Workout Exercise Classification

Edge AI demo by Ludwig Stumpp

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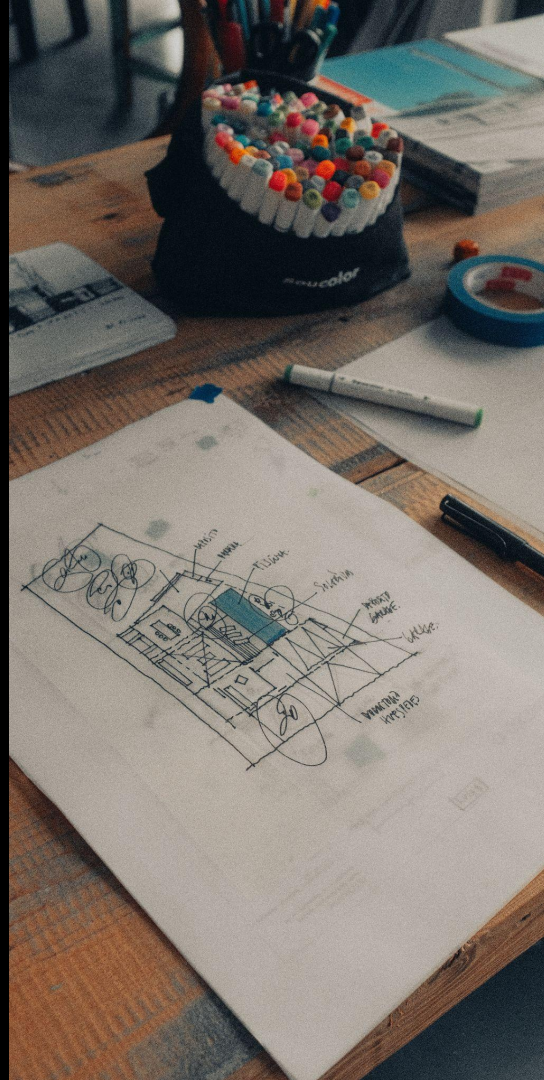
Motivation

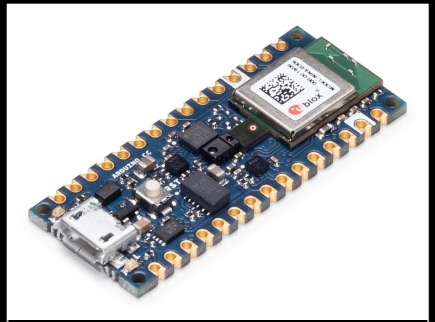
- reaching the smartphone app after exercises to start/stop the tracking feels unnatural
- familiarize with edge ai workflow and gather useful hands-on experience in the field
- motivate other fellow MLT members

Project Scope

- continuous classification of three exercise types: Jumping-Jacks, Push-Ups, Squats
- inference is running on an edge device
- total duration per exercise is accumulated and shown in some kind of visualization
- project time: 4 weeks besides regular job



Hardware Requirements



Arduino Nano 33 BLE Sense

- 45mm x 18mm
- 9 axis inertial sensor
- TensorflowLite support
- BLE capabilities

32 €

Silicone sleeve

- protects the board
- improves handling and stability in pocket

5 €

USB A to Micro B cable

- power and data connection

7 €

Powerbank

- allows for mobile usage of arduino board
- alternative: external battery

~25 €

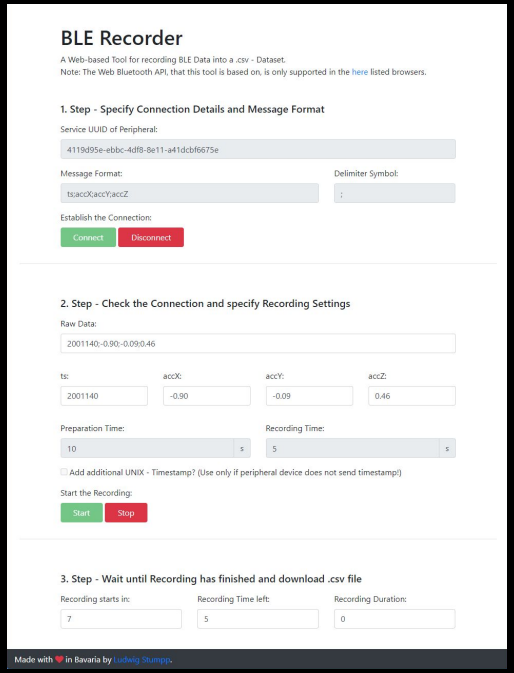
Software Requirements

			
Arduino IDE • write code and upload it to the board • support of external libraries	Edge Impulse Platform • offers end-to-end deep learning solution for edge ai devices • free for individuals	Chrome Web Browser • Web browser that supports bluetooth low energy (BLE) • for recording and visualization of data	Python Environment • for resampling of time series data
0 €	0 €	0 €	0 €

Edge AI Pipeline - Data Collection & Storage

- record accelerometer data (x, y, z) while doing exercises
- board in my pocket connected to power bank
- sending data over Bluetooth Low Energy (BLE) from the board to a web app running in my browser and storing it as .csv files on my local machine
- 30s per exercise in total, including data of 4 different board orientations each
- repository of ble-recorder: https://github.com/LudwigStumpp/ble-recorder
- data then uploaded to Edge Impulse Platform

Edge AI Pipeline - Data Collection & Storage



pushups_1.csv

	ts	accX	accY	accZ
2	116628	-3.93	-1.10	9.21
3	116648	-3.22	-1.66	10.27
4	116668	-3.19	-1.26	10.74
5	116690	-3.32	-0.01	9.75
6	116710	-3.41	-0.03	8.81
7	116734	-3.58	-1.50	9.34
8	116754	-3.21	-1.61	10.64
9	116774	-2.29	-0.44	10.48
10	116794	-2.61	0.28	9.74
11	116814	-3.44	-0.52	9.44
12	116876	-3.02	0.02	10.12
13	116896	-3.55	0.07	10.01
14	116916	-4.01	-0.30	10.53
15	116936	-3.39	-0.08	10.87
16	116956	-3.24	0.05	11.00
17	116980	-3.55	0.00	11.67
18	117000	-3.90	-0.02	11.72
19	117020	-3.84	0.10	11.62
20	117042	-3.93	0.16	10.62
21	117062	-3.59	-0.31	10.84
22	117082	-3.37	-0.44	10.96
23	117106	-3.46	-0.28	10.56
24	117126	-3.86	-0.17	10.00
25	117146	-3.71	-0.05	9.75
26	117166	-3.53	-0.21	9.62

Edge AI Pipeline - Preprocessing & Training Pipeline

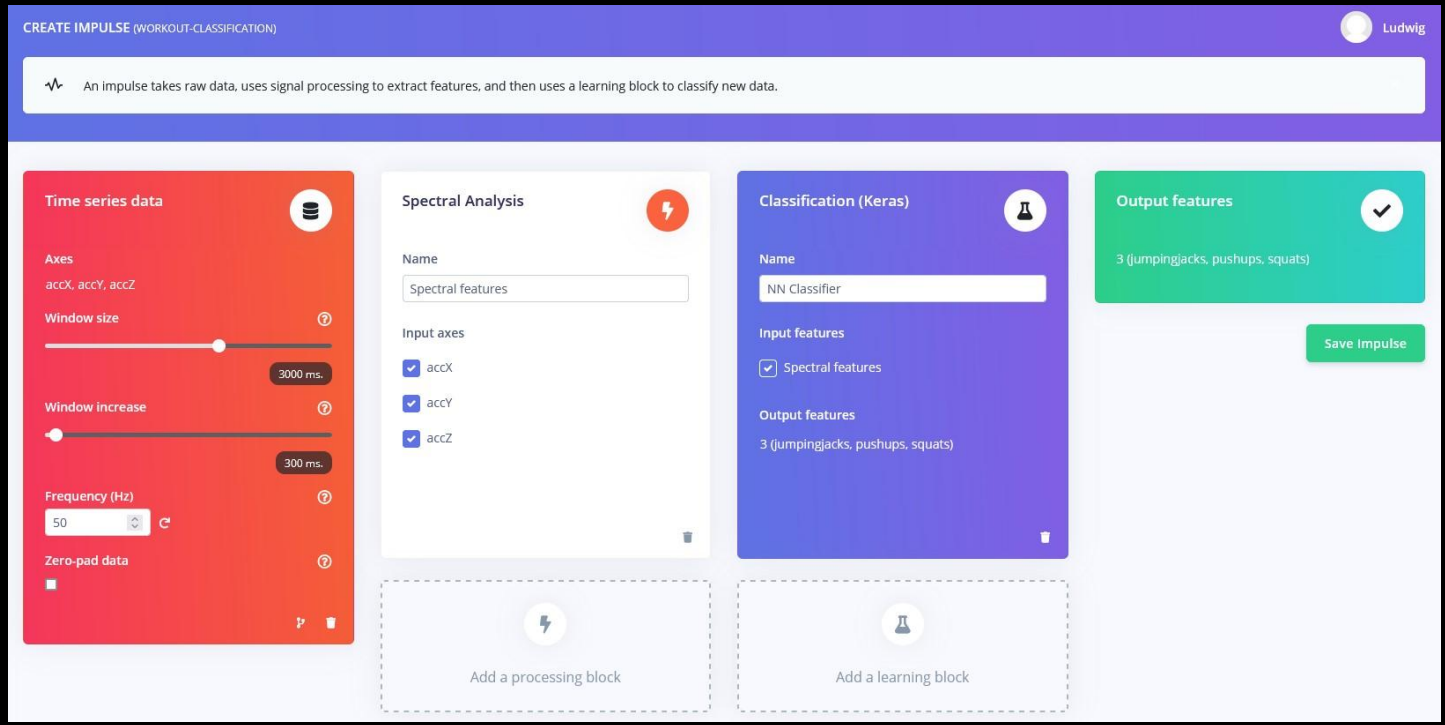
Preprocessing:

- resampled time series data to have constant rate of 50Hz using python script and standard linear interpolation

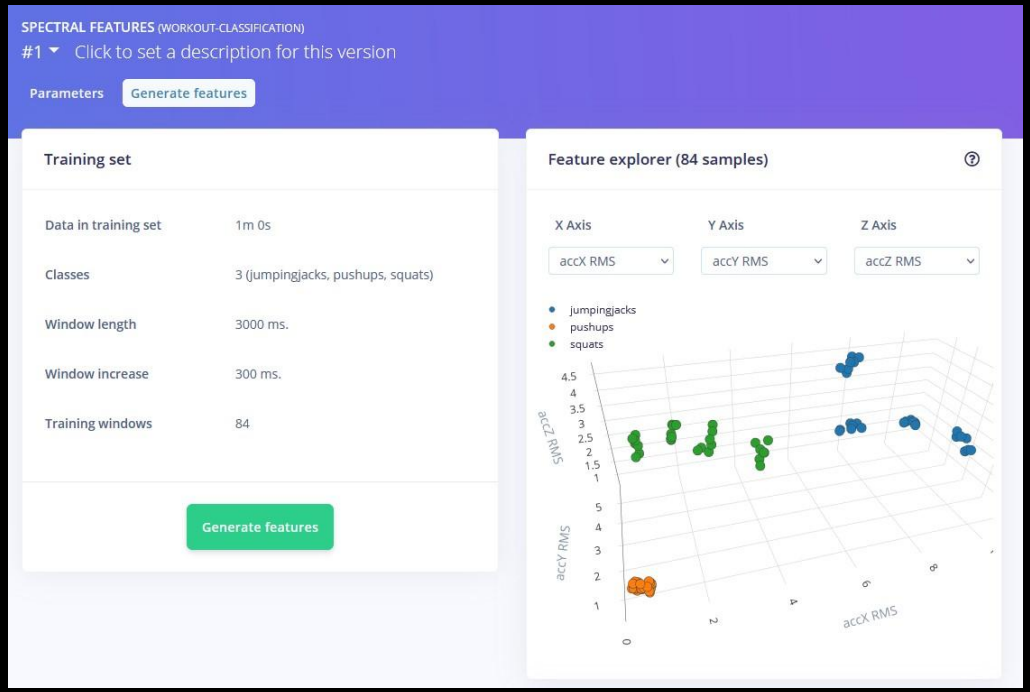
Training Pipeline:

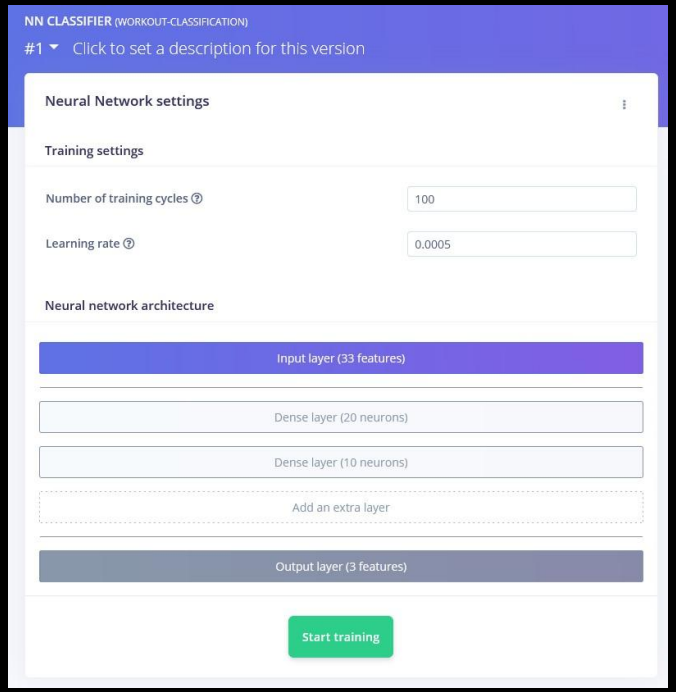
- use standard spectral analysis preprocessing of Edge Impulse platform
  - low pass
  - fast fourier transform on sliding windows
  - spectral analysis to generate 33 features for each window
- 3000ms window length led to 84 training samples
- Fully Connected FNN, 33 inputs, two hidden layers, 3 outputs

Edge AI Pipeline - Preprocessing & Training Pipeline



Edge AI Pipeline - Preprocessing & Training Pipeline





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Edge AI Pipeline - Model Deployment & Inference

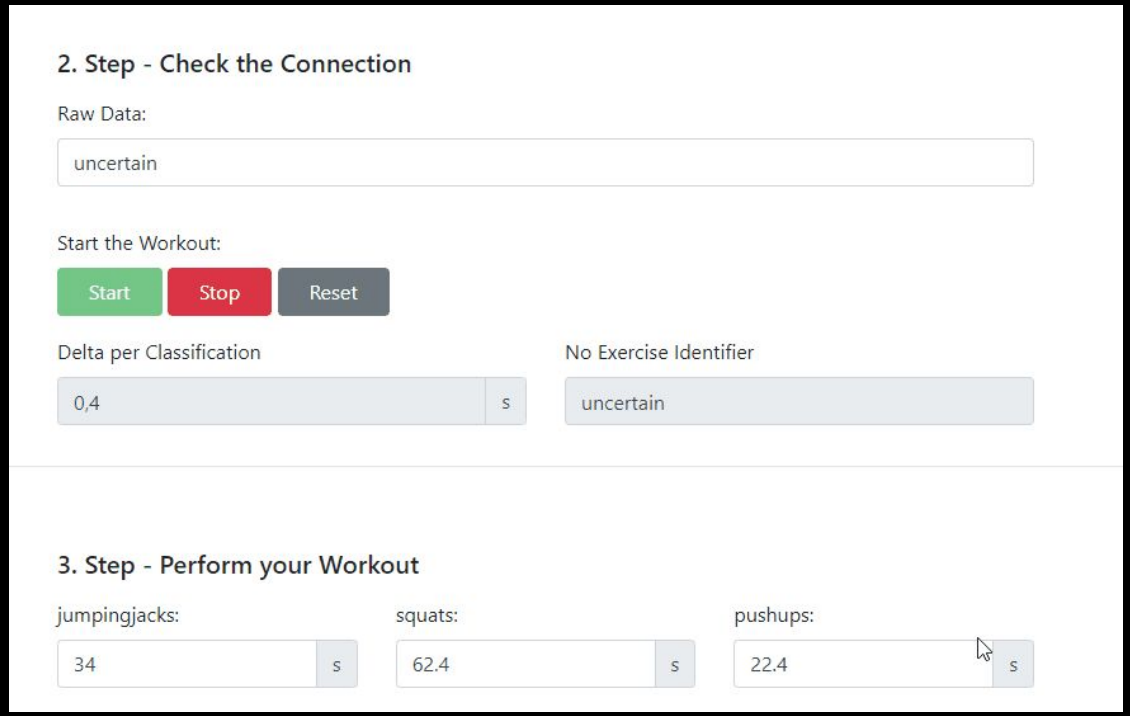
Model Deployment:

- compiled pipeline into arduino library using the Edge Impulse Deployment features
- used optimized version (int8) to increase on-device performance

Inference:

- extended sample code provided by Edge Impulse with BLE capabilities
- Inference in continuous fashion on the board and results sent via BLE to web app
- web app accumulates exercise durations

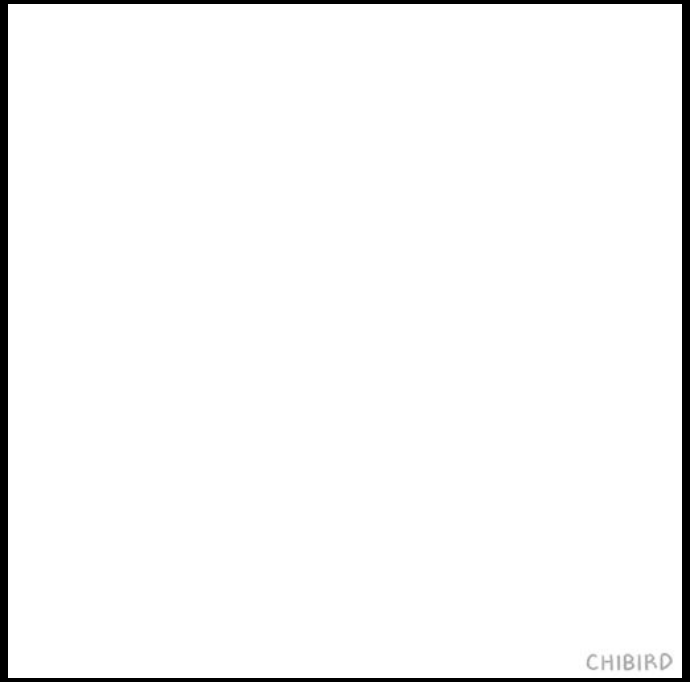
Edge AI Pipeline - Model Deployment & Inference



Challenges & Solutions

- recording of data by default requires connection to local machine via usb-cable:
  - developed tool to record data via Bluetooth Low Energy (BLE)
  - one then only requires connection to power bank
- features heavily rely on orientation of the board:
  - collect more data in different board orientations to make prediction more robust
  - alternative: apply PCA on raw data - untested since not supported by Edge Impulse
- board is slightly moving while performing the exercises:
  - still an issue
  - happening due to high weight of power bank and missing attachment to sport pants
  - ideas: use light weight battery instead of power bank, improve packaging

Call to Action



- getting started is very easy using the Edge Impulse platform
- no need of any prior knowledge regarding electrical engineering
- if I could do it, then you can too!

Thank you!

https://github.com/LudwigStumpp/ble-recorder

https://github.com/LudwigStumpp/arduino-workout-classification

https://twitter.com/ludwig_stumpp

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