SOUND EVENT DETECTION WITH MACHINE LEARNING

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Soundsensing AS

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EuroPython 2021

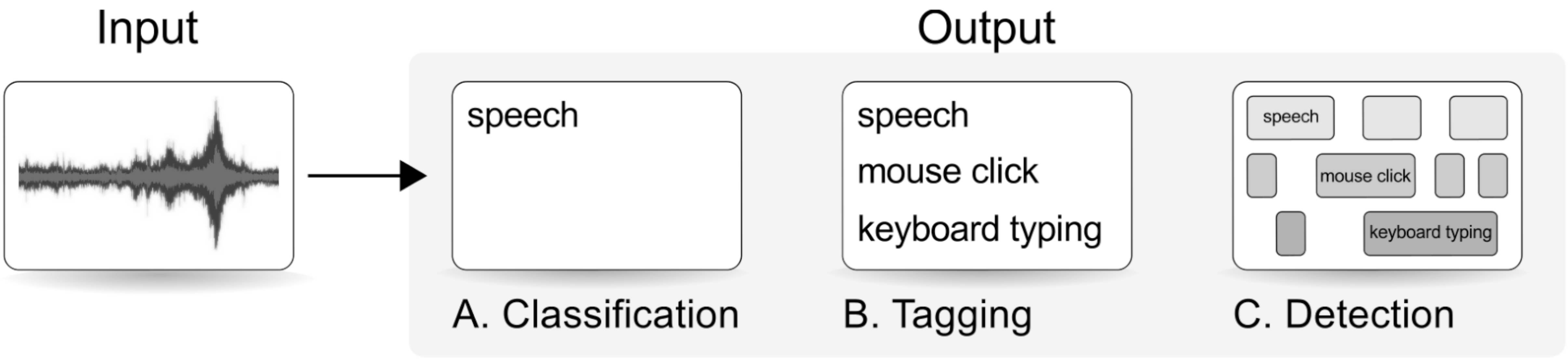
INTRODUCTION

ABOUT SOUNDSENSING

1. Sensor

2. Dashboard + API

SOUND EVENT DETECTION



Given input audio
return the timestamps (start, end)
for each event class

EVENTS AND NON-EVENTS

Events are sounds with a clearly-defined duration or onset.

Event (time limited)	Class (continious)
Car passing	Car traffic
Honk	Car traffic
Word	Speech
Gunshot	Shooting

APPLICATION

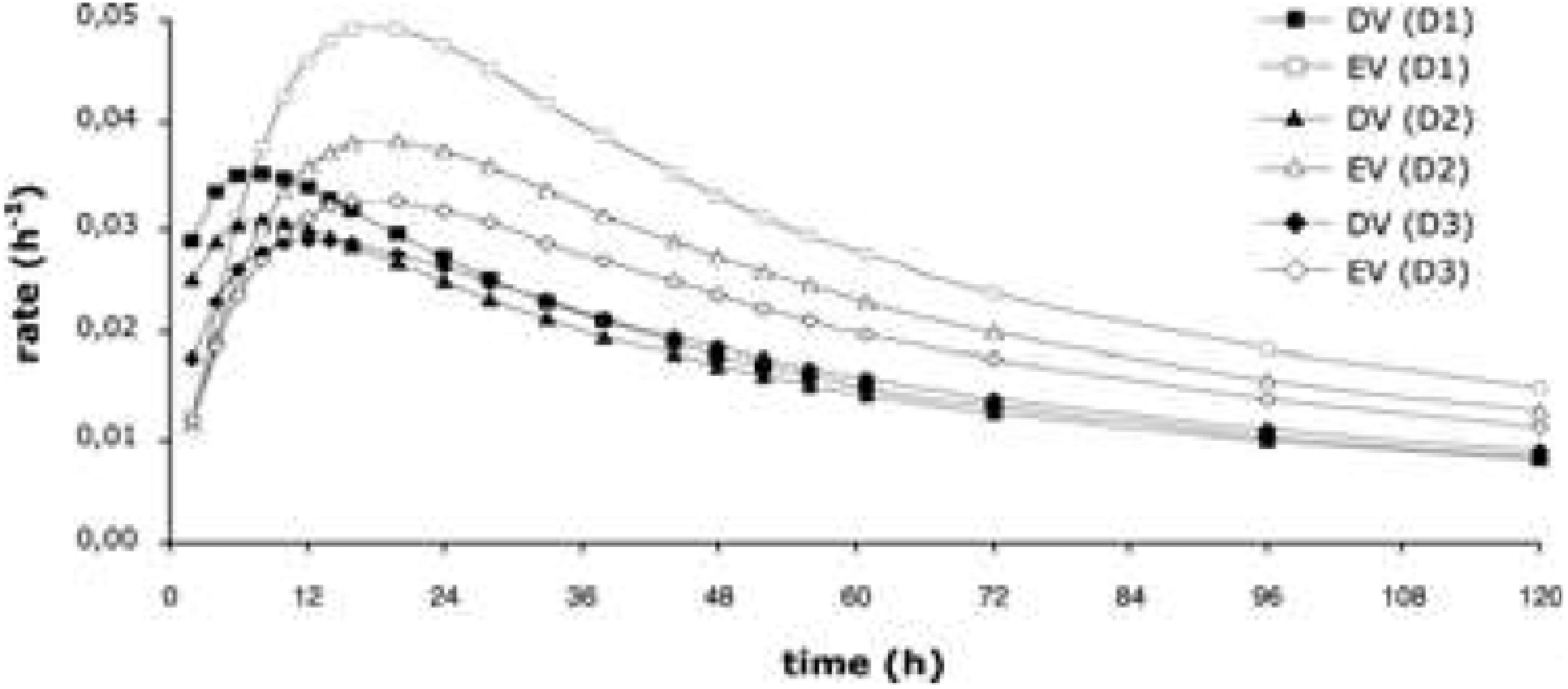
Fermentation tracking when making alcoholic beverages. Beer, Cider, Wine, etc.

ALCOHOL IS PRODUCED VIA FERMENTATION

AIRLOCK ACTIVITY

FERMENTATION TRACKING

Fermentation activity can be tracked as Bubbles Per Minute (BPM).



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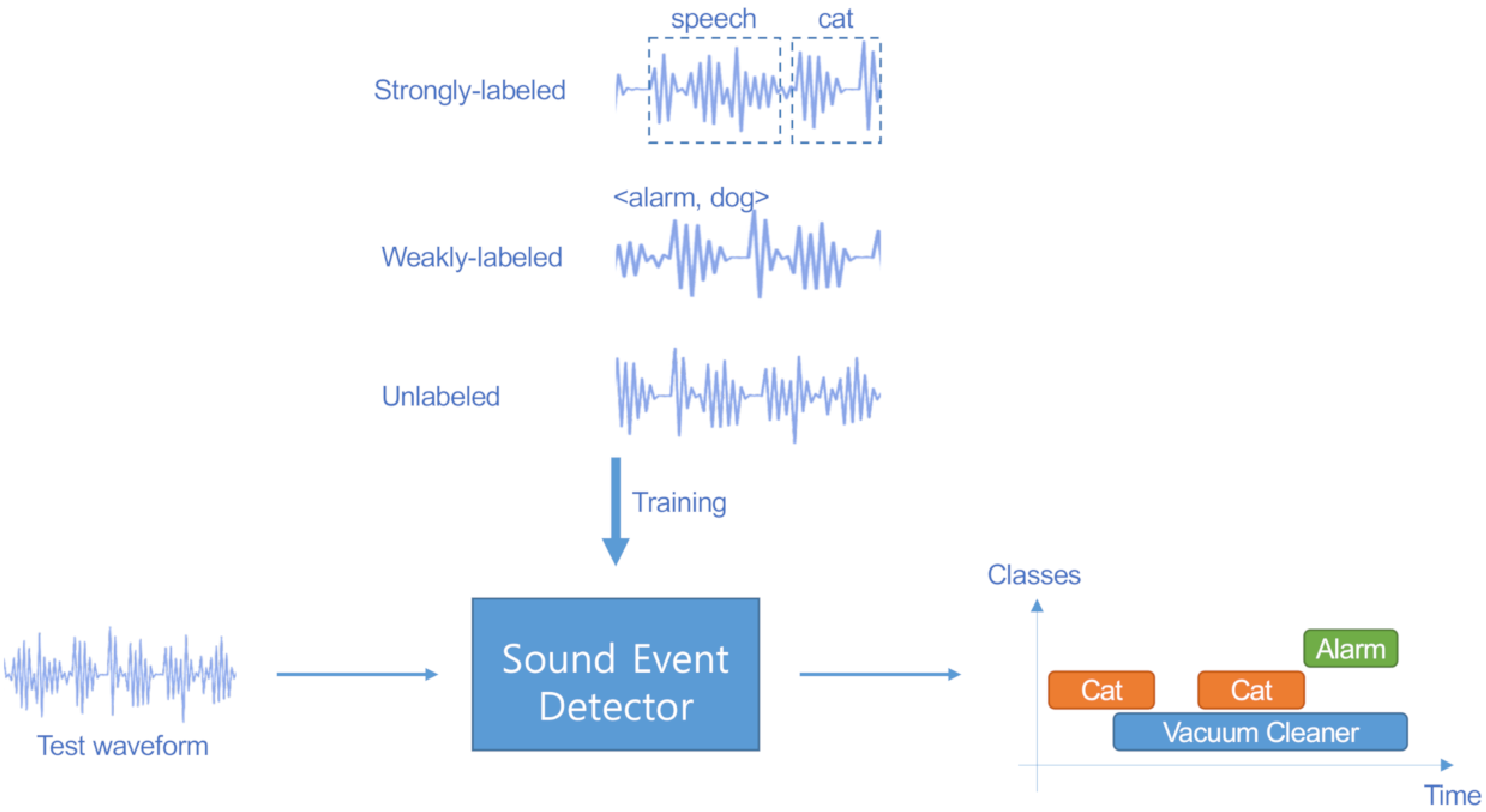
OUR GOAL

Make a system that can track fermentation activity,
outputting Bubbles per Minute (BPM),
by capturing airlock sound using a microphone,
using Machine Learning to count each “plop”

MACHINE LEARNING NEEDS DATA!

SUPERVISED MACHINE LEARNING



DATA REQUIREMENTS: QUANTITY

Need *enough* data.

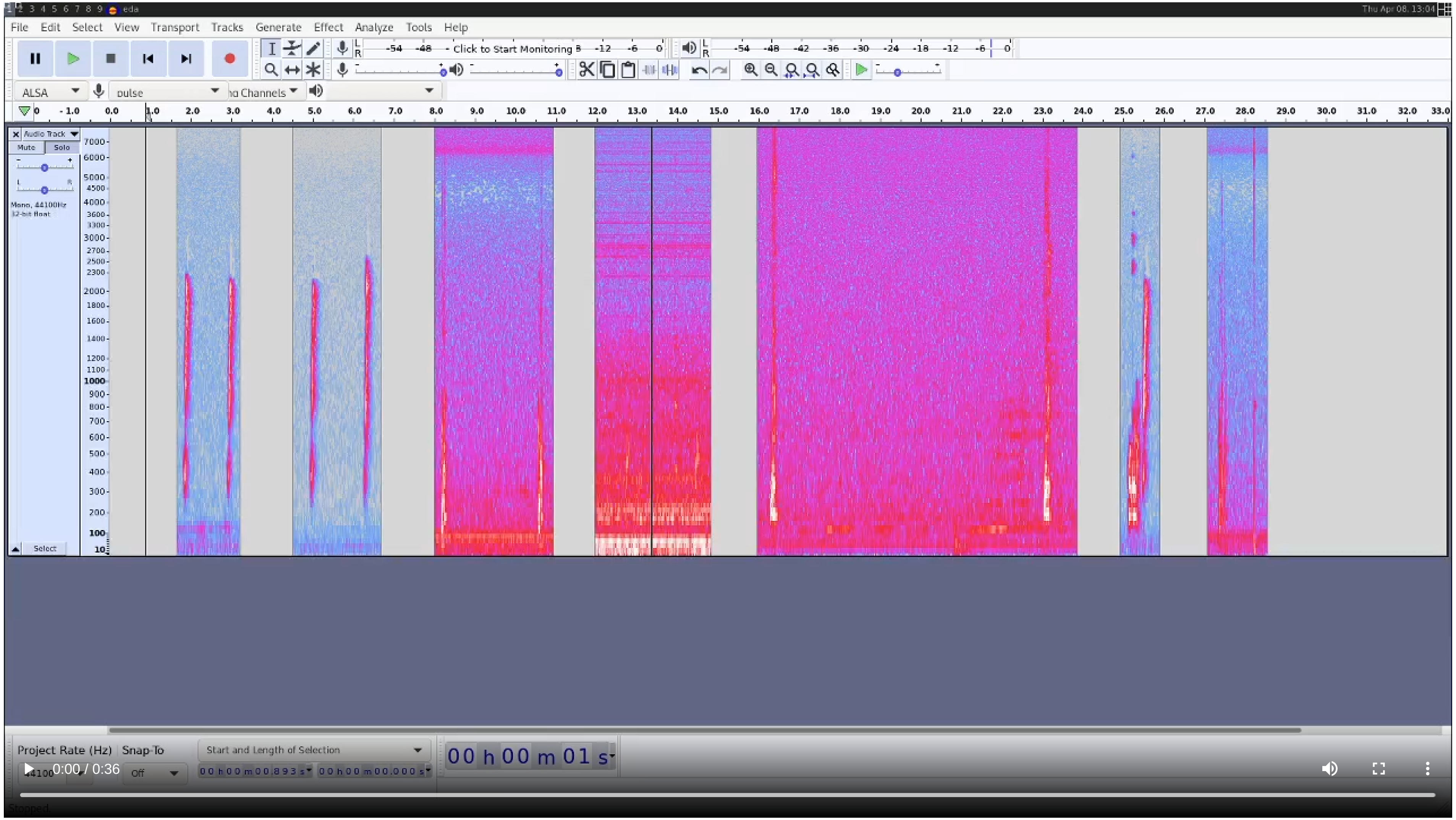
Instances per class	Suitability
100	Minimal
1000	Good
10000+	Very good

DATA REQUIREMENTS: QUALITY

Need *realistic* data. Capturing natural variation in

- the event sound
- recording devices used
- recording environment

CHECK THE DATA

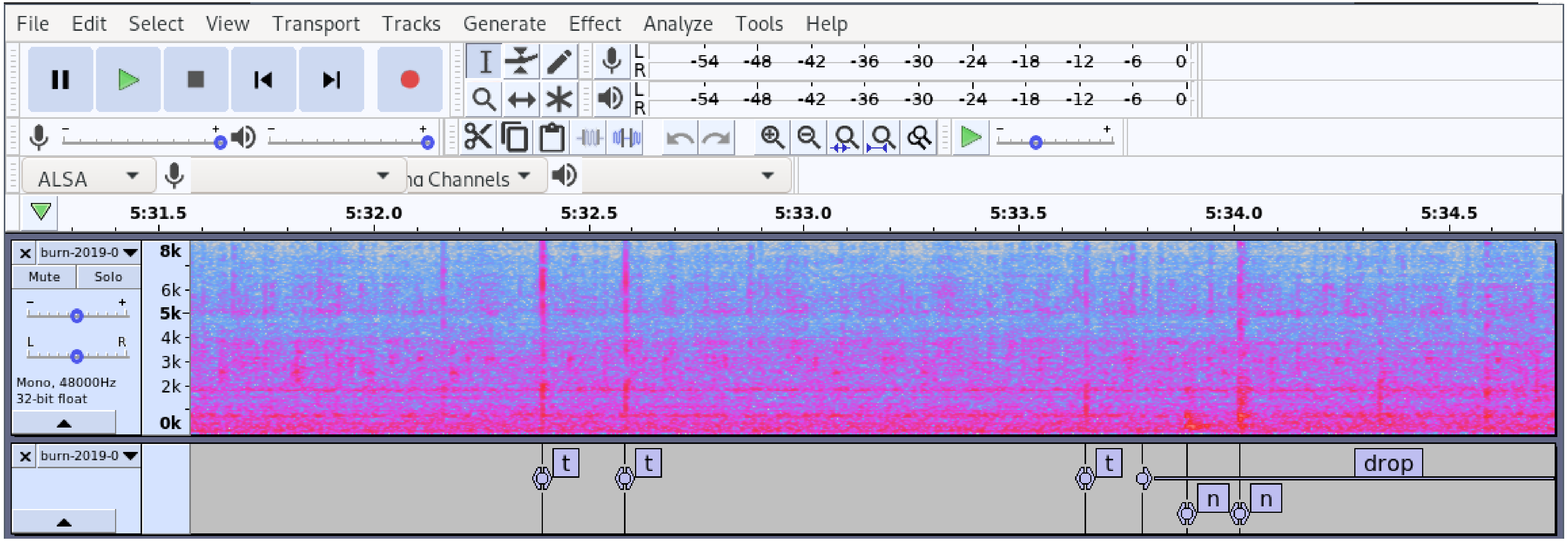


UNDERSTAND THE DATA

Note down characteristics of the sound

- Event length
- Distance between events
- Variation in the event sound
- Changes over time
- Differences between recordings
- Background noises
- Other events that could be easily confused

LABELING DATA MANUALLY USING AUDACITY




```python
import pandas

labels = pandas.read_csv(path, sep='\t', header=None,
                         names=['start', 'end', 'annotation'],
                         dtype=dict(start=float,end=float,annotation=str))
```

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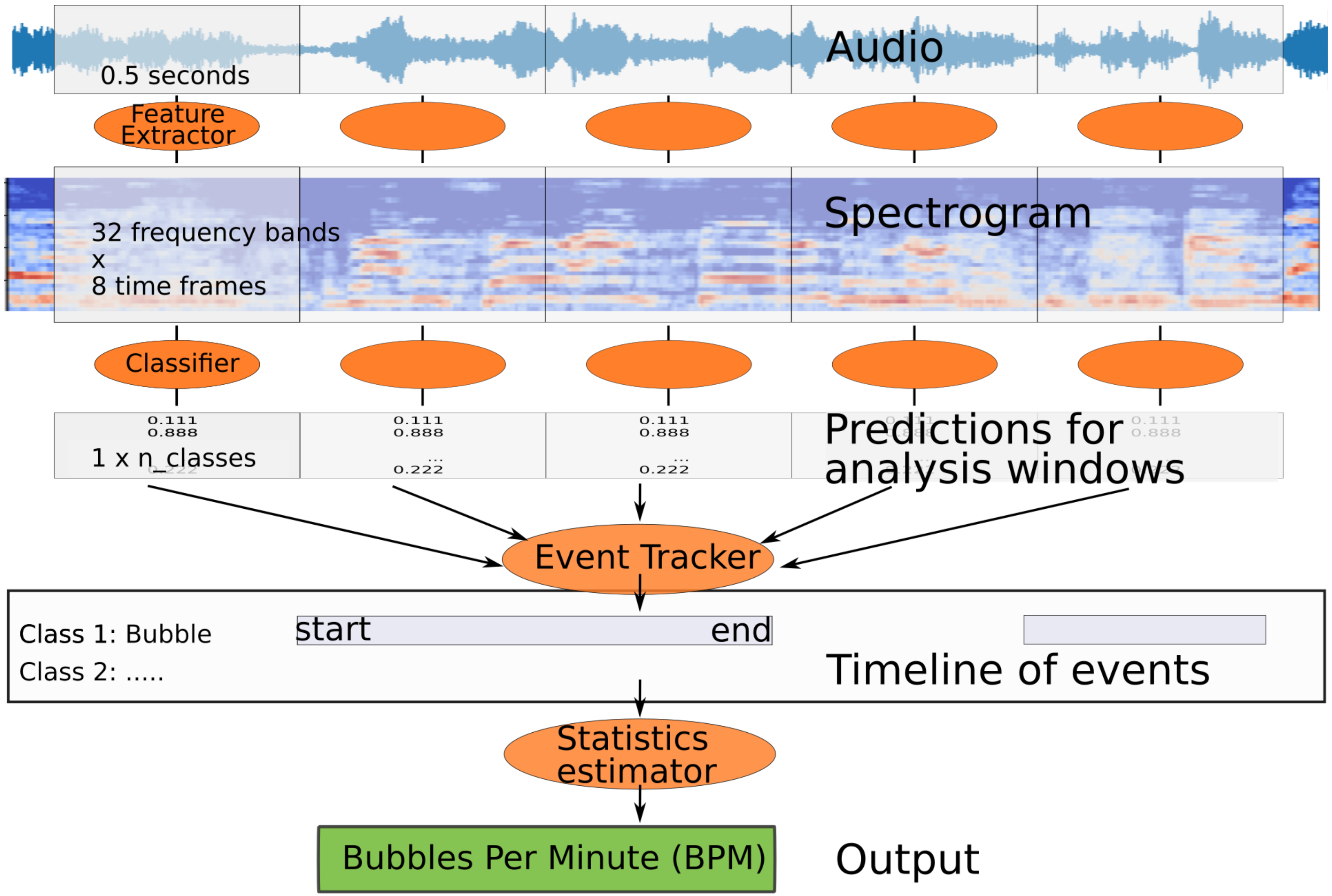
MACHINE LEARNING SYSTEM

AUDIO ML PIPELINE OVERVIEW



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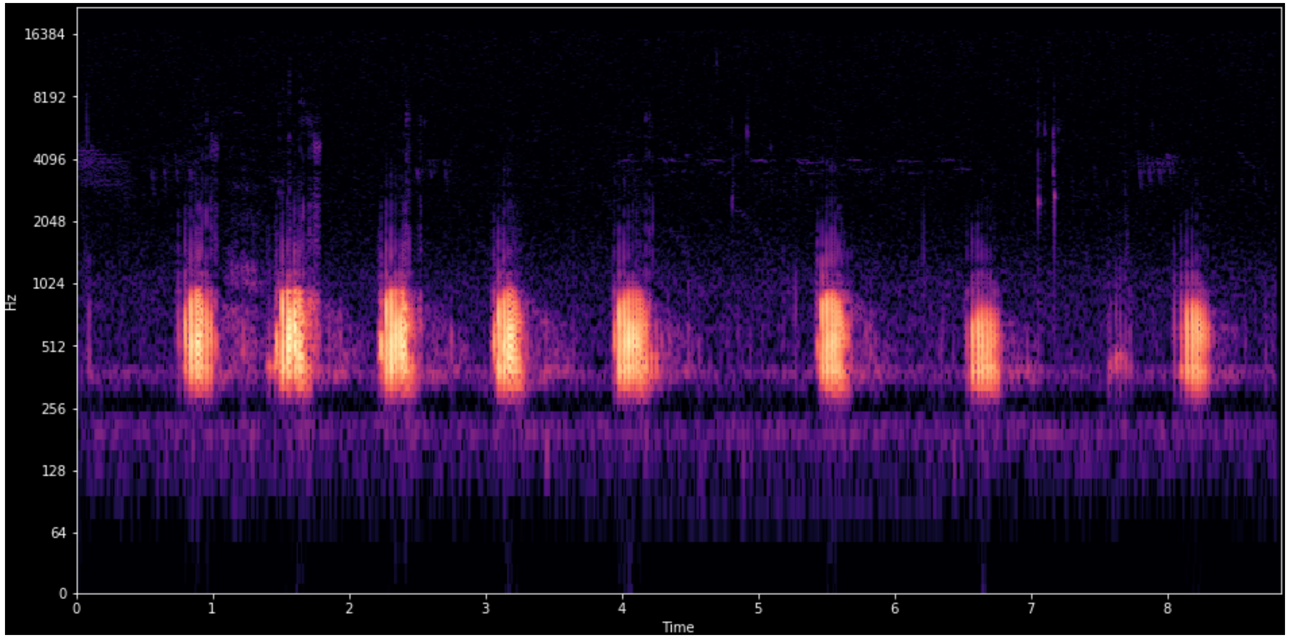
SPECTROGRAM




```
import librosa

audio, sr = librosa.load(path)
spec = librosa.feature.melspectrogram(y=audio, sr=sr)
spec_db = librosa.power_to_db(spec, ref=np.max)

lr.display.specshow(ps_db, x_axis='time', y_axis='mel')
```

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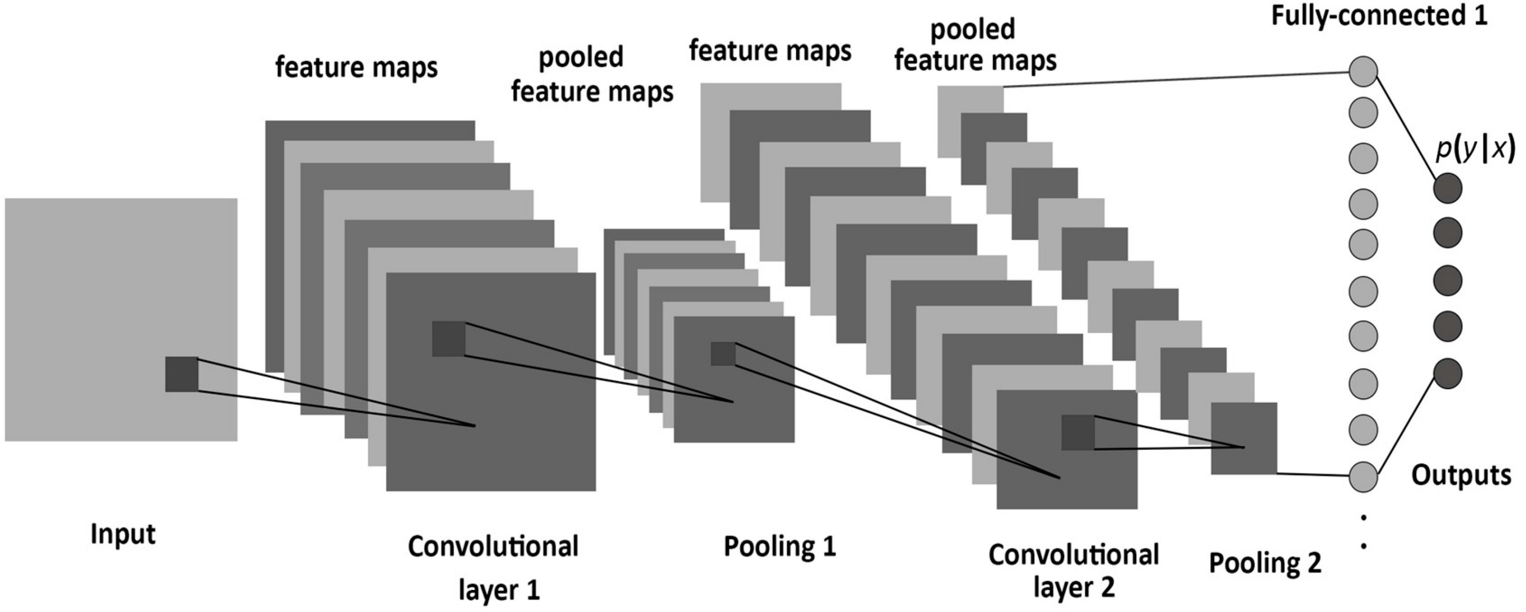
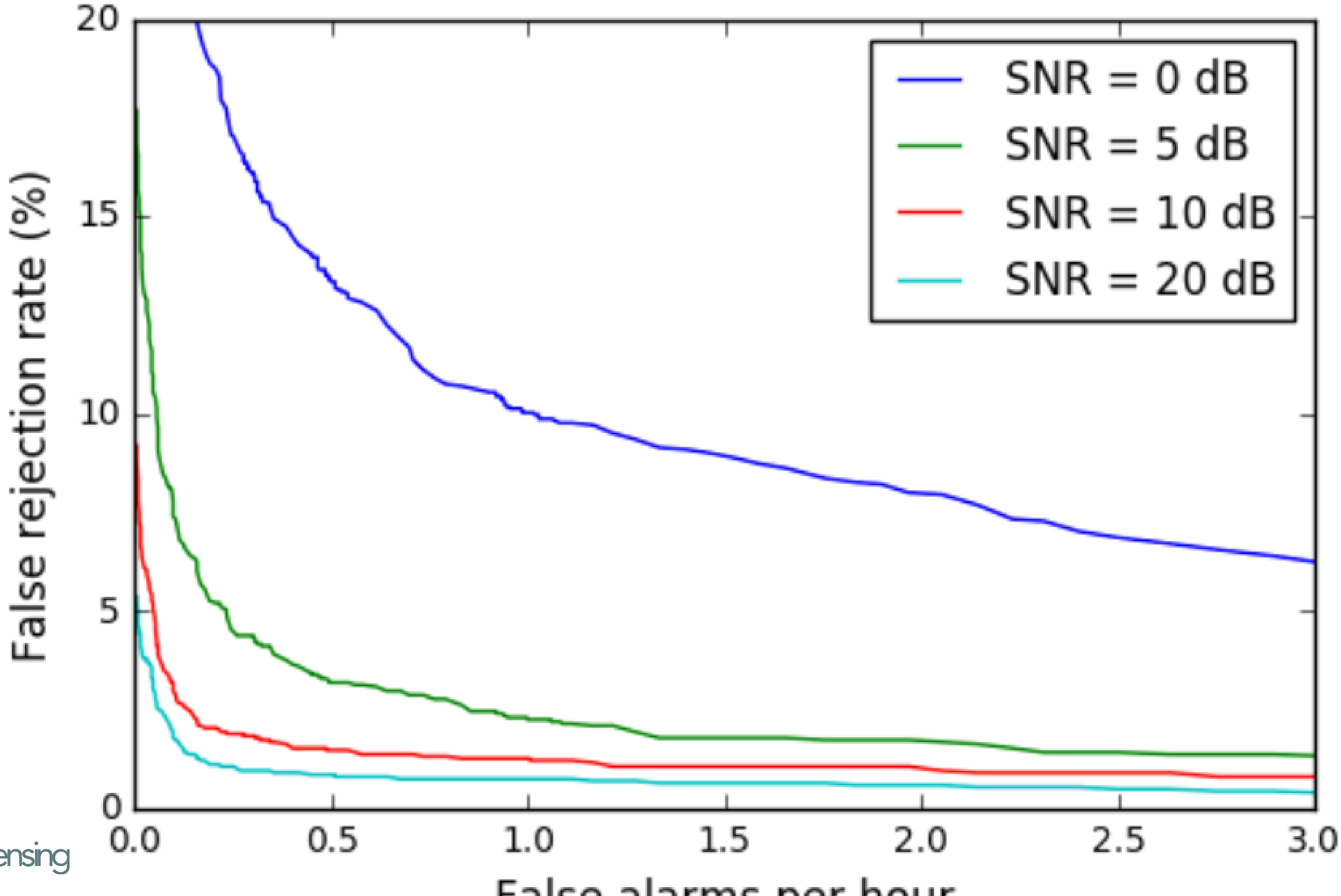
CNN CLASSIFIER MODEL




```
from tensorflow import keras
from keras.layers import Convolution2D, MaxPooling2D

model = keras.Sequential([
        Convolution2D(filters, kernel,
                      input_shape=(bands, frames, channels)),
        MaxPooling2D(pool_size=pool),
....
])
```

EVALUATION



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False alarms per hour

Figure 3: *FRR vs. FA per hour for the test set with various SNR values.*

EVENT TRACKER

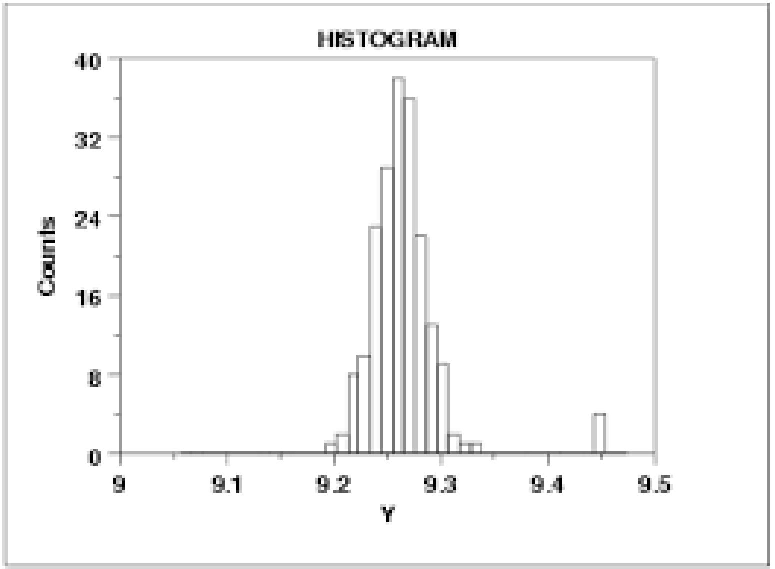
Converting to discrete list of events

- Threshold the probability from classifier
- Keep track of whether we are currently in an event or not

```
if not inside_event and probability >= on_threshold:
    inside_event = True
    print('EVENT on', t, probability)
if inside_event and probability <= off_threshold:
    inside_event = False
    print('EVENT off', t, probability)
```

STATISTICS ESTIMATOR

To compute the Bubbles Per Minute



- Using the typical time-between-events
- Assumes regularity
- Median more robust against outliers

TRACKING OVER TIME USING BREWFATHER


```python
# API documentation: https://docs.brewfather.app/integrations/custom-stream
import requests

url = 'http://log.brewfather.net/stream?id=9MmXXXXXXXXX'
data = dict(name='brewaed-0001', bpm=CALCULATED-BPM)
r = requests.post(url, json=data)
```

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OUTRO

MORE RESOURCES

Github project: jonnor/brewing-audio-event-detection

General Audio ML: jonnor/machinehearing

- Sound Event Detection: A tutorial. Virtanen et al.
- Audio Classification with Machine Learning (EuroPython 2019)
- Environmental Noise Classification on Microcontrollers (TinyML 2021)

Slack: Sound of AI community

WHAT DO YOU WANT MAKE?

Now that you know the basics of Audio Event Detection with Machine Learning in Python.

- Popcorn popping
- Bird call
- Cough
- Umm/aaa speech patterns
- Drum hits
- Car passing

CONTINIOUS MONITORING USING AUDIO ML

Want to deploy Continious Monitoring with Audio?
Consider using the Soundsensing sensors and data-platform.

1. Sensor

2. Dashboard + API

Get in Touch! contact@soundsensing.no

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JOIN SOUNDSENSING

Want to work on Audio Machine Learning in Python?
We have many opportunities.

- Full-time positions
- Part-time / freelance work
- Engineering thesis
- Internships
- Research or industry partnerships

Get in Touch! contact@soundsensing.no

QUESTIONS ?

Sound Event Detection with Machine Learning
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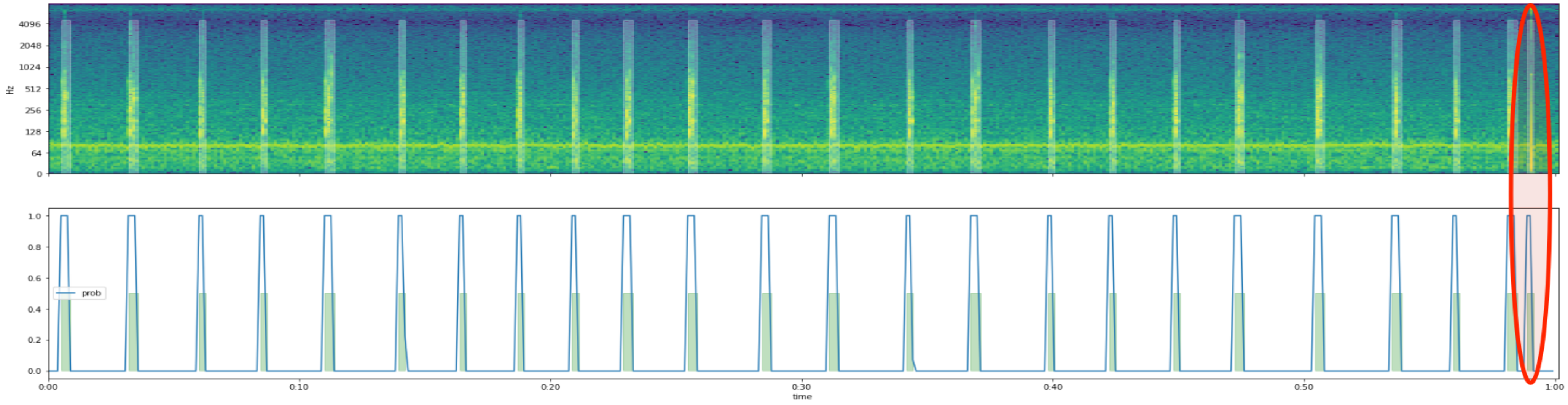
BONUS

Bonus slides after this point

SEMI-AUTOMATIC LABELLING

Using a Gaussian Mixture, Hidden Markov Model (GMM-HMM)




```
import hmmlearn.hmm, librosa, sklearn.preprocessing

features = librosa.feature.mfcc(audio, n_mfcc=13, ...)
model = hmmlearn.hmm.GMMHMM(n_components=2, ...)
X = sklearn.preprocessing.StandardScaler().fit_transform(data)
model.fit(X)
probabilities = model.score_samples(X)[1][:,1]
```

SYNTHESIZE DATA

How to get more data
without gathering “in the wild”?

- Mix in diffent kinds of background noise.
- Vary Signal to Noise ratio etc
- Useful to estimate performance on tricky, not-yet-seen data
- Can be used to compensate for small amount of training data
- *scaper* Python library: github.com/justinsalamon/scaper

STREAMING INFERENCE

Key: Chopping up incoming stream into (overlapping) audio windows

```
import sounddevice, queue

# Setup audio stream from microphone
audio_queue = queue.Queue()

def audio_callback(indata, frames, time, status):
    audio_queue.put(indata.copy())

stream = sounddevice.InputStream(callback=audio_callback, ...)
...

# In classification loop
    data = audio_queue.get()
    # shift old audio over, add new data
    audio_buffer = numpy.roll(audio_buffer, len(data), axis=0)
    audio_buffer[len(audio_buffer)-len(data):len(audio_buffer)] = data
    new_samples += len(data)
    # check if we have received enough new data to do new prediction
    if new_samples >= hop_length:
        p = model.predict(audio_buffer)
        if p < threshold:
            print(f'EVENT DETECTED time={datetime.datetime.now()}')
```

EVENT DETECTION WITH WEAKLY LABELED DATA

Can one learn Sound Event Detection
without annotating the times for each event?

Yes!

- Referred to as *weekly labeled* Sound Event Detection
- Can be tackled with *Multiple Instance Learning*
- Inputs: Audio clips consisting of 0-N events
- Labels: True if any events in clip, else false
- Multiple analysis windows per 1 label
- Using temporal pooling in Neural Network

DATA COLLECTION VIA YOUTUBE

Criteria for inclusion:

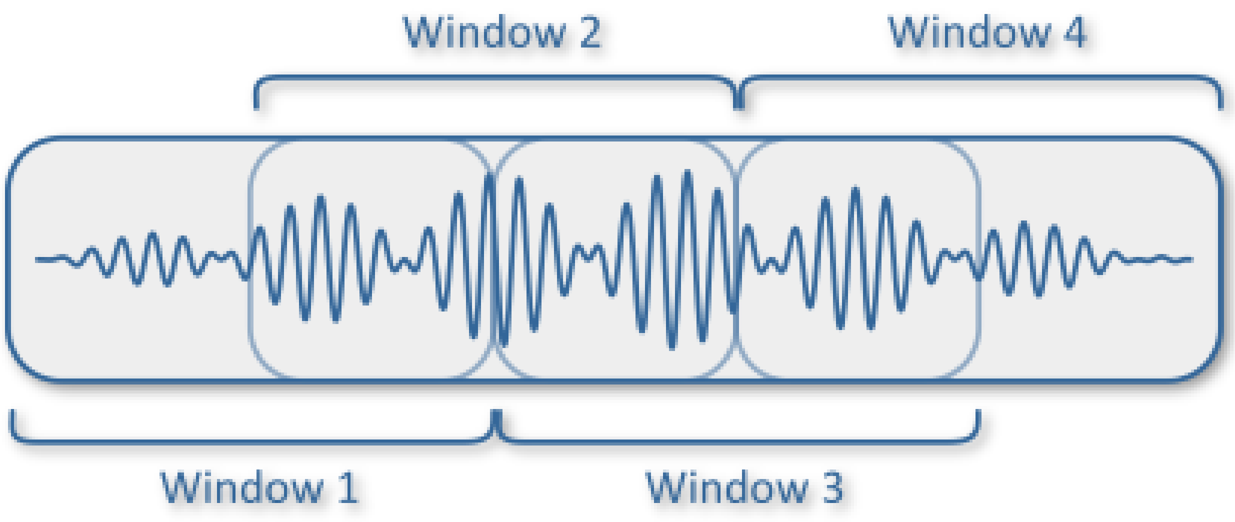
- Preferably couple of minutes long, minimum 15 seconds
- No talking to the camera
- Mostly stationary camera
- No audio editing/effects
- One or more airlocks bubbling
- Bubbling can be heard by ear

Approx 1000 videos reviewed, 100 usable

CHARACTERISTICS OF AUDIO EVENTS

- Duration
- Tonal/atonal
- Temporal patterns
- Percussive
- Frequency content
- Temporal envelope
- Foreground vs background
- Signal to Noise Ratio

ANALYSIS WINDOWS



Window length bit longer than the event length.

Overlapping gives classifier multiple chances at seeing each event.

Reducing overlap increases resolution! Overlap for AES: 10%