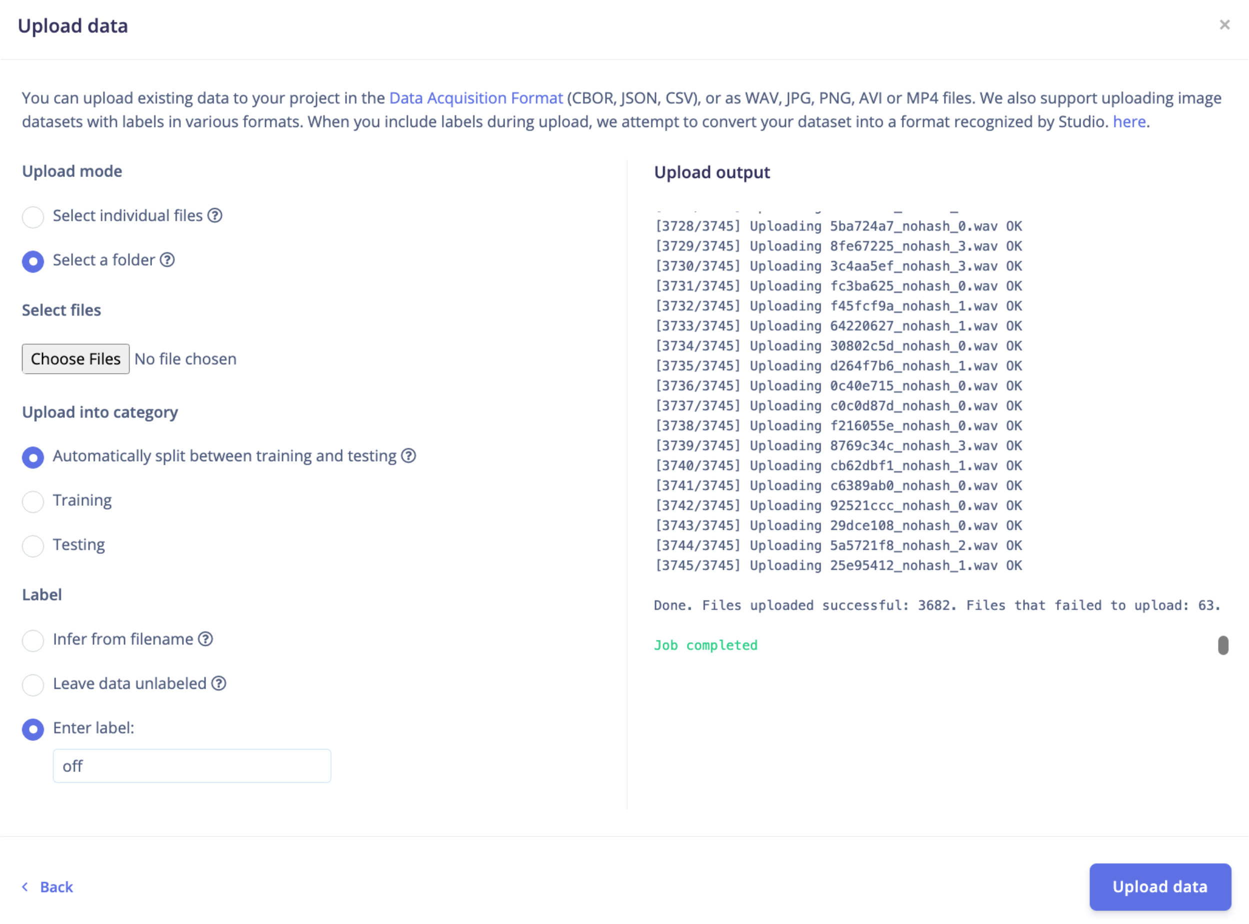
Homework-8: TinyML using Edge Impulse

Q1.1

off dataset



Upload data

×

You can upload existing data to your project in the Data Acquisition Format (CBOR, JSON, CSV), or as WAV, JPG, PNG, AVI or MP4 files. We also support uploading image datasets with labels in various formats. When you include labels during upload, we attempt to convert your dataset into a format recognized by Studio. here.

Upload mode

○ Select individual files ⓘ

● Select a folder ⓘ

Select files

Choose Files No file chosen

Upload into category

● Automatically split between training and testing ⓘ

○ Training

○ Testing

Label

○ Infer from filename ⓘ

○ Leave data unlabeled ⓘ

● Enter label:

off

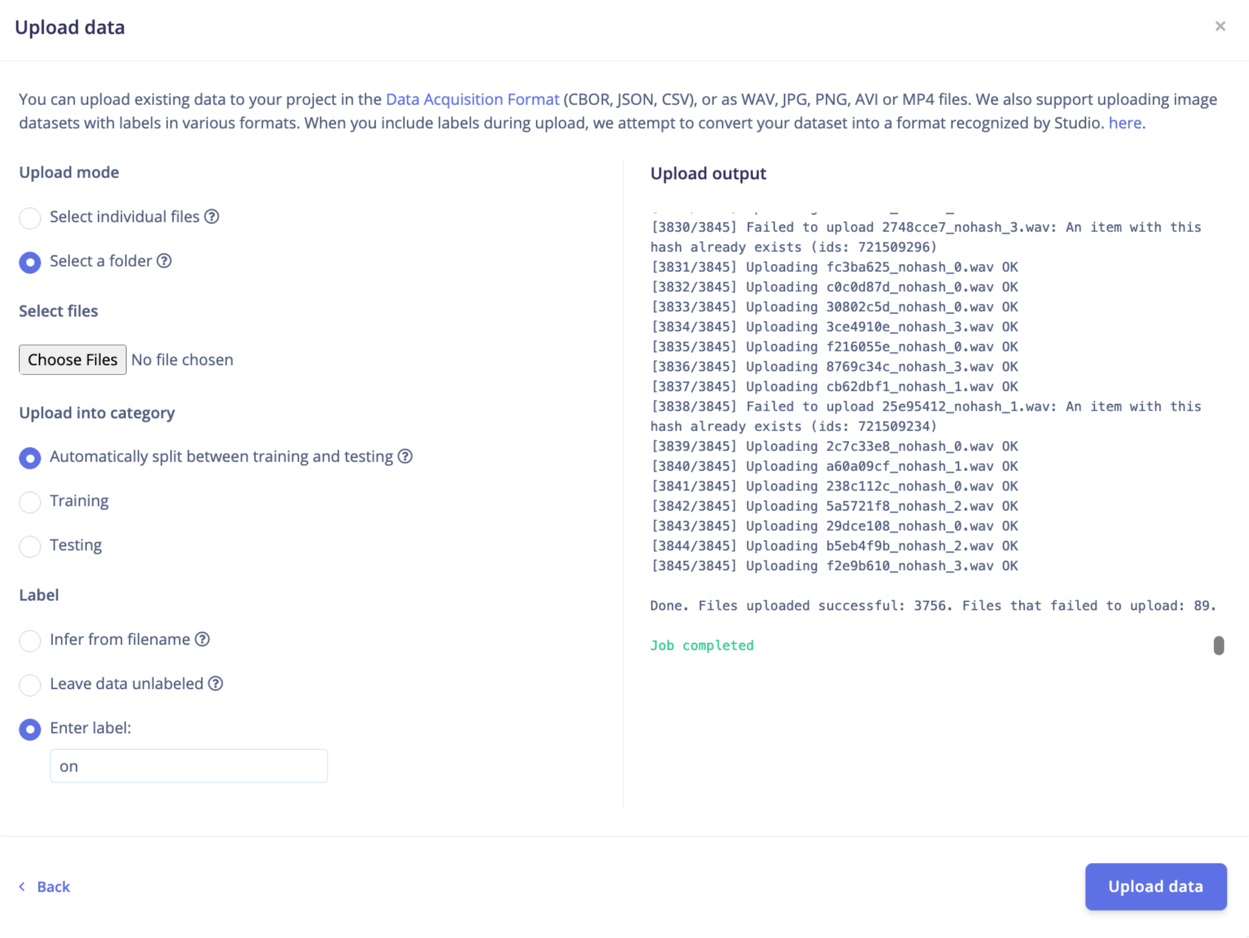
Upload output

```
[3728/3745] Uploading 5ba724a7_nohash_0.wav OK
[3729/3745] Uploading 8fe67225_nohash_3.wav OK
[3730/3745] Uploading 3c4aa5ef_nohash_3.wav OK
[3731/3745] Uploading fc3ba625_nohash_0.wav OK
[3732/3745] Uploading f45fcf9a_nohash_1.wav OK
[3733/3745] Uploading 64220627_nohash_1.wav OK
[3734/3745] Uploading 30802c5d_nohash_0.wav OK
[3735/3745] Uploading d264f7b6_nohash_1.wav OK
[3736/3745] Uploading 0c40e715_nohash_0.wav OK
[3737/3745] Uploading c0c0d87d_nohash_0.wav OK
[3738/3745] Uploading f216055e_nohash_0.wav OK
[3739/3745] Uploading 8769c34c_nohash_3.wav OK
[3740/3745] Uploading cb62dbf1_nohash_1.wav OK
[3741/3745] Uploading c6389ab0_nohash_0.wav OK
[3742/3745] Uploading 92521ccc_nohash_0.wav OK
[3743/3745] Uploading 29dce108_nohash_0.wav OK
[3744/3745] Uploading 5a5721f8_nohash_2.wav OK
[3745/3745] Uploading 25e95412_nohash_1.wav OK

Done. Files uploaded successful: 3682. Files that failed to upload: 63.

Job completed
```

on dataset



Upload data

You can upload existing data to your project in the Data Acquisition Format (CBOR, JSON, CSV), or as WAV, JPG, PNG, AVI or MP4 files. We also support uploading image datasets with labels in various formats. When you include labels during upload, we attempt to convert your dataset into a format recognized by Studio. here.

Upload mode

○ Select individual files ⓘ

● Select a folder ⓘ

Select files

Choose Files No file chosen

Upload into category

● Automatically split between training and testing ⓘ

○ Training

○ Testing

Label

○ Infer from filename ⓘ

○ Leave data unlabeled ⓘ

● Enter label:

on

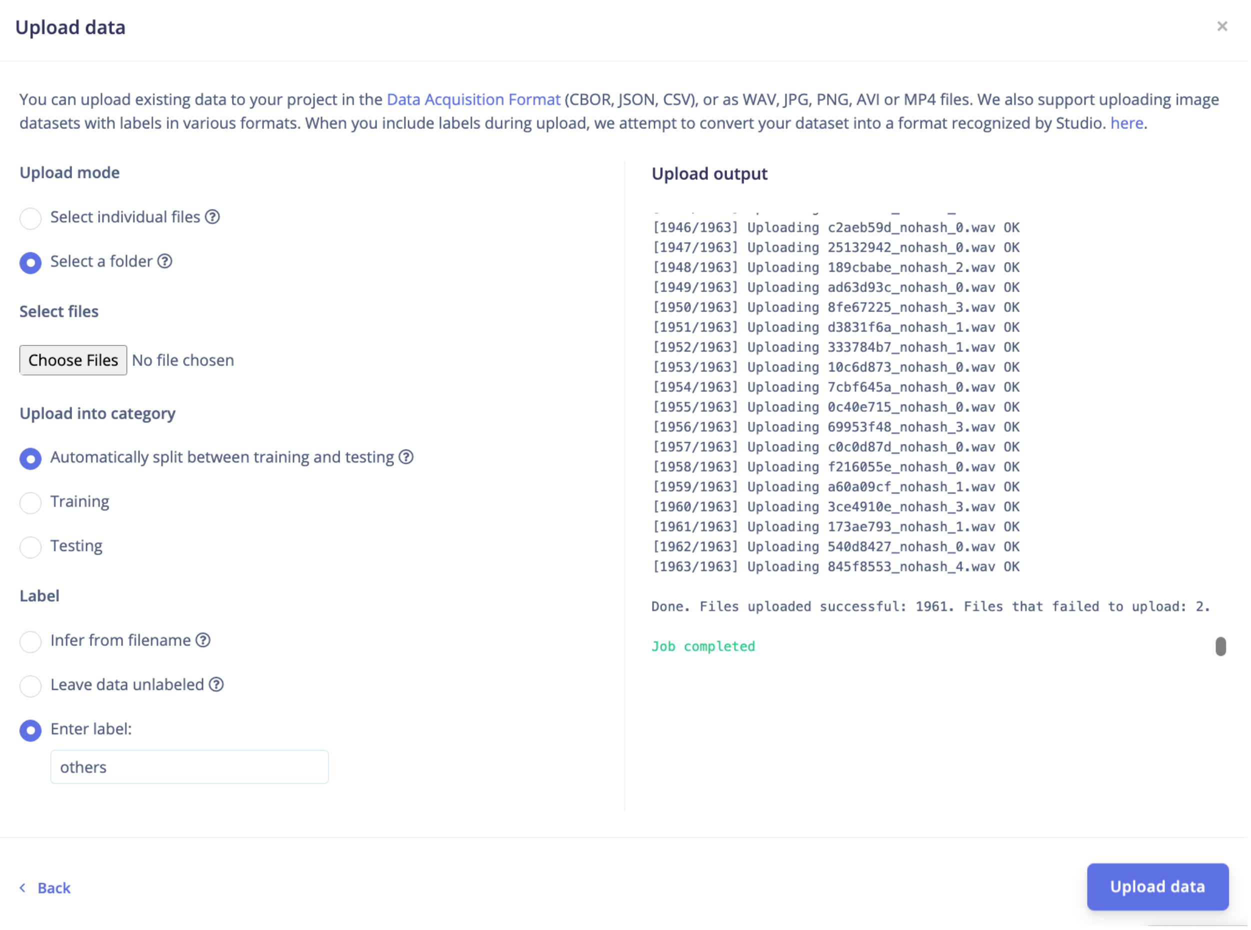
Upload output

```
[3830/3845] Failed to upload 2748cce7_nohash_3.wav: An item with this
hash already exists (ids: 721509296)
[3831/3845] Uploading fc3ba625_nohash_0.wav OK
[3832/3845] Uploading c0c0d87d_nohash_0.wav OK
[3833/3845] Uploading 30802c5d_nohash_0.wav OK
[3834/3845] Uploading 3ce4910e_nohash_3.wav OK
[3835/3845] Uploading f216055e_nohash_0.wav OK
[3836/3845] Uploading 8769c34c_nohash_3.wav OK
[3837/3845] Uploading cb62dbf1_nohash_1.wav OK
[3838/3845] Failed to upload 25e95412_nohash_1.wav: An item with this
hash already exists (ids: 721509234)
[3839/3845] Uploading 2c7c33e8_nohash_0.wav OK
[3840/3845] Uploading a60a09cf_nohash_1.wav OK
[3841/3845] Uploading 238c112c_nohash_0.wav OK
[3842/3845] Uploading 5a5721f8_nohash_2.wav OK
[3843/3845] Uploading 29dce108_nohash_0.wav OK
[3844/3845] Uploading b5eb4f9b_nohash_2.wav OK
[3845/3845] Uploading f2e9b610_nohash_3.wav OK

Done. Files uploaded successful: 3756. Files that failed to upload: 89.

Job completed
```

Others dataset



You can upload existing data to your project in the Data Acquisition Format (CBOR, JSON, CSV), or as WAV, JPG, PNG, AVI or MP4 files. We also support uploading image datasets with labels in various formats. When you include labels during upload, we attempt to convert your dataset into a format recognized by Studio. here.

Upload mode

○ Select individual files ⓘ

● Select a folder ⓘ

Select files

Choose Files No file chosen

Upload into category

● Automatically split between training and testing ⓘ

○ Training

○ Testing

Label

○ Infer from filename ⓘ

○ Leave data unlabeled ⓘ

● Enter label:

others

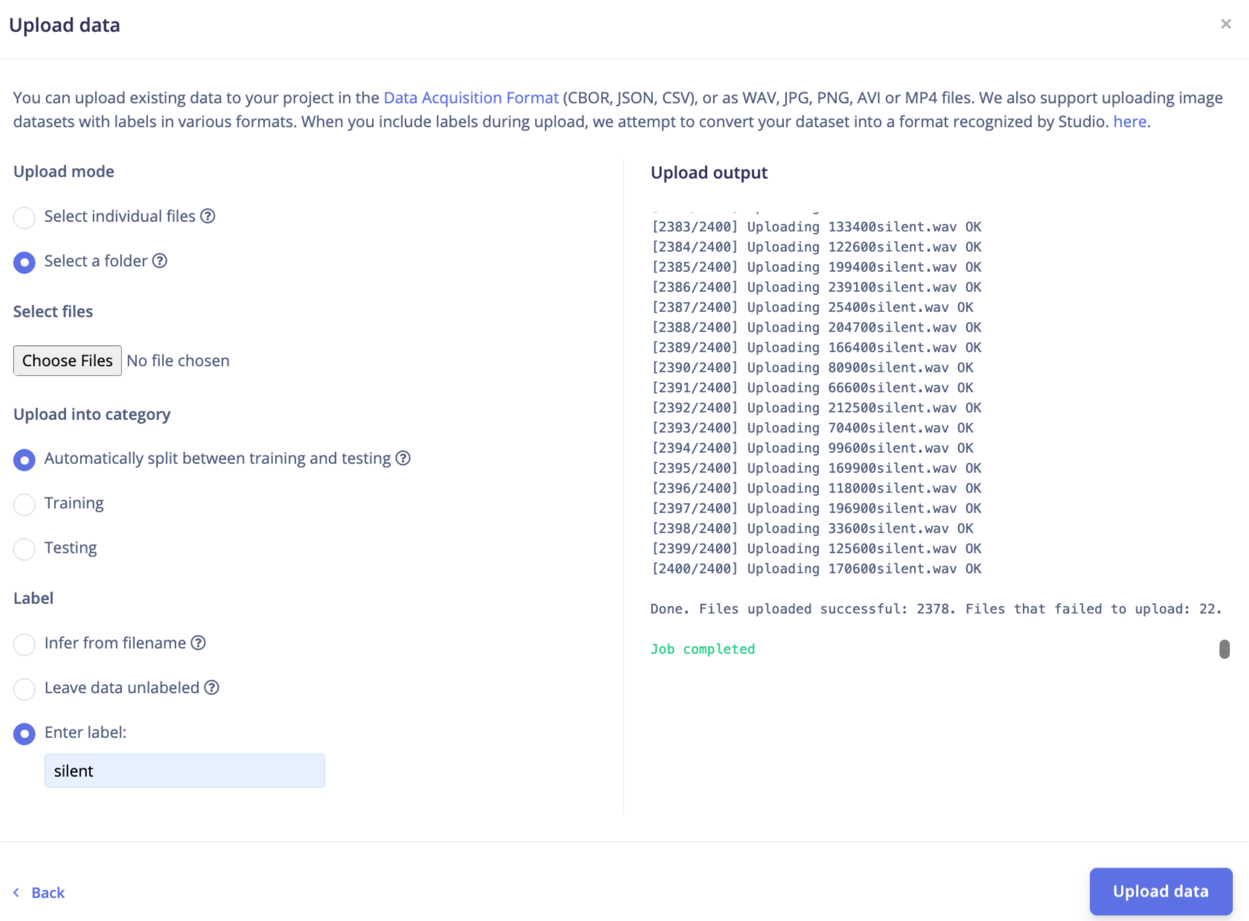
Upload output

```
[1946/1963] Uploading c2aeb59d_nohash_0.wav OK
[1947/1963] Uploading 25132942_nohash_0.wav OK
[1948/1963] Uploading 189cbabe_nohash_2.wav OK
[1949/1963] Uploading ad63d93c_nohash_0.wav OK
[1950/1963] Uploading 8fe67225_nohash_3.wav OK
[1951/1963] Uploading d3831f6a_nohash_1.wav OK
[1952/1963] Uploading 333784b7_nohash_1.wav OK
[1953/1963] Uploading 10c6d873_nohash_0.wav OK
[1954/1963] Uploading 7cbf645a_nohash_0.wav OK
[1955/1963] Uploading 0c40e715_nohash_0.wav OK
[1956/1963] Uploading 69953f48_nohash_3.wav OK
[1957/1963] Uploading c0c0d87d_nohash_0.wav OK
[1958/1963] Uploading f216055e_nohash_0.wav OK
[1959/1963] Uploading a60a09cf_nohash_1.wav OK
[1960/1963] Uploading 3ce4910e_nohash_3.wav OK
[1961/1963] Uploading 173ae793_nohash_1.wav OK
[1962/1963] Uploading 540d8427_nohash_0.wav OK
[1963/1963] Uploading 845f8553_nohash_4.wav OK

Done. Files uploaded successful: 1961. Files that failed to upload: 2.

Job completed
```

Silent dataset



Upload data

×

You can upload existing data to your project in the Data Acquisition Format (CBOR, JSON, CSV), or as WAV, JPG, PNG, AVI or MP4 files. We also support uploading image datasets with labels in various formats. When you include labels during upload, we attempt to convert your dataset into a format recognized by Studio. here.

Upload mode

○ Select individual files ⓘ

● Select a folder ⓘ

Select files

Choose Files No file chosen

Upload into category

● Automatically split between training and testing ⓘ

○ Training

○ Testing

Label

○ Infer from filename ⓘ

○ Leave data unlabeled ⓘ

● Enter label:

silent

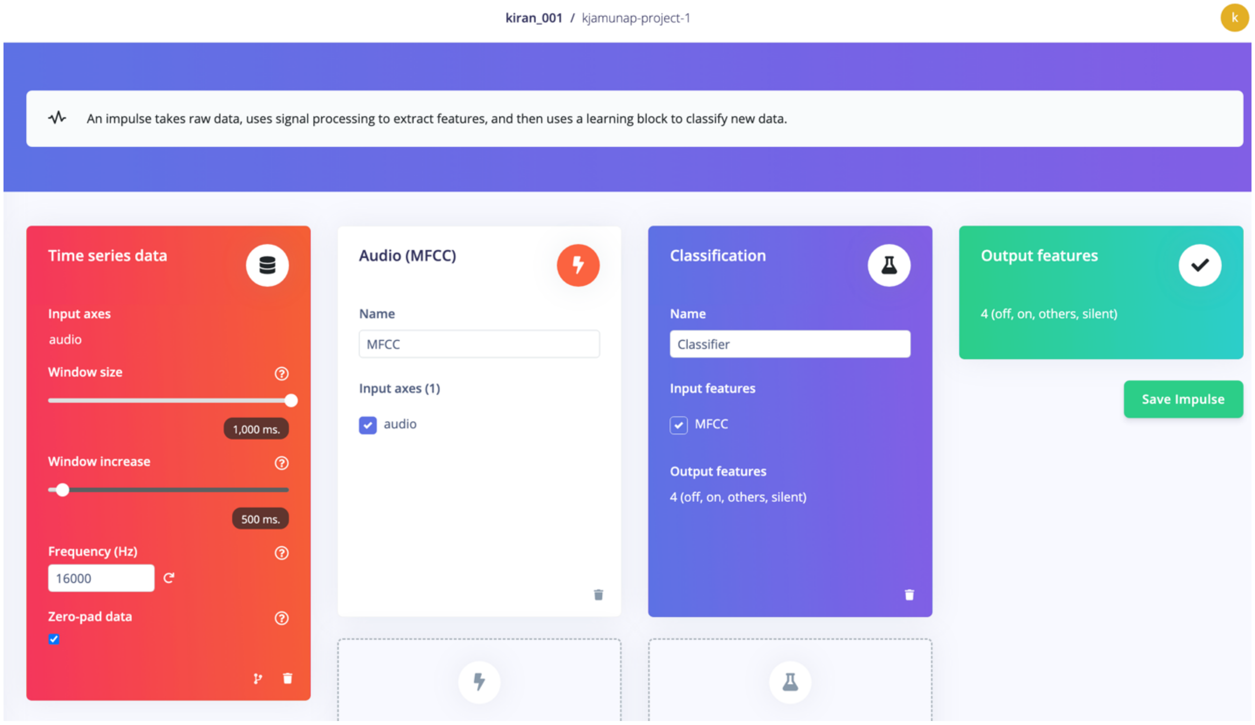
Upload output

```
[2383/2400] Uploading 133400silent.wav OK
[2384/2400] Uploading 122600silent.wav OK
[2385/2400] Uploading 199400silent.wav OK
[2386/2400] Uploading 239100silent.wav OK
[2387/2400] Uploading 25400silent.wav OK
[2388/2400] Uploading 204700silent.wav OK
[2389/2400] Uploading 166400silent.wav OK
[2390/2400] Uploading 80900silent.wav OK
[2391/2400] Uploading 66600silent.wav OK
[2392/2400] Uploading 212500silent.wav OK
[2393/2400] Uploading 70400silent.wav OK
[2394/2400] Uploading 99600silent.wav OK
[2395/2400] Uploading 169900silent.wav OK
[2396/2400] Uploading 118000silent.wav OK
[2397/2400] Uploading 196900silent.wav OK
[2398/2400] Uploading 33600silent.wav OK
[2399/2400] Uploading 125600silent.wav OK
[2400/2400] Uploading 170600silent.wav OK

Done. Files uploaded successful: 2378. Files that failed to upload: 22.

Job completed
```

Q1.2



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: 1,000 ms.

Window increase: 500 ms.

Frequency (Hz): 16000

Zero-pad data: ☑

Audio (MFCC)

Name: MFCC

Input axes (1): ☑ audio

Classification

Name: Classifier

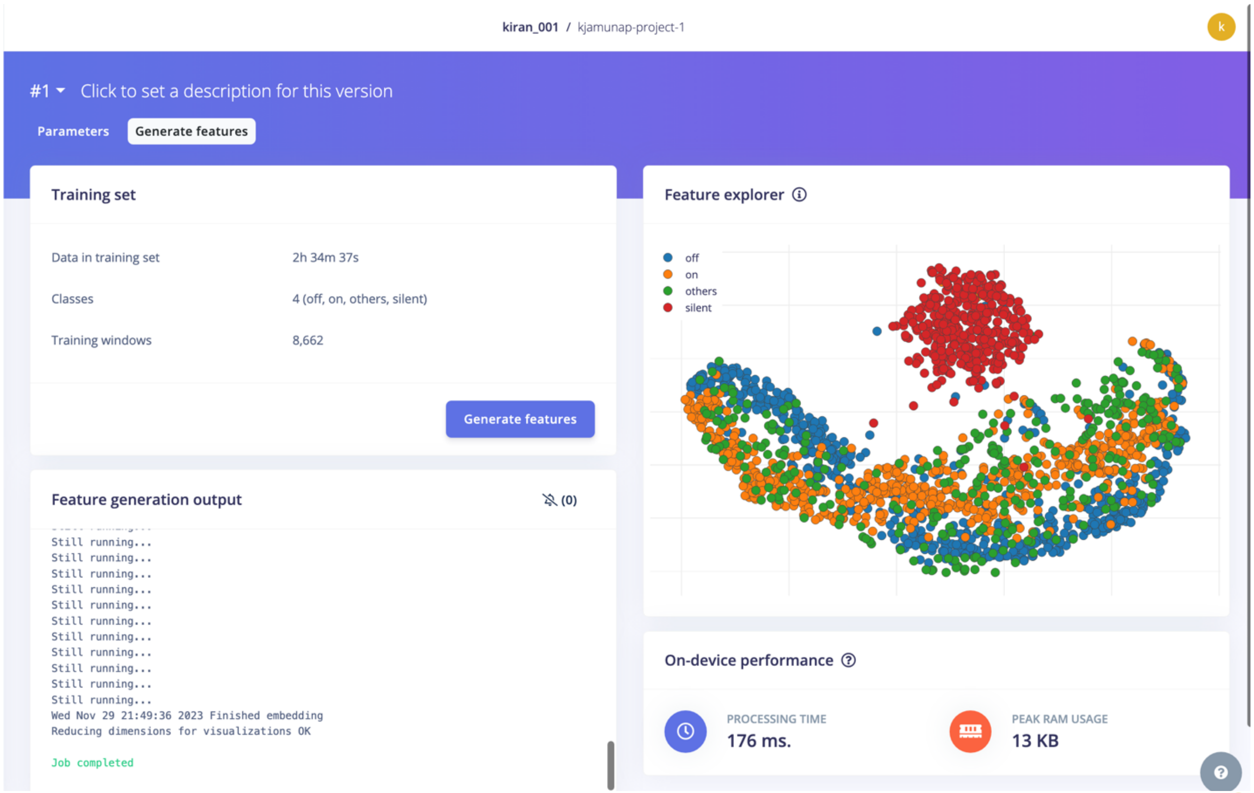
Input features: ☑ MFCC

Output features: 4 (off, on, others, silent)

Output features

4 (off, on, others, silent)

Q1.3



Training set

Data in training set	2h 34m 37s
Classes	4 (off, on, others, silent)
Training windows	8,662

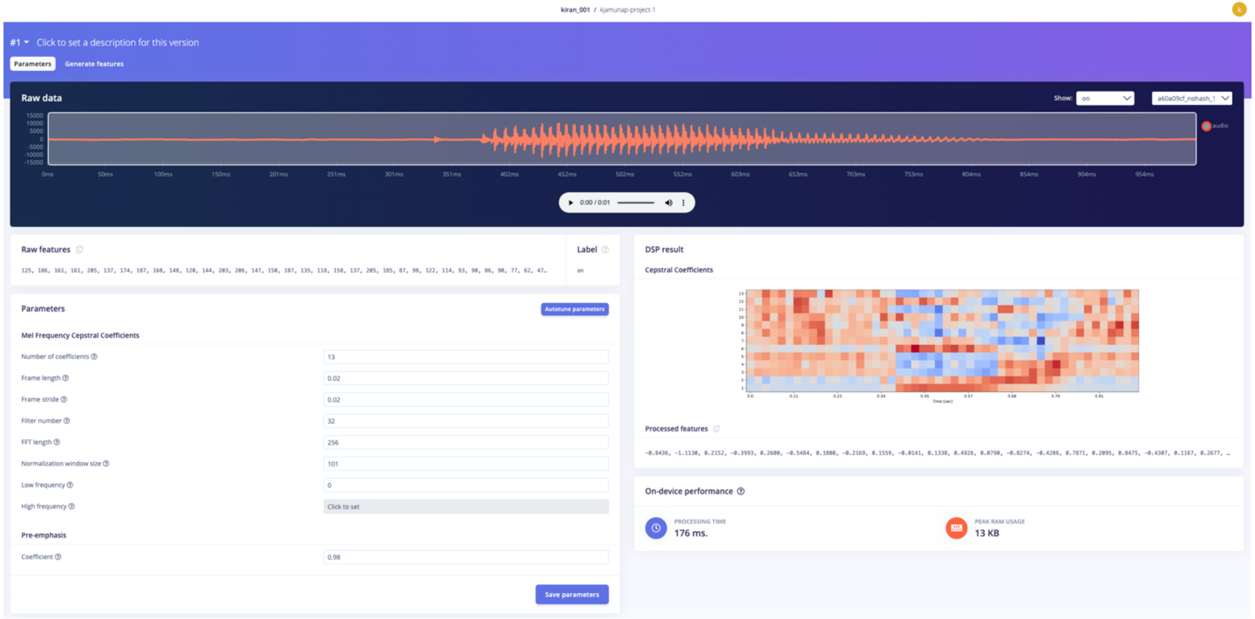
Feature generation output

```
Still running...
Still running...
Still running...
Still running...
Still running...
Still running...
Still running...
Still running...
Still running...
Still running...
Still running...
Wed Nov 29 21:49:36 2023 Finished embedding
Reducing dimensions for visualizations OK

Job completed
```

PROCESSING TIME
176 ms.

PEAK RAM USAGE
13 KB



Raw features

```
125, 186, 161, 161, 205, 137, 174, 187, 168, 148, 120, 144, 203, 206, 147, 150, 187, 135, 118, 158, 137, 205, 185, 87, 98, 122, 114, 93, 90, 86, 90, 77, 62, 47…
```

Label: on

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
High frequency	Click to set

Pre-emphasis

Coefficient	0.98

Processed features

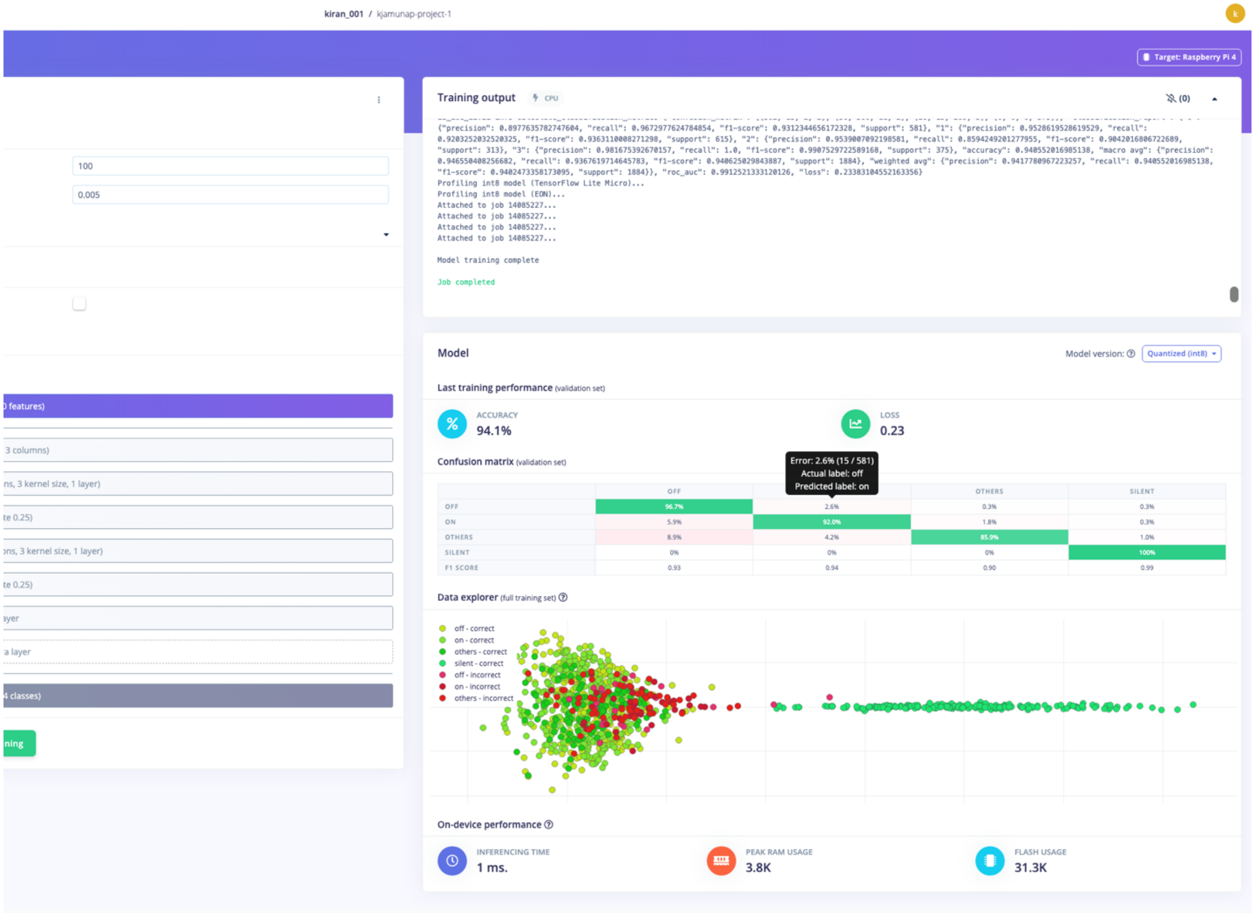
```
-0.8436, -1.1130, 0.2152, -0.3993, 0.2600, -0.5484, 0.1800, -0.2169, 0.1559, -0.0141, 0.1338, 0.4926, 0.0790, -0.8274, -0.4286, 0.7871, 0.2095, 0.8475, -0.4307, 0.1167, 0.2677, …
```

On-device performance

PROCESSING TIME
176 ms.

PEAK RAM USAGE
13 KB

Q1.4



Training output CPU (0)

```
{"precision": 0.8977635782747604, "recall": 0.9672977624784854, "f1-score": 0.9312344656172328, "support": 581}, "1": {"precision": 0.9528619528619529, "recall":
0.9203252032520325, "f1-score": 0.9363110008271298, "support": 615}, "2": {"precision": 0.9539007092198581, "recall": 0.8594249201277955, "f1-score": 0.9042016806722689,
"support": 313}, "3": {"precision": 0.981675392670157, "recall": 1.0, "f1-score": 0.9907529722589168, "support": 375}, "accuracy": 0.940552016985138, "macro avg": {"precision":
0.946550408256682, "recall": 0.9367619714645783, "f1-score": 0.940625029843887, "support": 1884}, "weighted avg": {"precision": 0.9417780967223257, "recall": 0.940552016985138,
"f1-score": 0.9402473358173095, "support": 1884}}, "roc_auc": 0.9912521333120126, "loss": 0.23383104552163356}
Profiling int8 model (TensorFlow Lite Micro)...
Profiling int8 model (EON)...
Attached to job 14085227...
Attached to job 14085227...
Attached to job 14085227...
Attached to job 14085227...

Model training complete

Job completed
```

Model

Model version: Quantized (int8)

Last training performance (validation set)

ACCURACY
94.1%

LOSS
0.23

Confusion matrix (validation set)

Error: 2.6% (15 / 581)
Actual label: off
Predicted label: on

	OFF		OTHERS	SILENT
OFF	96.7%	2.6%	0.3%	0.3%
ON	5.9%	92.0%	1.8%	0.3%
OTHERS	8.9%	4.2%	85.9%	1.0%
SILENT	0%	0%	0%	100%
F1 SCORE	0.93	0.94	0.90	0.99

Data explorer (full training set)

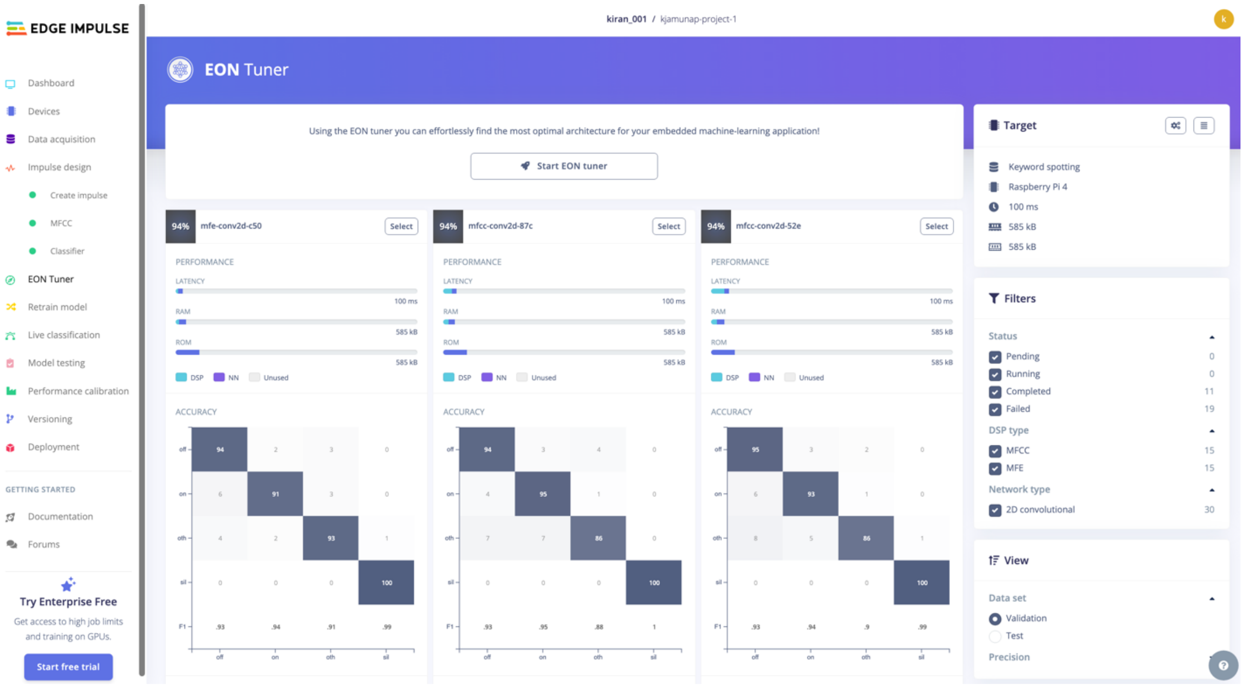
On-device performance

INFERENCING TIME
1 ms.

PEAK RAM USAGE
3.8K

FLASH USAGE
31.3K

Q2



Using the EON tuner you can effortlessly find the most optimal architecture for your embedded machine-learning application!

94% mfe-conv2d-c50

Latency 100 ms; RAM 585 kB; ROM 585 kB

	off	on	oth	sil
off	94	2	3	0
on	6	91	3	0
oth	4	2	93	1
sil	0	0	0	100
F1	.93	.94	.91	.99

94% mfcc-conv2d-87c

Latency 100 ms; RAM 585 kB; ROM 585 kB

	off	on	oth	sil
off	94	3	4	0
on	4	95	1	0
oth	7	7	86	0
sil	0	0	0	100
F1	.93	.95	.88	1

94% mfcc-conv2d-52e

Latency 100 ms; RAM 585 kB; ROM 585 kB

	off	on	oth	sil
off	95	3	2	0
on	6	93	1	0
oth	8	5	86	1
sil	0	0	0	100
F1	.93	.94	.9	.99

Target

Keyword spotting
Raspberry Pi 4
100 ms
585 kB
585 kB

Filters

Status

☑ Pending	0
☑ Running	0
☑ Completed	11
☑ Failed	19

DSP type

☑ MFCC	15
☑ MFE	15

Network type

☑ 2D convolutional	30

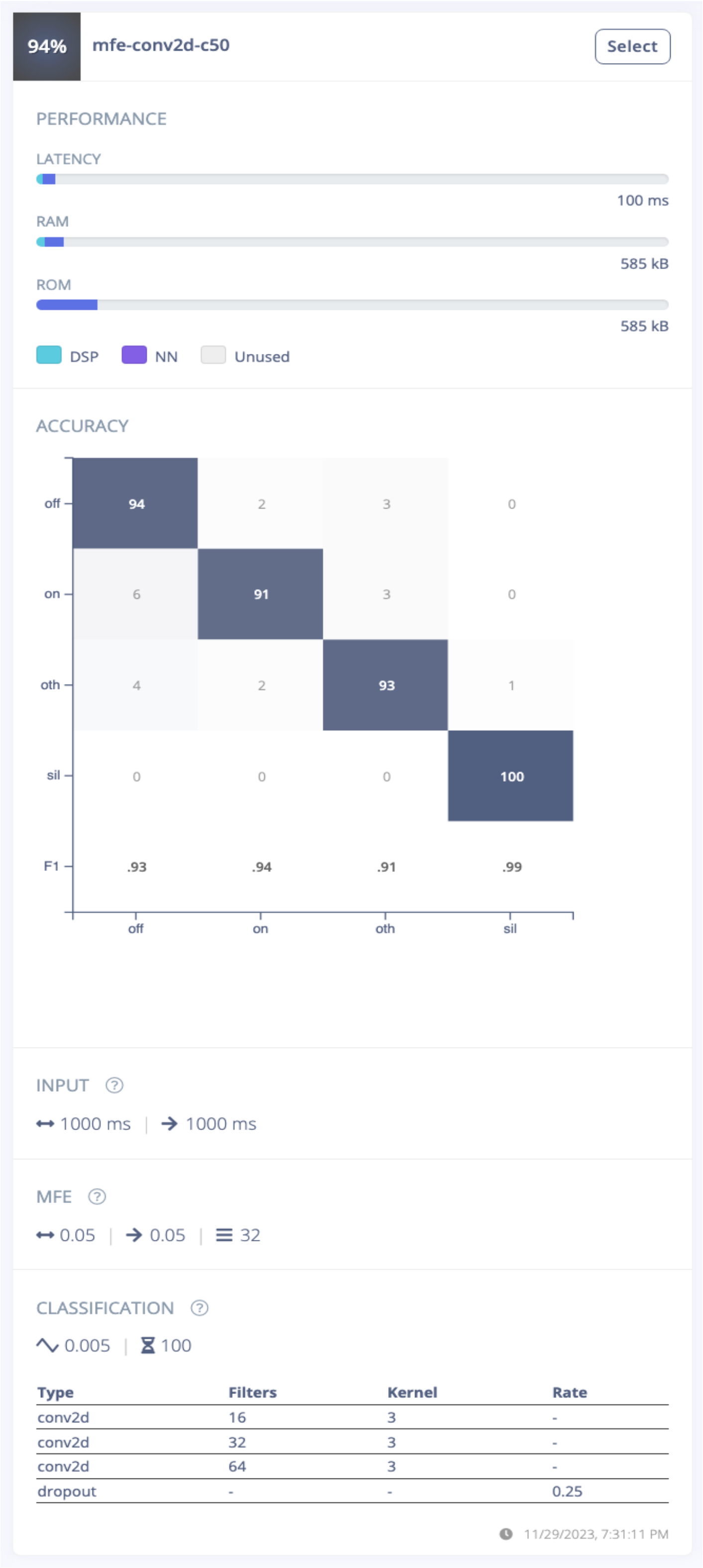
View

Data set

● Validation
○ Test

Precision

Best model



94% mfe-conv2d-c50 Select

PERFORMANCE

LATENCY

100 ms

RAM

585 kB

ROM

585 kB

🟦 DSP 🟪 NN ⬜ Unused

ACCURACY

	off	on	oth	sil
off	94	2	3	0
on	6	91	3	0
oth	4	2	93	1
sil	0	0	0	100
F1	.93	.94	.91	.99

INPUT ⓘ

↔ 1000 ms | → 1000 ms

MFE ⓘ

↔ 0.05 | → 0.05 | ≡ 32

CLASSIFICATION ⓘ

∿ 0.005 | ⧗ 100

Type	Filters	Kernel	Rate
conv2d	16	3	-
conv2d	32	3	-
conv2d	64	3	-
dropout	-	-	0.25

🕒 11/29/2023, 7:31:11 PM

The model is optimized for Raspberry Pi 4 as my latency did not exceed.
My accuracy is around 94%.
Comparing other 2 model which had same accuracy but had bit more latency and the F1 score were less compared to the best model.
So the best model has 94% accuracy, minimum latency, F1 score above 90% for all classes (off - .93, on - .94, others - .91, silent - .91).