Interim Presentation

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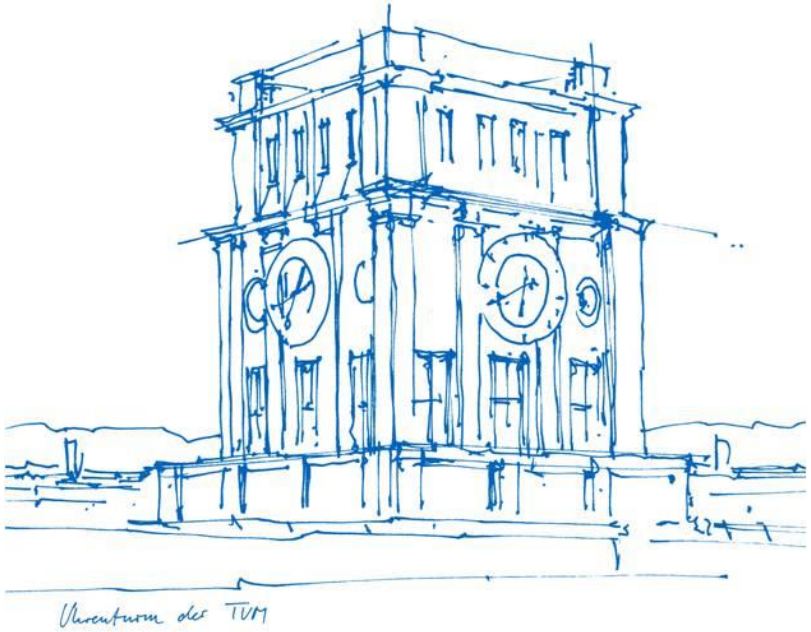
Edge Computing and the Internet of Things

Technische Universität München

München, 15.12.2023



Introduction

Objective

- ESP32s equipped with microphones for recording bird calls
- On-device classification of bird species using deep learning
- Aggregated statistics accessible to researchers, hikers etc.

Motivation

- Reduces human intervention and enables real-time monitoring
- Essential for studying bird populations and ecosystem health
- Casual interest: tourism, hiking ...

Introduction

Requirements

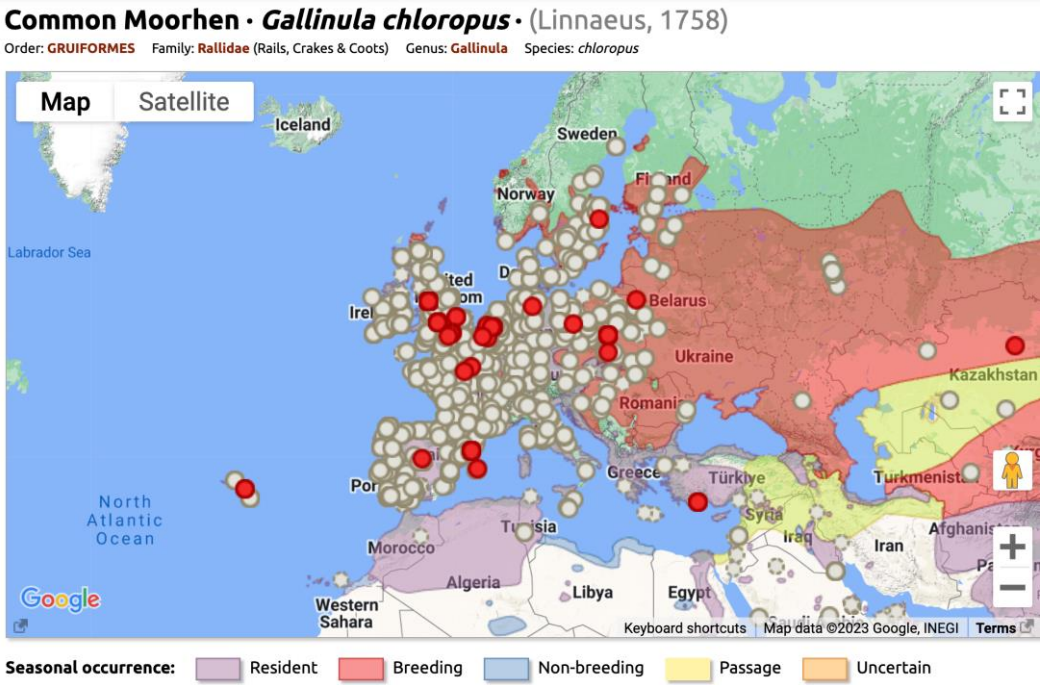
- Local / edge computing to minimize data transmission
- Energy-efficient operation due to remote deployment
- embedded and low-level development

Challenges

- Introduce a Deep Neural Network inside a ESP32
- Implement an optimized audio preprocessing module in the ESP32
- Achieve an acceptable prediction accuracy

Xeno-canto

- "Website dedicated to sharing wildlife sounds from all over the world"



ESC-50

- Dataset for environmental sound classification (50 semantical classes)
- E.g., dog, insects, rain, thunderstorm, wind, siren, chainsaw

Example

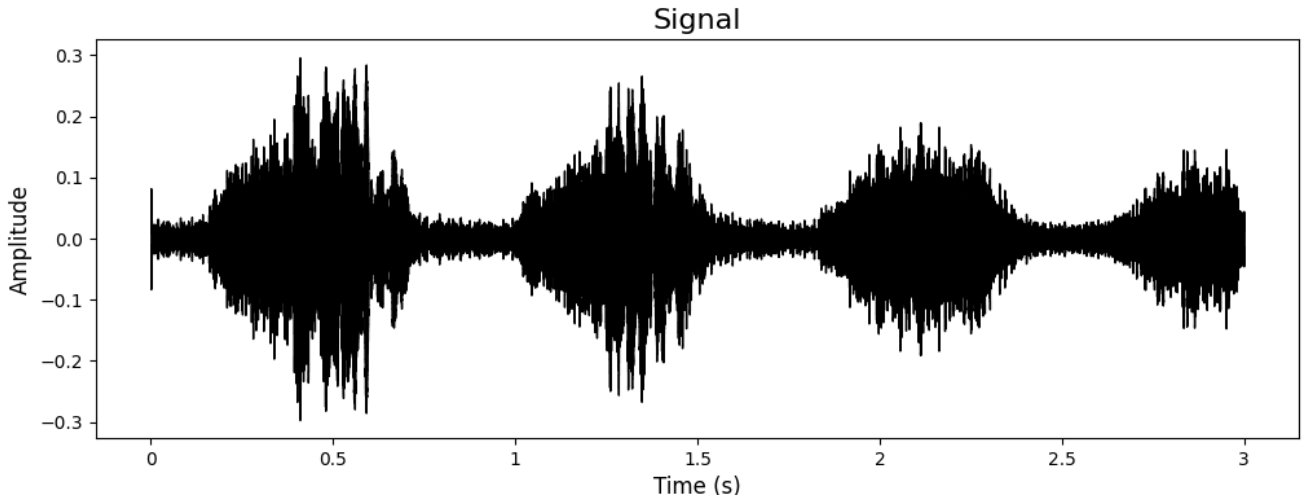
Water rail

Cetti's warbler

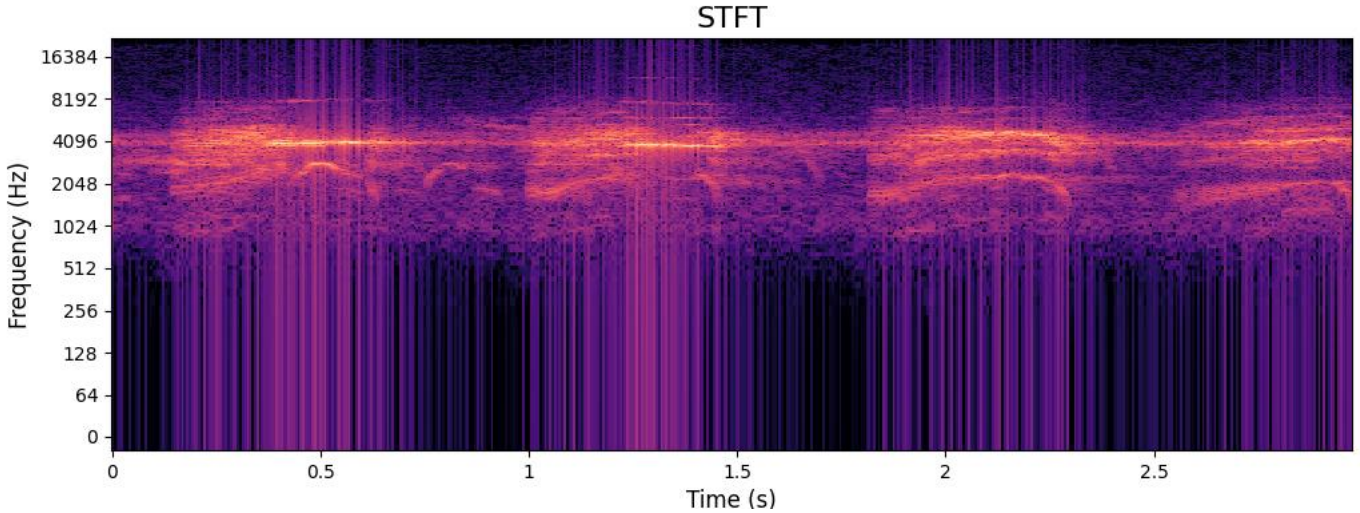
Common moorhen

Fake bird

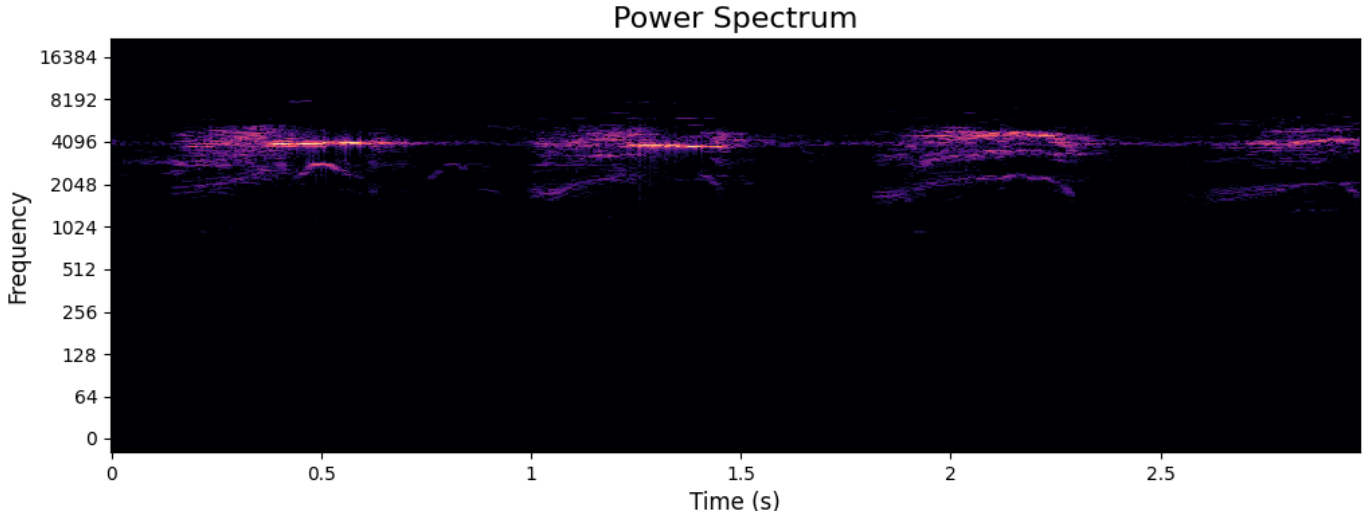
Audio Signal



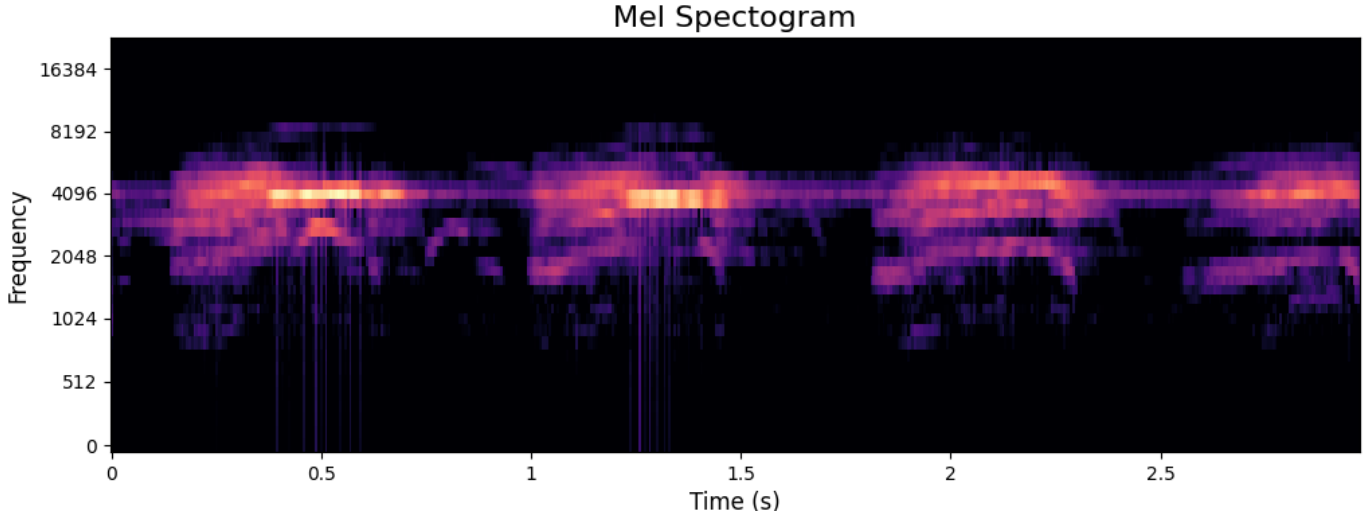
Short-Time Fourier-Transform



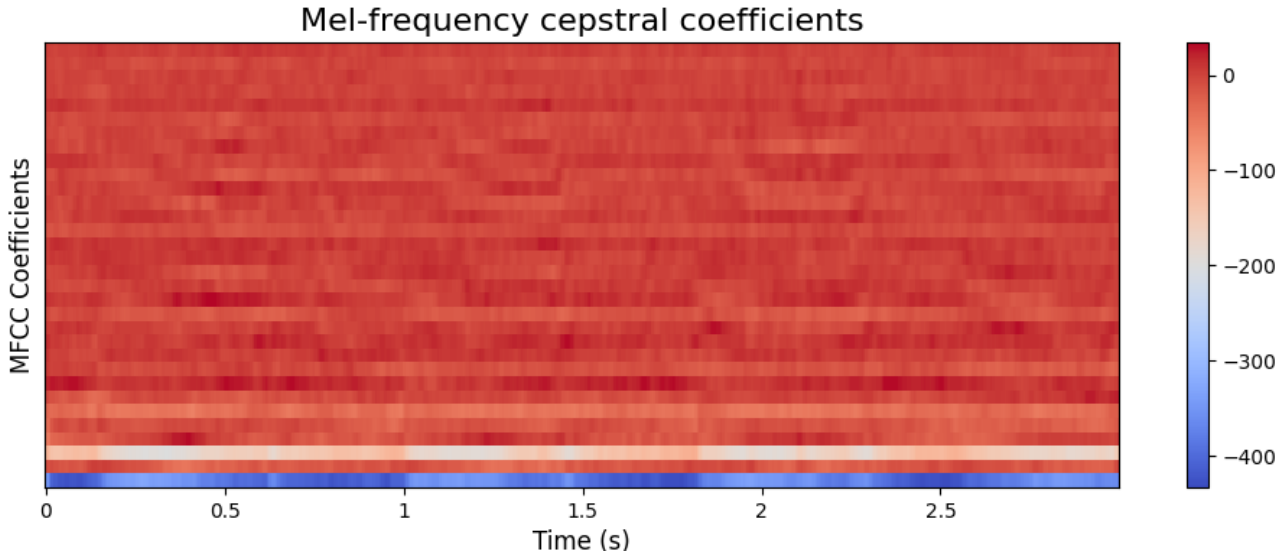
Power Spectrum



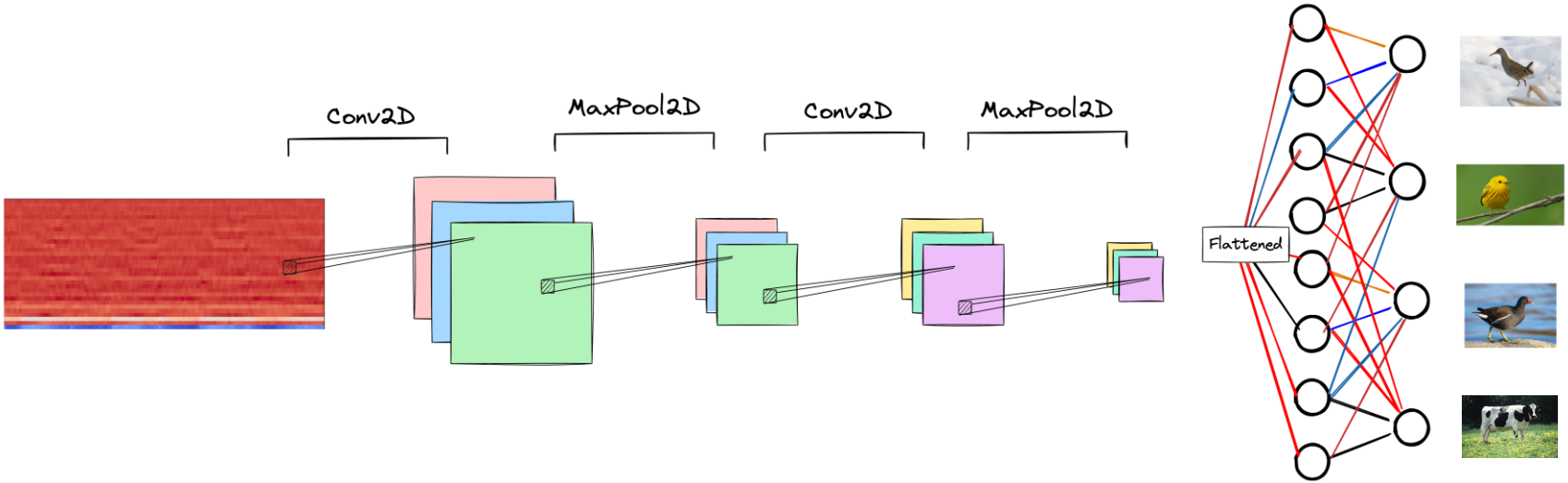
Mel-spaced Filterbank



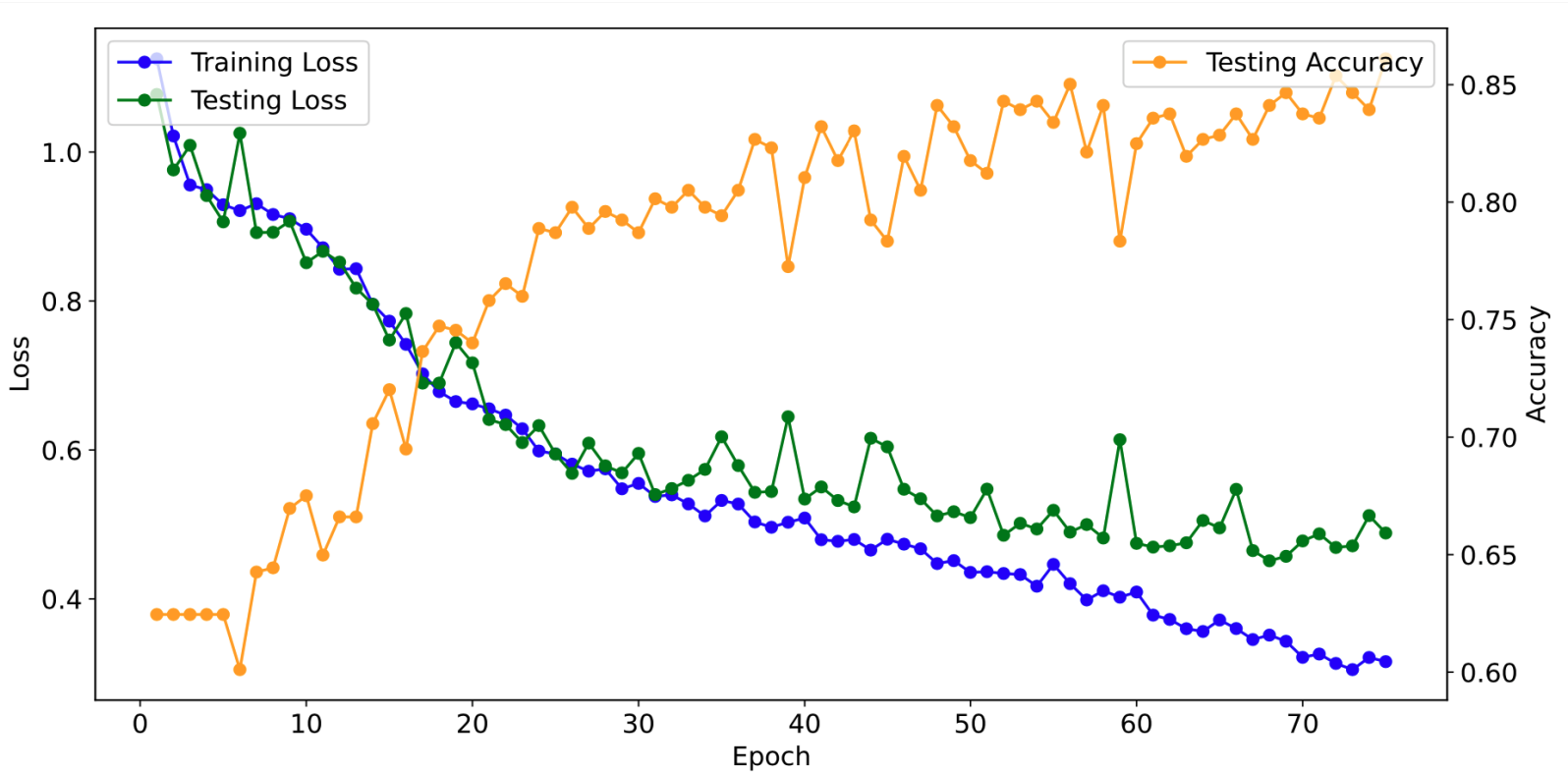
Mel-frequency cepstral coefficients



CNN



Training

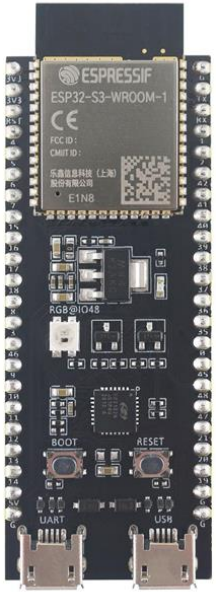

Training Loss
Testing Loss
Testing Accuracy
Loss
Accuracy
Epoch
1.0
0.8
0.6
0.4
0.85
0.80
0.75
0.70
0.65
0.60
0
10
20
30
40
50
60
70

Python to C++


```
const static __attribute__((aligned(16))) int16_t _co
    -1782,   1660,   1449,   4278,   -995,   1297,
    -1205,   1112,   1364,  11567,   4035,   1949,
     1322,  -1022,   3667,   3183,  -1290,  -1773,
    -1139,   7841,  -1045,   3881,  -1795,   -251,
     1661,  -1897,   2759,   1978,  -2340,   4560,
```

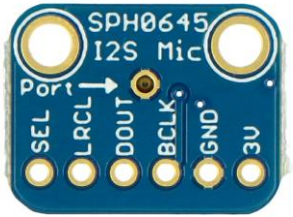
Edge device

ESP32S3

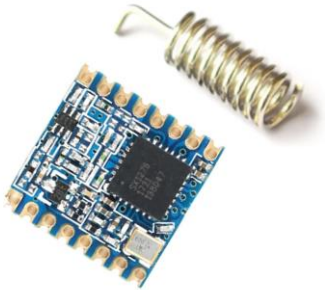


GPS

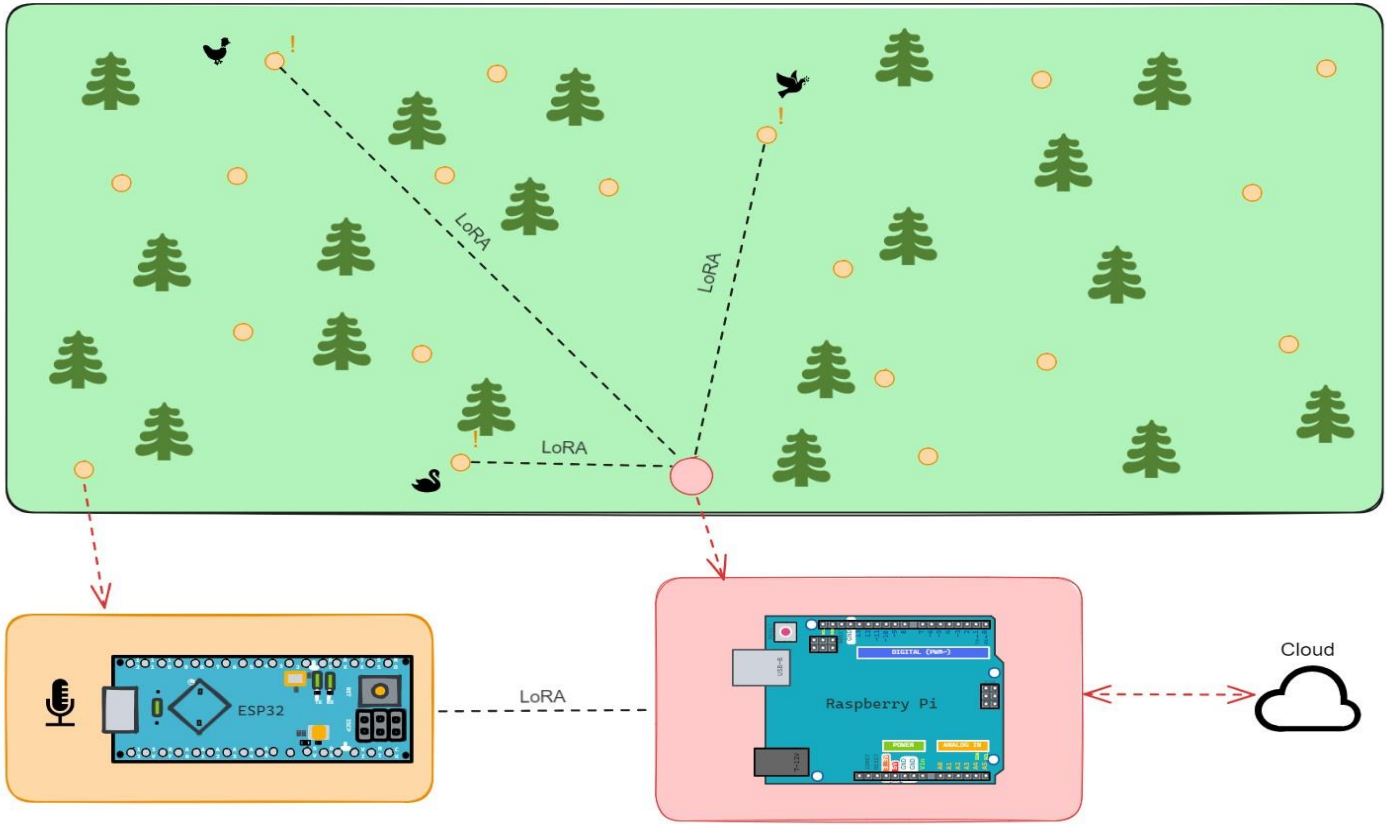
Microphone



LoRa modules



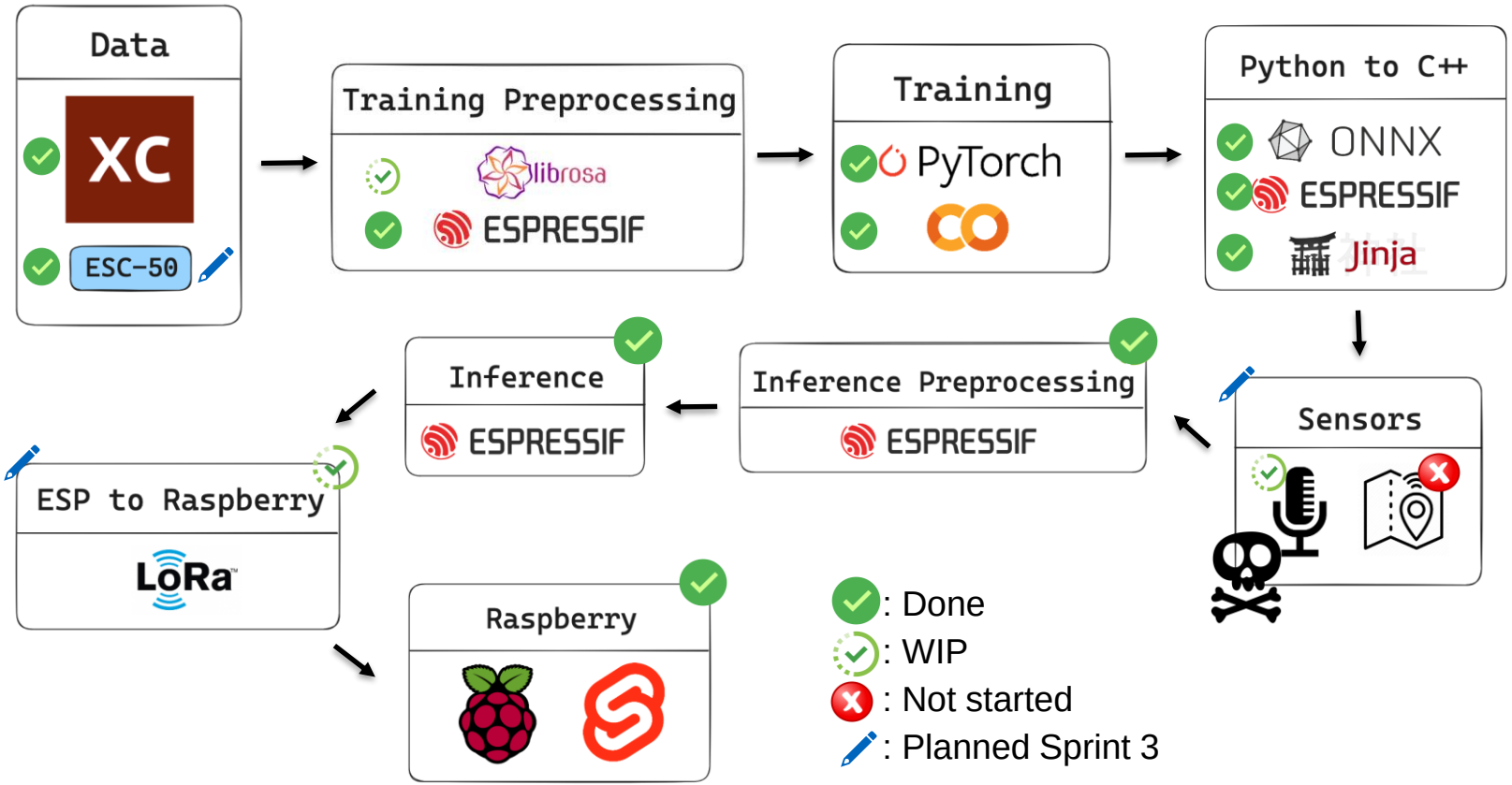
Architecture



Raspberry Pi and Dashboard

Raspberry Pi and Dashboard - Demo

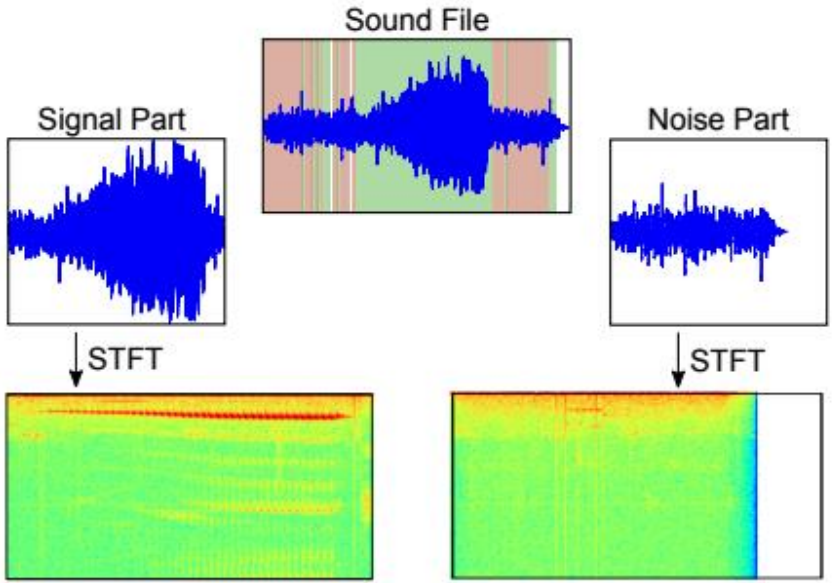
Overview


Data
XC
ESC-50
Training Preprocessing
librosa
ESPRESSIF
Training
PyTorch
Python to C++
ONNX
ESPRESSIF
Jinja
Sensors
Inference Preprocessing
ESPRESSIF
Inference
ESPRESSIF
ESP to Raspberry
LoRa
Raspberry
: Done
: WIP
: Not started
: Planned Sprint 3

DEMO

Future Work

- Deep-sleep / Light-sleep
- Heap / CPU monitoring
- Distinguish salient audio segments



[Sprengel, Elias, et al. "Audio based bird species identification using deep learning techniques]