Predictive Maintenance with an Arduino-based LoRa solution

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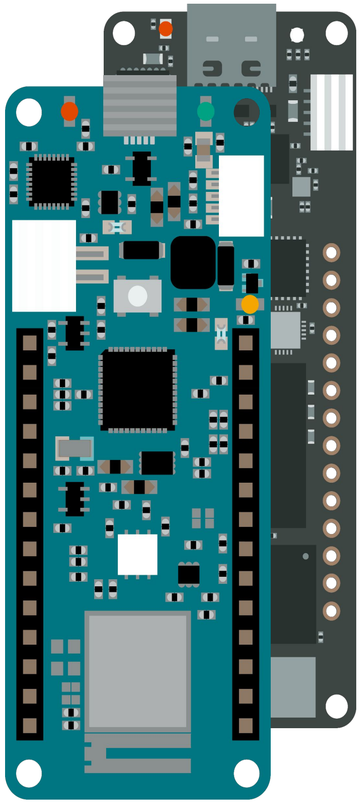
What is Arduino?

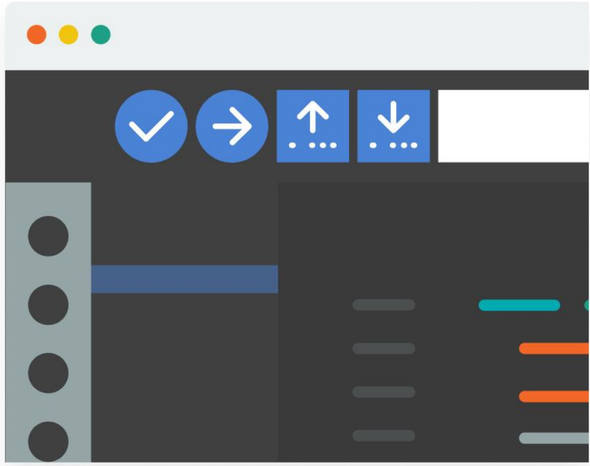
Arduino is an open electronics platform based on **easy-to-use** hardware and software.

- Started 2005 as a low cost prototyping solution.
- Arduino Pro brings the knowledge and the experience that we collected over the years to the professionals.



The Arduino Platform

- A complete **platform** to simplify developing hardware solutions
- Thousands of **libraries** to support almost any sensor / actuator
- Huge worldwide **community** to provide support and inspiration



Maintenance vs Repair

Repair: Mending something that is already broken.
Usually urgent for time sensitive processes.

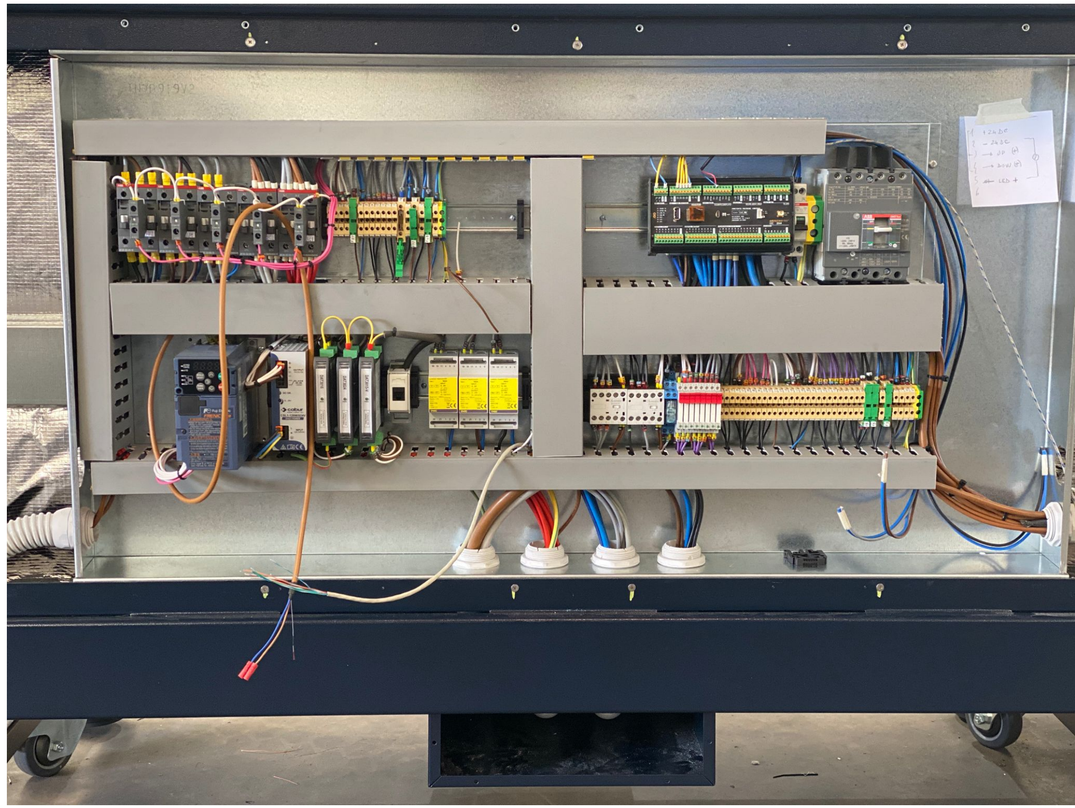
Maintenance: Preventive measures to keep a machine functional for as long as possible. → Failure prevention

Scheduled 📅 vs **predictive** 💡 maintenance

Predictive Maintenance

- Techniques to **analyse** the condition of hardware and **predict** when maintenance should be performed **before** an inconvenient moment comes.

- Replacement for scheduled maintenance.



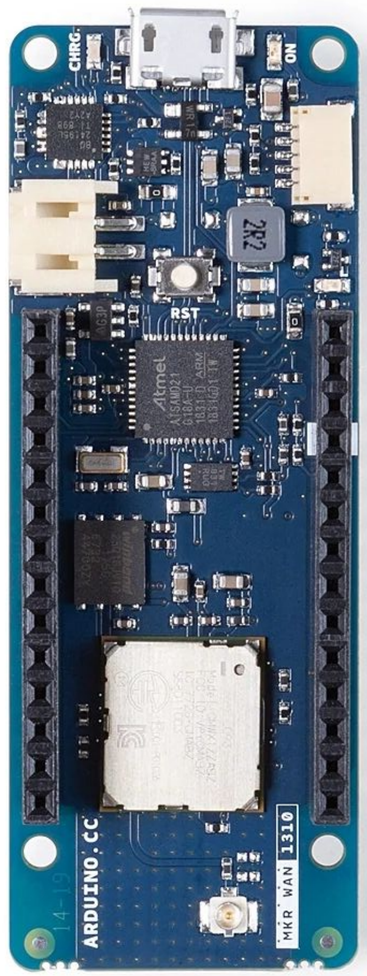
Predictive Maintenance Benefits

- Save cost on repair of broken equipment
- Shorter outage (if any)
- Optimized use of maintenance staff
- Optimized spare part stocking
- Technology agnostic (mostly)
- No hardware modification → no warranty issues

LoRa Based Predictive Maintenance

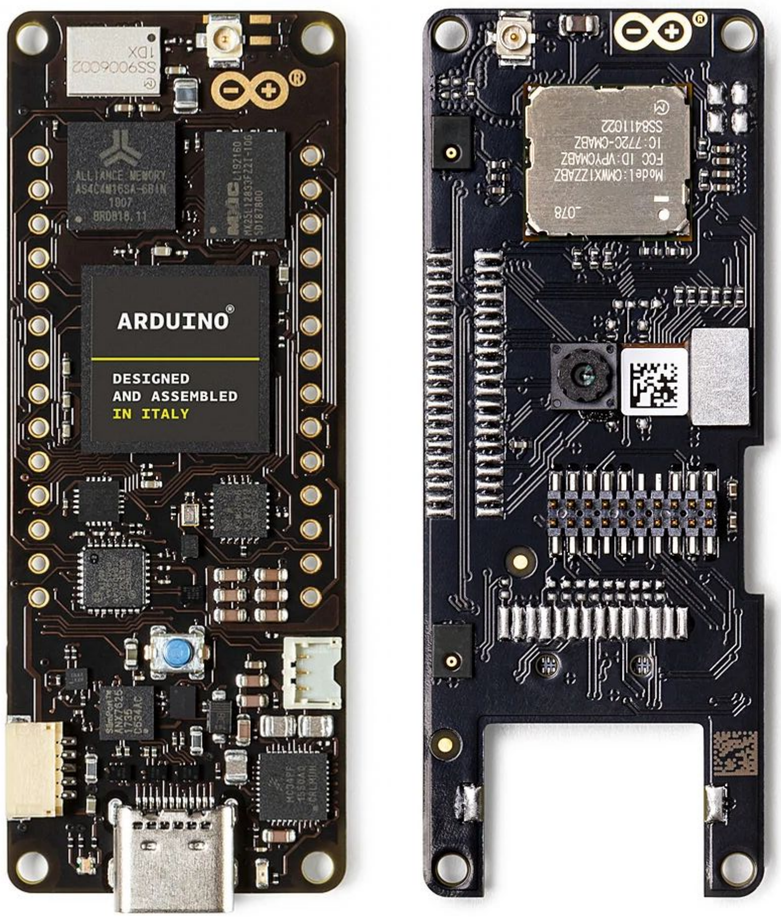
1. Choose the Hardware You Need
2. Make It Smart
3. Connect It to the Cloud
4. Inspect the Data

1. Choose the Hardware You Need 👈



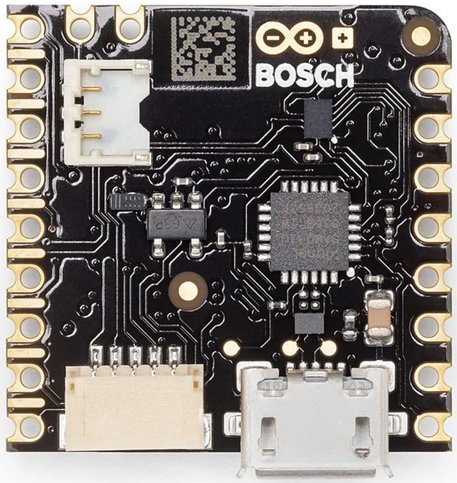
MKR WAN 1310

- SAMD21 Cortex-M0+ 32bit low power ARM MCU 48 MHz
- CMWX1ZZABZ LoRa Module
- Battery connector
- ATECC508A Secure Element
- Carrier frequency: 433/868/915 MHz



Portenta H7 + Vision Shield

- STM32H747 dual Cortex ® 480 + 240 MHz
- Murata 1DX dual WiFi / Bluetooth
- LiPo battery charger
- Murata CMWX1ZZABZ LoRa Module
- Himax HM-01B0 Lo-Power camera
- 2 microphones (directional sound)
- SD-Card connector



Nicla Sense ME

- Cortex-M4 nRF52832
- ANNA B112 Bluetooth module
- 6 axis IMU, pressure sensor, magnetometer, gas sensor
- LiPo battery charger

2. Make it Smart 🧠

Machine Learning on MCUs

Augment the intelligence of billions of appliances

- **Low-cost** hardware: Easily embed in everyday products
- **Low power**: Works with a battery (portable)
- No internet **connection** required
- **Data** stays on device (privacy)

How: Sound & Machine Learning

Use machine learning to detect anomalies in sound.

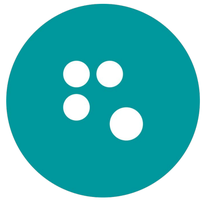
- E.g. the rattling sound of a broken dishwasher.
- E.g. the sound of broken glass in a factory
- Accuracy influenced by background noise ⚠️

How: Machine Vision

Use machine vision to detect visual anomalies.

- E.g. broken light bulbs
- E.g. distorted saw blade
- Accuracy influenced by lighting ⚠️

How: Gas & Machine Learning



Use machine learning to detect anomalies in gases.

- E.g. detect wine going bad while ageing in a barrel
- E.g. leaking gases in a factory

How: Vibration & Machine Learning

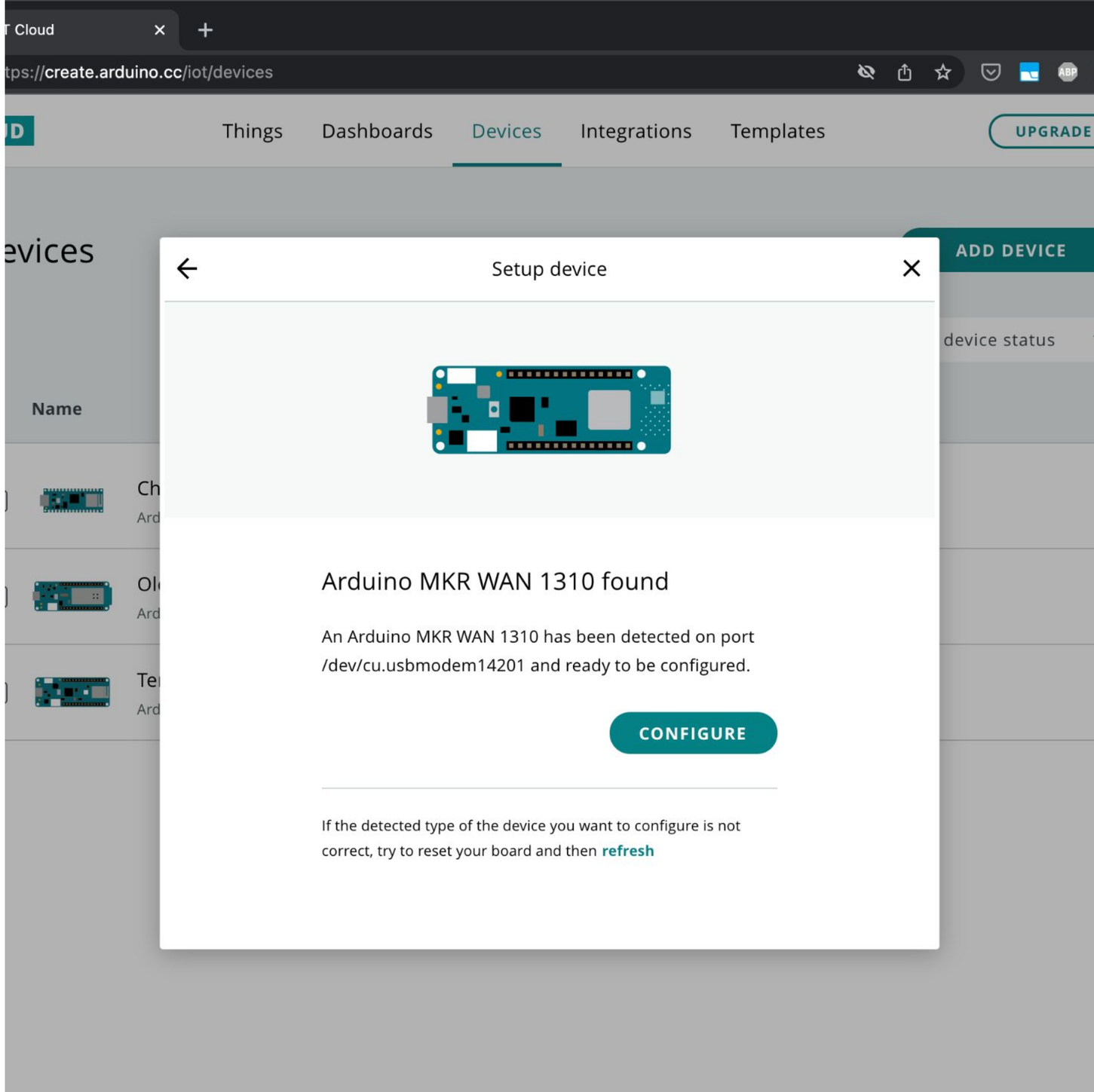
Use machine learning to detect anomalies
in vibrations (focus of the demo).

- e.g. worn out drill bits (life expectancy estimation)
- e.g. displaced washing machine drum

3. Connect it to the Cloud ☁️

IoT Cloud meets The Things Network 👬

- MKR WAN boards can connect to **IoT Cloud** via a TTN LoRaWAN® backend 🎉
- Automatic configuration of the TTN app.



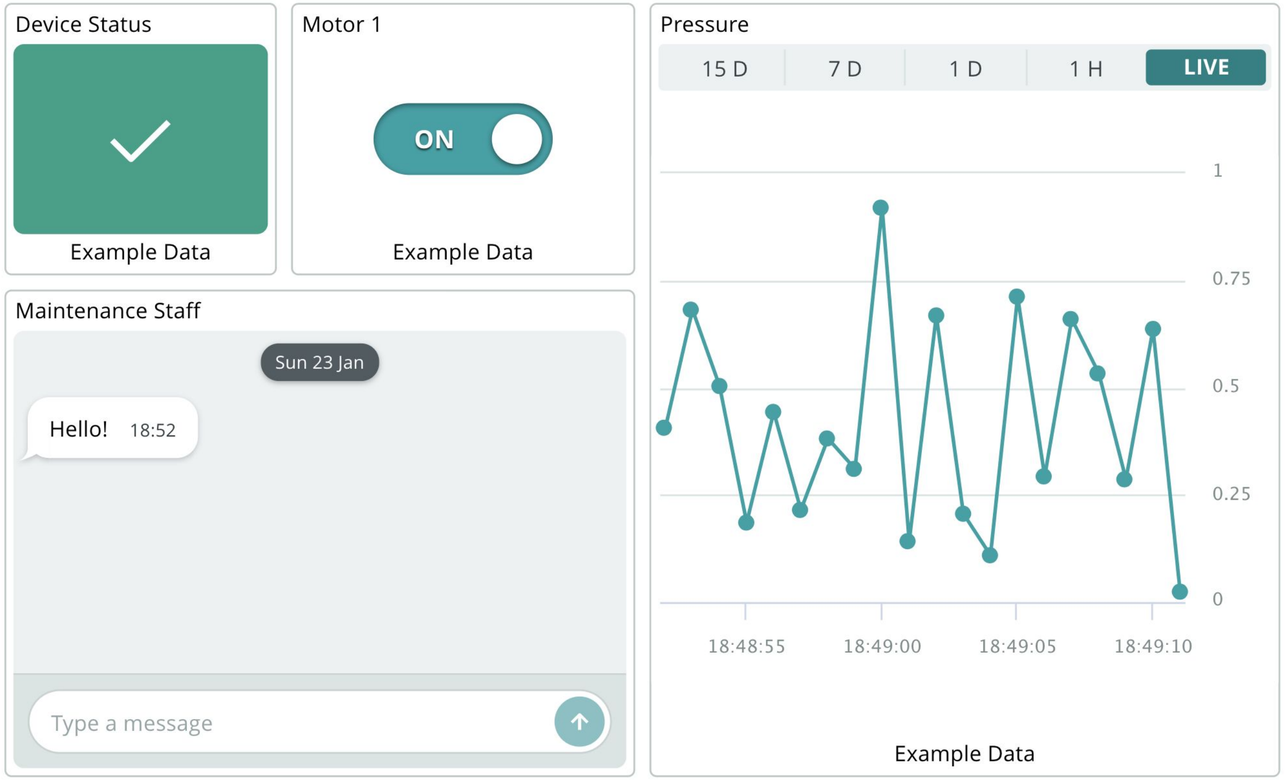
Why LoRa is a Good Choice 👌

- Resistance to noise
- Cover wider area (even public infrastructure)
- Simplified wiring (one gateway connected to internet)
- Low power (can operate with batteries/solar panel)
- No network configuration (no IPs etc.)
- Outdoor usage (e.g. predictive maintenance in the nature)

4. Inspect the Data 👀

IoT Cloud Dashboard

- Inspect hardware status
- Read sensor data
- Track sensor history
- Send messages
  (e.g. alert maintenance staff)
- Trigger actions
  (e.g. turn device off)

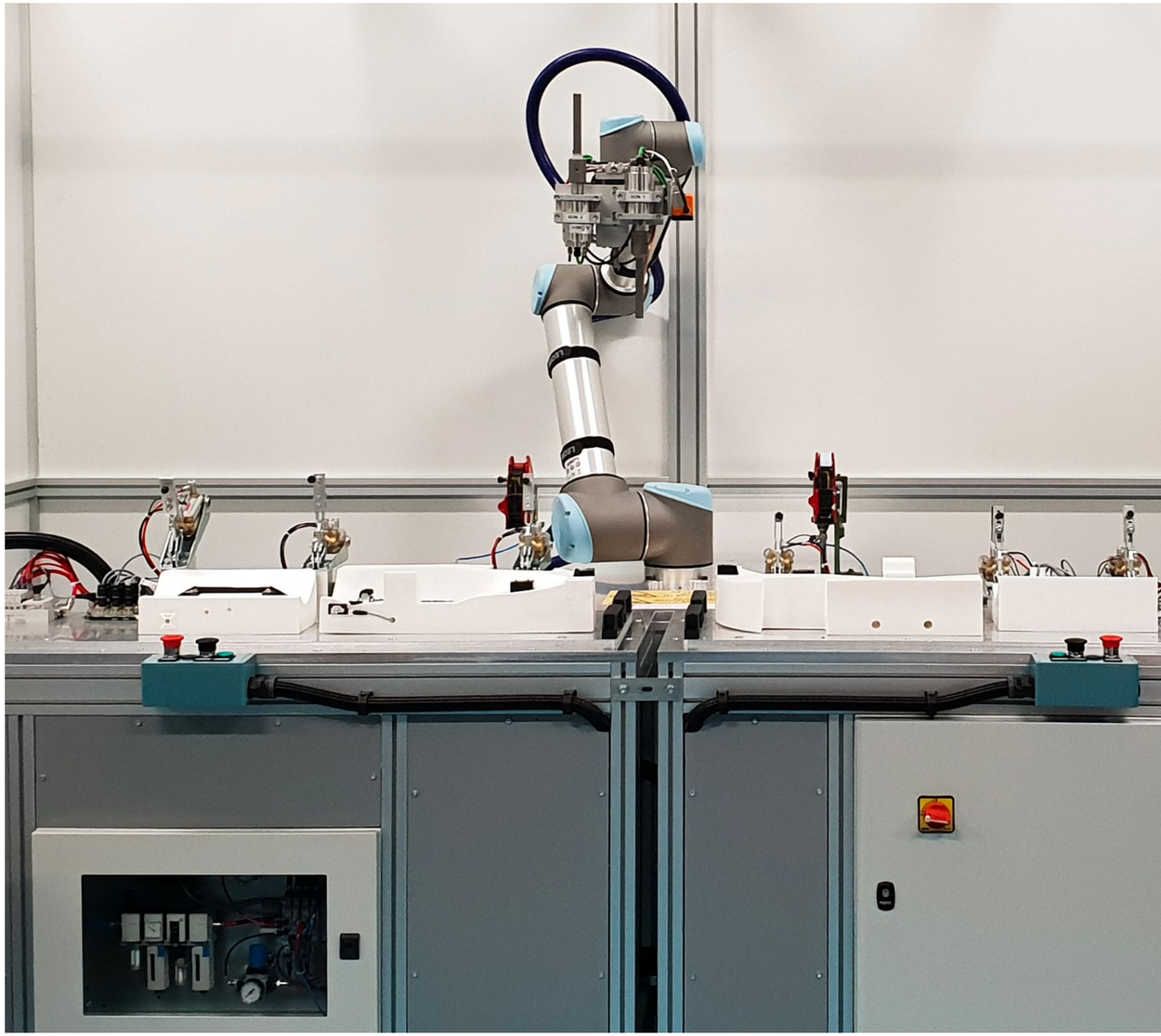


APPLICATION EXAMPLE

Detecting Vibration Anomalies

Predict Mechanical Failure Through Vibration

- **Analyse** vibration patterns
- **Predict** if a machine may fail in the near future.
- Perform **maintenance** before it fails.

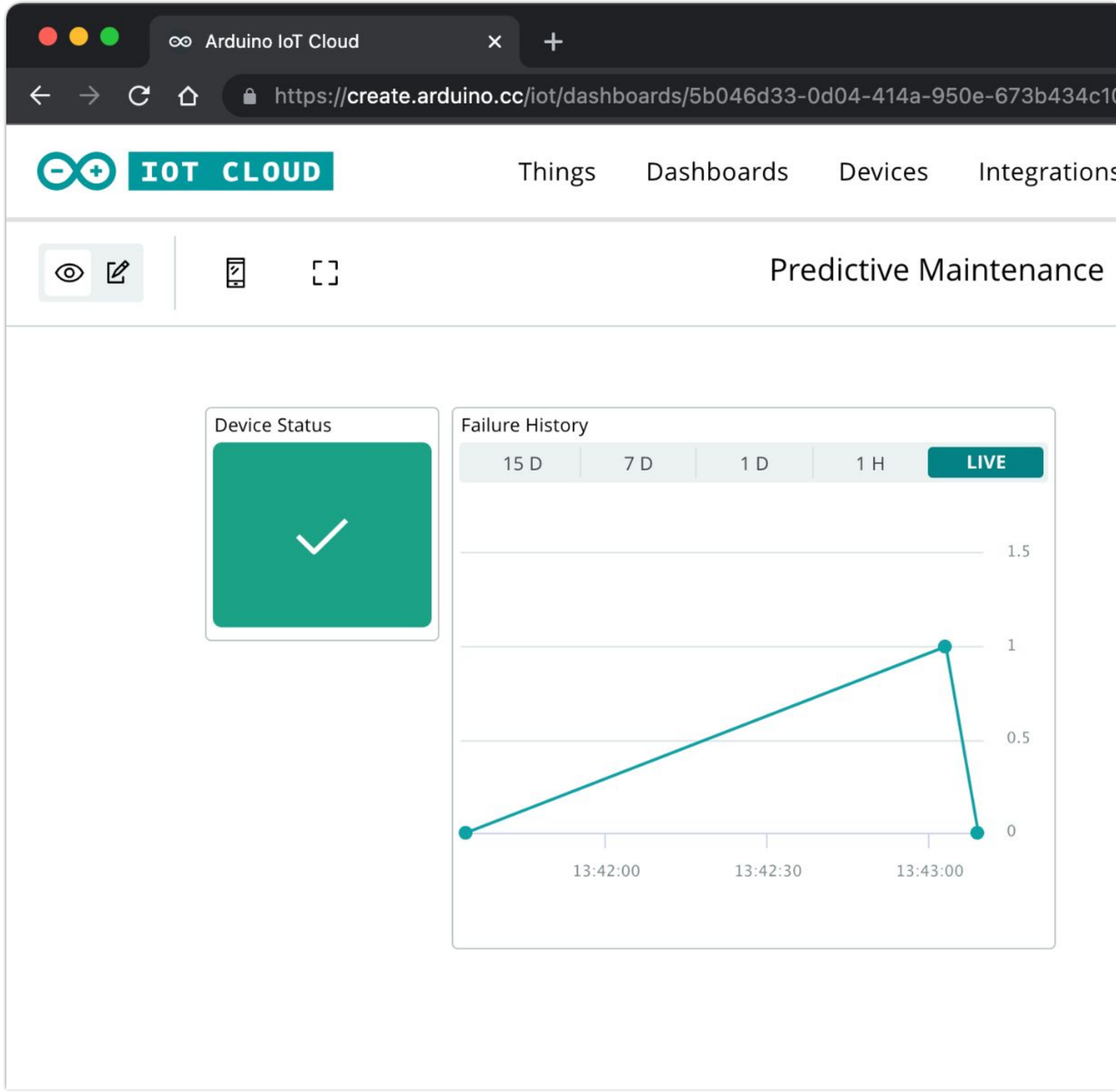


Rule Based vs Machine Learning

- The simple **intensity** or **frequency** of a vibration anomaly could be detected with a rule based approach...
- ...but vibration patterns are not exactly same every time.
- ML can easily deal with these variations. 💪

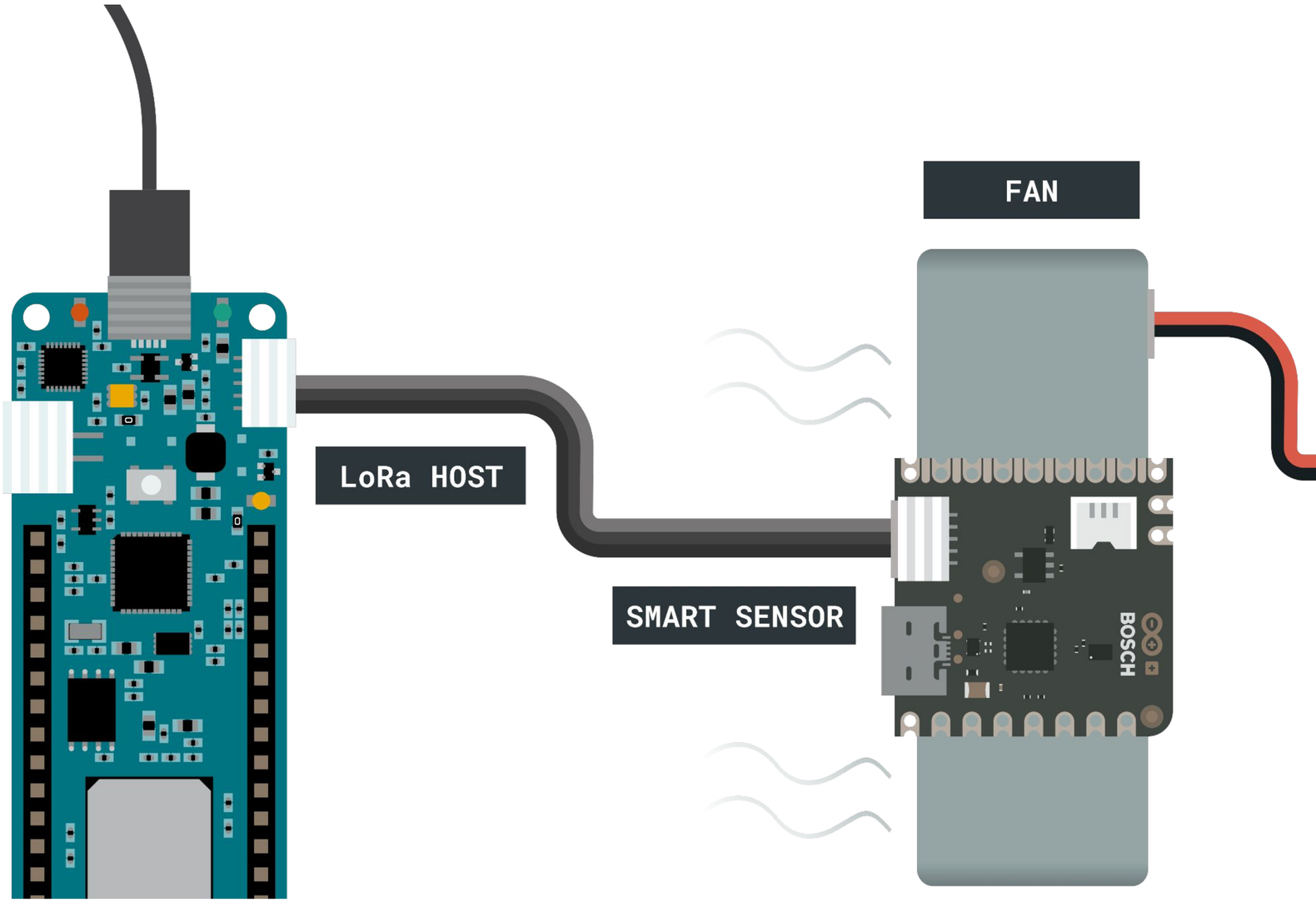
Goal: IoT Cloud Dashboard

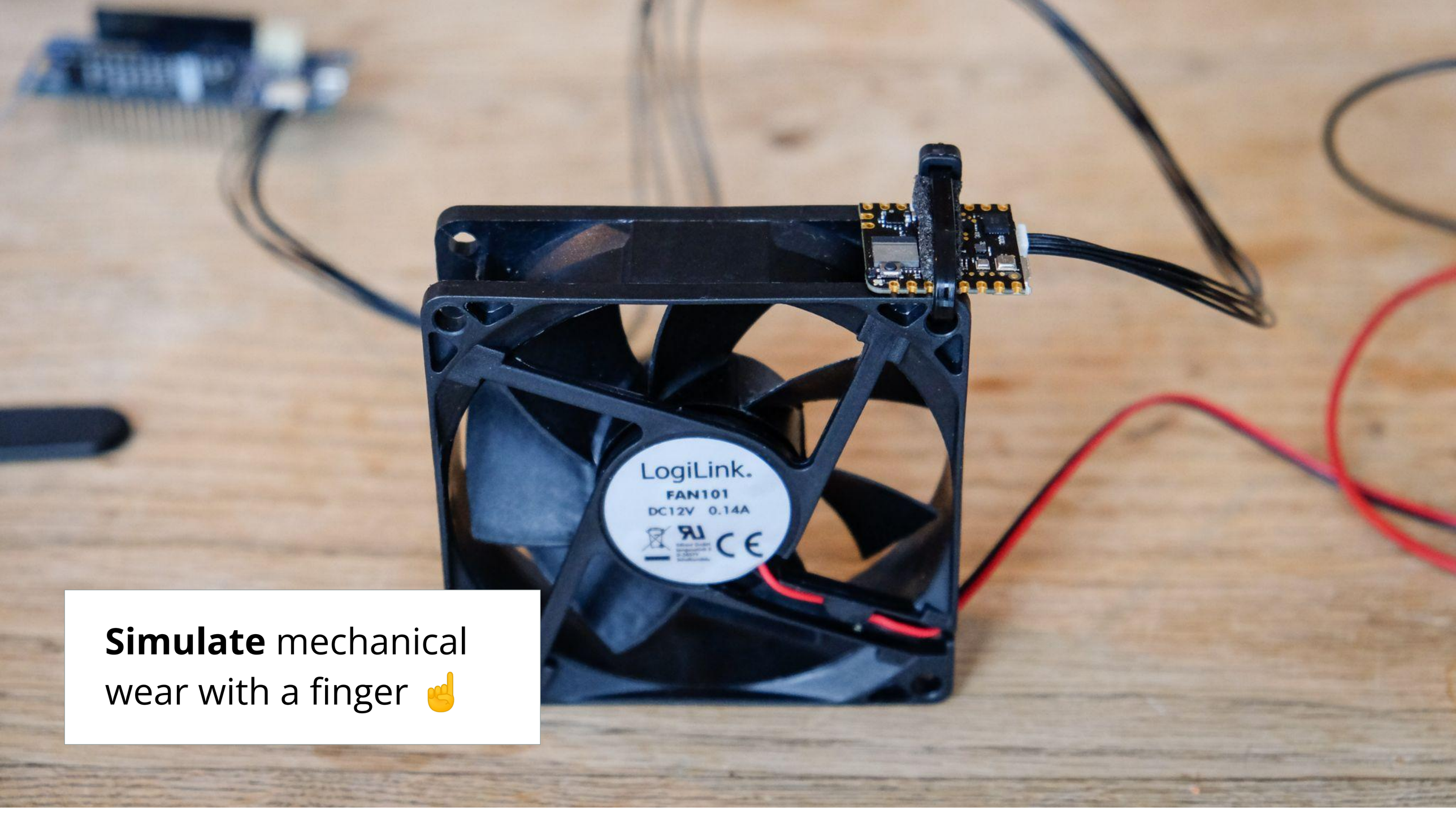
- Track device status
- Inspect failure history
- Intervene (e.g. turn device off)



Hardware Setup for Demo

- MKR WAN 1310
- Nicla Sense ME
- ESLOV Cable
- PC Fan
- Finger ☝





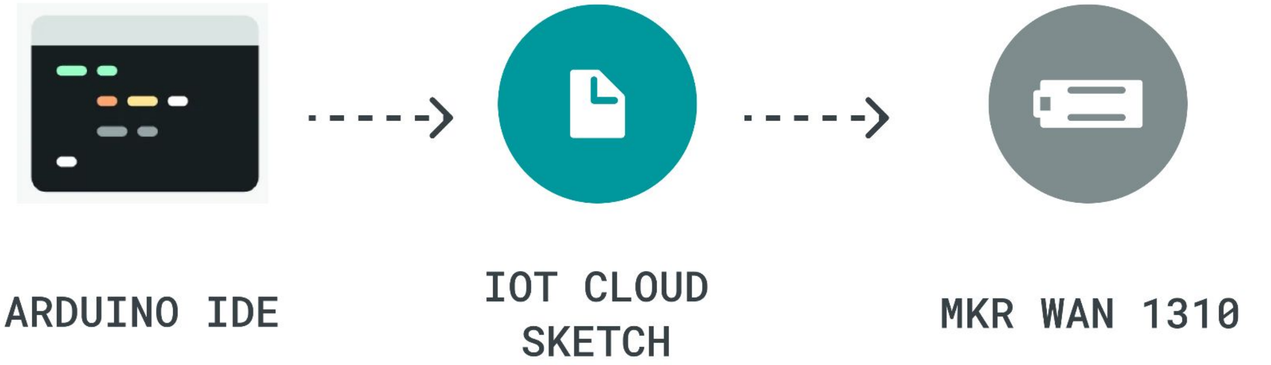
Simulate mechanical wear with a finger ☝️

Training Process

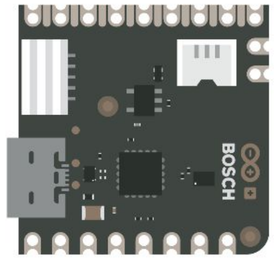
Deployment

SENSOR NODE

HOST BOARD



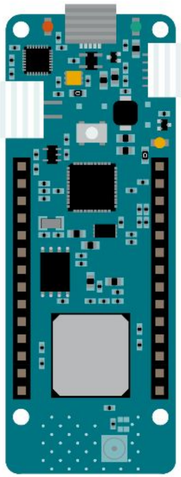
Detection Process



READ ACCELERO-
METER DATA

CLASSIFY
VIBRATION

SEND DATA OVER
ESLOV TO MKR WAN



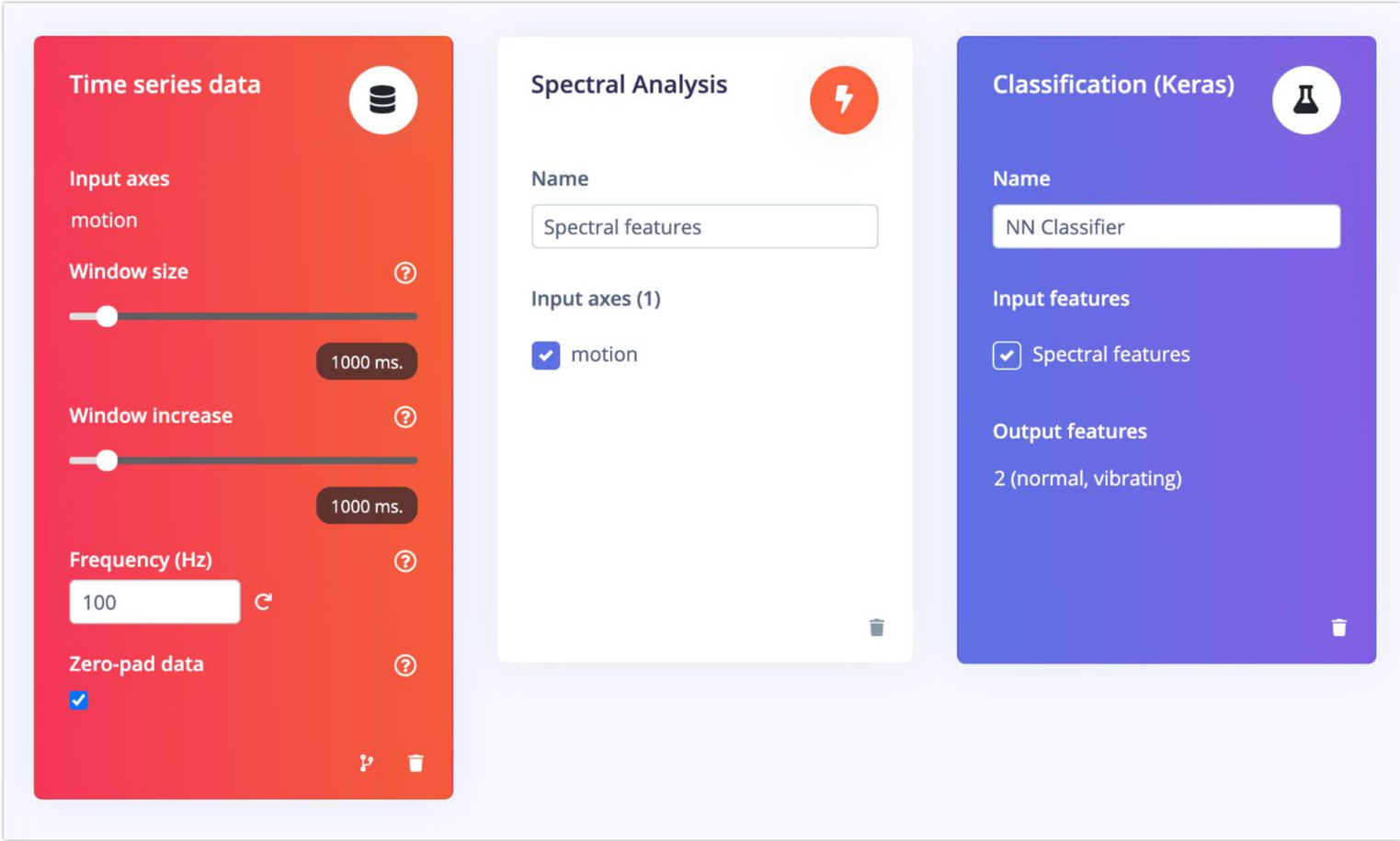
READ DATA FROM
NICLA SENSE ME

UPLOAD DATA
TO IOT CLOUD

DISPLAY STATUS
IN DASHBOARD

Machine Learning: Edge Impulse Studio

- Gather Raw Data
- Process Data
- Extract Features
- Train ML Model

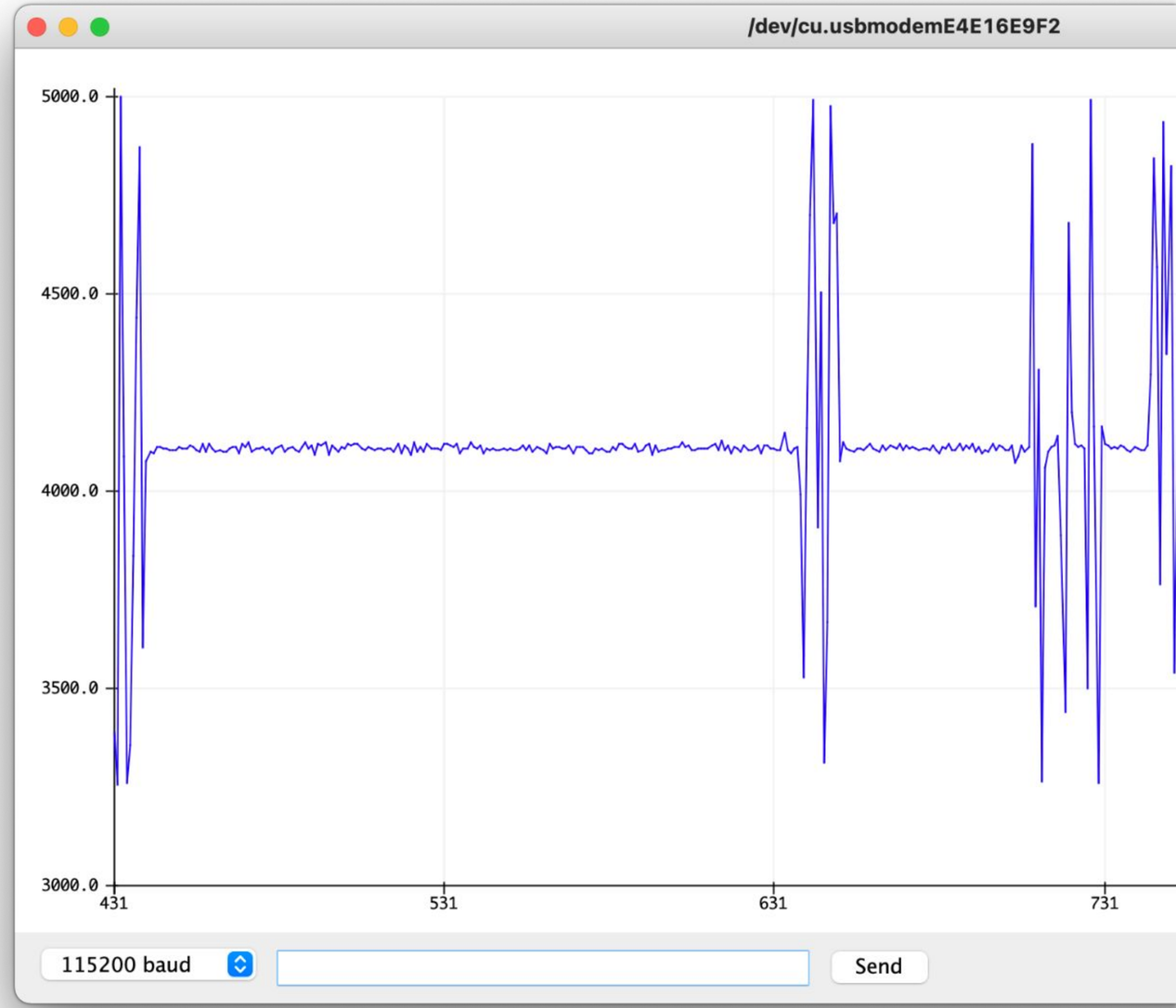


1. Gather Raw Data

- On-board accelerometer to gather vibration data
- Motion on 3 axes
- Orientation matters ⚠️

- Simplification: Magnitude of motion vector

$$|M| = \sqrt{x^2 + y^2 + z^2}$$



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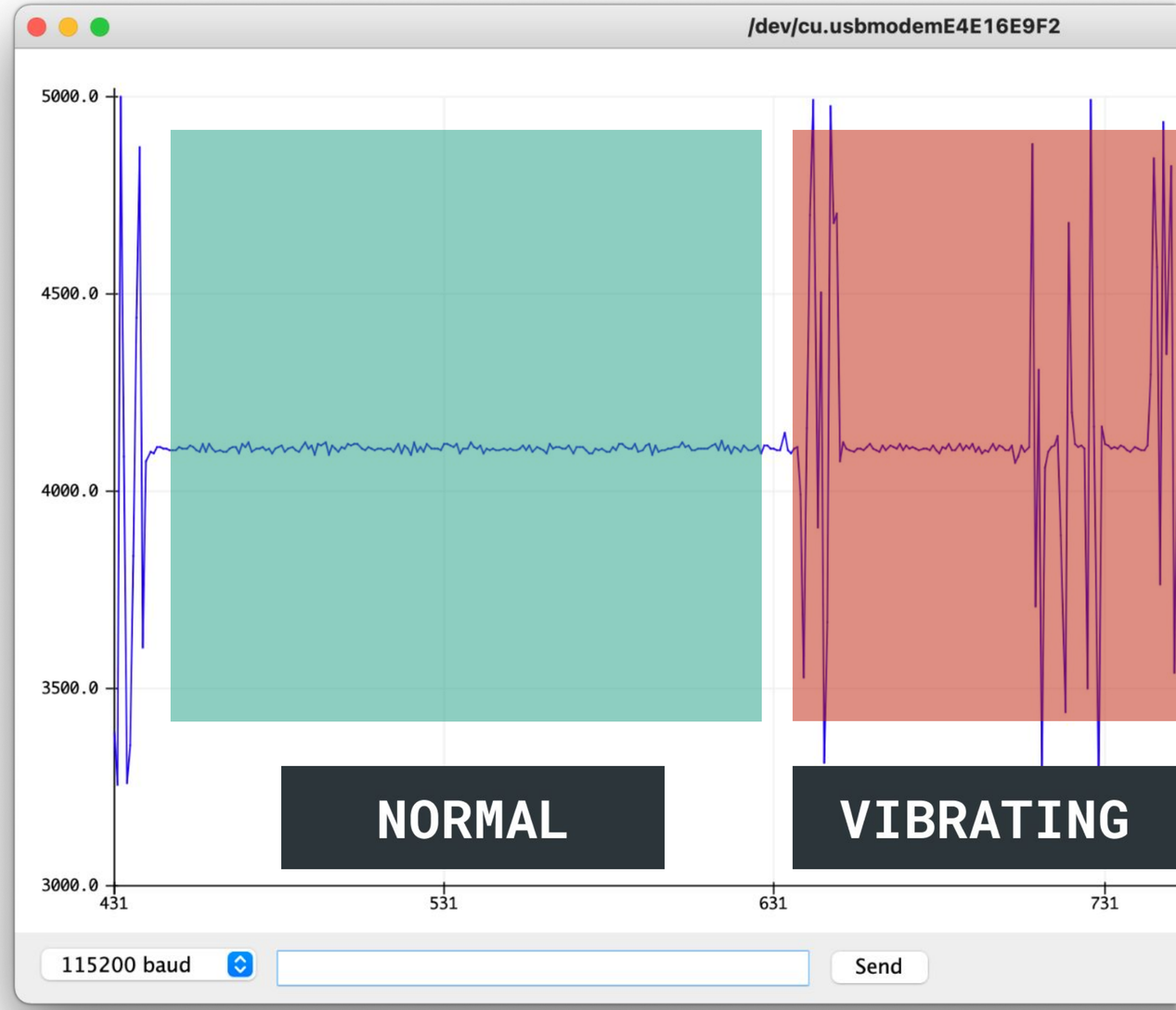
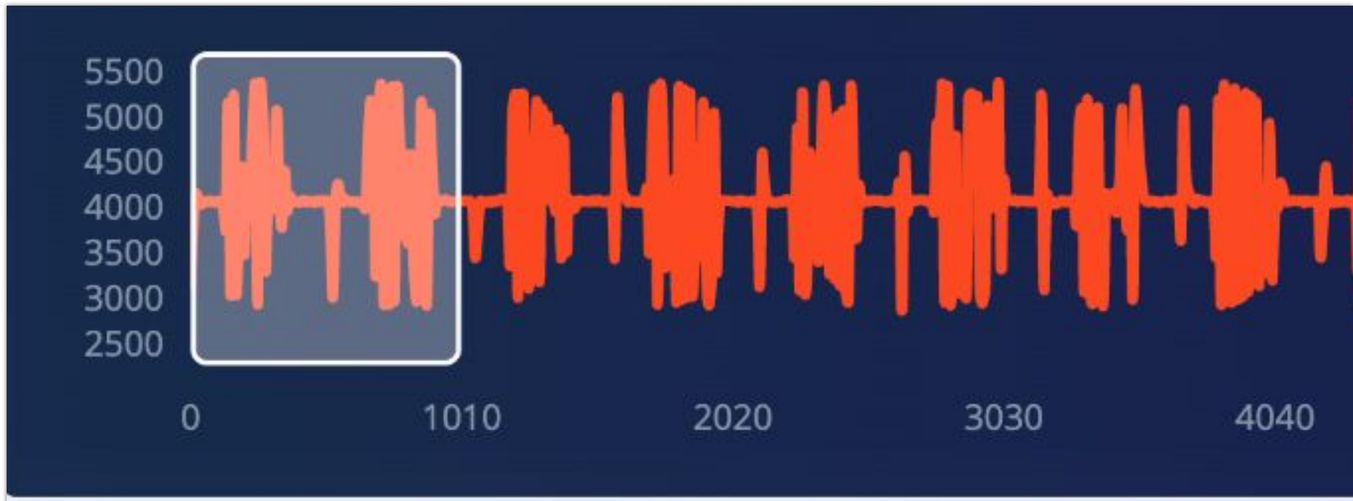


2. Process Data

Window Size

- Defines how many ms of sensor data should be considered for a classification.
- Depends on vibration pattern
- For constant vibration a small window may suffice.



Raw features

3133.4800, 3864.9500, 4184.3100, 4124.5000, 4068.0700, 4093.0700,

Parameters

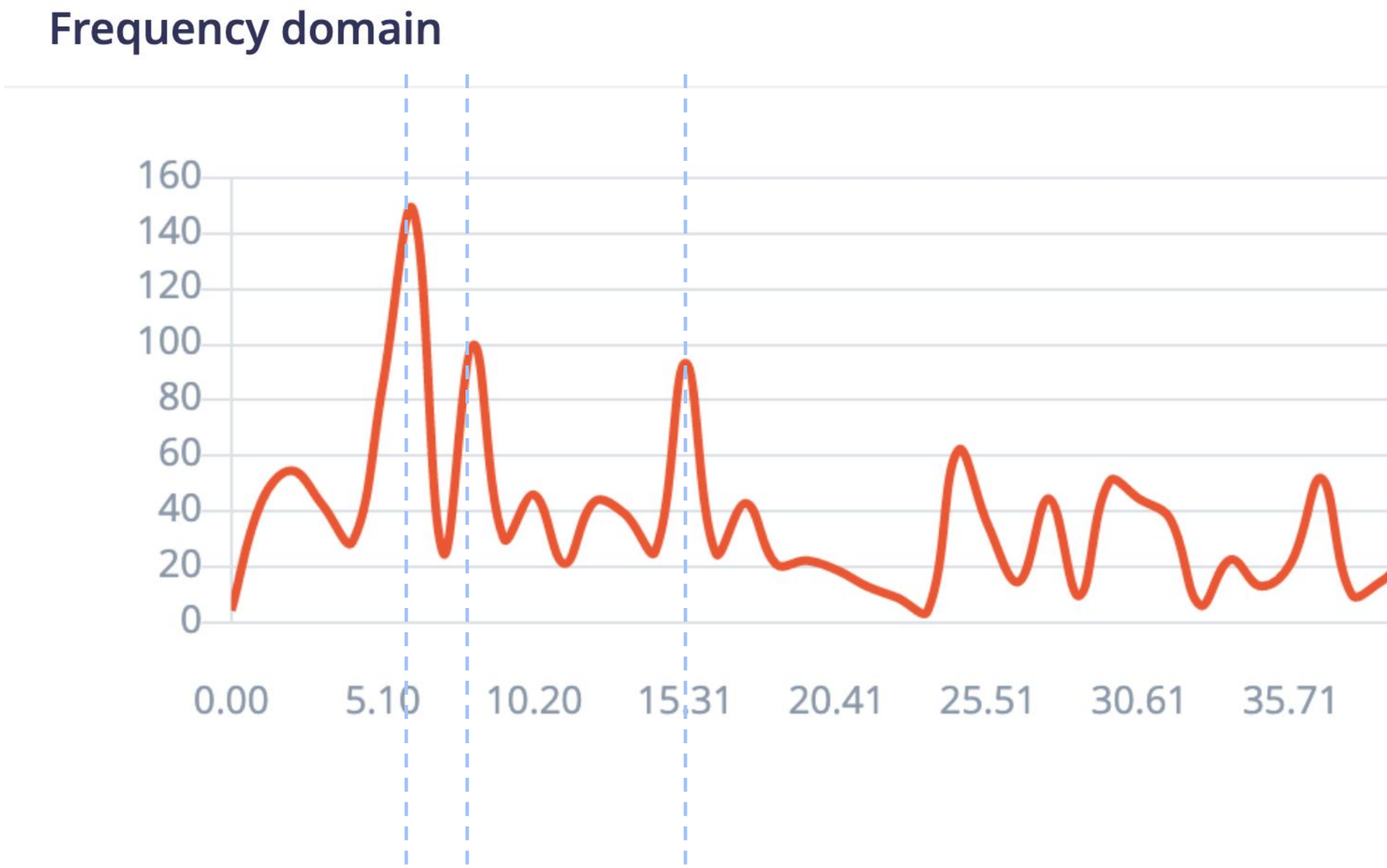
Scaling

Scale axes 1

2. Process Data

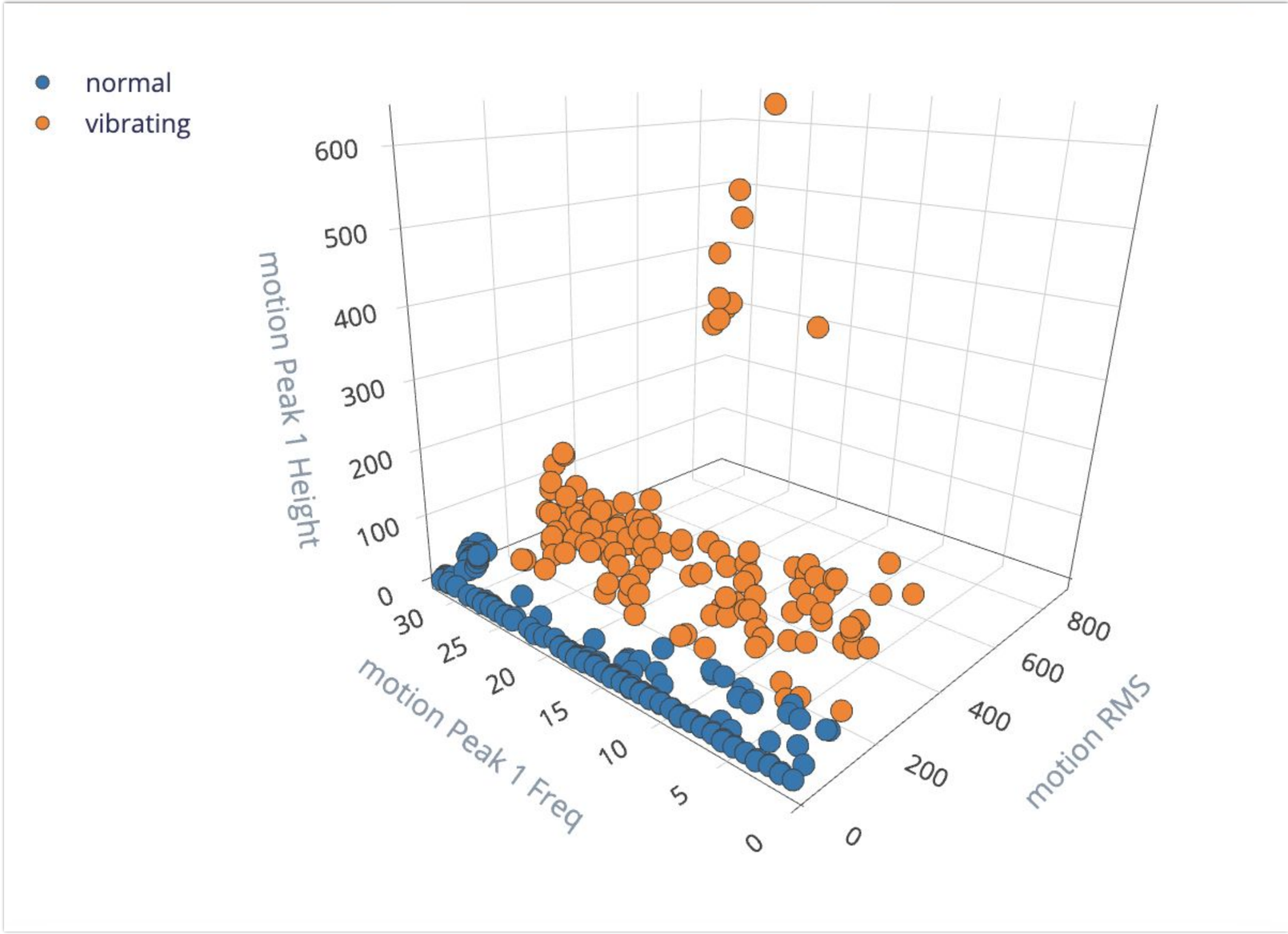
Spectral Analysis

- Filter relevant frequency
- Vibration characteristics
- Find peaks



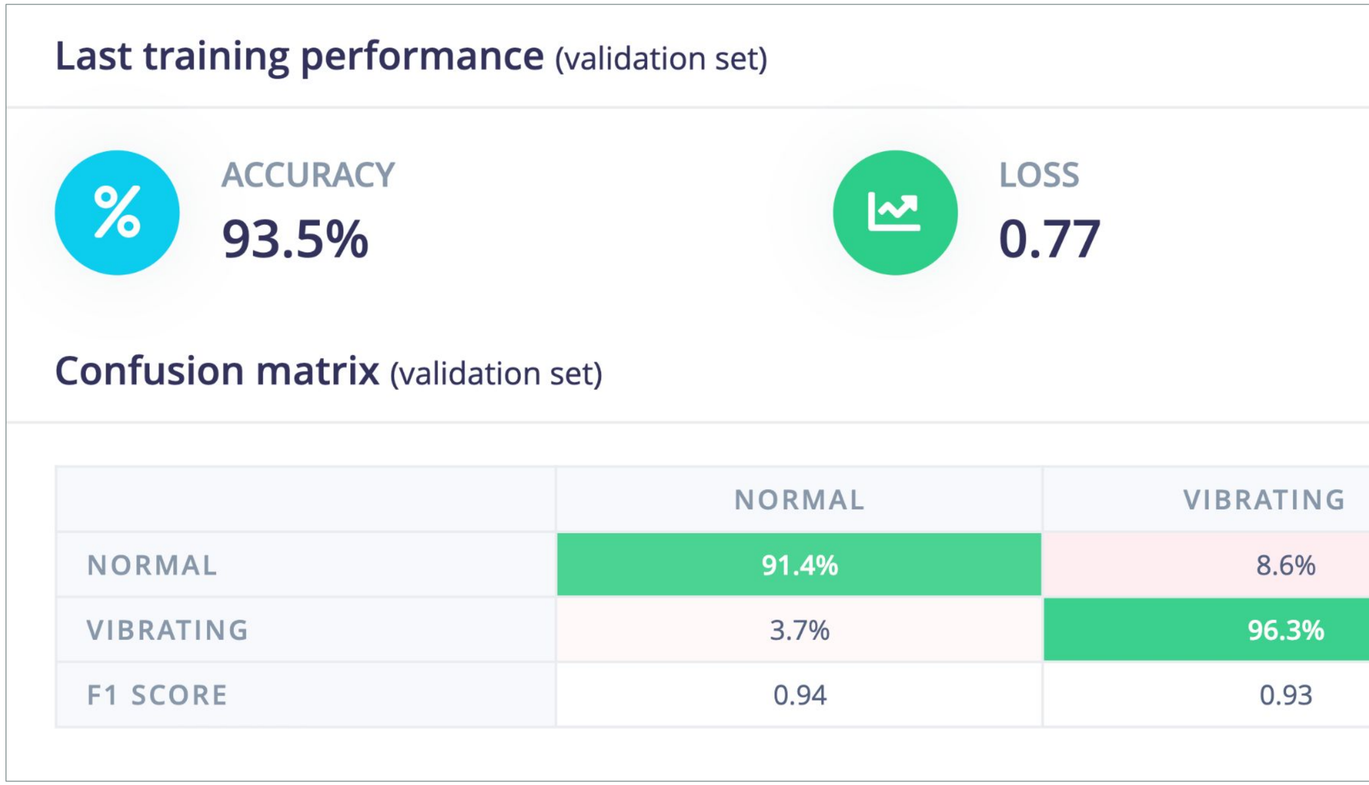
3. Extract Features

- Unique characteristics
- Separation of classes
- Find bad training data



4. Train ML Model

- Learns based on provided vibration samples
- Adjust learning cycles as needed
- Watch out for overfitting ⚠️



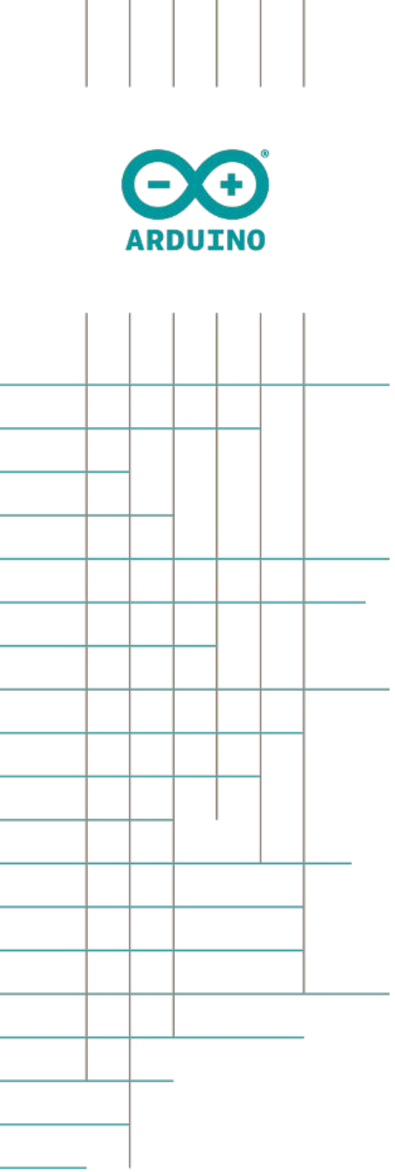
Last training performance (validation set)

ACCURACY
93.5%

LOSS
0.77

Confusion matrix (validation set)

	NORMAL	VIBRATING
NORMAL	91.4%	8.6%
VIBRATING	3.7%	96.3%
F1 SCORE	0.94	0.93



Thank you!