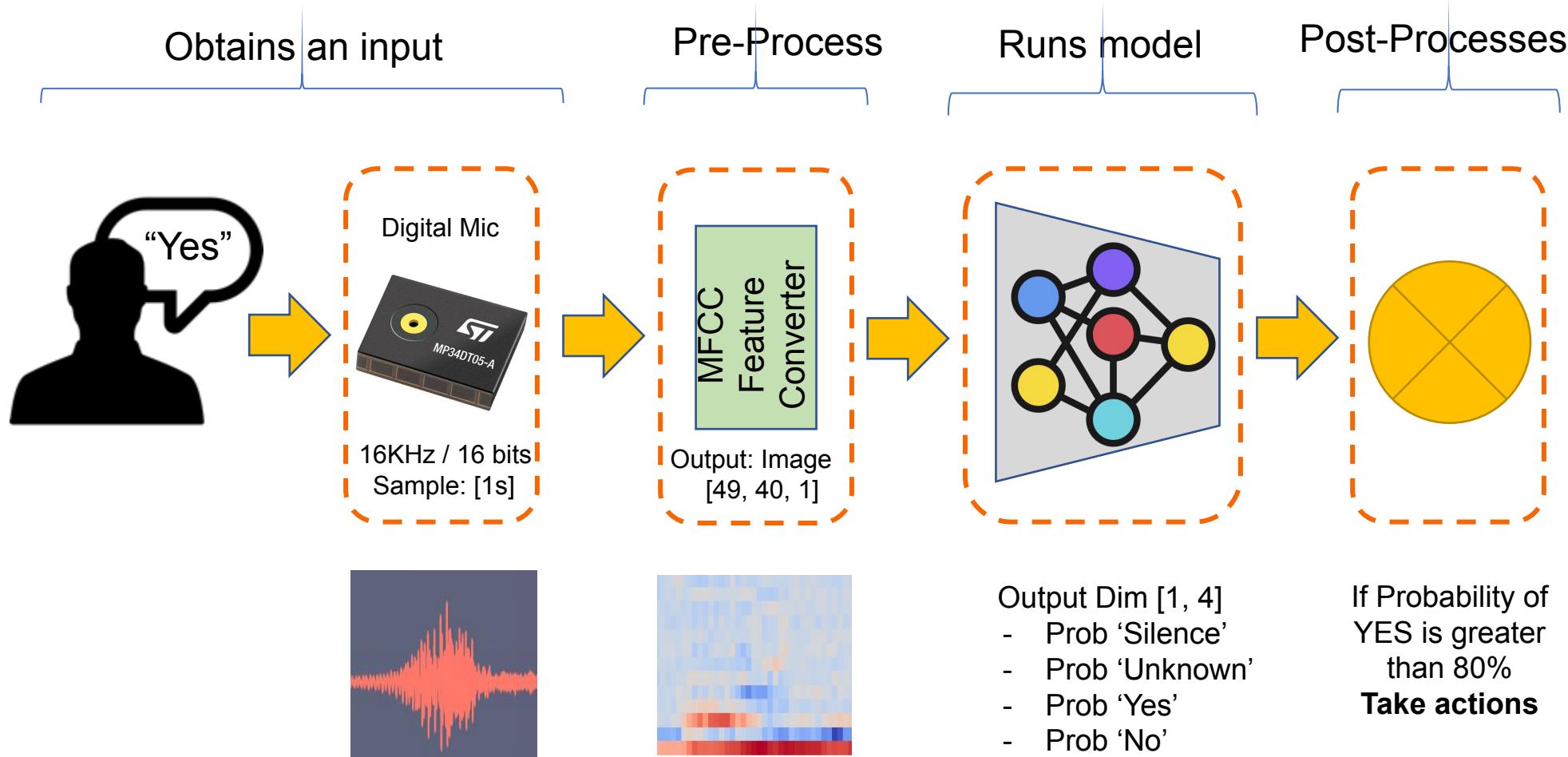
KeyWord Spotting (KWS) - Inference



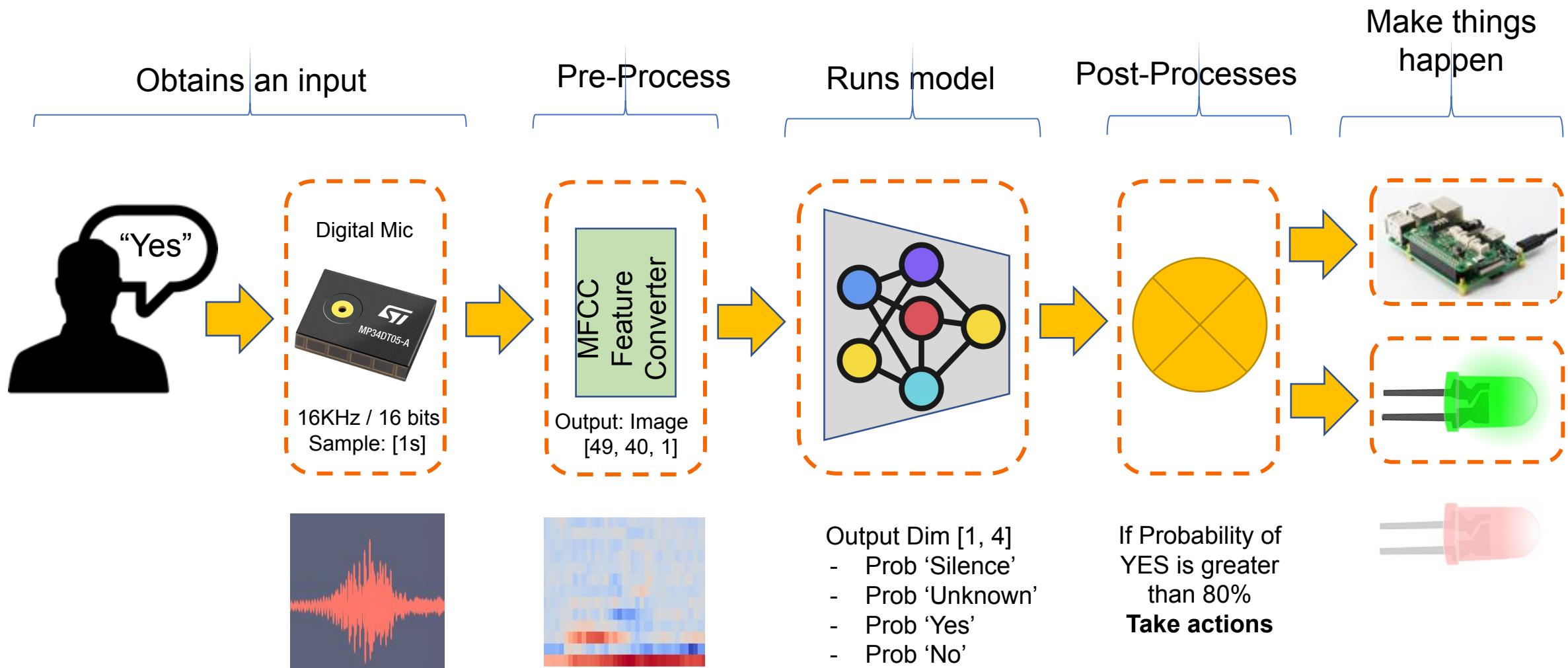
KeyWord Spotting (KWS) - Inference



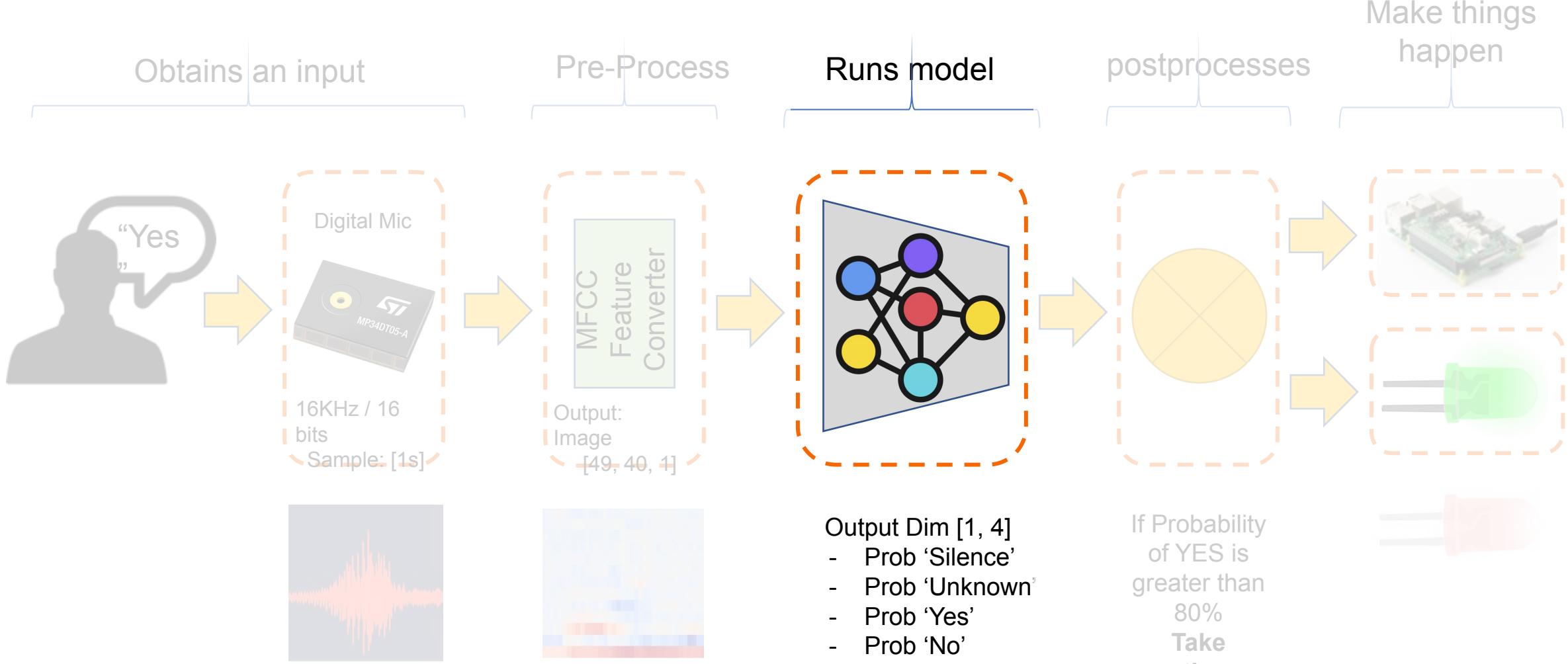
KeyWord Spotting (KWS) - Inference



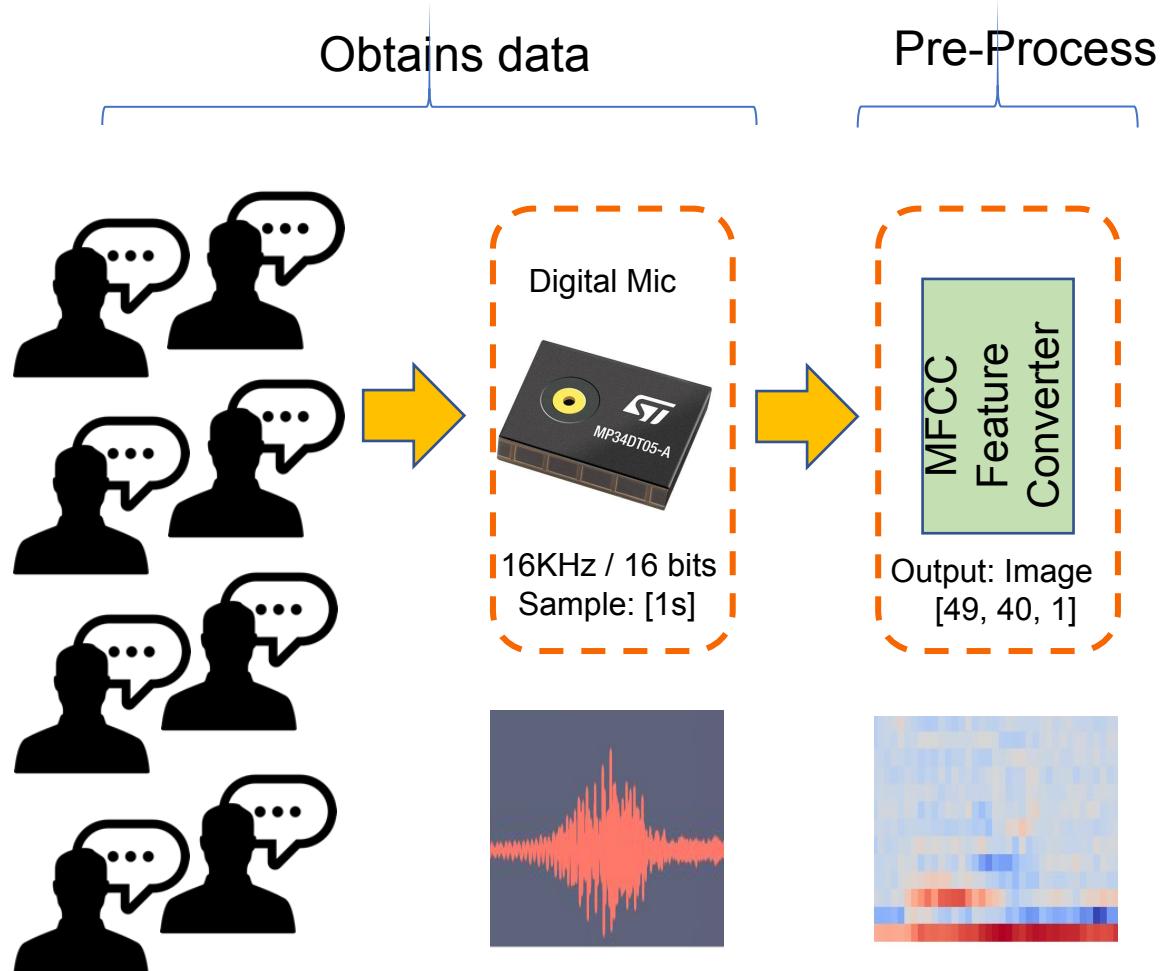
KeyWord Spotting (KWS) - Inference



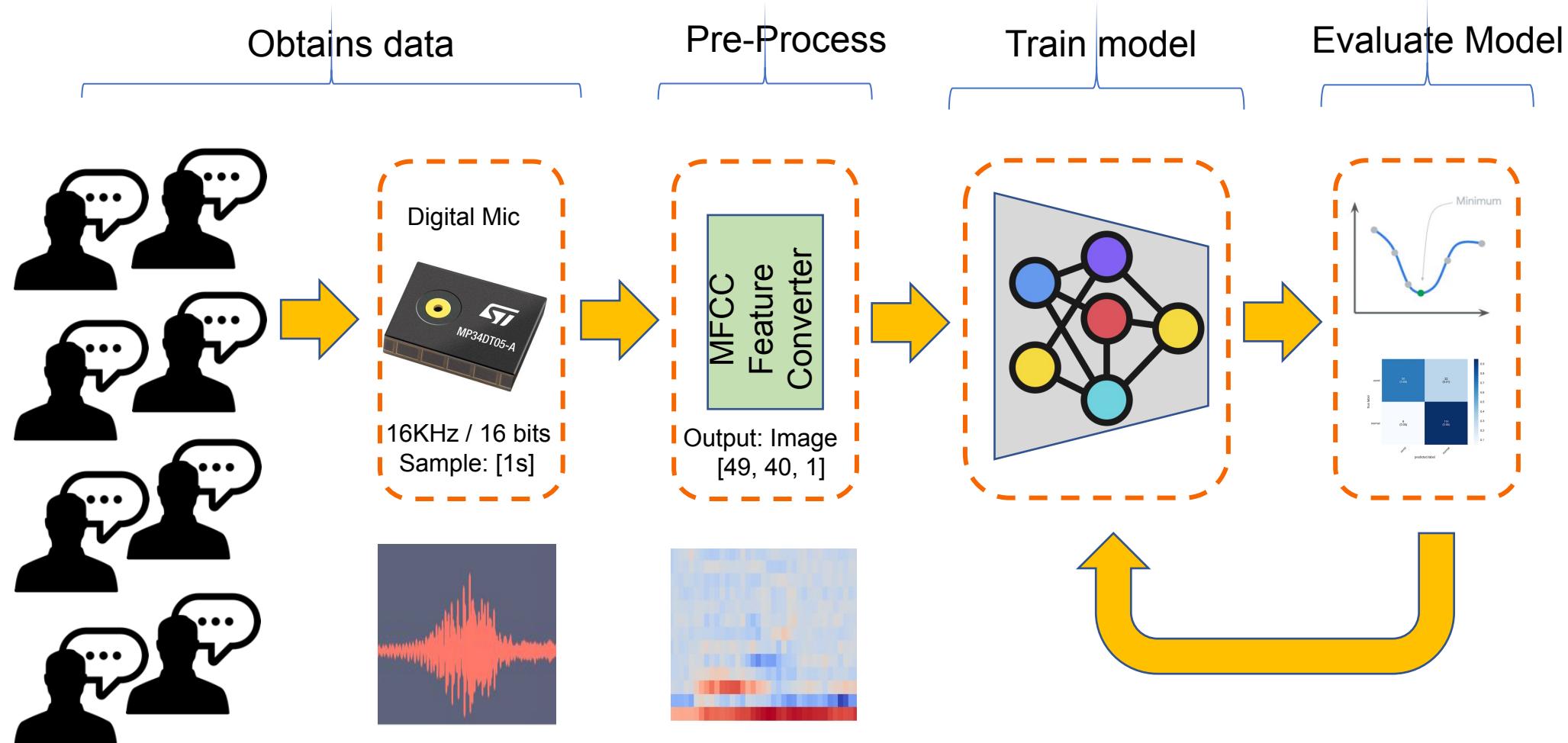
KeyWord Spotting (KWS) - Model



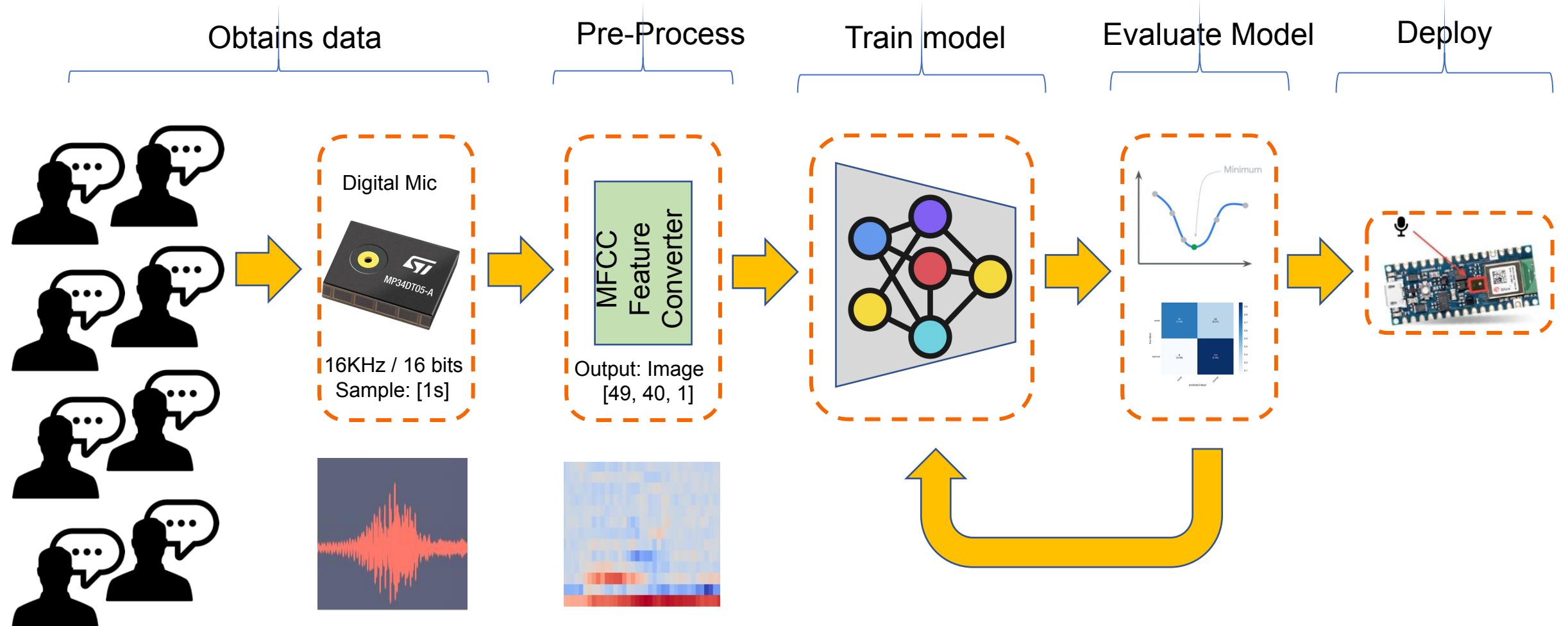
KeyWord Spotting (KWS) – Create Model (Training)



KeyWord Spotting (KWS) – Create Model (Training)



KeyWord Spotting (KWS) – Create Model (Training)









More than just voice

- Security (Broken Glass)
- Industry (Anomaly Detection)
- Medical (Snore, Toss)
- Nature (Bee, insect sound)





Moez Altayeb
University of Khartoum, Sudan
ICTP, Trieste, Italy
mohedahmed@hotmail.com

ABSTRACT

Every year more than one billion people are infected and more than one million people die from vector-borne diseases including malaria, dengue, zika and chikungunya. Mosquitoes are the best known disease vector and are geographically spread worldwide. It is important to raise awareness of mosquito proliferation by monitoring their incidence, especially in poor regions. Acoustic detection of mosquitoes has been studied for long and ML can be used to automatically identify mosquito species by their wingbeat. We present a prototype solution based on an openly available dataset on the Edge Impulse platform and on three commercially-available TinyML devices. The proposed solution is low-power, low-cost and can run without human intervention in resource-constrained areas. This insect monitoring system can reach a global scale.

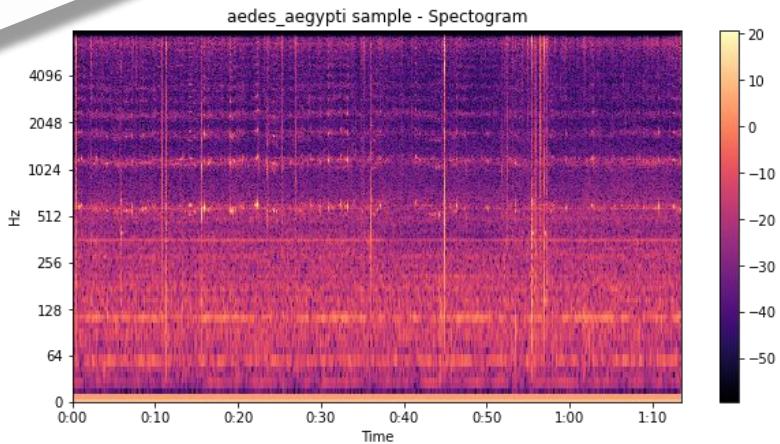
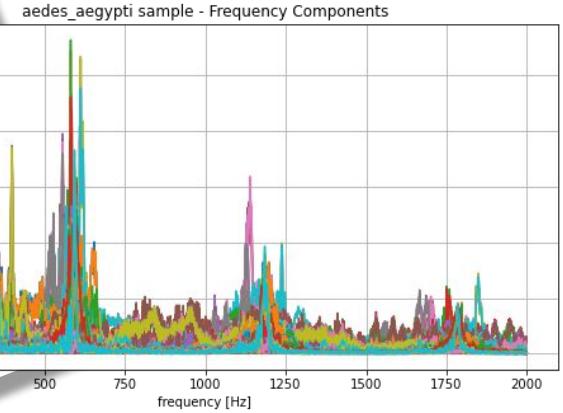
Classifying mosquito wingbeat sound using TinyML

Marcelo Rovai
Universidade Federal de Itajubá
Itajubá, Brazil
rovai@unifei.edu.br

Marco Zennaro
ICTP
Trieste, Italy
mzennaro@ictp.it

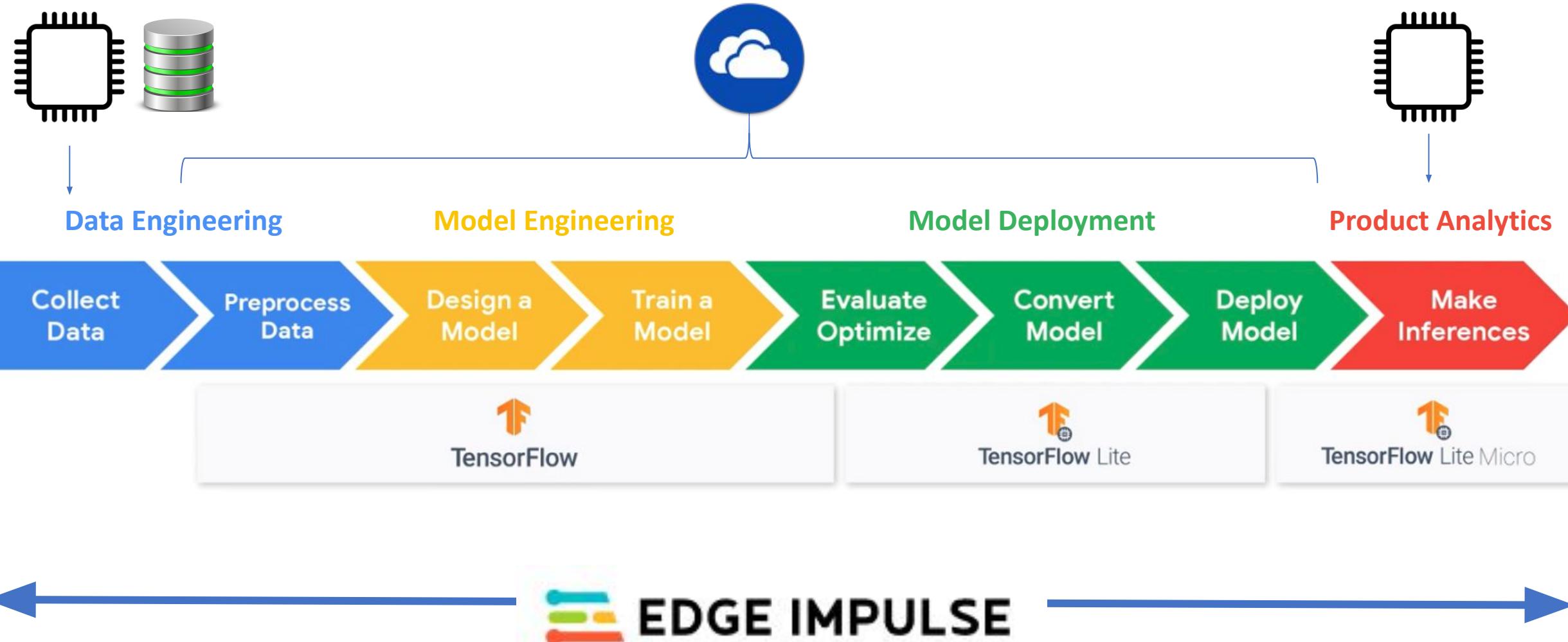
affected. People from poor communities with little access to health care and clean water sources are also at risk. Although anti-malarial drugs exist, there's currently no malaria vaccine. Vector-borne diseases also exacerbate poverty. Illness prevent people from working and supporting themselves and their families, impeding economic development. Countries with intensive malaria have much lower income levels than those that don't have malaria.

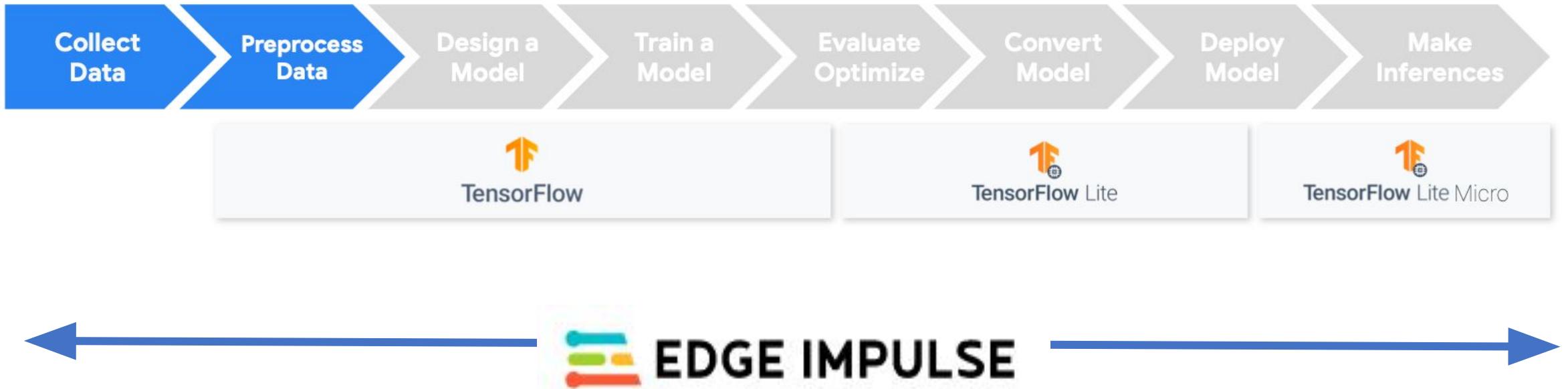
Countries affected by malaria turn to control rather than elimination. Vector control means decreasing contact between humans and disease carriers on an area-by-area basis. It is therefore of great interest to be able to detect the presence of mosquitoes in a specific area. This paper presents an approach based on TinyML and on embedded devices.



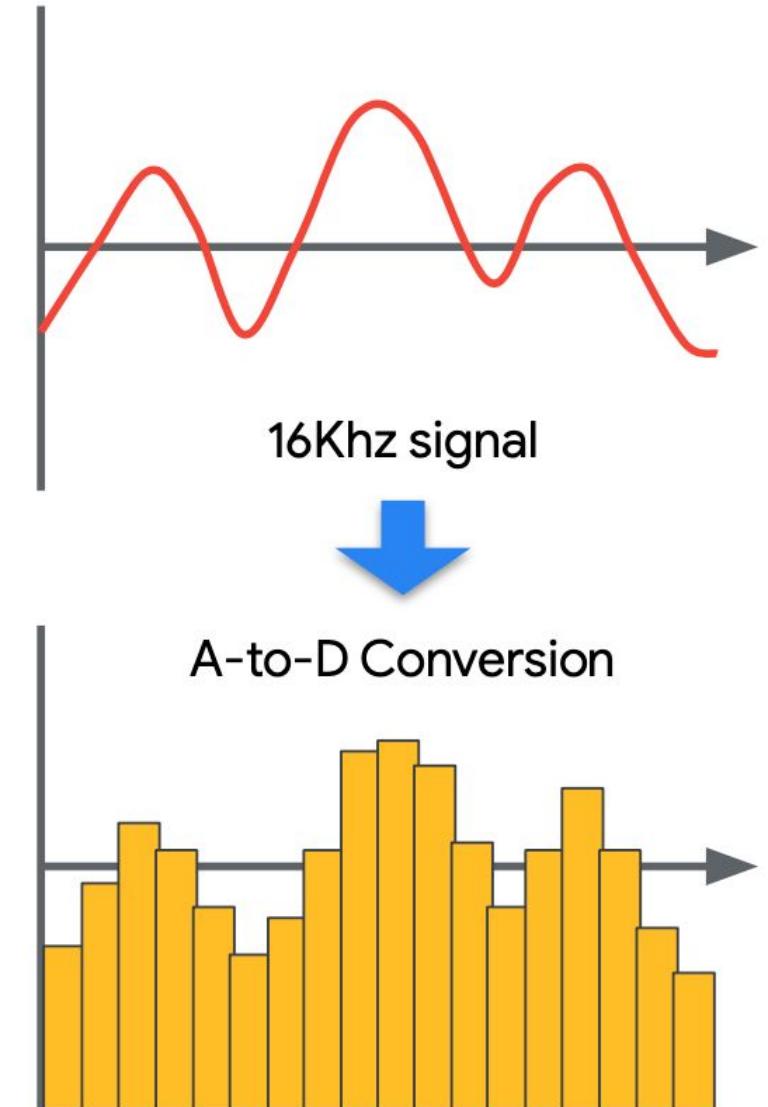
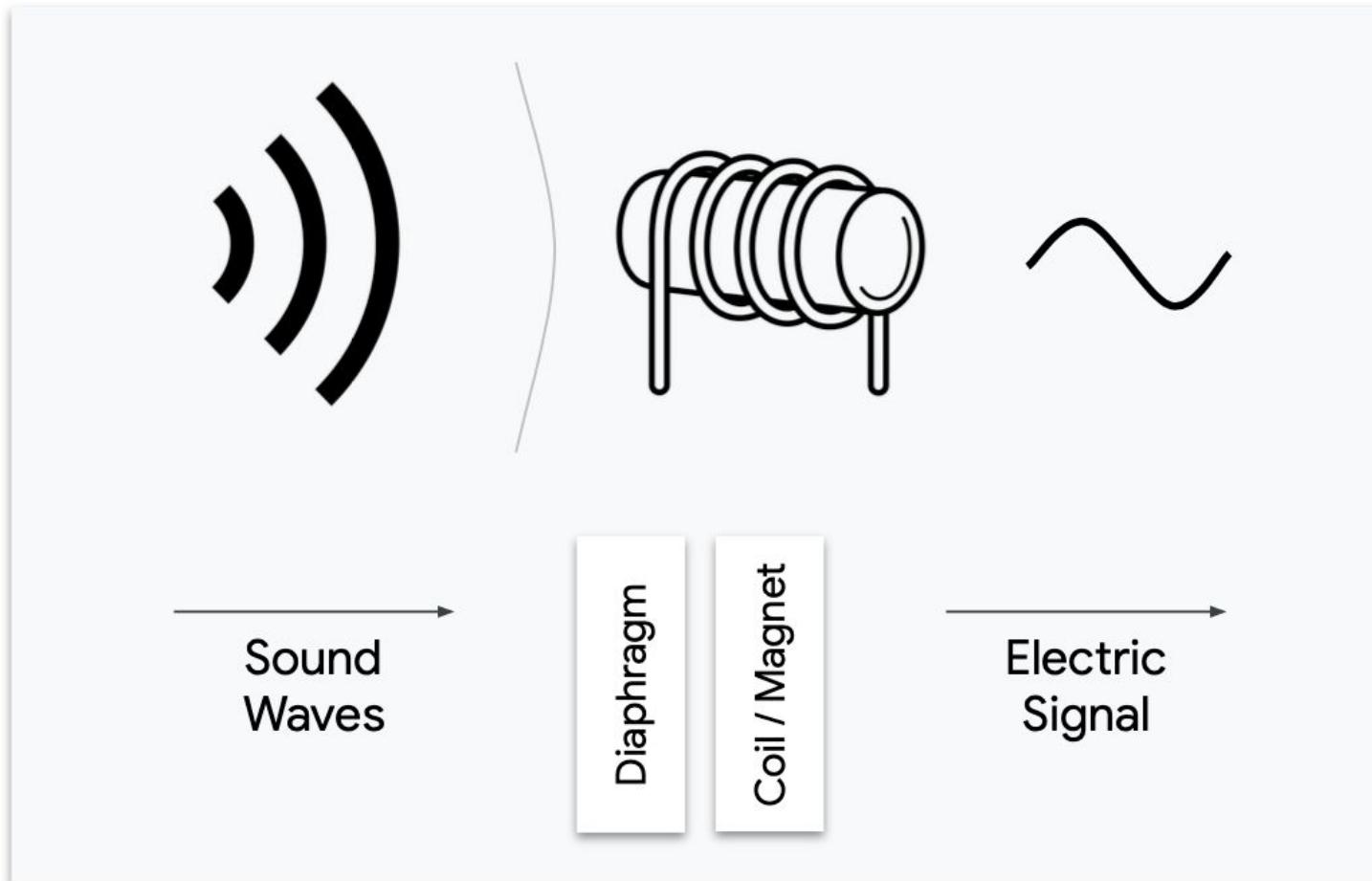
<https://github.com/Mjrovai/wingbeat-mosquito-tinyml>

KWS Data Collection & Pre-Processing

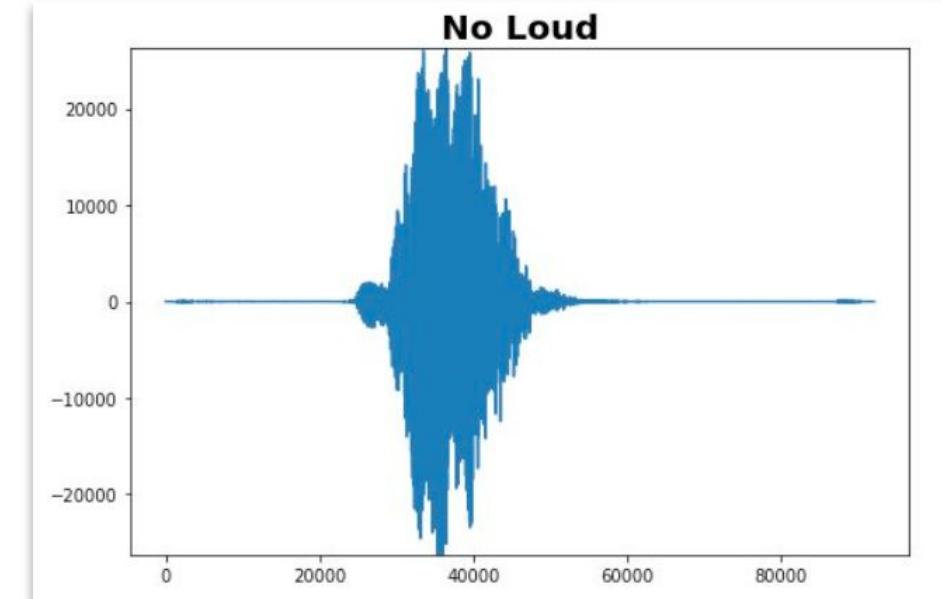
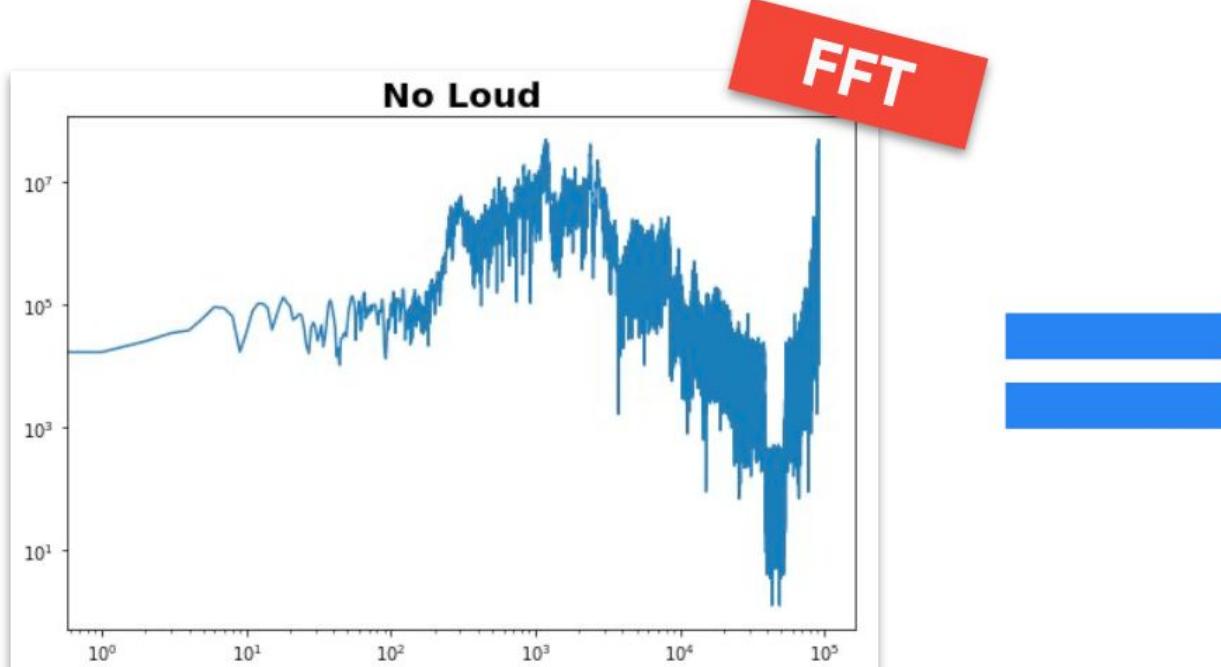




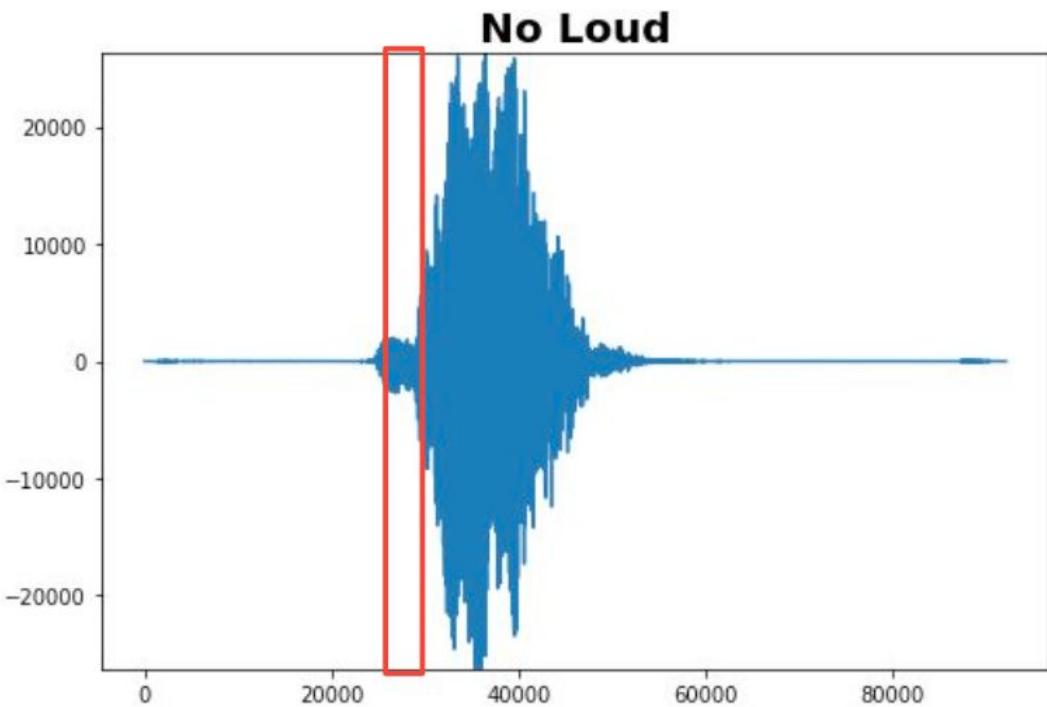
Sensor Data



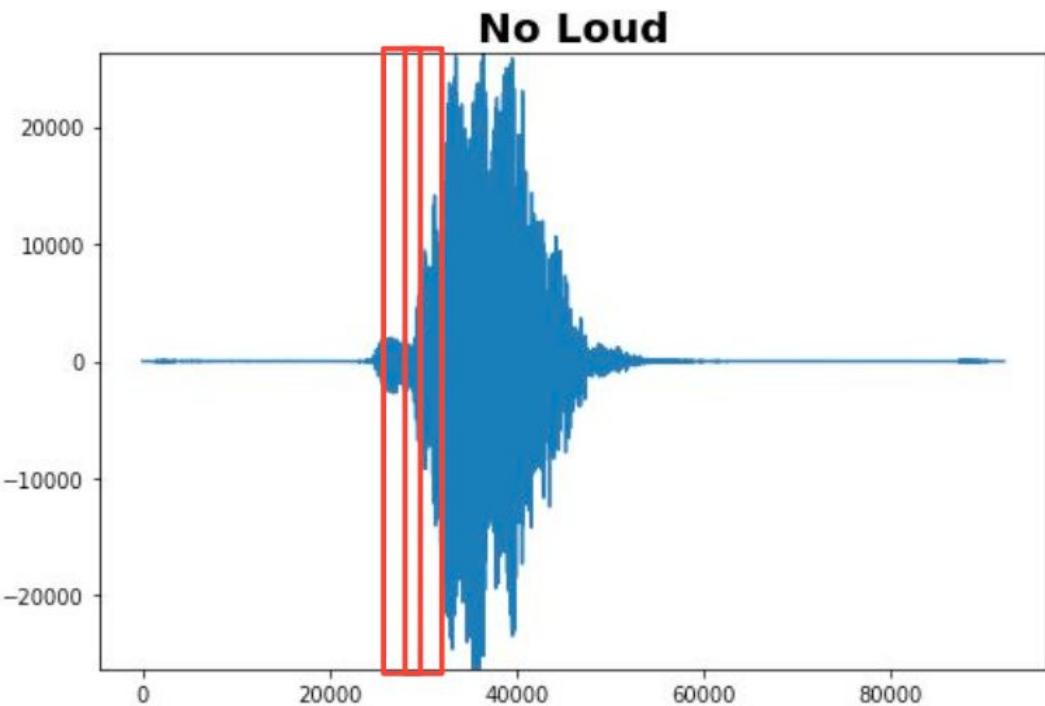
Signal Components?



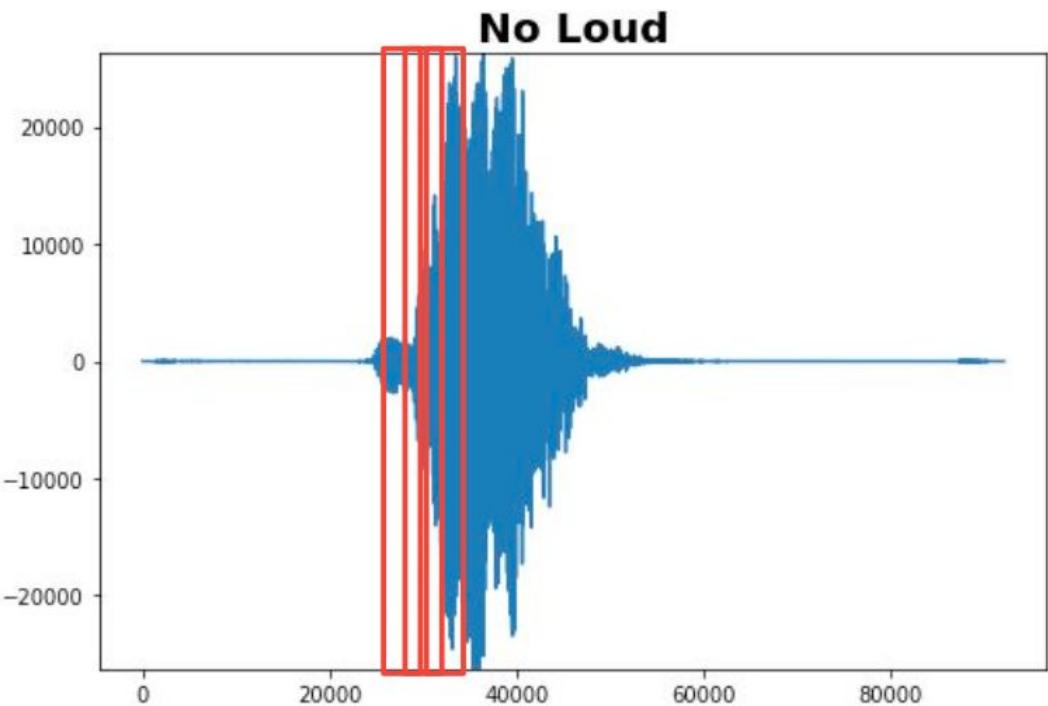
Data Preprocessing



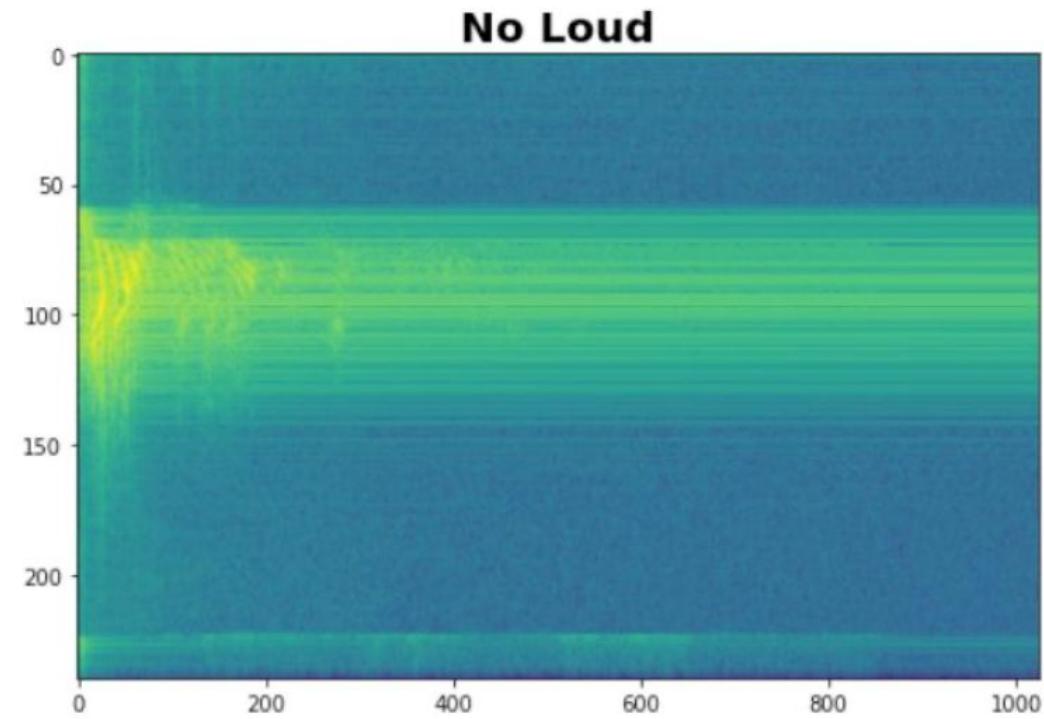
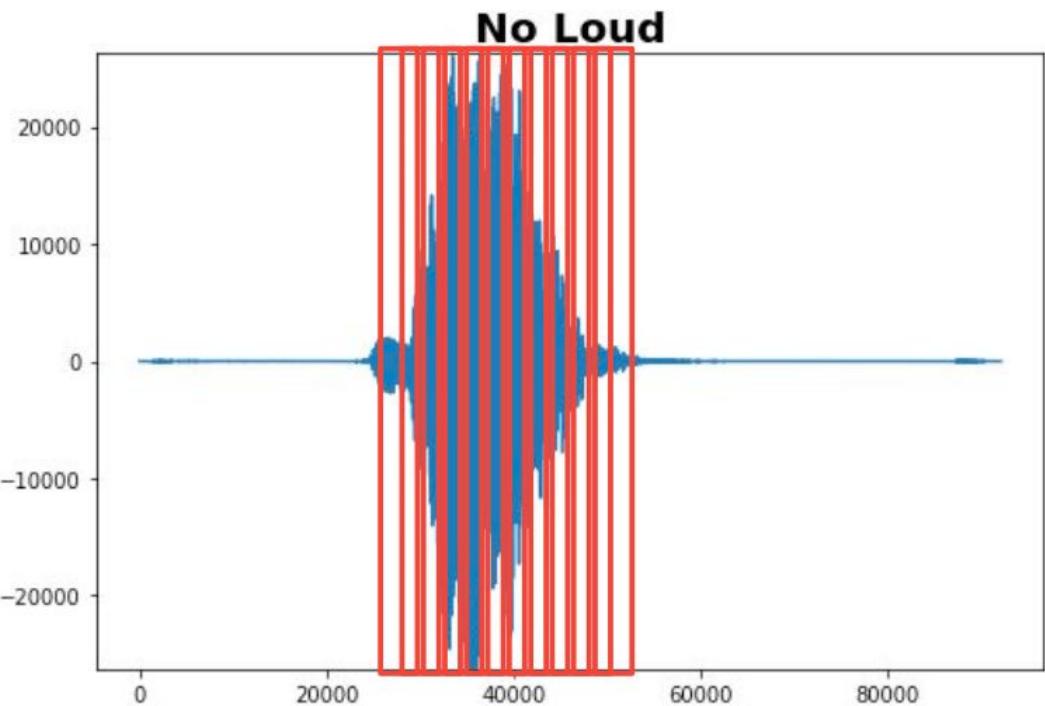
Data Preprocessing



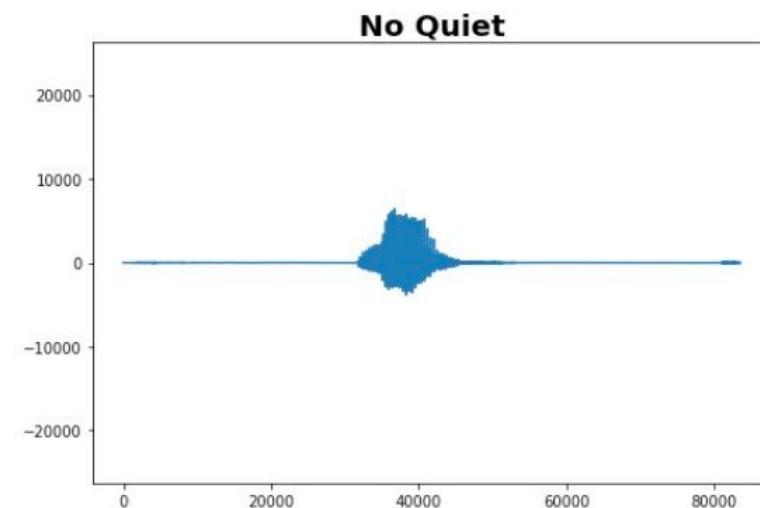
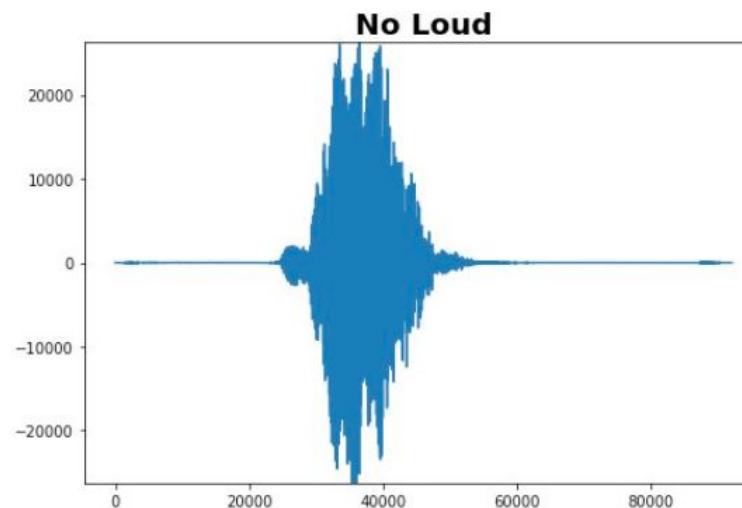
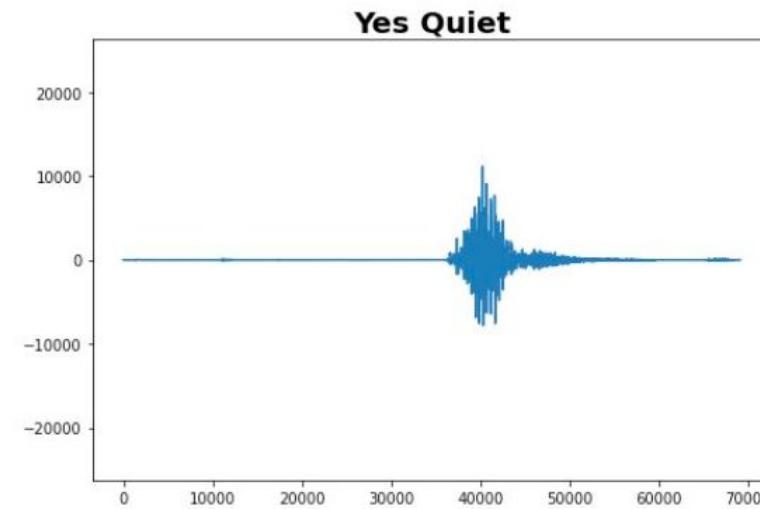
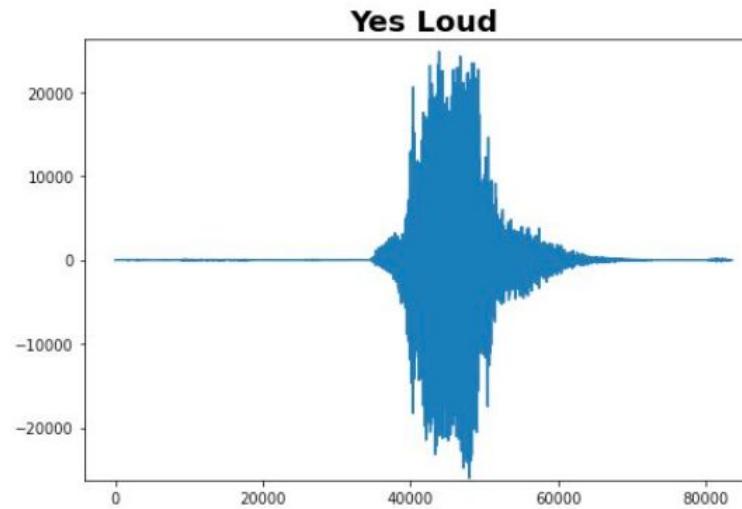
Data Preprocessing



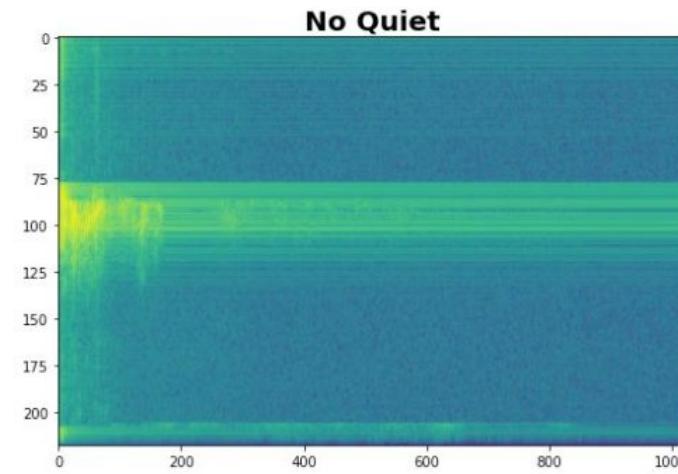
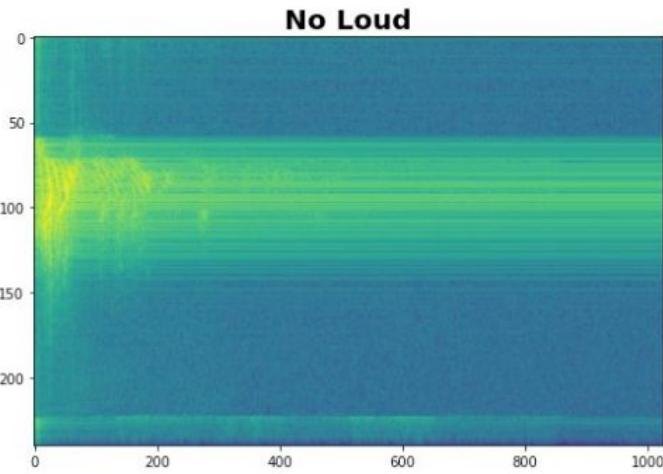
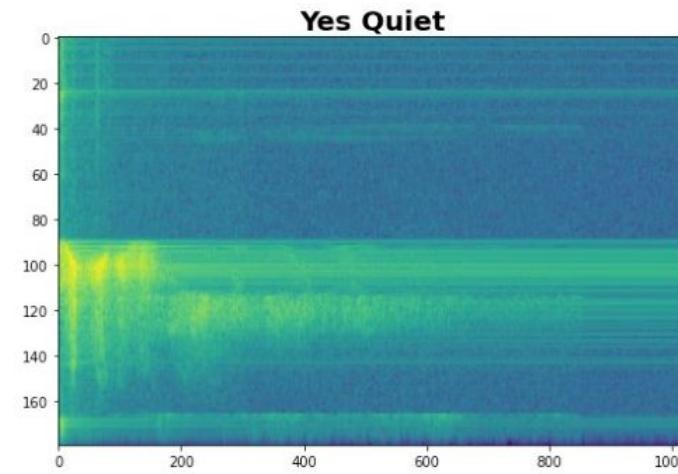
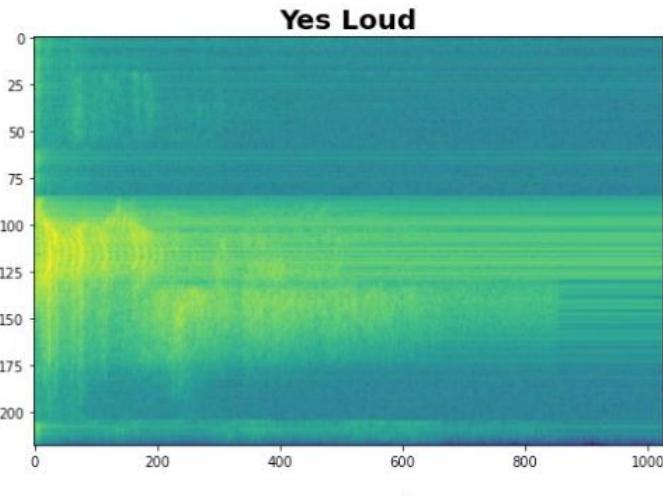
Data Preprocessing: Spectrograms



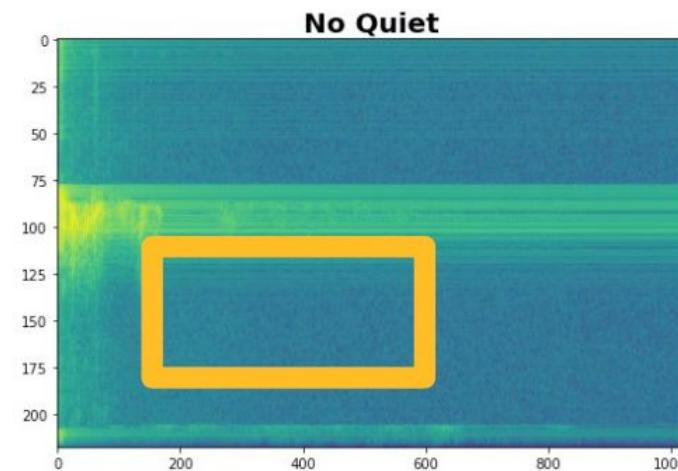
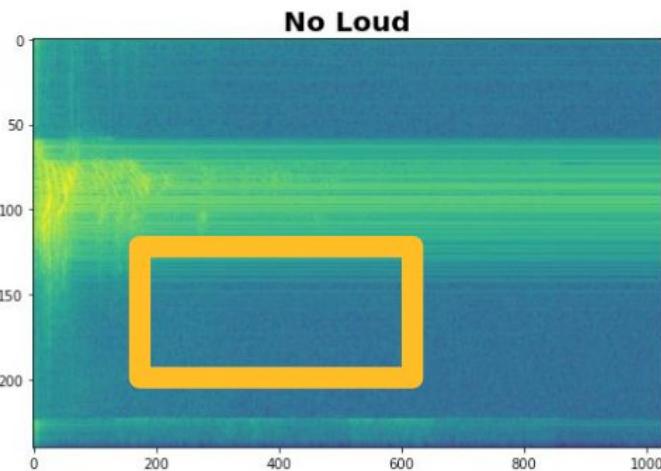
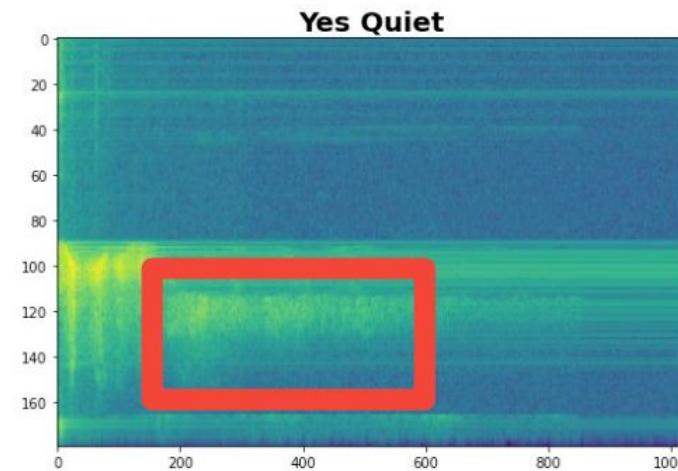
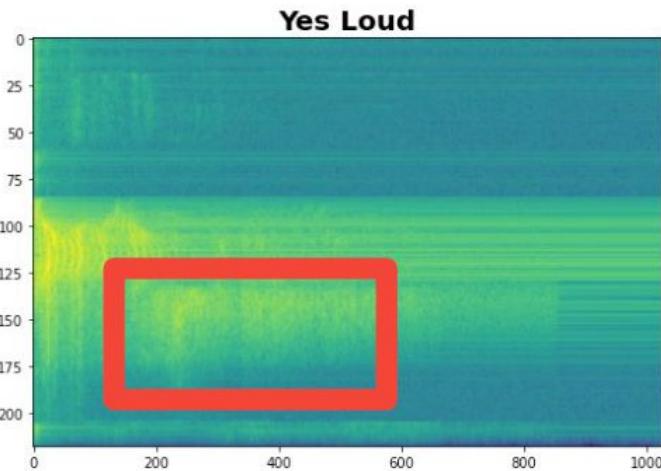
Data Preprocessing: Spectrograms

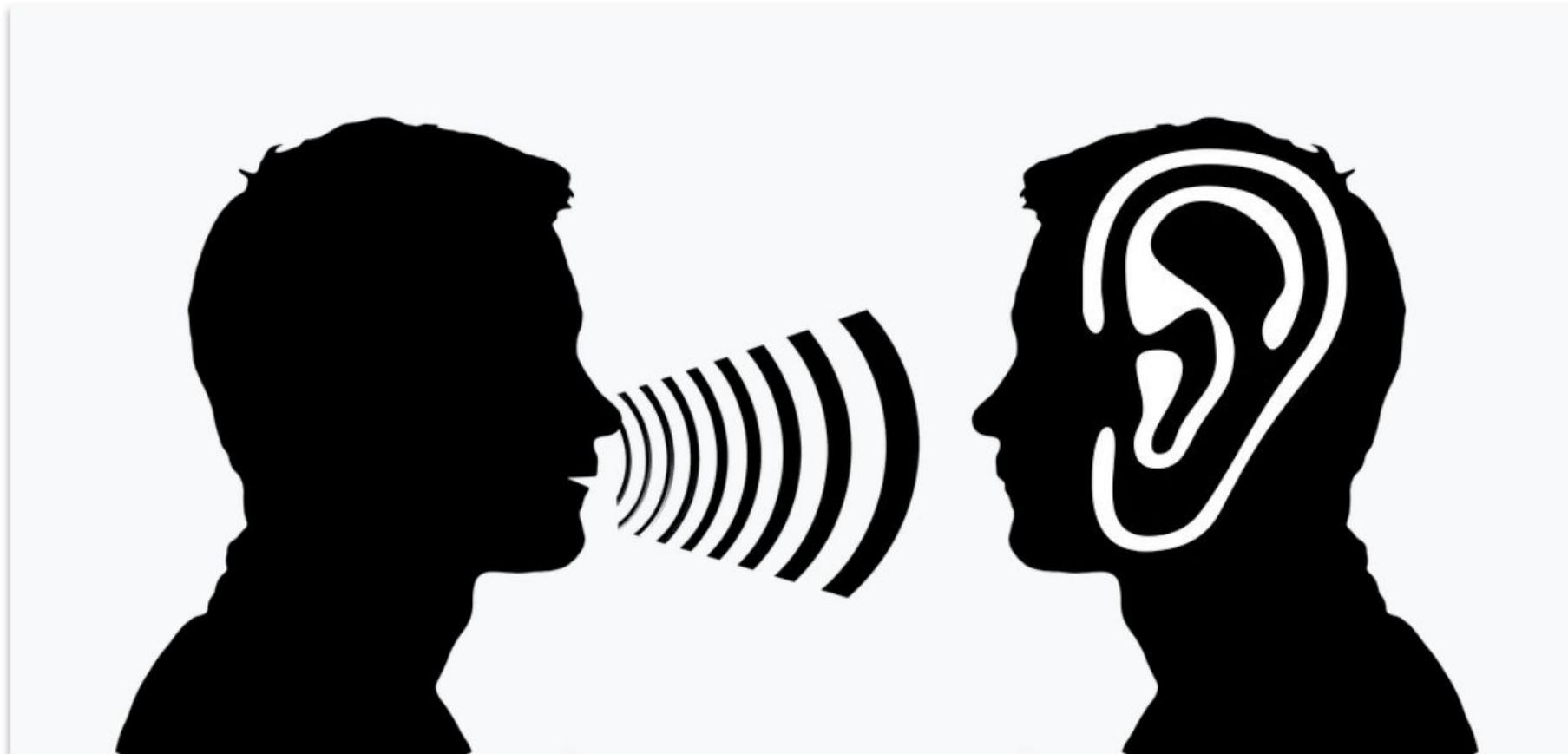


Data Preprocessing: Spectrograms



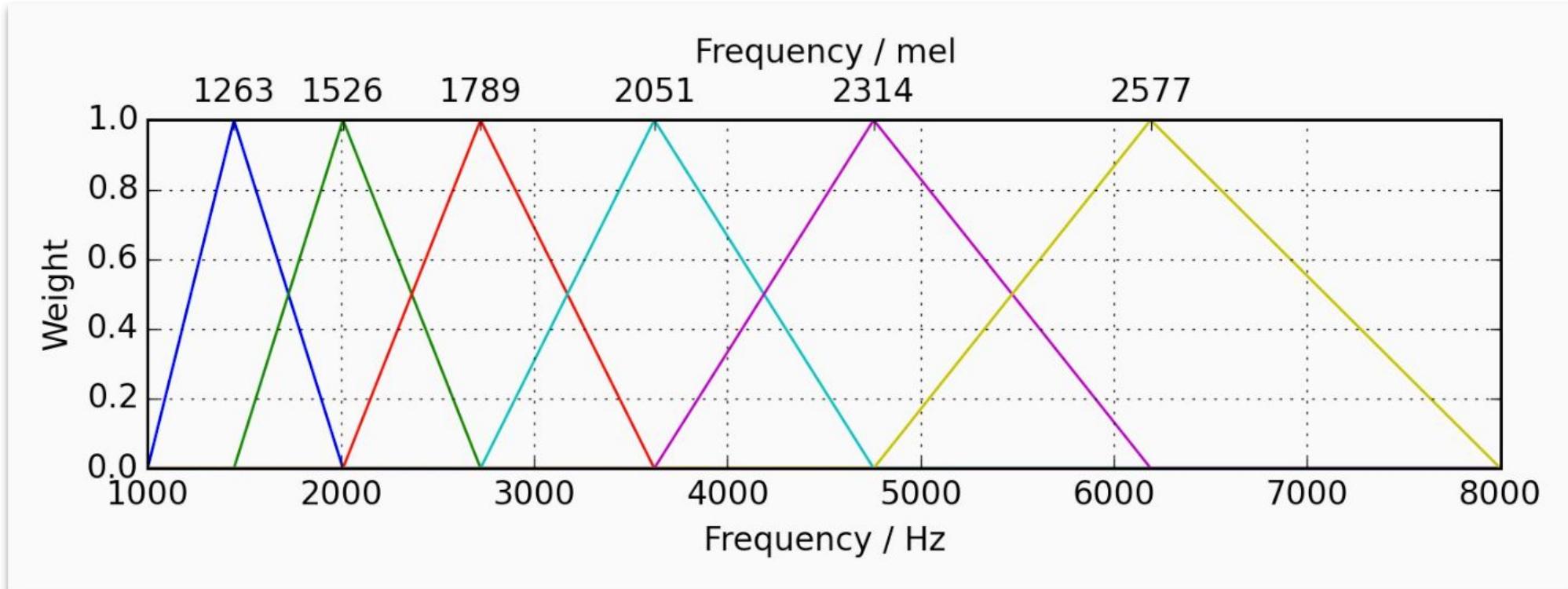
Data Preprocessing: Spectrograms



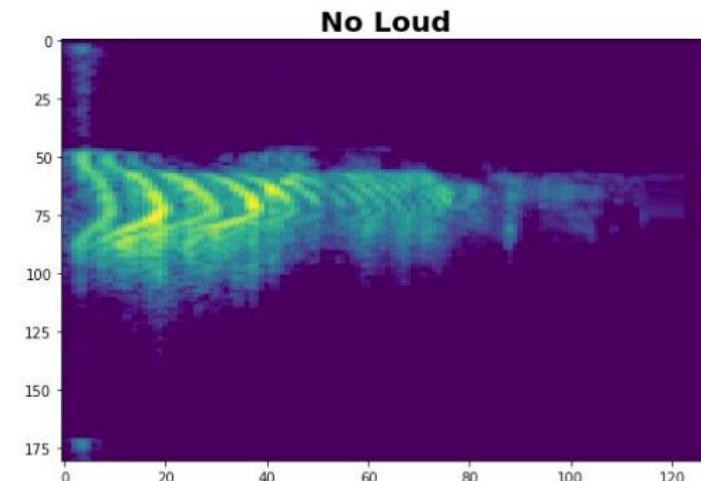
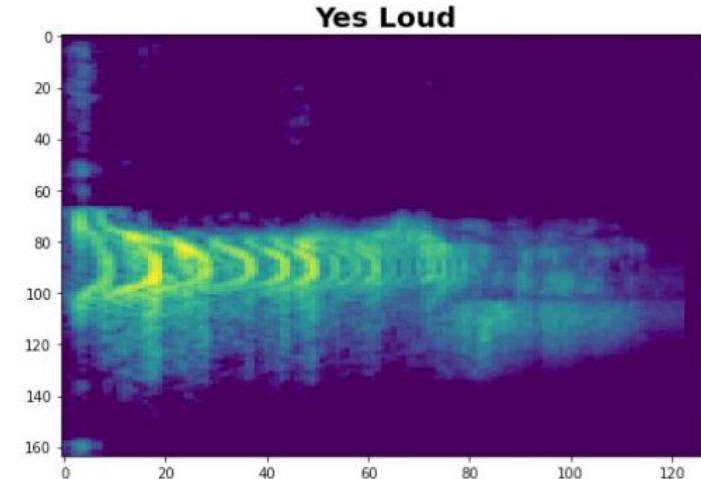
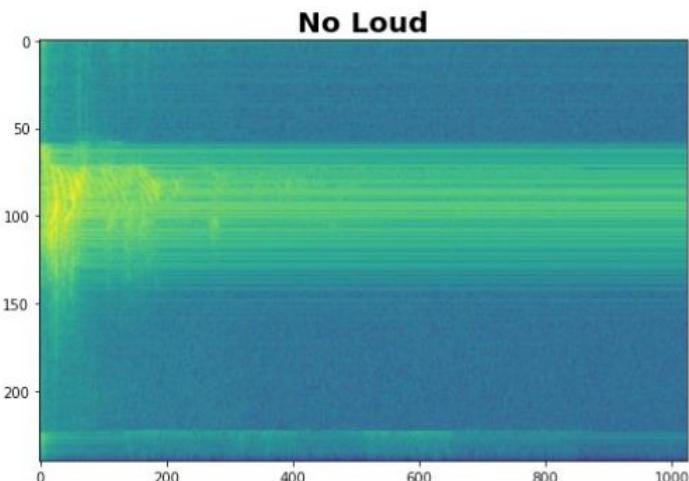
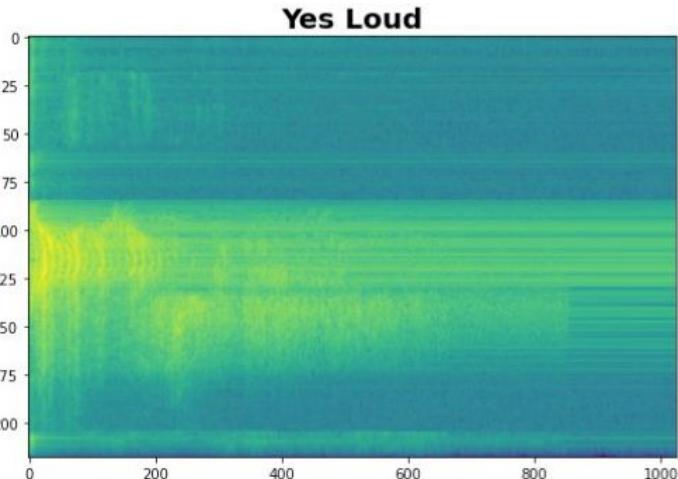


The **lower band frequencies** is much more crisper to us

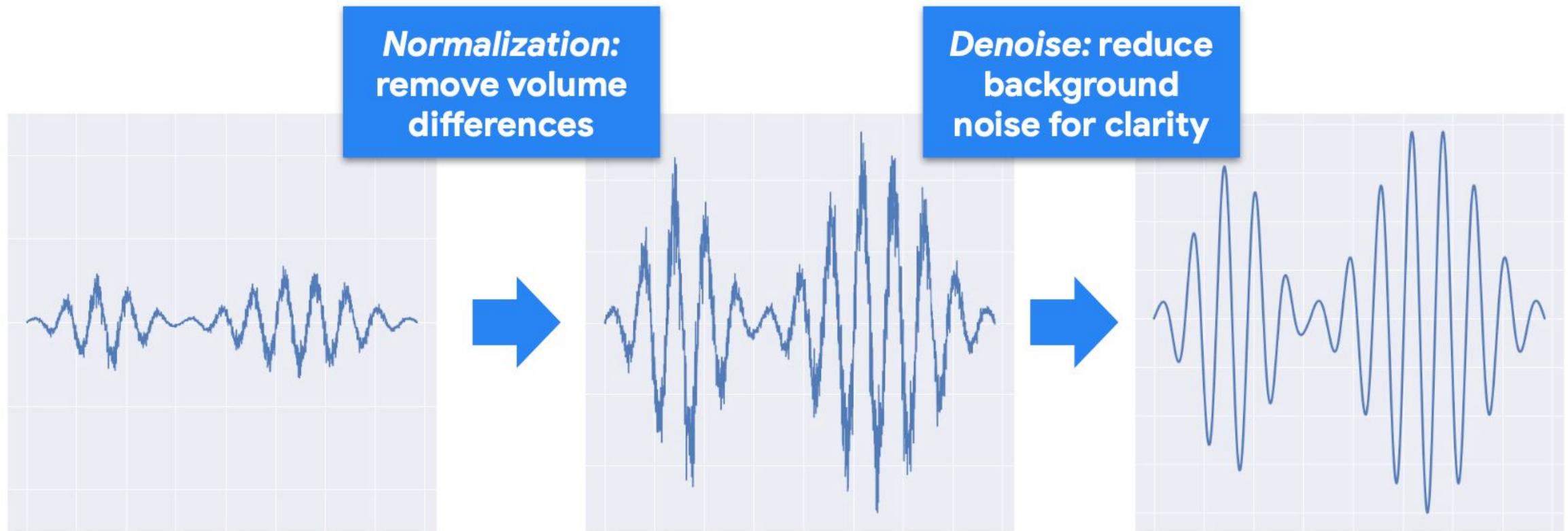
Mel Filterbanks



Spectrograms v. MFCCs



Additional Feature Engineering



Spectrograms and MFCCs

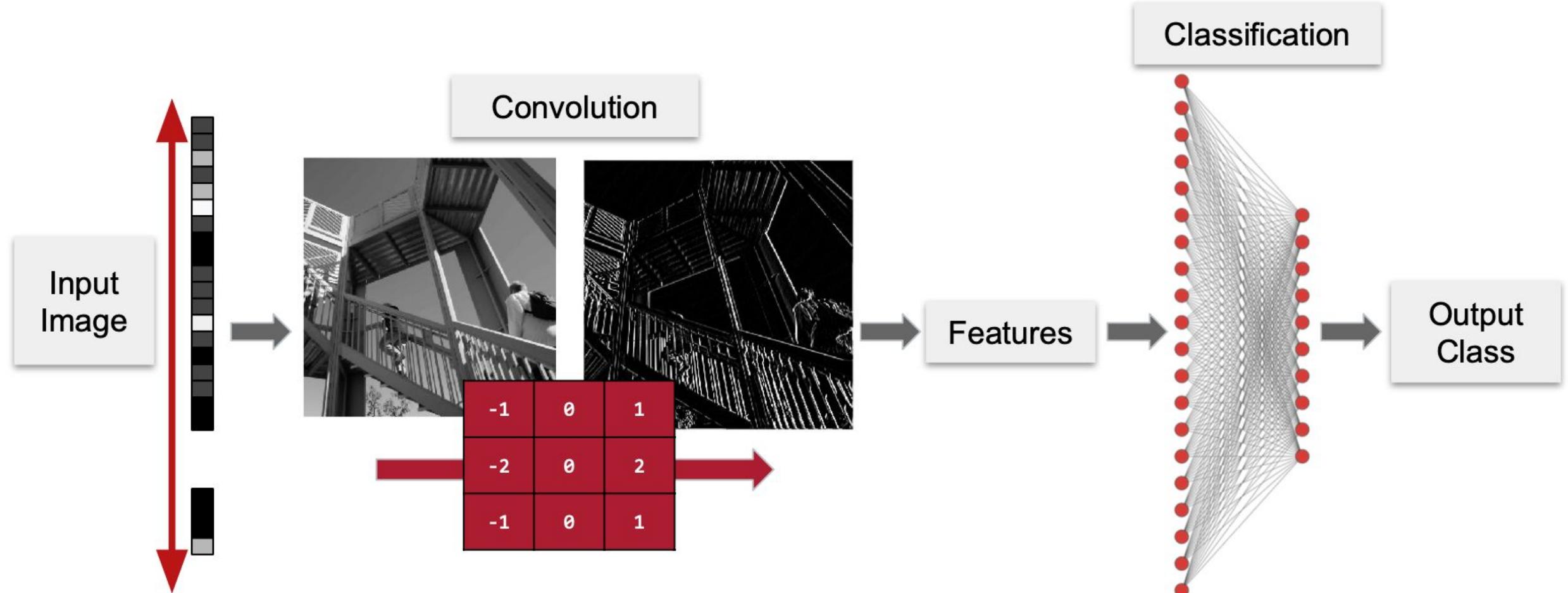
[SpectrogramsMFCCs.ipynb](#)



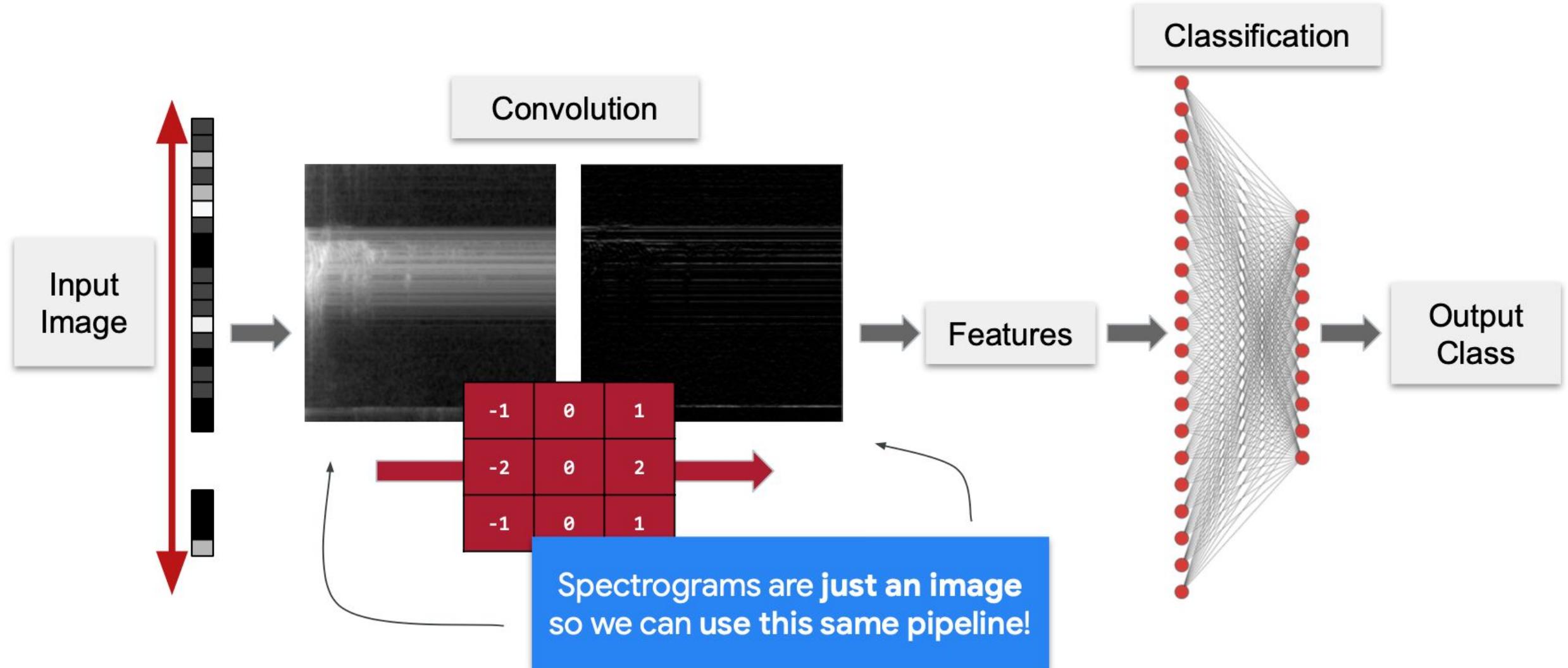
A Keyword Spotting Model



A model for Keyword Spotting

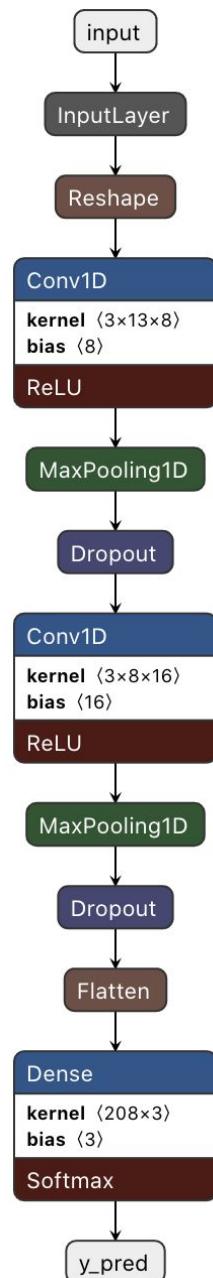


A model for Keyword Spotting



Model: "sequential"

Layer (type)	Output Shape	Param #
<hr/>		
reshape (Reshape)	(None, 50, 13)	0
conv1d (Conv1D)	(None, 50, 8)	320
max_pooling1d (MaxPooling1D)	(None, 25, 8)	0
dropout (Dropout)	(None, 25, 8)	0
conv1d_1 (Conv1D)	(None, 25, 16)	400
max_pooling1d_1 (MaxPooling1 (None, 13, 16)		0
dropout_1 (Dropout)	(None, 13, 16)	0
flatten (Flatten)	(None, 208)	0
y_pred (Dense)	(None, 3)	627
<hr/>		
Total params:	1,347	
Trainable params:	1,347	
Non-trainable params:	0	



Model size: 200KB

KWS

Keyword Spotting Project

- First keyword: UNIFEI
- Second keyword: IESTI
- Silence: (Background Noise)

<https://studio.edgeimpulse.com/public/139843/latest>



Select project - Edge Impulse

studio.edgeimpulse.com/studio/select-project

EDGE IMPULSE

Select project

Create a new project

Enter the name for your new project:

CNMAC_Keyword_Spotting

Choose your project type:

Developer
20 min job limit, 4GB or 4 hours of data, limited collaboration.

Enterprise
No job or data size limits, higher performance, custom blocks. [Learn more](#)

Create new project

Marcelo Rovai / Image Test - Africa Workshop

Marcelo Rovai / SciTinyML22-KWS

Marcelo Rovai / Cifar10_Image_Classification

49

CNMAC_Keyword_Spotting - X +

studio.edgeimpulse.com/studio/139843/devices

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EDGE IMPULSE

Dashboard

Devices

Data sources

Data acquisition

Impulse design

- Create impulse
- MFCC
- NN Classifier

EON Tuner

Retrain model

Live classification

Model testing

Versioning

Deployment

GETTING STARTED

Documentation

Marcelo Rovai / CNMAC_Keyword_Spotting

+ Connect a new device

Your d These a

Collect data

You can collect data from any smartphone. From your smartphone go to [this URL](#), or scan the QR code below.



© 2022 Edge Impulse Inc.

The screenshot shows the Edge Impulse studio interface. On the left, a sidebar lists various features: Dashboard, Devices, Data sources, Data acquisition, Impulse design, Create impulse, MFCC, NN Classifier, EON Tuner, Retrain model, Live classification, Model testing, Versioning, Deployment, and Documentation. The main area is titled "Your devices" and displays a table with one row:

NAME	LAST SEEN
phone_l8bsl7fs	Today, 10:37:10

A modal window titled "Collect data" is open over the table, containing a large green checkmark icon and the text "Device phone_l8bsl7fs is now connected". A "Get started!" button is at the bottom of the modal. To the right of the table, a small inset shows a smartphone screen with the same "Connected as phone_l8bsl7fs" message. Below the inset, three status boxes are shown: "Collecting images?", "Collecting audio?", and "Collecting motion?". The "Collecting audio?" box is highlighted with an orange border.

The screenshot shows the Edge Impulse Studio interface. On the left is a sidebar with various project management and development tools. The main area is titled "Your devices" and lists a single connected device: "phone_l8bsl7fs". The device details are as follows:

NAME	ID	TYPE	SENSORS	REMO...	LAST SEEN
phone_l8bsl7fs	phone_l8bsl7fs	MOBILE_CLIENT	Accelerometer, Micropho...	●	Today, 10:37:10

On the right side of the screen, there is a "Data collection" panel. It includes fields for "Label: unifei", "Length: 10s.", and "Category: Training". A "Start recording" button is present. Below the panel, it says "Audio captured with current settings: 0s". The top of the screen shows the URL "studio.edgeimpulse.com/studio/139843/devices" and the user "Marcelo Rovai / CNMAC_Keyword_Spotting". The top right corner shows the time "10:39" and other system icons.

CNMAC_Keyword_Spotting - X + studio.edgeimpulse.com/studio/139843/acquisition/training?page=1

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Collected data

SAMPLE NAME	LABEL	ADDED	LENGTH
unifei.3dfbegg5	unifei	Today, 10:39:45	10s
silence.29lsqcc5.s3	silence	Jul 04 2021, 14:...	1s
silence.29lsqcc5.s2	silence	Jul 04 2021, 14:...	1s
silence.29lsqcc5.s1	silence	Jul 04 2021, 14:...	1s
silence.29lsrbmq.s3	silence	Jul 04 2021, 14:...	1s
silence.29lsrbmq.s2	silence	Jul 04 2021, 14:...	1s
silence.29lsrbmq.s1	silence	Jul 04 2021, 14:...	1s
silence.29lss69b.s10	silence	Jul 04 2021, 14:...	1s
silence.29lss69b.s9	silence	Jul 04 2021, 14:...	1s
silence.29lss69b.s8	silence	Jul 04 2021, 14:...	1s
silence.29lss69b.s7	silence	Jul 04 2021, 14:...	1s
silence.29lss69b.s6	silence	Jul 04 2021, 14:...	1s

No devices connected

Label

Label name: unifei

Sample length (ms.): 5000

Sensor

Frequency: 5000

Start sampling

RAW DATA
unifei.3dfbegg5

0 1040 2080 3120 4160 5200 6240 7280 8320 9360

0:10 / 0:10

GETTING STARTED

Documentation

10:39 AA 🔘 85 one.edgeimpulse.com ↗

Data collection

Label: unifei Length: 10s.

Category: Training

Recording...

Audio captured with current settings: 0s

2s

< > ⌂ ⌄ ⌁ ⌂

CNMAC_Keyword_Spotting - X + studio.edgeimpulse.com/studio/139843/acquisition/training?page=1 Edge Impulse Imagine! Join us for the latest innovations in edge machine learning for the real world, Sept 28-30. Learn more.

Collected data

SAMPLE NAME	LABEL	ADDED	LENGTH
unifei.3dfbegg5	unifei	Today, 10:39:45	10s
silence.29lsqcc5.s3	silence	Jul 04 2021, 14:00:00	1s
silence.29lsqcc5.s2	silence	Jul 04 2021, 14:00:00	1s
silence.29lsqcc5.s1	silence	Jul 04 2021, 14:00:00	1s
silence.29lsrbmq.s3	silence	Jul 04 2021, 14:00:00	1s
silence.29lsrbmq.s2	silence	Jul 04 2021, 14:00:00	1s
silence.29lsrbmq.s1	silence	Jul 04 2021, 14:00:00	1s
silence.29lss69b.s10	silence	Jul 04 2021, 14:00:00	1s
silence.29lss69b.s9	silence	Jul 04 2021, 14:00:00	1s
silence.29lss69b.s8	silence	Jul 04 2021, 14:00:00	1s
silence.29lss69b.s7	silence	Jul 04 2021, 14:00:00	1s
silence.29lss69b.s6	silence	Jul 04 2021, 14:00:00	1s

No devices connected

Label

Sample length (ms.)

Label name: 5000

Sensor

Frequency

Start sampling

RAW DATA

unifei.3dfbegg5

audio

0:10 / 0:10

GETTING STARTED

https://studio.edgeimpulse.com/studio/139843/acquisition/training?page=1#

The screenshot shows the Edge Impulse Studio interface. On the left, a sidebar lists various project management and development tools. The main area displays a table of collected data samples, with a context menu open over the first sample ('unifei.3dfbegg5'). The menu options include Rename, Edit label, Move to test set, Disable, Crop sample, Split sample (which is highlighted with an orange box), Download, and Delete. To the right of the data table is a section for device connection status, followed by fields for labeling and sensor configuration, and a large button labeled 'Start sampling'. Below these is a detailed audio waveform visualization for the selected sample, showing raw data values from -20000 to 20000 across a time range from 0 to 9360 ms. A play button indicates the audio is currently playing at 0:10 of its duration.

CNMAC_Keyword_Spotting - X +

studio.edgeimpulse.com/studio/139843/acquisition/training?page=1

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Collected data No devices connected

EDGE IMPULSE

Dashboard Devices Data sources Data acquisition Impulse design Create impulse MFCC NN Classifier EON Tuner Retrain model Live classification Model testing Versioning Deployment

Split sample 'unifei.3dfbegg5'

Zoom + Add Segment Set segment length (ms.): 1000 Apply

Remove segment

audio

0:00 / 0:00 ► 0:10 / 0:10 ►

Cancel Shift samples ? Split

GETTING STARTED Documentation

Sample length (ms.)

Frequency

Start sampling

8320 9360

55

Data acquisition - IESTI01_Key...

studio.edgeimpulse.com/studio/38744/acquisition/training?page=1

EDGE IMPULSE

DATA ACQUISITION (IESTI01_KEYWORD_SPOTTING_PROJECT)

Training data Test data

Did you know? You can capture data from any device or development board, or upload your existing datasets - Show options

DATA COLLECTED 1m 37s

LABELS 1

Collected data

SAMPLE NAME	LABEL	ADDED	LENGTH
<input checked="" type="checkbox"/> unifei.29lq8ugs	unifei	Today, 12:29:12	10s
<input checked="" type="checkbox"/> unifei.29lq80v9	unifei	Today, 12:28:42	10s
<input type="checkbox"/> unifei.29lq760p	unifei	Today, 12:28:14	10s
<input type="checkbox"/> unifei.29lq6a2p	unifei	Today, 12:27:46	10s
<input type="checkbox"/> unifei.29lq5fvd	unifei	Today, 12:27:19	10s
<input type="checkbox"/> unifei.29lq4m8v	unifei	Today, 12:26:53	10s
<input type="checkbox"/> unifei.29lq3t92	unifei	Today, 12:26:27	10s
<input type="checkbox"/> unifei.29lq286o	unifei	Today, 12:25:33	10s
<input type="checkbox"/> unifei.29jskg44	unifei	Yesterday, 18:31...	10s
<input type="checkbox"/> unifei.29js37tq.s6	unifei	Yesterday, 18:28...	1s

[Delete selected \(2\)](#) [Edit labels \(2\)](#) [Move to test set \(2\)](#)

Record new data [Connect using WebUSB](#)

Device ? nano

Label unifei Sample length (ms.) 10000

Sensor Built-in microphone Frequency 16000Hz

Start sampling

RAW DATA
Click on a sample to load...

The screenshot shows the Edge Impulse Data Acquisition interface. On the left, a sidebar lists various project management and development tools. The main area displays 'Collected data' with a table listing 14 samples. Two specific samples, 'unifei.29lq8ugs' and 'unifei.29lq80v9', are highlighted with orange boxes around their row numbers. Above this table is a row of buttons: 'Delete selected (2)', 'Edit labels (2)', and 'Move to test set (2)', with the last one also highlighted by an orange box. To the right, there's a 'Record new data' section with fields for 'Device' (set to 'nano'), 'Label' ('unifei'), 'Sample length (ms.)' (set to '10000'), 'Sensor' ('Built-in microphone'), and 'Frequency' (set to '16000Hz'). A large blue 'Start sampling' button is at the bottom of this section. At the very bottom, a dark bar says 'RAW DATA' and 'Click on a sample to load...'.

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studio.edgeimpulse.com/studio/139843/acquisition/training?page=1

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EDGE IMPULSE

Training data Test data | Data explorer | Upload data Export data

Did you know? You can capture data from any device or development board, or upload your existing datasets - [Show options](#)

DATA COLLECTED 4m 46s

TRAIN / TEST SPLIT 77% / 23%

Collected data

SAMPLE NAME	LABEL	ADDED	LENGTH	⋮
unifei.3dfbegg5.s9	unifei	Today, 10:43:14	1s	⋮
unifei.3dfbegg5.s8	unifei	Today, 10:43:14	1s	⋮
unifei.3dfbegg5.s7	unifei	Today, 10:43:14	1s	⋮
unifei.3dfbegg5.s6	unifei	Today, 10:43:14	1s	⋮
unifei.3dfbegg5.s5	unifei	Today, 10:43:14	1s	⋮
unifei.3dfbegg5.s4	unifei	Today, 10:43:14	1s	⋮
unifei.3dfbegg5.s3	unifei	Today, 10:43:14	1s	⋮
unifei.3dfbegg5.s2	unifei	Today, 10:43:14	1s	⋮
unifei.3dfbegg5.s1	unifei	Today, 10:43:13	1s	⋮

Record new data [Connect using WebUSB](#)

No devices connected to the remote management API.

RAW DATA unifei.3dfbegg5.s9

0:00 / 0:00

57

CNMAC_Keyword_Spotting - X + studio.edgeimpulse.com/studio/139843/acquisition/training?page=1

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EDGE IMPULSE

Training data Test data | Data explorer | Upload data Export data

Did you know? You can capture data from any device or development board, or upload your existing datasets - [Show options](#)

DATA COLLECTED
4m 46s

TRAIN / TEST SPLIT
77% / 23%

Filter your data

Collected data

Apply filters

By label

- iesti (96)
- silence (95)
- unifei (103)

By name

Enter a sample name

By length

406ms 1337ms

By signature validity

Valid & invalid signatures

Enabled & disabled samples

Enabled & disabled samples

Record new data

Connect using WebUSB

No devices connected to the remote management API.

RAW DATA
unifei.3dfbegg5.s9

25000
20000
15000
10000
5000
0
-5000
-10000
-15000
-20000

0 104 208 312 416 520 624 728 832 936

audio

▶ 0:00 / 0:00

SAMPLE NAME LABEL ADDED LENGTH

Documentation

Create impulse - IESTI01_Keyw X Uaiirrior | UNIFEI x +

studio.edgeimpulse.com/studio/38744/create-impulse

EDGE IMPULSE

CREATE IMPULSE (IESTI01_KEYWORD_SPOTTING_PROJECT)

MJRoBot (Marcelo Rova)

An impulse takes raw data, uses signal processing to extract features, and then uses a learning block to classify new data.

Time series data

Axes: audio

Window size: 1000 ms.

Window increase: 500 ms.

Zero-pad data:

Add a processing block

Add a learning block

Output features

Save impulse

Dashboard

Devices

Data acquisition

Impulse design

Create impulse

Retrain model

Live classification

Model testing

Versioning

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CNMAC_Keyword_Spotting - X + studio.edgeimpulse.com/studio/139843/create-impulse Edge Impulse Imagine! Join us for the latest innovations in edge machine learning for the real world, Sept 28-30. [Learn more.](#)

EDGE IMPULSE

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Time series

Input axes

Window

Frequency

16000

Zero-padding

Add a processing block

Did you know? You can bring your own DSP code.

DESCRIPTION	AUTHOR	RECOMMENDED
Audio (MFCC) Extracts features from audio signals using Mel Frequency Cepstral Coefficients, great for human voice.	Edgelimpulse Inc. ★	Add
Audio (MFE) Extracts a spectrogram from audio signals using Mel-filterbank energy features, great for non-voice audio.	Edgelimpulse Inc. ★	Add
Spectrogram Extracts a spectrogram from audio or sensor data, great for non-voice audio or data with continuous frequencies.	Edgelimpulse Inc.	Add
Audio (Syntiant) Syntiant only. Compute log Mel-filterbank energy features from an audio signal.	Edgelimpulse Inc.	Add
Raw Data Use data without pre-processing. Useful if you want to use deep learning to learn features.	Edgelimpulse Inc.	Add

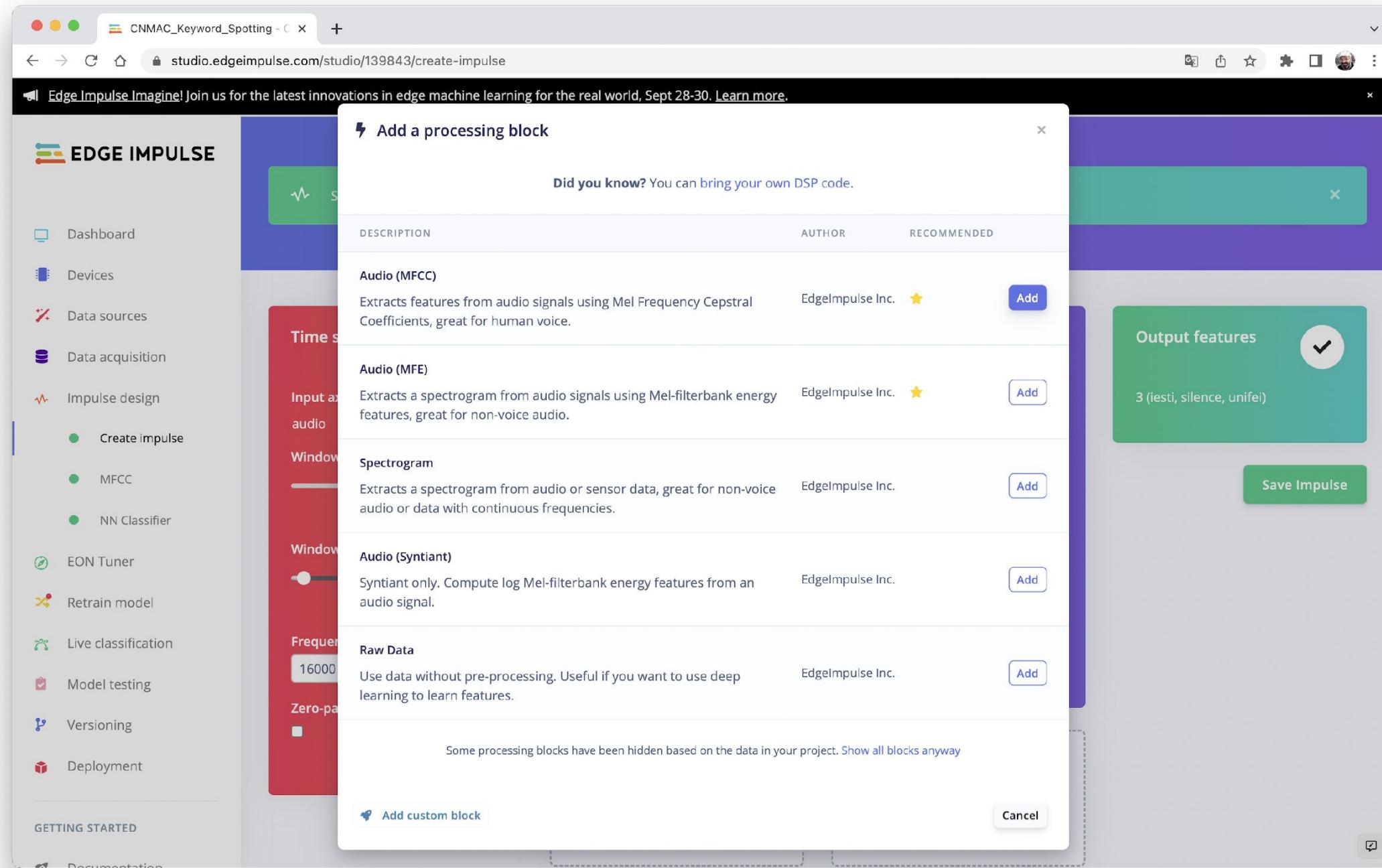
Some processing blocks have been hidden based on the data in your project. [Show all blocks anyway](#)

Add custom block Cancel

Output features

3 (iesti, silence, unifei)

Save Impulse



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studio.edgeimpulse.com/studio/139843/create-impulse

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EDGE IMPULSE

Successfully stored impulse. Configure the signal processing and learning blocks in the navigation bar.

Dashboard

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Time series data

Input axes: audio

Window size: 1000 ms.

Window increase: 500 ms.

Frequency (Hz): 16000

Zero-pad data:

Audio (MFCC)

Name: MFCC

Input axes (1): audio

Neural Network (Keras)

Name: NN Classifier

Input features: MFCC

Output features: 3 (iesti, silence, unifei)

Output features: 3 (iesti, silence, unifei)

Save Impulse

Add a processing block

Add a learning block

GETTING STARTED

Documentation

The screenshot shows the Edge Impulse studio interface. On the left, a sidebar lists various tools and features: Dashboard, Devices, Data sources, Data acquisition, Impulse design, Create impulse (selected), MFCC, NN Classifier, EON Tuner, Retrain model, Live classification, Model testing, Versioning, Deployment, and Getting Started. Below this is a 'Documentation' link. The main area is titled 'Time series data' and contains configuration for 'Input axes' (audio), 'Window size' (1000 ms), 'Window increase' (500 ms), 'Frequency (Hz)' (16000), and 'Zero-pad data'. To the right are four blocks: 'Audio (MFCC)', 'Neural Network (Keras)', and 'Output features' (set to 3 categories: iesti, silence, unifei). A green 'Save Impulse' button is visible. At the bottom, there are dashed boxes for 'Add a processing block' and 'Add a learning block'. A success message at the top states 'Successfully stored impulse. Configure the signal processing and learning blocks in the navigation bar.'

CNMAC_Keyword_Spotting - M X +

studio.edgeimpulse.com/studio/139843/dsp/mfcc/3

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Show: All labels unifei.3dfbegg5.s9 (unifei)

EDGE IMPULSE

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Raw data

Raw features

4, 0, 3, 4, 3, 8, 14, 19, 20, 14, 10, 9, 8, 6, 3, 9, 12, 12, 2, -4, -7, -6, -9, -3, -1, -5, -4, -1, 0, -1, 0, -3, 2, 6, 8, 10...

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	300
High frequency	0

Pre-emphasis

Coefficient	0.98
Shift	1

DSP result

Cepstral Coefficients

Processed features

-1.0019, -0.1025, -1.8570, -0.4356, 0.0810, -0.5326, 1.1981, 0.2336, 0.7386, 1.3958, -0.8044, -0.9786, -0.2971, -0.9416, -0.1...

On-device performance

PROCESSING TIME 177 ms. PEAK RAM USAGE 17 KB

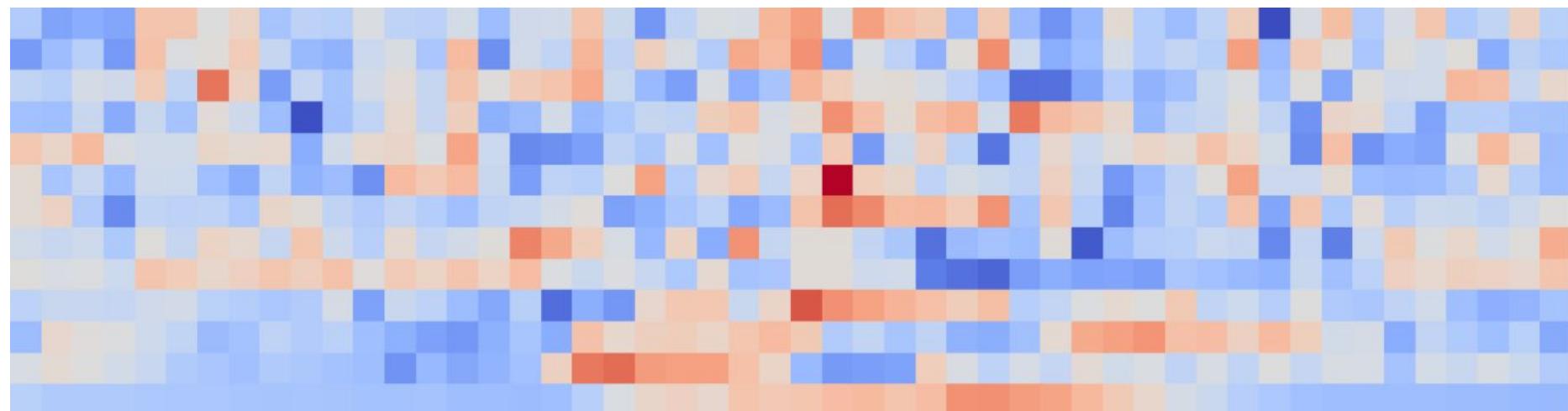
Save parameters

Raw data



1 second of Sound raw data

MFCC



$$\begin{aligned}Dim &= 13 \times 50 \\&= 650\end{aligned}$$

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studio.edgeimpulse.com/studio/139843/dsp/mfcc/3/generate-features

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Marcelo Rovai / CNMAC_Keyword_Spotting

#1 ▾ Click to set a description for this version

EDGE IMPULSE

Parameters Generate features

Training set

Data in training set 4m 46s

Classes 3 (iesti, silence, unifei)

Training windows 262

Generate features

Feature explorer

liesti silence unifei

Estimate for calculating features on Raspberry Pi 4

On-device performance ⓘ

PROCESSING TIME 5 ms.

PEAK RAM USAGE 17 KB

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KWS Classifier Project

Audio Raw Data Analysis

[IESTI01 Audio Raw Data Analisys.ipynb](#)



CNMAC_Keyword_Spotting - N X

studio.edgeimpulse.com/studio/139843/learning/keras/5

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EDGE IMPULSE

Neural Network settings

Training settings

- Number of training cycles: 100
- Learning rate: 0.005
- Validation set size: 20 %
- Auto-balance dataset:

Audio training options

- Data augmentation:

Neural network architecture

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

Input layer (650 features)

- Reshape layer (13 columns)
- 2D conv / pool layer (8 filters, 3 kernel size, 1 layer)
- Dropout (rate 0.5)
- 2D conv / pool layer (16 filters, 3 kernel size, 1 layer)
- Dropout (rate 0.5)
- Flatten layer
- Add an extra layer

Output layer (3 classes)

Start training

Training output

Creating embeddings OK (took 5 seconds)

Calculating performance metrics...
 Calculating inferencing time...
 Calculating inferencing time OK
 Profiling float32 model...
 Profiling float32 model (tflite)...
 Profiling float32 model (EON)...
 Profiling int8 model...
 Profiling int8 model (tflite)...
 Profiling int8 model (EON)...

Model training complete

Job completed

Model

Model version: Quantized (int8)

Last training performance (validation set)

ACCURACY	96.2%
LOSS	0.13

Confusion matrix (validation set)

	IESTI	SILENCE	UNIFEI
IESTI	100%	0%	0%
SILENCE	0%	94.1%	5.9%
UNIFEI	4.2%	0%	95.8%
F1 SCORE	0.95	0.97	0.96

Data explorer (full training set)

Legend: iesti - correct, silence - correct, unifei - correct, silence - incorrect, unifei - incorrect

On-device performance

- INFERRING TIME: 2 ms.
- PEAK RAM USAGE: 9.6K
- FLASH USAGE: 30.1K

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studio.edgeimpulse.com/studio/139843/validation

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This lists all test data. You can manage this data through Data acquisition.

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Test data

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

SAMPLE NAME	EXPECTED OUTCOME	LENGTH	ACCURACY	RESULT
testing.29lufkik	silence	10s	73%	14 silence, 3 uncertain, 1 iesti, 1 unifei
testing.29lu6v0r	iesti	10s	31%	6 iesti, 6 silence, 4 uncertain, 3 unifei
testing.29lu1guk	unifei	10s	63%	12 unifei, 5 silence, 2 uncertain
silence.29lsp17j.s10	silence	1s	100%	1 silence
silence.29lsp17j.s9	silence	1s	100%	1 silence
silence.29lsp17j.s8	silence	1s	100%	1 silence
silence.29lsp17j.s7	silence	1s	100%	1 silence
silence.29lsp17j.s6	silence	1s	100%	1 silence
silence.29lsp17j.s5	silence	1s	100%	1 silence
silence.29lsp17j.s4	silence	1s	100%	1 silence
silence.29lsp17j.s3	silence	1s	100%	1 silence
silence.29lsp17j.s2	silence	1s	0%	1 unifei
silence.29lsp17j.s1	silence	1s	100%	1 silence
silence.29lt4rkv.s9	silence	1s	0%	1 uncertain
silence.29lt4rkv.s8	silence	1s	100%	1 silence
silence.29lt4rkv.s7	silence	1s	100%	1 silence

Model testing output

```

completed 200 / 500 epochs
completed 300 / 500 epochs
completed 350 / 500 epochs
completed 400 / 500 epochs
completed 450 / 500 epochs
Thu Sep 22 14:14:41 2022 Finished embedding
Reducing dimensions for visualizations OK
Classifying data for NN Classifier...
Classifying data for float32 model...
Scheduling job in cluster...
Job started

Job completed
  
```

Model testing results

ACCURACY 71.30%

	iesti	silence	unifei	uncertain
iesti	48.5%	21.2%	9.1%	21.2%
SILENCE	2.5%	81.6%	5.3%	10.5%
UNIFEI	0%	13.5%	81.1%	5.4%
F1 SCORE	0.64	0.77	0.83	

Feature explorer

ei-cnmac_keywo....zip Show All X

CNMAC_Keyword_Spotting - X +

studio.edgeimpulse.com/studio/139843/deployment

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Silabs Thunderboard Sense 2

Infinion PSoC 62S2 Wi-Fi RT Pioneer Kit

Silabs xG24 Dev Kit

Nordic nRF52840 DK + IKS02A1

Himax WE-I Plus

Nordic nRF9160 DK + IKS02A1

TI LAUNCHXL-CC1352P

Custom firmware

Scan this QR code

To run your impulse on your mobile phone, click [here](#) or scan the QR code.

Run your impulse directly

Run this impulse directly on your mobile phone or computer, no additional hardware required.

Computer

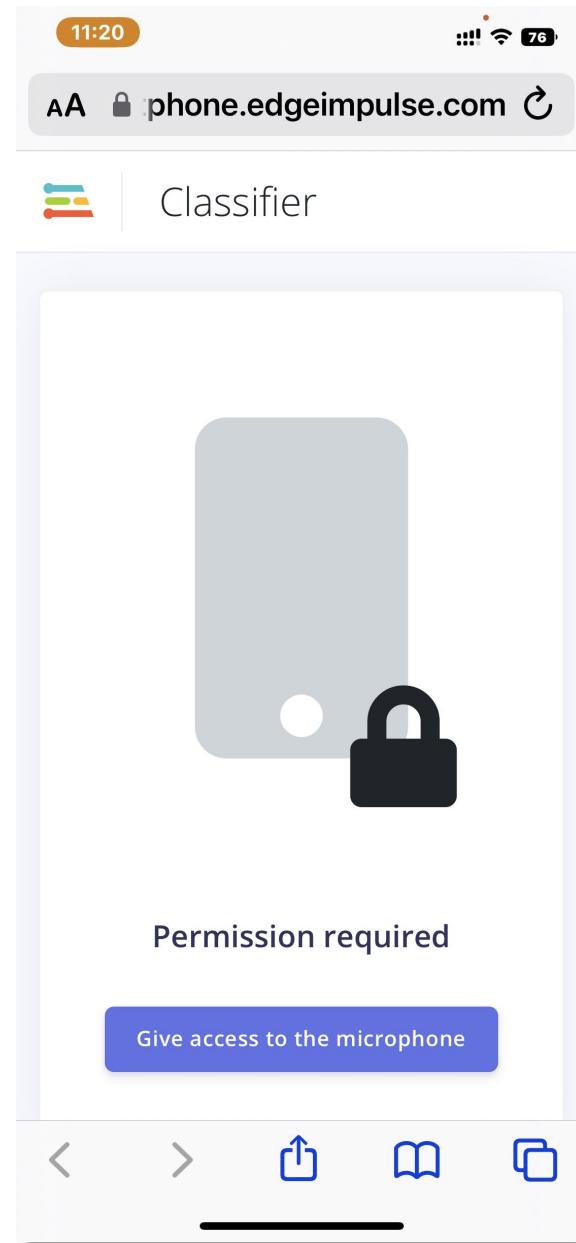
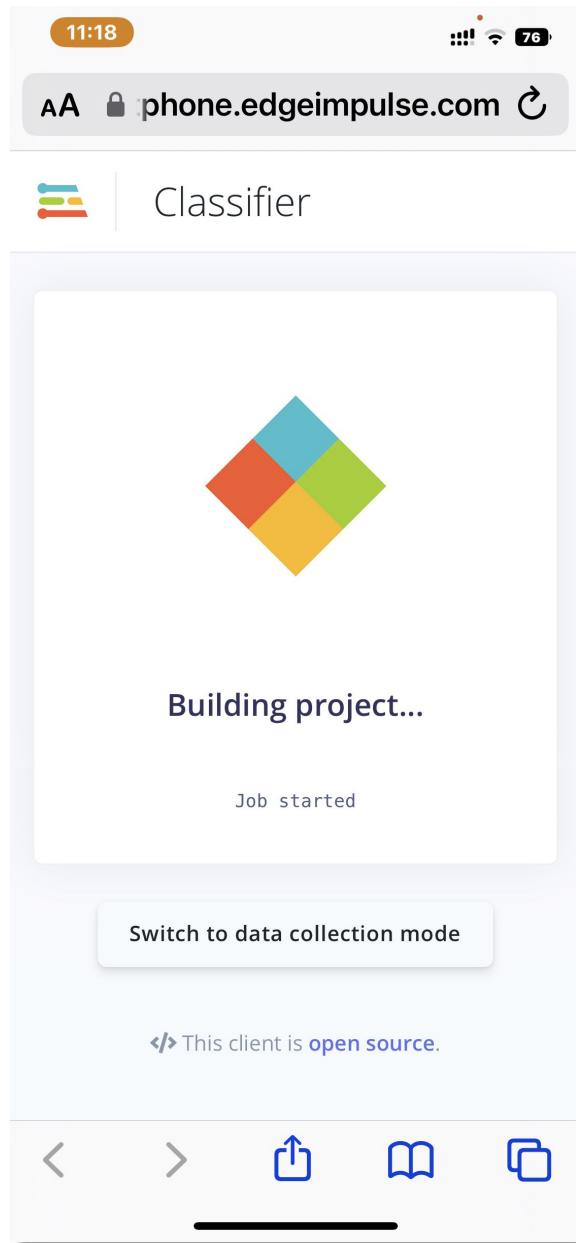
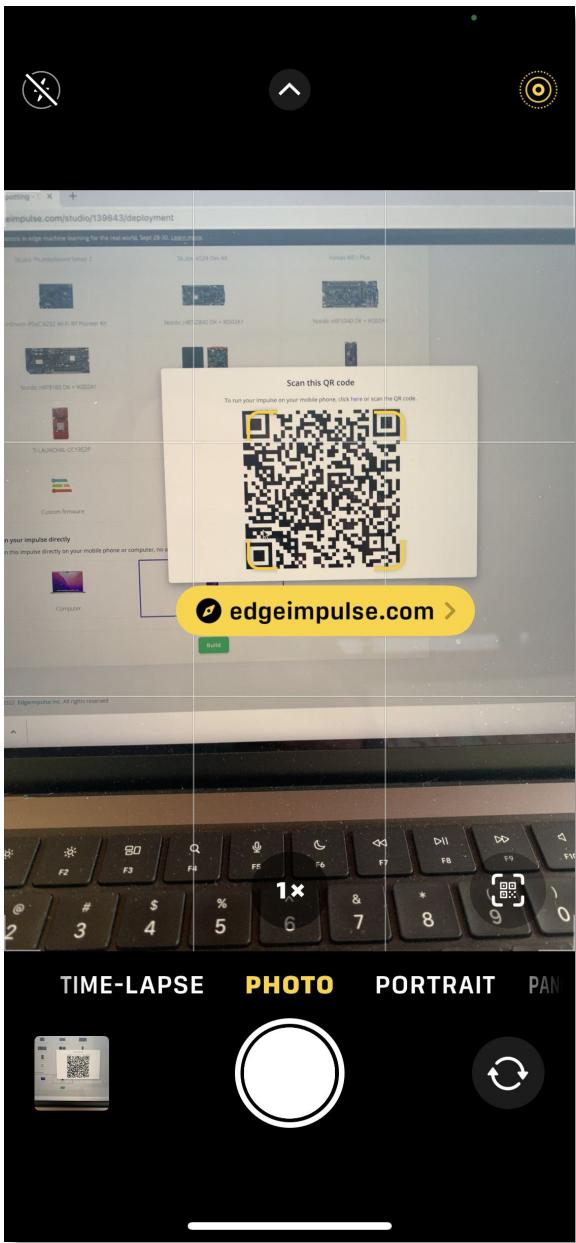
Mobile phone

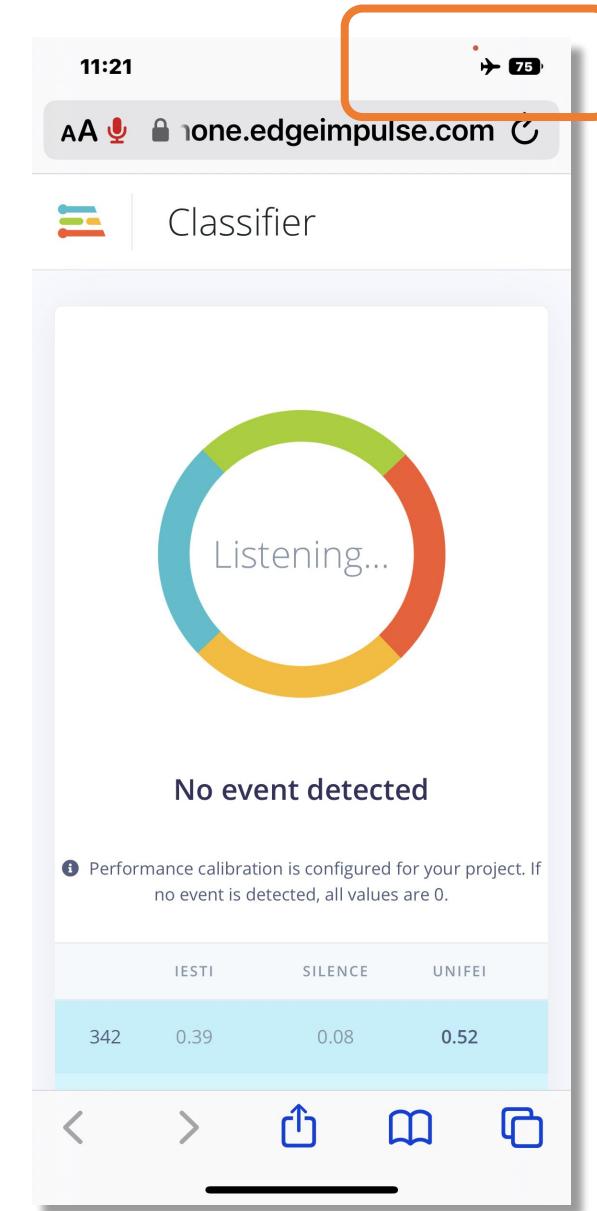
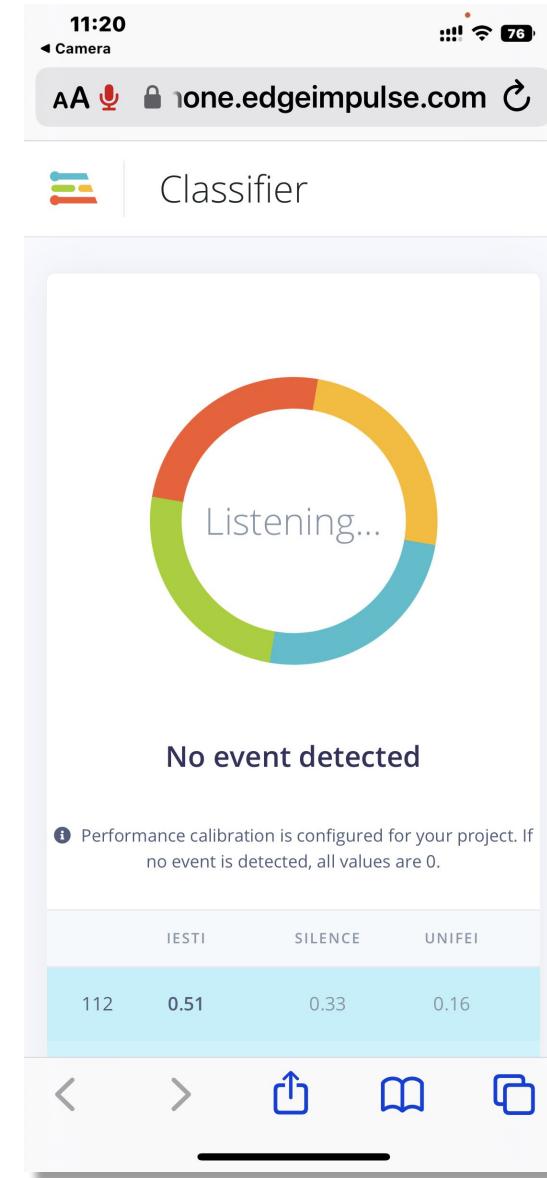
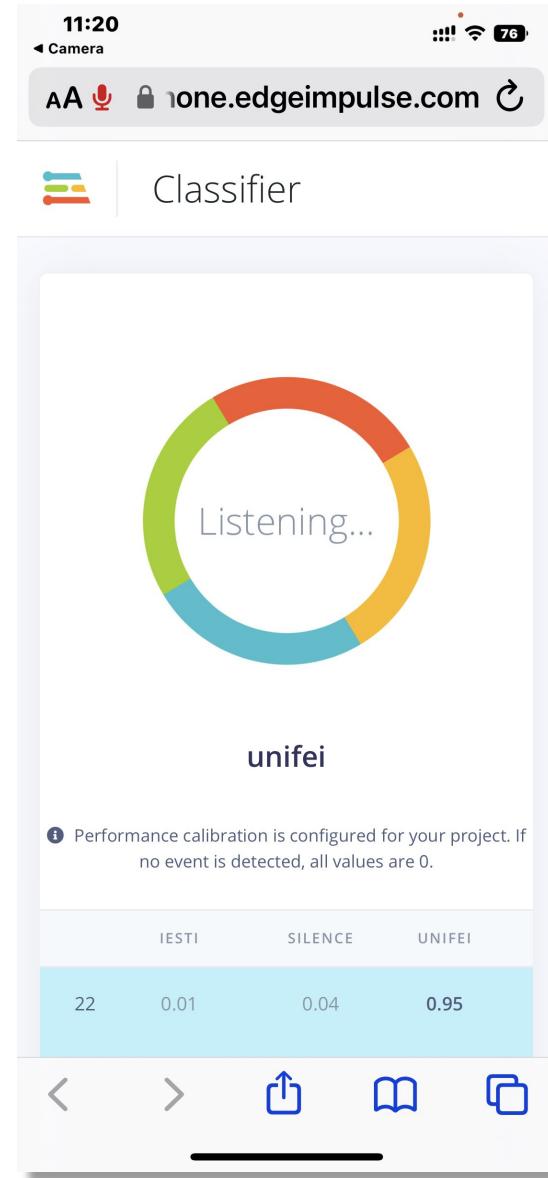
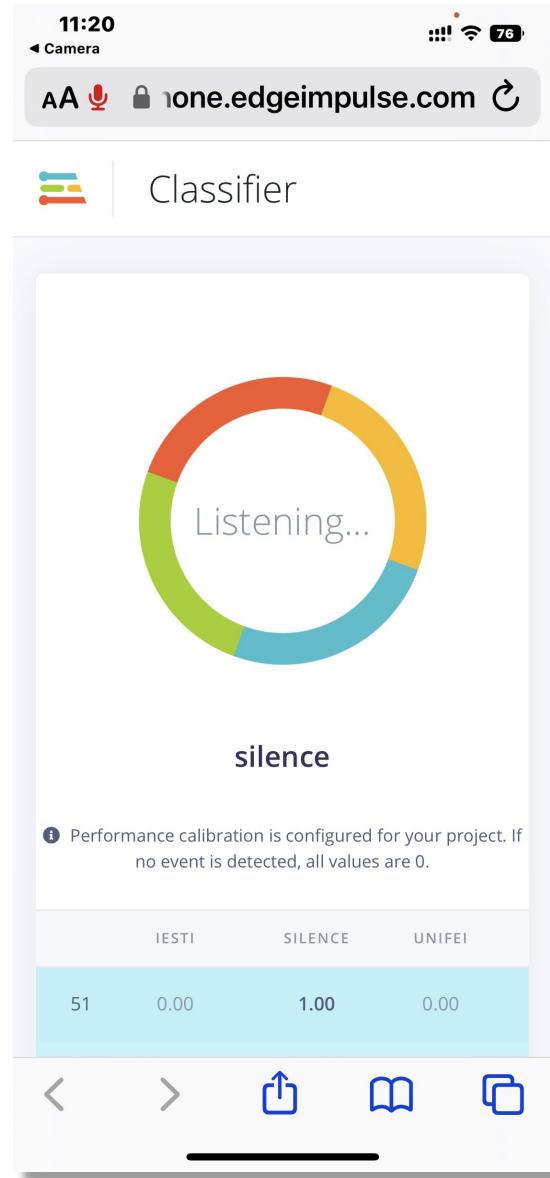
Build

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ei-cnmac_keywo....zip

Show All X





To learn more about Edge AI

- UNIFEI - IESTI01 TinyML - Machine Learning for Embedding Devices
- Professional Certificate in Tiny Machine Learning (TinyML) – edX/Harvard
- Introduction to Embedded Machine Learning - Coursera/Edge Impulse
- Computer Vision with Embedded Machine Learning - Coursera/Edge Impulse
- "Deep Learning with Python" book by François Chollet
- "TinyML" book by Pete Warden, Daniel Situnayake
- "TinyML Cookbook" by Gian Marco Iodice
- "AI at the Edge" book by Daniel Situnayake, Jenny Plunkett

Thanks

