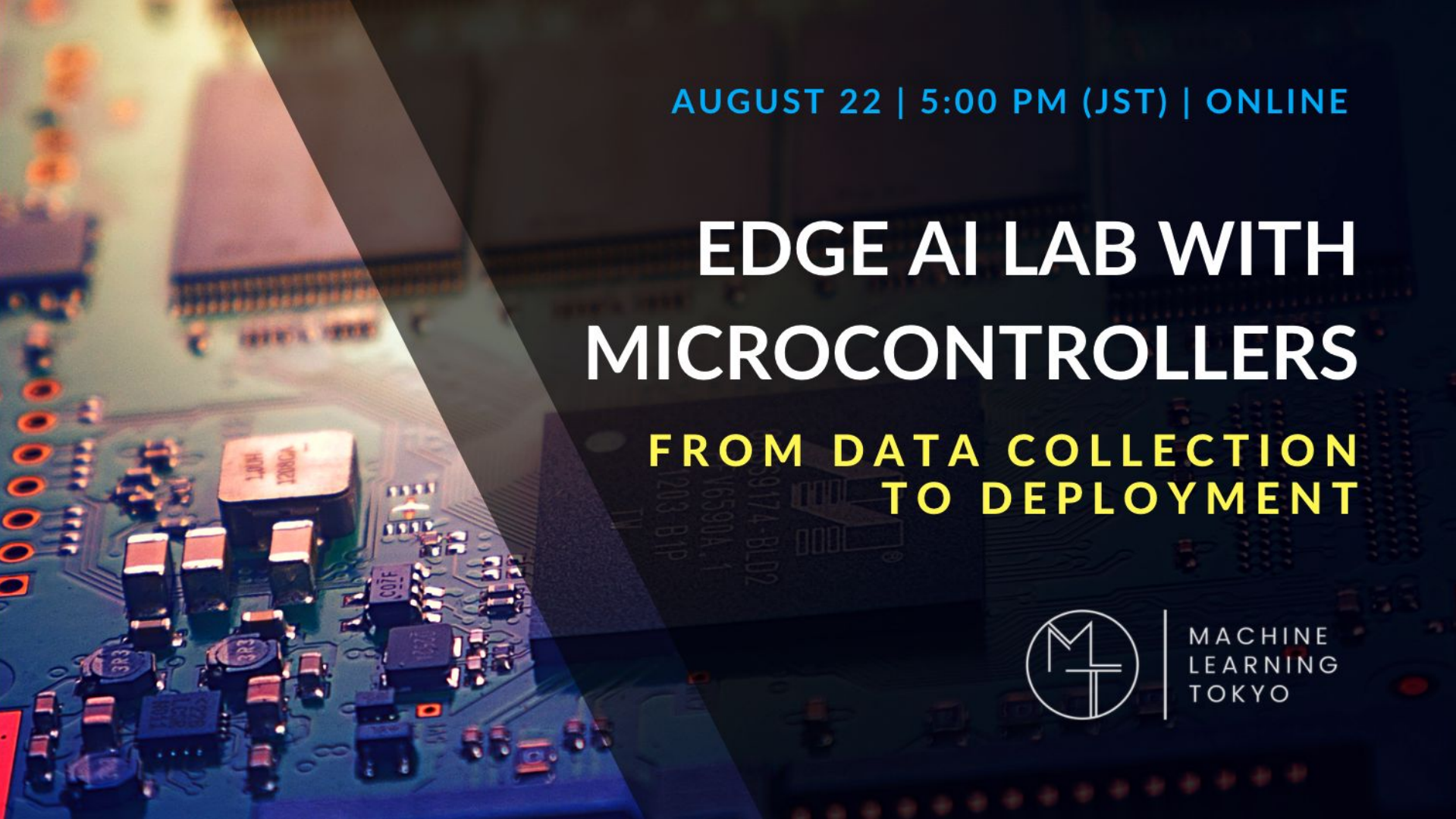
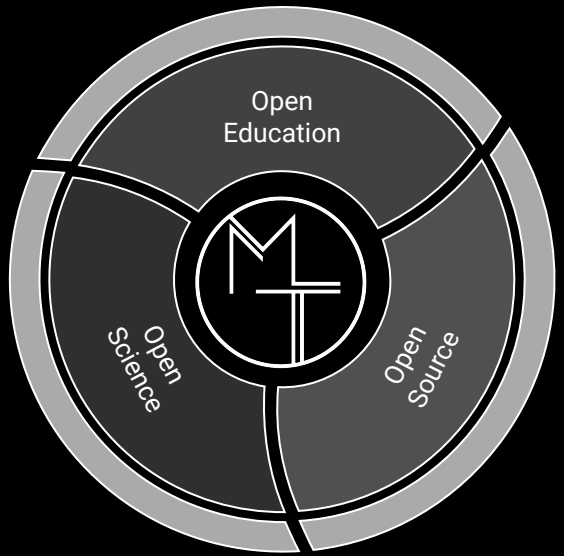

AUGUST 22 | 5:00 PM (JST) | ONLINE
EDGE AI LAB WITH MICROCONTROLLERS
FROM DATA COLLECTION TO DEPLOYMENT
MACHINE LEARNING TOKYO

MLT

Machine Learning Tokyo (MLT) is an award-winning nonprofit organization 一般社団法人 based in Japan.

MLT is dedicated to democratizing Machine Learning through open education, open source and open science.

We support an international research- and engineering community of more than 9,400 members.



MACHINE
LEARNING
TOKYO

Ref : https://machinelearningtokyo.com

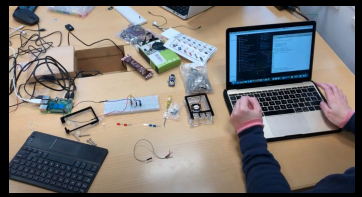
MLT EdgeAI Lab

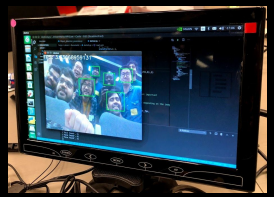
MLT Agritech team visiting Hacker Farm in Chiba

Signate 3rd AI Edge

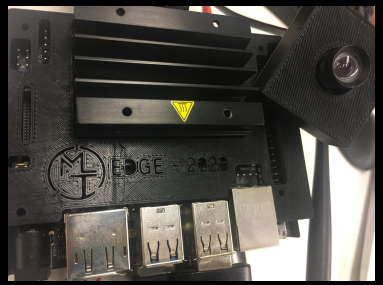
Final Rank	Teamname / Username	Private
1st	RailStar737A	0.62610
2nd	IRAFM-AI	0.61198
3rd	MLT	0.60545

EdgeAI Lab Hardware Working Session





Jetson Nano deployment on bicycle



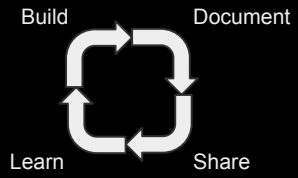
Join **#edge_ai_lab** on MLT Slack
https://machinelearningtokyo.slack.com

MACHINE LEARNING TOKYO

Introduction of Series

Goal is to help you build your Edge AI application by end of the series

- Build / Document / Share / Learn



Overview of entire Series

➔ Session #1 : Overview of Edge AI Applications
➔ Session #2 : Motion Based Application using IMU
➔ Session #3 : Audio Based Application using Microphone
➔ Session #4 : Wrap-up session

Today's Agenda (Session #1)

➔ 05:00 - 05:10: Introduction
➔ 05:10 - 05:30: Presentation
➔ 05:30 - 05:45: Brainstorming
➔ 05:45 - 06:00: Sharing / QA

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Join **#edge_ai_lab** on MLT Slack
https://machinelearningtokyo.slack.com

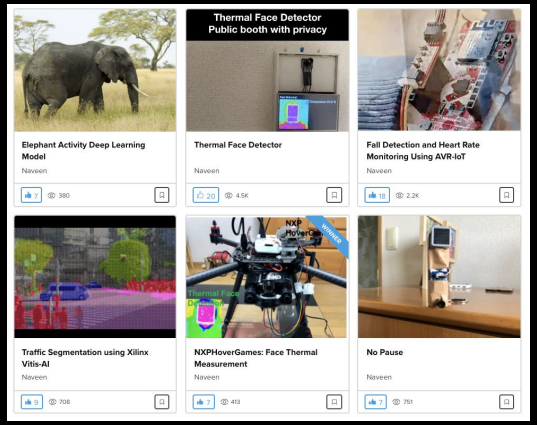
Introduction of Organizers

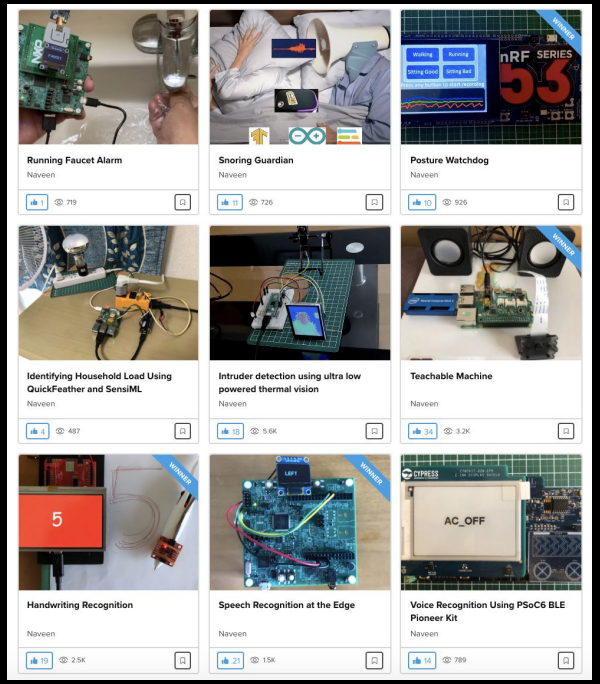
Naveen Kumar

- Watching movies
- Nature photography
- Playing with microcontrollers

@knaveen

My Edge AI projects at
hackster.io/naveenbskumar





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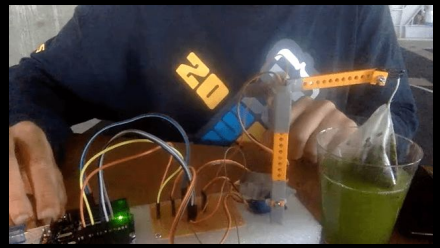
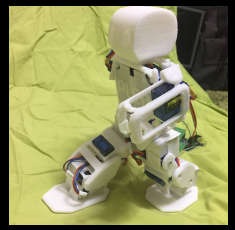
Introduction of Organizers

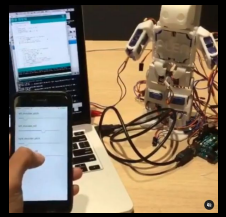
Yoovraj Shinde

- Love Eating Food
- Playing with robots



Past Projects





Personal Plen Robot

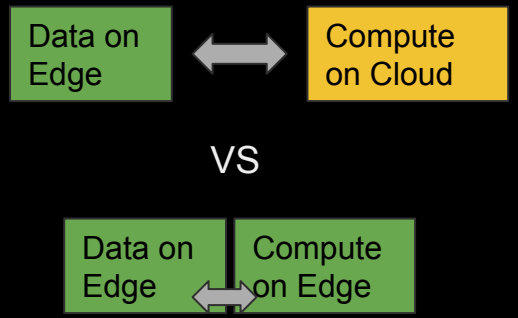
- 3d printed parts
- Arduino
- iOS App

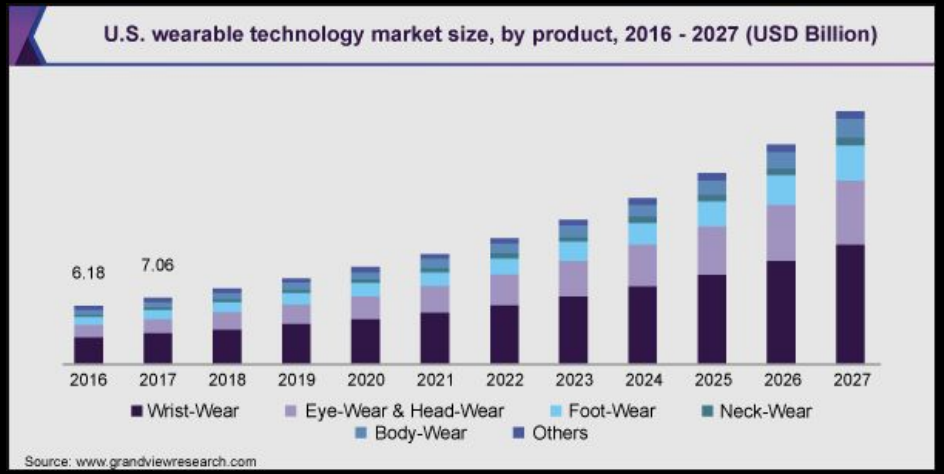
Robot Car for Kids

- Tamiya Kits
- Raspberry Pi
- Scratch

Why Edge AI is so important

- Offline Processing (independent system)
- User Privacy & Security
- Low Power / Low Cost
- Portability





Ref : https://www.grandviewresearch.com/industry-analysis/wearable-technology-market

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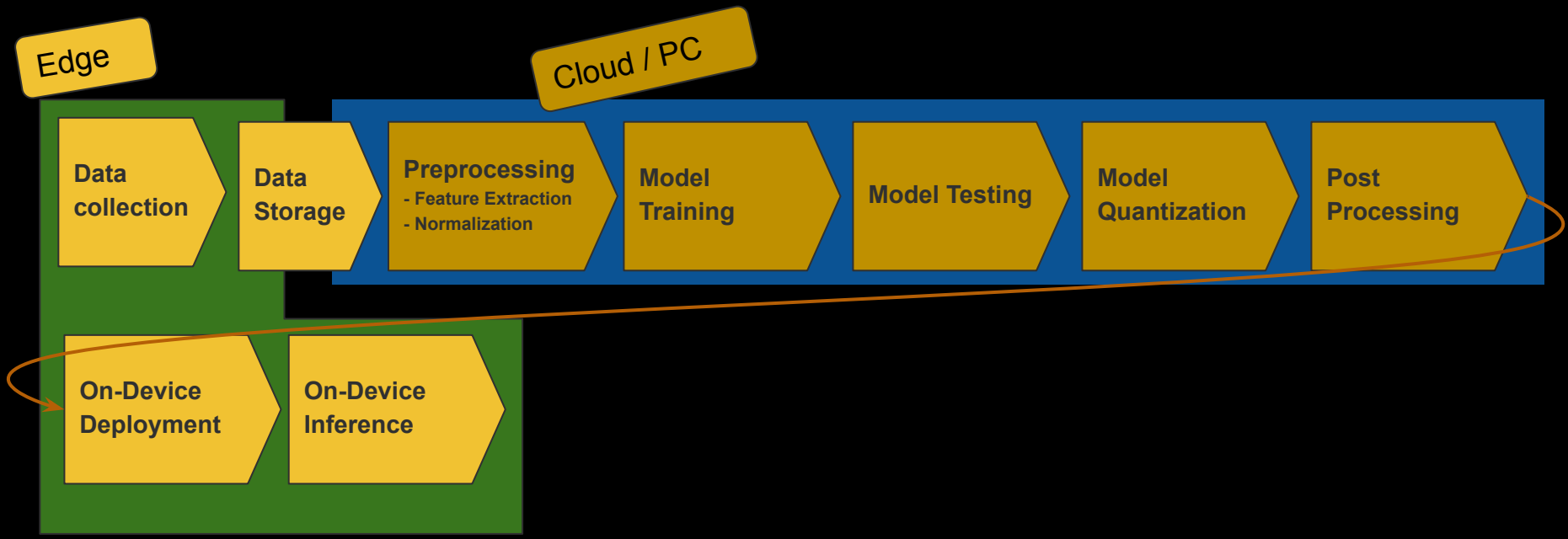
Blocks of Edge AI Pipeline



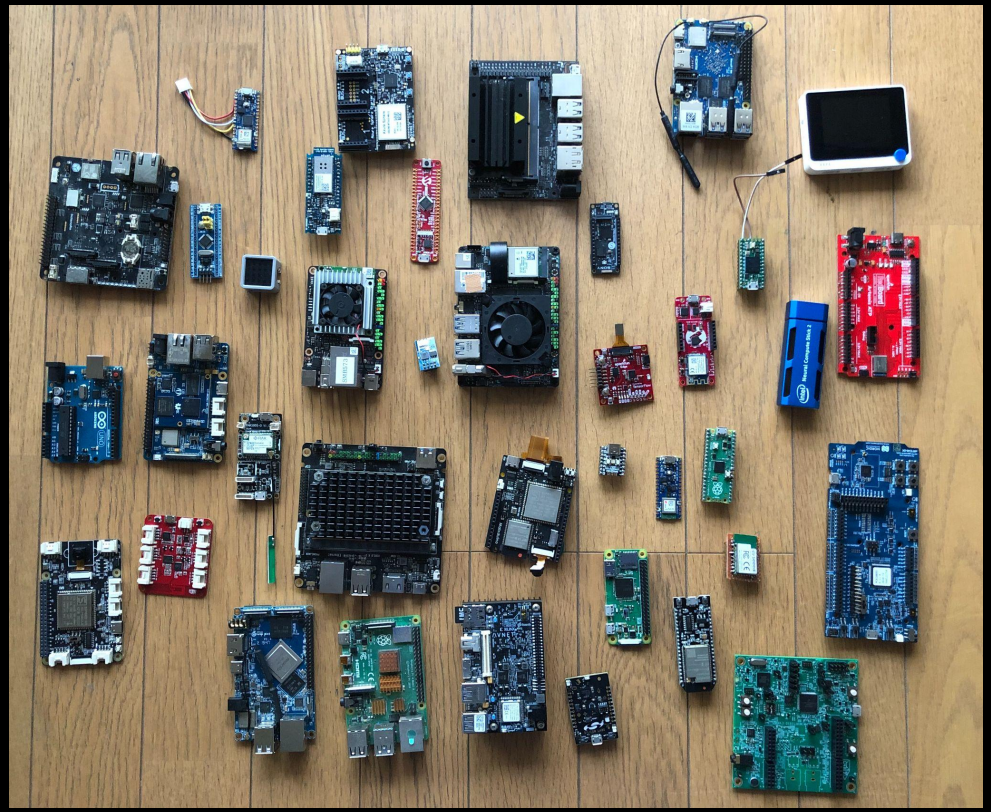
MACHINE LEARNING TOKYO

Example Use cases for Edge AI

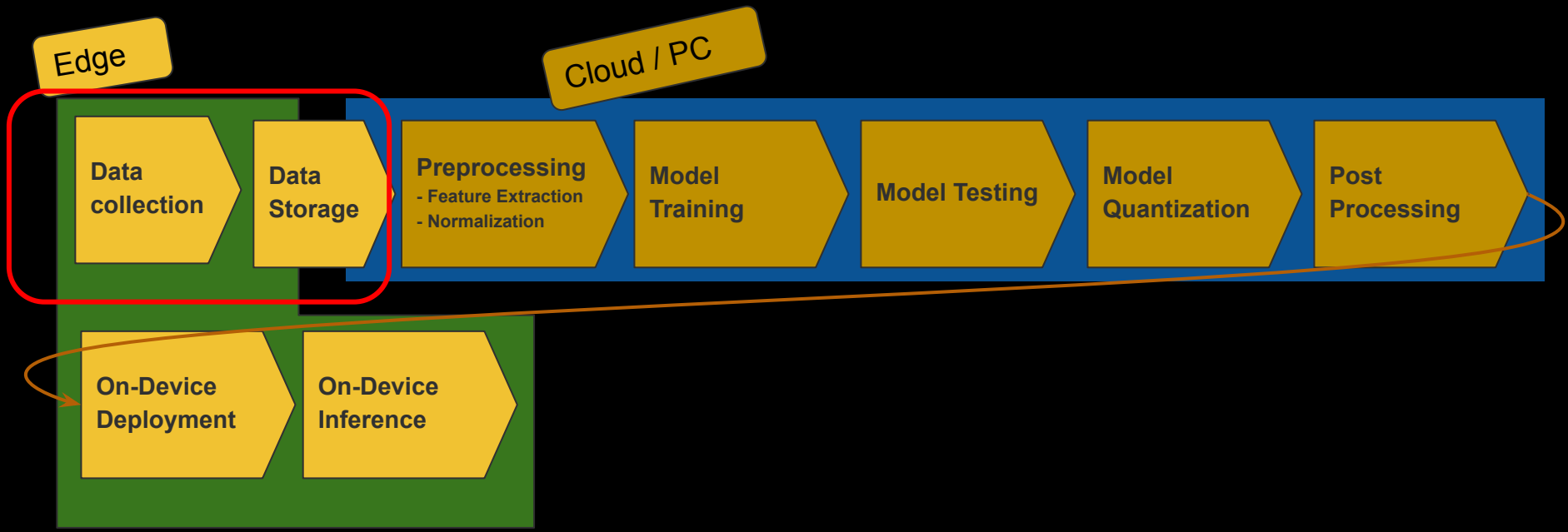
- ➔ Inertial Sensor/Environmental Sensor Analytics
  - ◆ Predictive Maintenance
  - ◆ Body Monitoring
- ➔ Audio Analytics
  - ◆ Audio Scene Classification
  - ◆ Audio Event Detection
  - ◆ Keyword Recognition
- ➔ Image Analytics
  - ◆ Surveillance and Monitoring
  - ◆ Autonomous Vehicles
  - ◆ Expression Analysis to improve shopping, advertising, or driving

Types of Edge Hardware Boards

- ➔ Bare-metal
- ➔ RTOS based
- ➔ Embedded Linux
- ➔ ML Accelerators (GPU/TPU)
- ➔ 16MHz to >1.5GHz
- ➔ 100mW to 10W
- ➔ 2KB to 8GB RAM



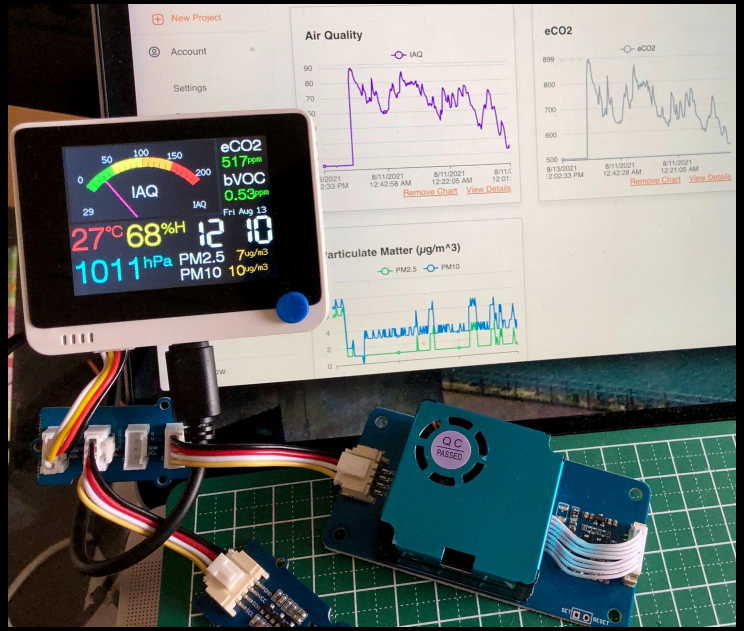
Blocks of Edge AI Pipeline



Data Collection and Storage

- ➔ Sensor Interfaces
  - ◆ I2C (Accelerometer)
  - ◆ SPI (Camera)
  - ◆ PDM/I2S (Audio)
  - ◆ UART (GPS)
  - ◆ Analogue (Light)
- ➔ Sampling rate
  - ◆ 40 ms or 25 Hz accelerometer data
  - ◆ 16 kHz audio data
- ➔ Sensor calibration
- ➔ Sensor fusion
- ➔ Time series/Non-time series

Collecting Particulate Matter and Environmental/Gas sensors data over I2C



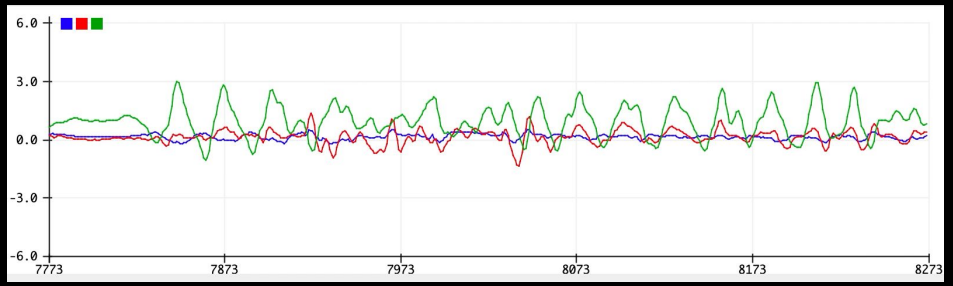
Data Collection and Storage

- Offline
  - Micro SD card
  - Flash Memory
  - SPI memory
- Online
  - Cloud
  - Local (Raspberry Pi)
- Hybrid
  - Store locally and upload to cloud when internet is available or batch update
- Low bandwidth communication protocol
  - LoRaWAN
  - LTE-M / NB-IoT
  - MQTT
  - BLE

Capturing thermal image over I2C into Micro SD card using Wio Terminal and far infrared thermal sensor (MLX90640).

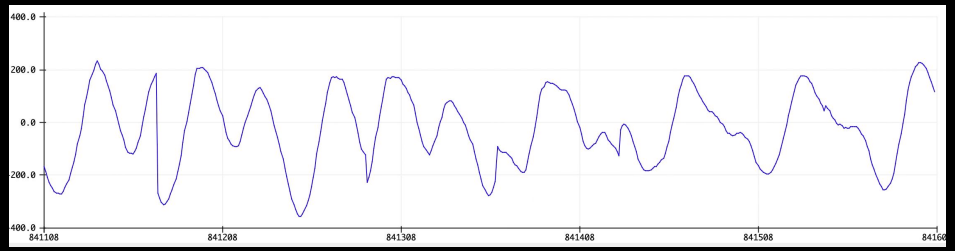
Real-time Sensors Data

Accelerometer (3-axis, sample rate: 119Hz)



X	Y	Z
0.34	0.10	3.74
0.26	0.38	3.68
0.22	0.60	3.54
0.14	0.77	3.22
0.06	085	2.68
-0.02	0.77	1.99

Microphone (PDM, sample rate: 16kHz, mono channel)



21,16,20,29,23,35,29,34,42,46,44,49,48,5
1,57,53,61,58,58,54,57,63,59,62,60,55,62
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53,58,54,56,58,59,59,-43,-25,-26,-40,-13,
-30,-28,-23,-31,-23,-21,-9,-12,-6

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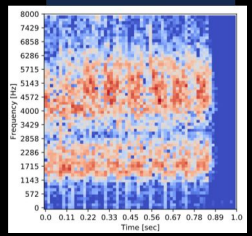
Digital Signal Processing/Feature extraction

- ➔ Scaling
- ➔ Filtering
- ➔ Normalization
- ➔ Flatten (Average, Min/Max, RMS, Standard deviation, Skewness/Kurtosis)
- ➔ Spectral Analysis (Accelerometer)
- ➔ Mel Frequency Cepstral Coefficients (Audio)
- ➔ Mel-filterbank energy (Audio)
- ➔ Spectrogram (Audio)

Raw Audio Data

Spectrogram



MACHINE LEARNING TOKYO

Model building

- ➔ TensorFlow Lite for Microcontrollers Arduino/C++ library
- ➔ Support for a limited subset of TensorFlow operations
- ➔ Not all model architectures are possible
- ➔ Must be small enough to fit within the target device's memory
- ➔ Model Size/complexity vs workload/duty cycle tradeoff
- ➔ Train model for 1 or 2 iterations to check model size/supported operations
- ➔ Convert to a TensorFlow Lite model using the TensorFlow Lite converter
- ➔ Convert to a C byte array to store it on device

Quantization

Most of the low-end edge devices have limited floating-point support so quantization is used.

Post-training quantization

- reduces model size
- improving CPU and hardware accelerator latency
- little degradation in model accuracy

Usually 8-bit quantization approximates floating point values using the following formula:

*real_value = (int8_value - zero_point) * scale*

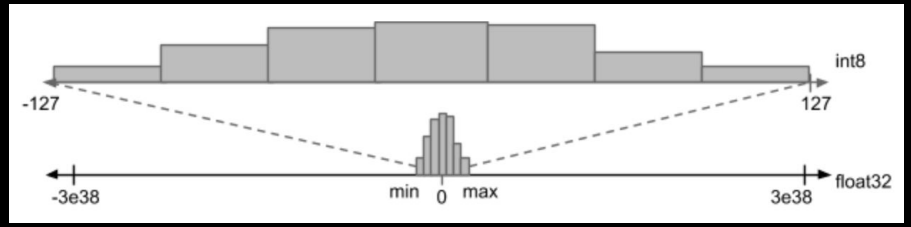
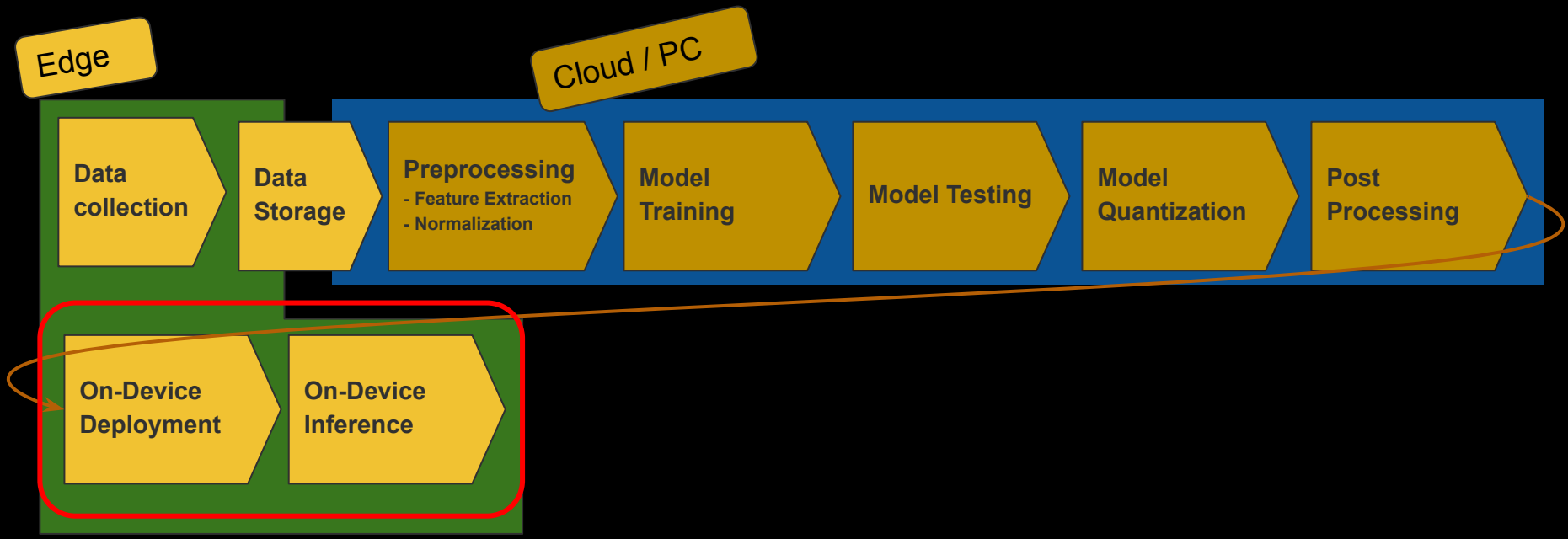


Image credit: tensorflow.org

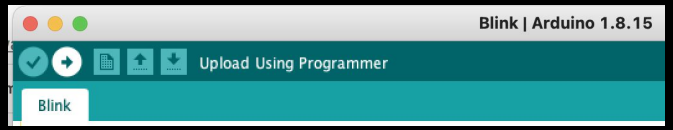
Blocks of Edge AI Pipeline

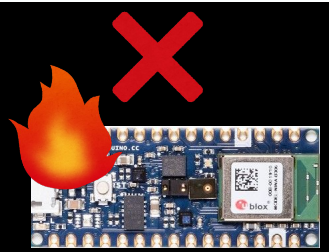


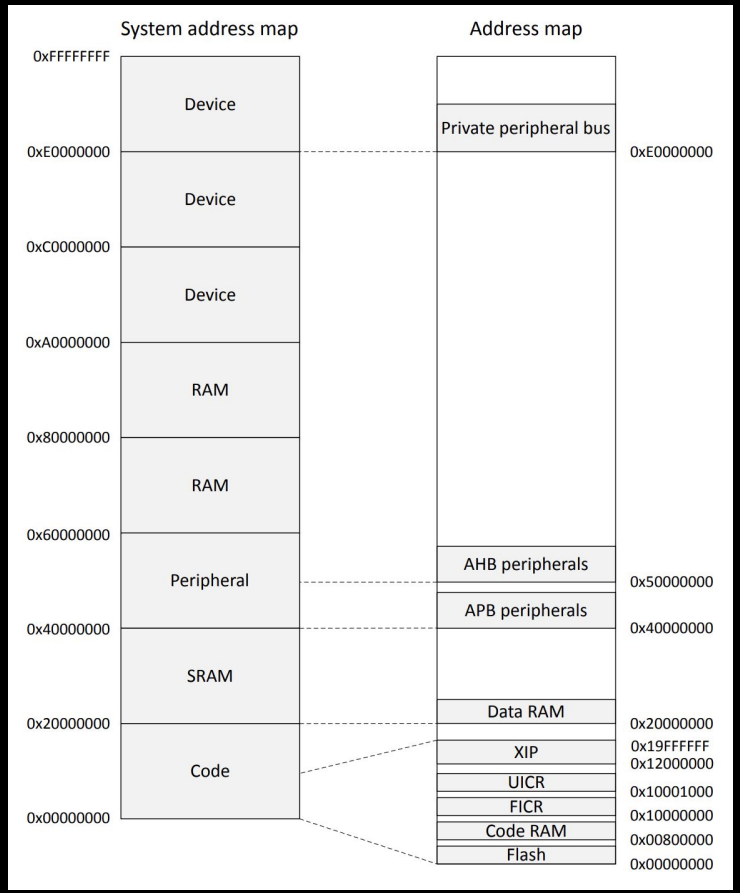
MACHINE LEARNING TOKYO

On-Device Deployment

- Inferencing optimization (CMSIS-DSP and CMSIS-NN on Arm Cortex M)
- Compile the firmware
- Burning (Uploading/Flashing) the compiled firmware image to target device







Ref: https://content.arduino.cc/assets/Nano_BLE_MCU-nRF52840_PS_v1.1.pdf

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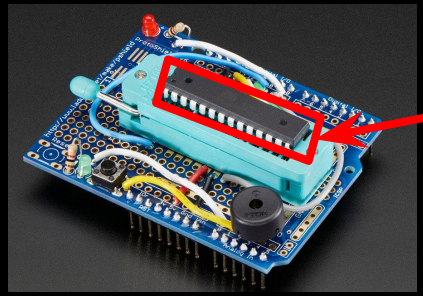
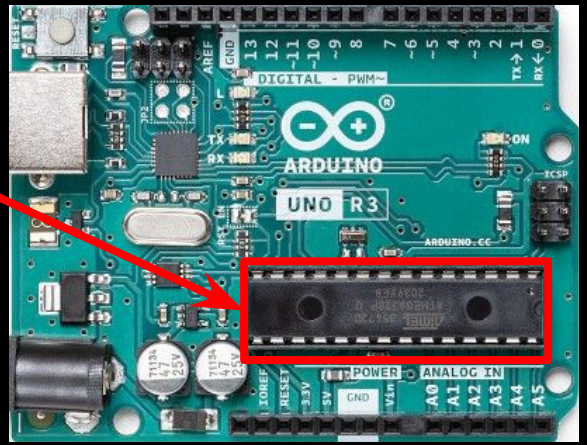
Microcontrollers

- ➔ Microcontrollers are typically small and low-powered, specialized computers, tasked with a single program
- ➔ Bridging the physical and digital worlds using electronic interfaces
- ➔ Ease of programming using modern tools

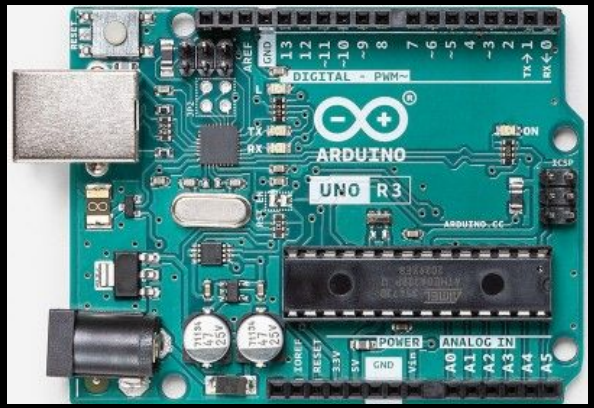


ATmega328P



Arduino

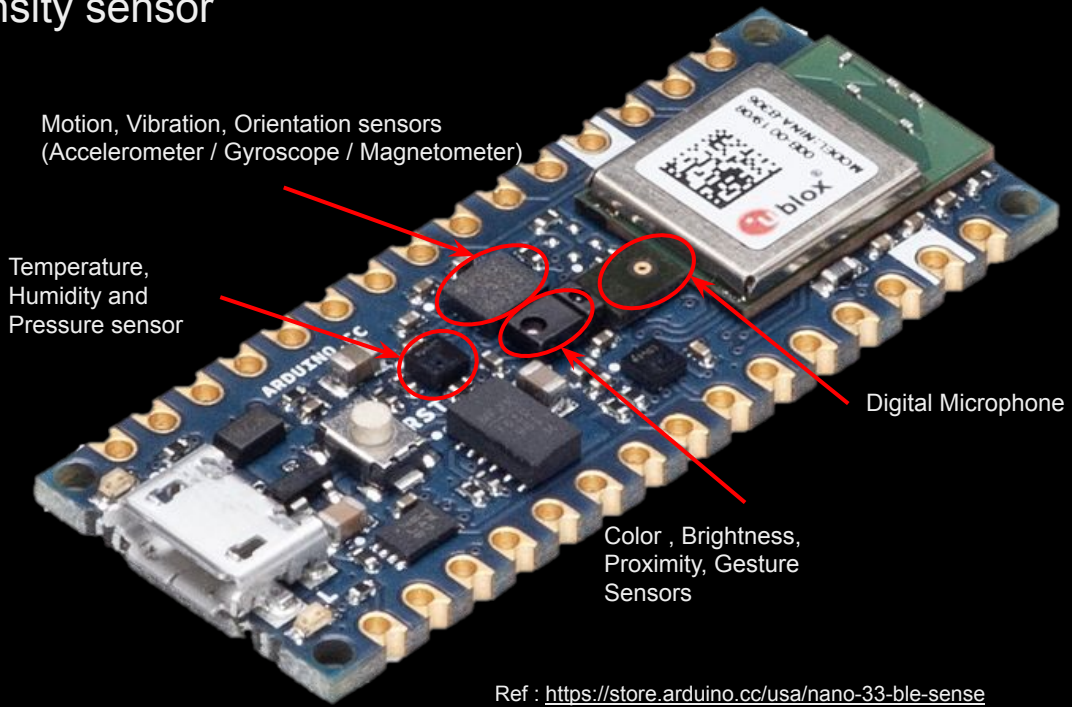
- ➔ Arduino was born in 2005 as a tool for fast prototyping, aimed at students without a background in electronics and programming.
- ➔ Open-source electronics platform based on easy-to-use hardware and software
- ➔ Large user community
- ➔ Cross platform IDE
- ➔ Many libraries available for common tasks



Ref :https://www.arduino.cc/

Arduino Nano BLE Sense Board

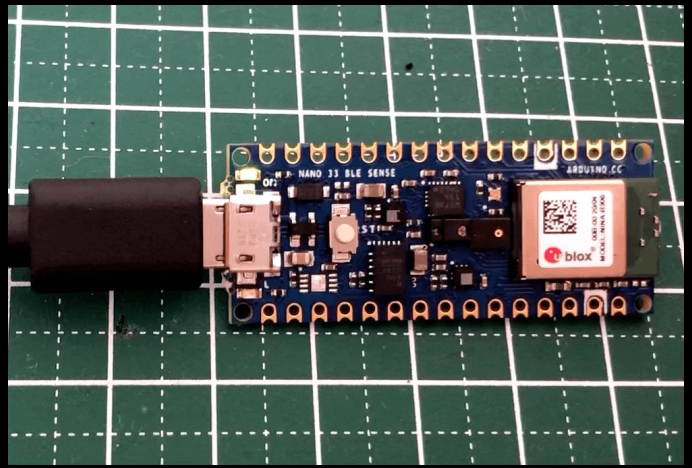
- ➔ 9 axis inertial sensor (accelerometer, gyroscope, magnetometer)
- ➔ Humidity, barometric pressure and temperature sensor
- ➔ Gesture, proximity, light color/intensity sensor
- ➔ Microphone
- ➔ Price ~30 USD / ~4000 JPY
- ➔ 64 MHz Clock Speed
- ➔ 1 MB Flash Memory
- ➔ 256KB SRAM



Ref : https://store.arduino.cc/usa/nano-33-ble-sense

Development Environment Setup

- ➔ Download and install Arduino IDE 1.8.15
- ➔ Install Arduino core (Nano 33 BLE Sense
- ➔ Run **Blink** example



Demo: On-Device data collection/inferencing

Brainstorming Session

- Breakout Rooms (Random Teams)
- Think of some edge AI applications, and figure out different blocks (15 min)
- Summarize and share your ideas by 1-2 members from the team.(2min)
- Will share the team whiteboard on slack after the session to continue discussion for ideas

WhiteBoards for Brainstorming

Team1:
https://app.mural.co/t/mltedgeailab3396/m/mltedgeailab3396/1629004925401/f3018a40dd38481a19ebd438080e4fd81d7ab410?sender=u95ce3da66ee17f1954ba5414

Team 2:
https://app.mural.co/t/mltedgeailab3396/m/mltedgeailab3396/1629005197838/c71484addd603e0de284da41e7329682aafea500?sender=u95ce3da66ee17f1954ba5414

Team 3:
https://app.mural.co/t/mltedgeailab3396/m/mltedgeailab3396/1629005207313/cfdd36833f34ff6db2cd9aaa5c2b76043c947933?sender=u95ce3da66ee17f1954ba5414

Team 4:
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Team 5:
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https://machinelearningtokyo.slack.com

Next Session

- ➔ Session #2 : Motion Based Application using IMU on Aug 29 (5:00 PM - 6:00 PM JST)
  - ◆ Will be announced soon on MLT Meetup page.