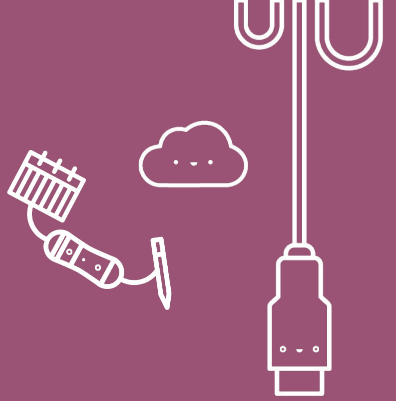
Tiny machine learning

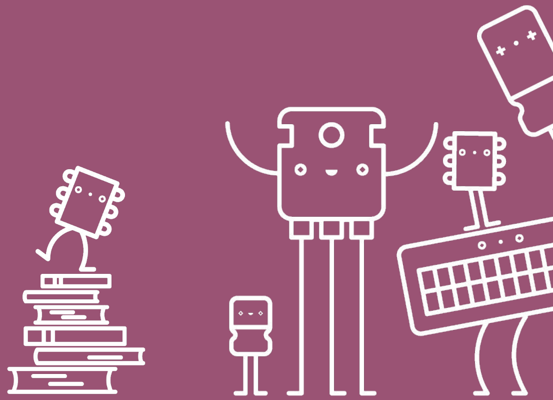
Arduino Education

June 23rd 2021

Agenda

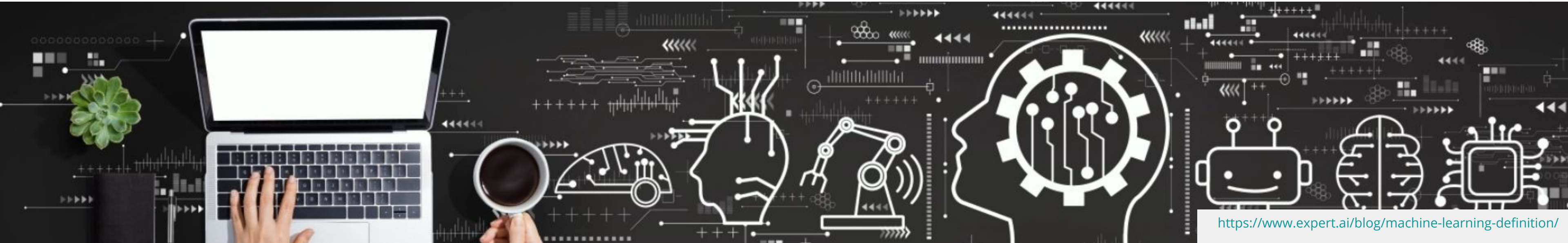
- What is Machine Learning
- Applications
- Tiny Machine learning
- Tiny Machine learning kit
- Examples





Machine Learning

- Day to day tasks like scrolling through social media, taking a picture, checking the weather, all depend on machine learning models.
- **Machine learning** is a subset of AI.
- Machines take data and 'learn' for themselves.
- Machine learning systems can quickly apply knowledge and **training** from large datasets to excel at **facial recognition, speech recognition, object recognition, translation, and many other tasks.**
- Machine learning allows a system to **learn to recognize patterns on its own and make predictions**, contrary to hand-coding a software program with specific instructions to complete a task.



https://www.expert.ai/blog/machine-learning-definition/

Machine Learning

- It started from games.
- Computers were trained to play games for example checkers with humans.
- The term *machine learning* was coined in 1959 by Arthur Samuel, pioneer in the field of computer gaming and artificial intelligence.
- Blue an IBM computer beat world chess champion Garry Kasparov in 1996.

Photograph: Stan Honda/AFP/Getty Images

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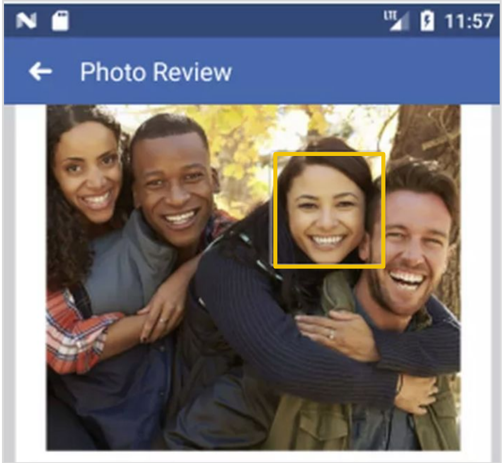
Machine Learning applications for everyday life

- Fraud detection
- Online recommender systems
- Google search algorithms
- The self-driving cars
- Face recognition



https://www.cnet.com/news/

Why to learn ML?

Retail

- Predictive inventory planning
- Recommendation engines
- Market segmentation & targeting

Healthcare

- Alerts & diagnosis from real time patient data
- Disease identification
- Proactive health management

Travel & transportation

- Aircraft scheduling
- Customer complaint resolution
- Traffic patterns
- Safety monitoring
- Dynamic pricing

Financial services

- Risk analytics
- Sales & marketing campaign management
- Customer segmentation
- Fraud detection

Energy

- Power usage analytics
- Energy demand & supply administration
- Smart grid management

Manufacturing

- Predictive maintenance
- Propensity to buy
- Demand forecasting
- Process optimization

Challenges of Machine Learning

Machine Learning allows a computer to internalize concepts found in data to form predictions for new situations.

Training these models are computationally expensive.

Running inference on these models are computationally expensive as well.

We need computing systems that are fast enough to handle it.

Most of these models run on huge data centres with clusters of CPUs and GPUs

To reach reliable levels of accuracy, models require large datasets to 'learn' from.

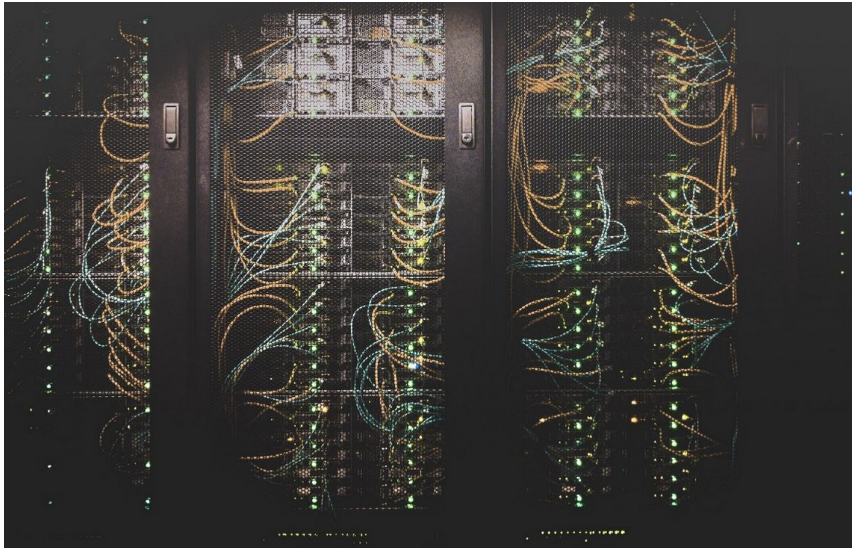
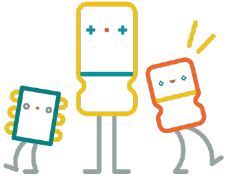


Photo by Taylor Vick on Unsplash



Challenges of Machine Learning

When you take a picture, you want the machine learning magic to happen instantly.

In this case, you we would want the machine learning model to run locally.

When you say “Alexa” or “Ok, Google”, you want your devices **to respond to instantly.**

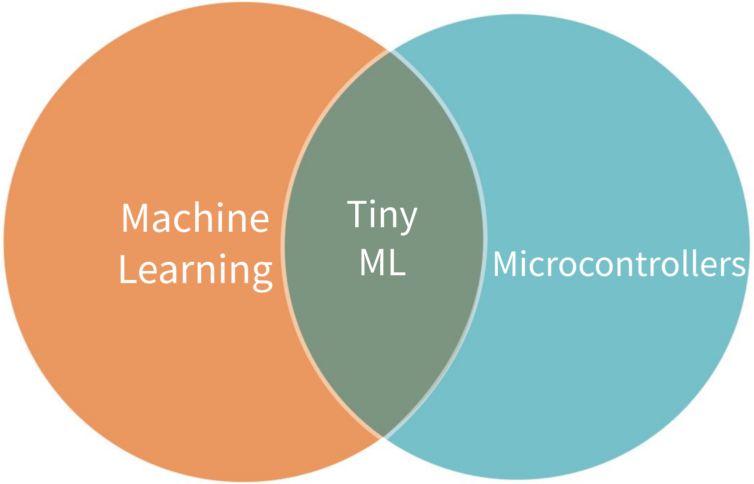
1. **Energy**: Efficiency issues / large data centers of computers
2. **Privacy & data acquisition:** Machine Learning requires massive data sets to train on, and these should be inclusive/unbiased, and of good quality
3. **Latency:** Send the data up and down takes time
4. **Reliability:** What happen if the network is down

Tiny machine learning

Tiny Machine Learning

Collaboration of machine learning and embedded ultra-low power internet of things devices that explores the types of models you can run on small, low-powered devices like microcontrollers.

The philosophy of TinyML is doing more on the device with less resources – in smaller form-factors, less energy and lower cost.



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Advantages of Tiny Machine Learning

1. **Low Power Consumption:** Microcontrollers consume very little power. This enables them to run without being charged for a really long time.

2. **Low Latency:** Since the model runs on the edge, the data doesn't have to be sent to a server to run inference. This reduces the latency of the output.

3. **Low Bandwidth:** As the data doesn’t have to be sent to the server constantly, less internet bandwidth is used.

4. **Privacy:** Since the model is running on the edge, your data is not stored in any servers (privacy by design)

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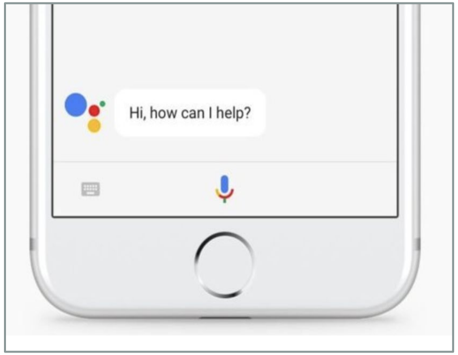
Tiny machine learning

Tiny ML started with Ok google.
Ok google it is a machine learning model that runs on all of our phones, does not run on a big data centre.
It runs in the single processing little chip that is always on.

How they do that?
TinyML is focused on **inferencing**, we want a response to an event coming in.
The training of this model, the million of voices and keywords to distinguish between the phrases, happens somewhere in the cloud, but the final inference can happen on this small devices.



What do we need?

1. **Hardware:**

   Arduino Nano 33 BLE Sense
   It provides enough power to run TinyML models. It has a colour, brightness, proximity, gesture, motion, vibration, orientation, temperature, humidity, and pressure sensors. It also contains a digital microphone and a Bluetooth low energy(BLE) module.

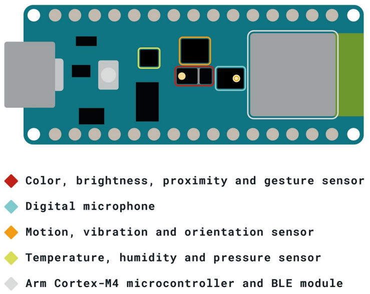
2. **Software - Framework**

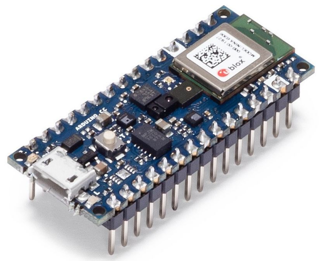
   TensorFlow Lite is the most popular and has the most community support. Using TensorFlow Lite Micro, we can deploy models on microcontrollers.

   Arduino IDE: There is an arduino library available for TensorFlow Lite, on the Nano 33 BLE Sense
   It comes with 4 examples showing how to run speech, accelerometer and image machine learning on a microcontroller.

3. **Resources**

   Since TinyML is an emerging field, there aren't many learning materials as of today. Harvard University's Course on TinyML by Vijay Janapa Reddi





TensorFlow

Arduino content NOT included

TINY Machine Learning KIT

- Arduino Nano 33 BLE Sense
  that sense movement, acceleration, rotation, temperature, humidity, barometric pressure, sounds, gestures, proximity, color, and light intensity.
- A camera module (OV7675)
- Custom Arduino shield to attach your components and create unique TinyML projects.
- University students can use the kit to explore practical ML use cases using classical algorithms as well as deep neural networks powered by TensorFlow Lite Micro.

TINY Machine Learning KIT

Arduino content NOT included

COURSE 1

- Understand what machine learning (ML) Is
- Deep learning and embedded machine learning
- Understand neural networks
- Background responsibilities and Real Examples

COURSE 2

- Train your device using your own datasets
- Using external training models for your project
- Basics of AI, real user cases and scenarios
- Know and play with some of the most used technics
- Real world industry applications

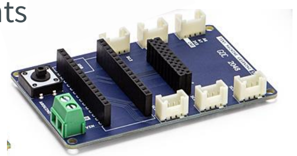
COURSE 3

- Hardware basics
- Code your own projects with TinyML
- Train your TinyML device
- Deploy, test, and correct your TinyML projects

Arduino Nano 33 BLE Sense

- Senses: movement, acceleration, rotation, temperature, humidity, barometric pressure, sounds, gestures, proximity, color, and light intensity.

Custom Arduino shield to attach your components



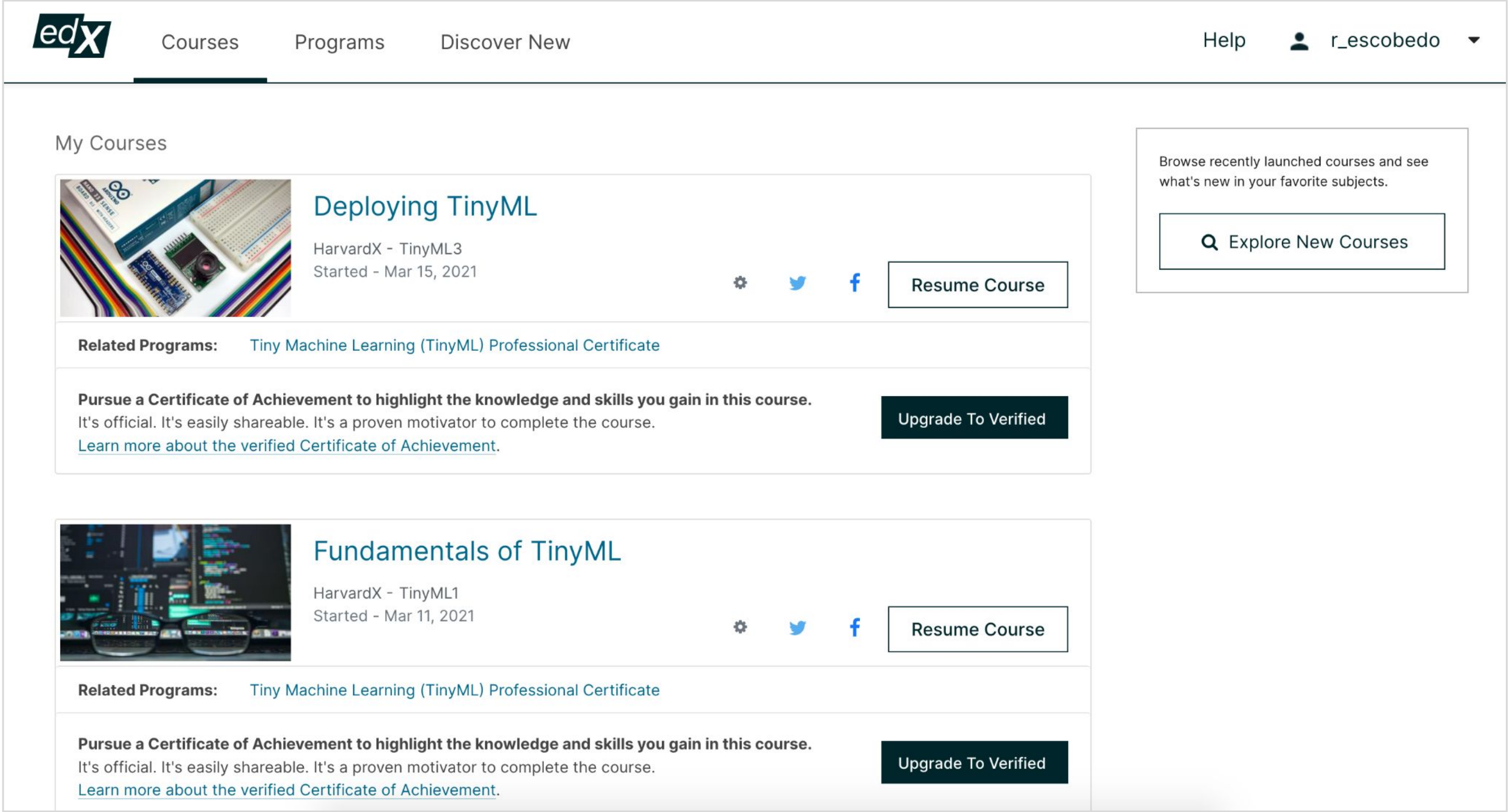
Camera module (OV7675)

Arduino IDE
Tensor Flow
Google Colab

External content:

- There is **NO Arduino content** for this kit
- Use the freely available content & courses from **Harvard University at EdX**

edX: Tiny machine learning course



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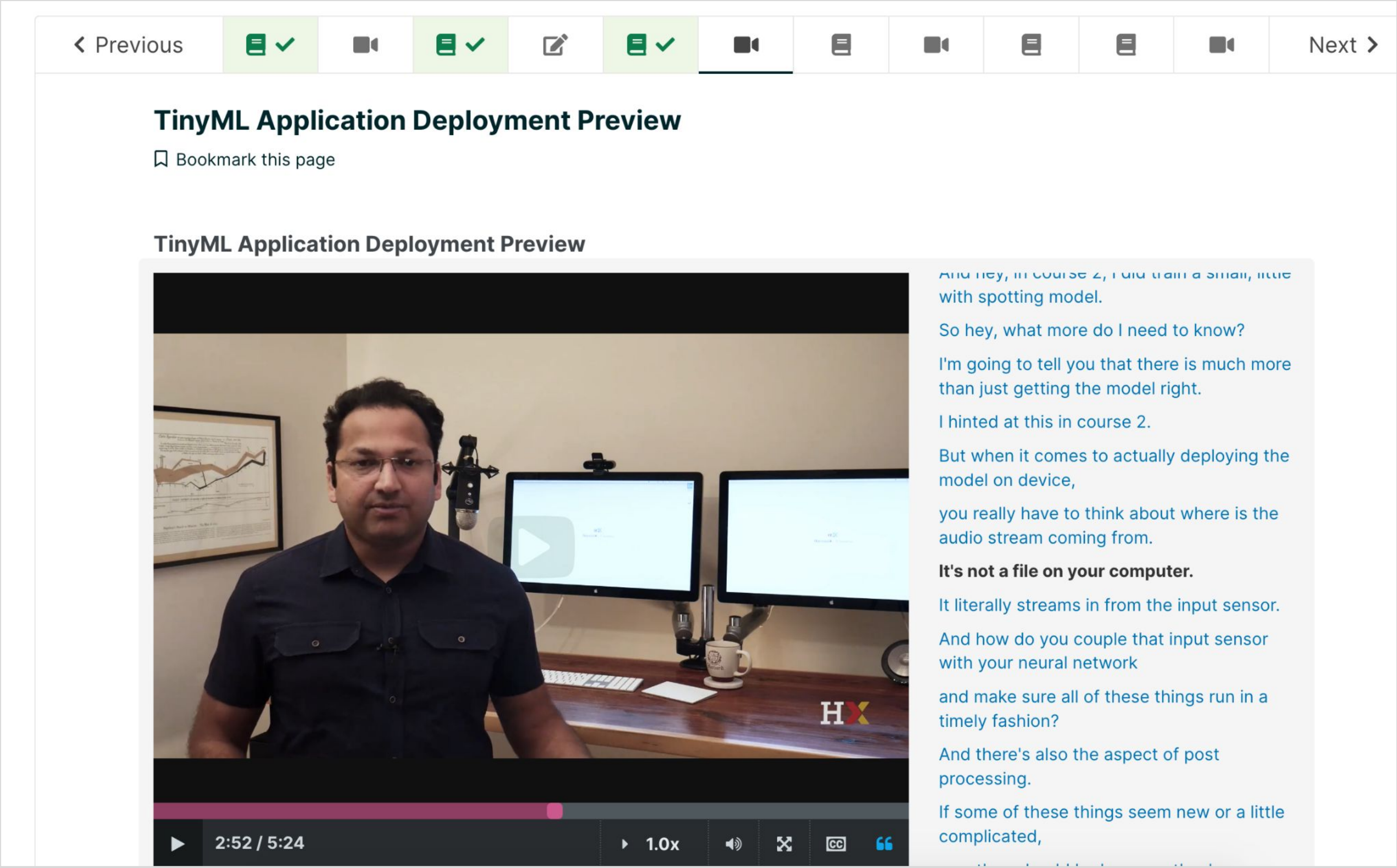
edX: Tiny machine learning course



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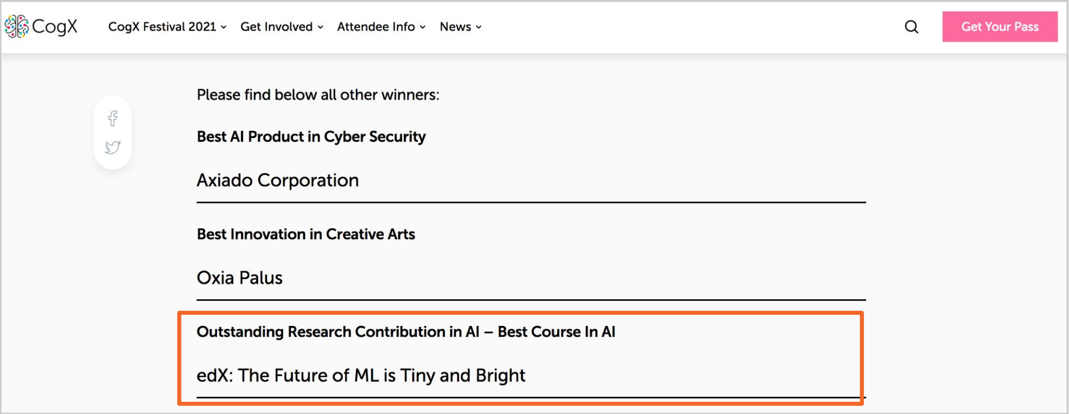
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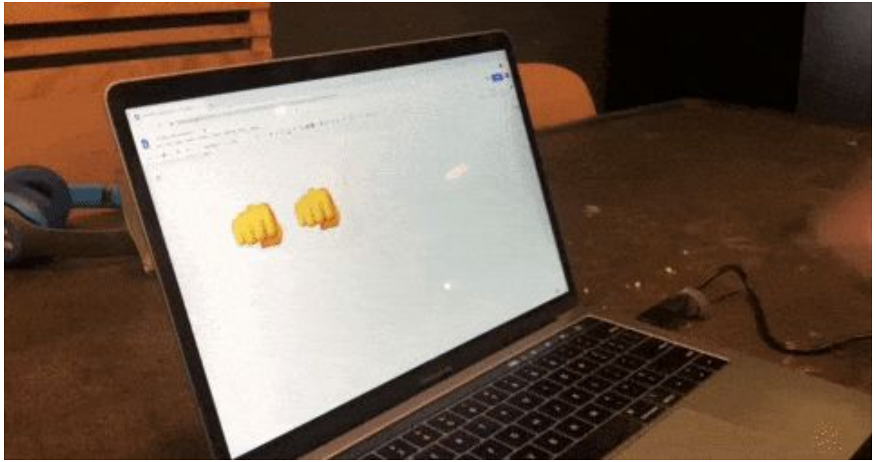
Tiny machine learning

Examples with Arduino

Tiny machine learning examples

Fruit identification using Arduino and TensorFlow

TensorFlow Lite Micro library and the Arduino Nano 33 BLE Sense's colorimeter and proximity sensor to classify objects



Gesture classification

Training your own gesture classification model, output as emojis

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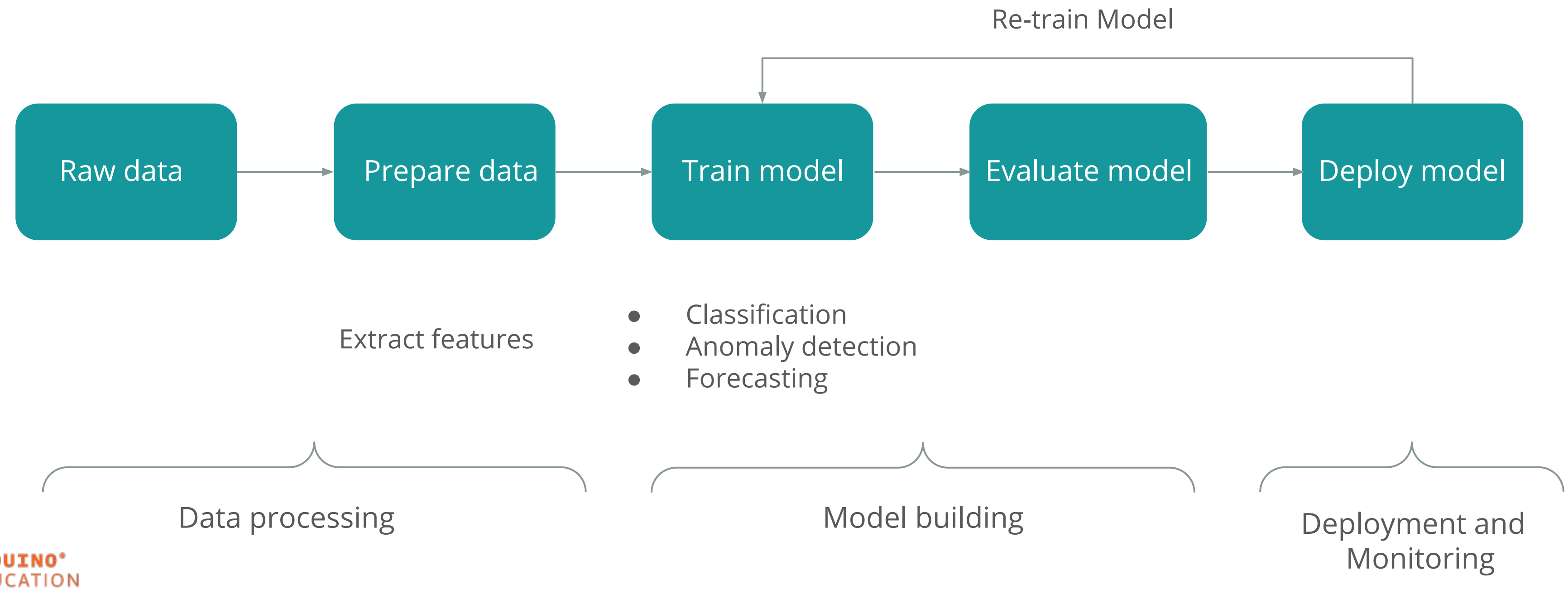
Tiny machine workflow



Gesture classification

The objective of the project is to **create a virtual keyboard** that turns a **gesture into an emoji.**

What you need: Nano Ble 33 sense, Arduino IDE, Tensorflow and Jupiter notebook.

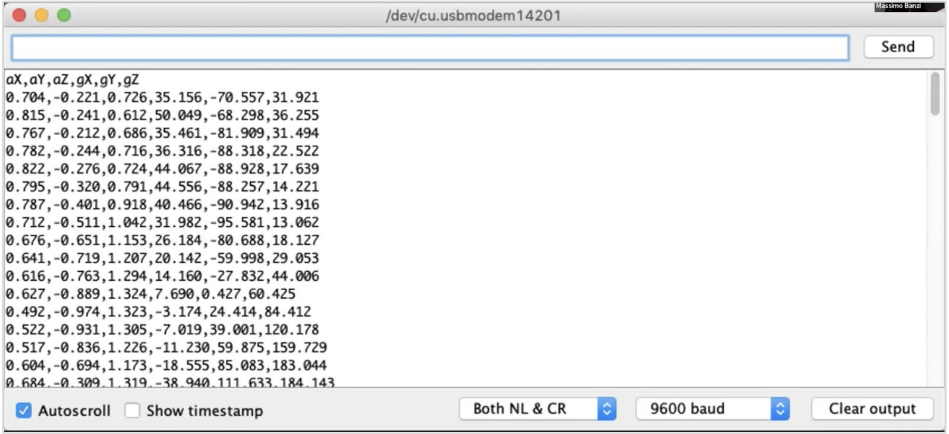
-Open the Arduino IDE

-Go to Sketches/IMU_Capture/IMU_Capture.ino

-We will get data from the gyroscope

-Compile the sketch and upload to the board

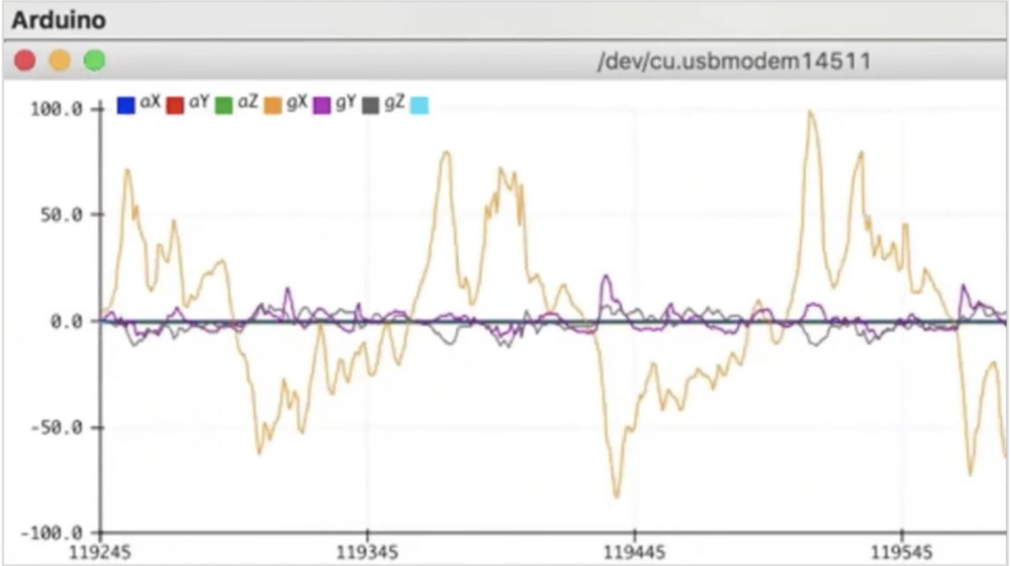
-Open the serial monitor



Gesture classification

-We can also get the data in from of a graph in real time

- if we use the serial plotter on the Arduino IDE



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Gesture classification

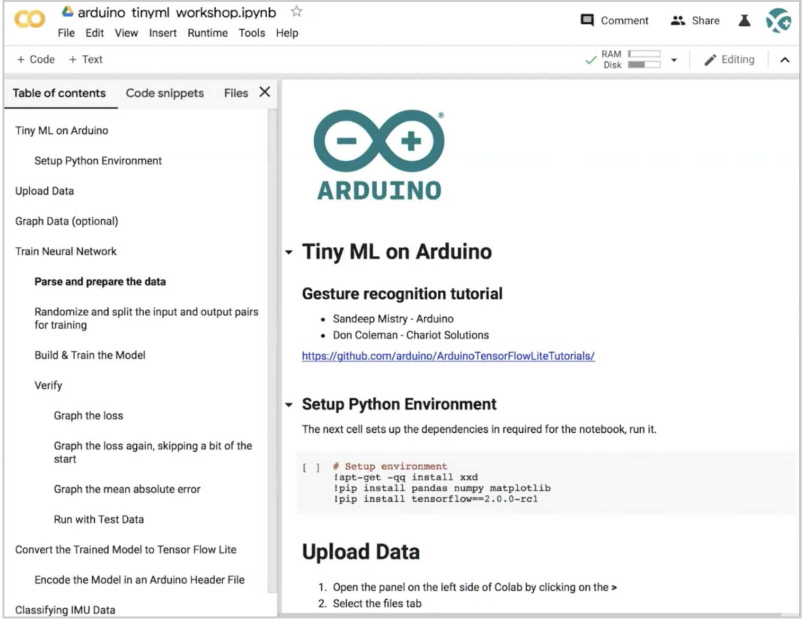
With the board in our hand we do the punch and flex gesture 10 times

We copy that info and create 2 csv files: one for punch and other for flex

Go to a Jupyter notebook, hosted on google colab

You can go through the code that does all the training and also the snipet of code that takes the model generated by tensorflow and gets the file converted into a “ .h” file for Arduino.

There is a section on the notebook where you can drag your two files. And then you get the model.h



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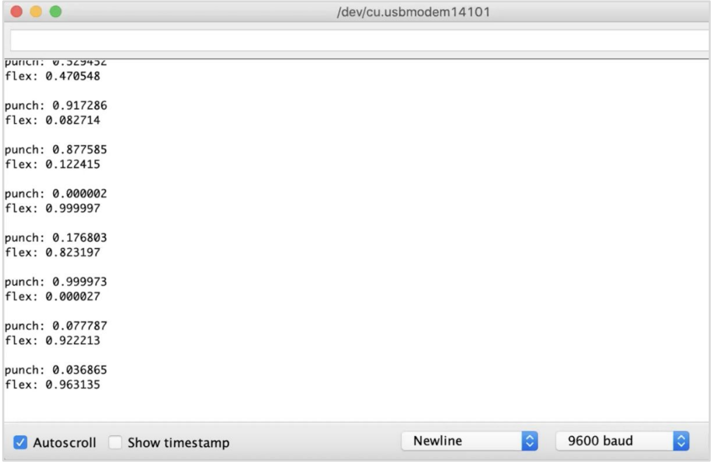
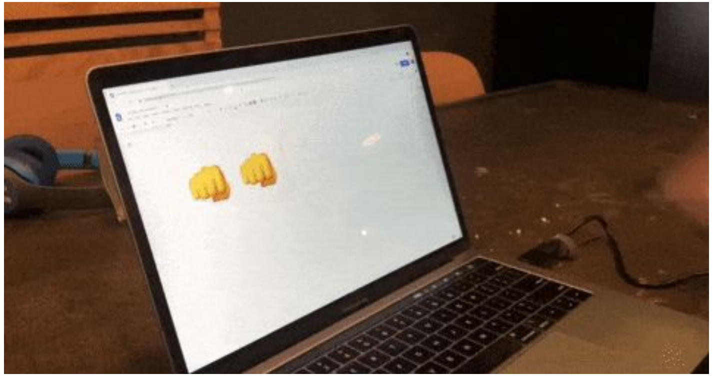
Gesture classification

You go to the IDE, there is another example called IMU classifier paste the model.h files from google and you will see this on the serial monitor which the level of confidence of each gesture.

Practical use of this example:

Someone with disability could operate an equipment with gestures





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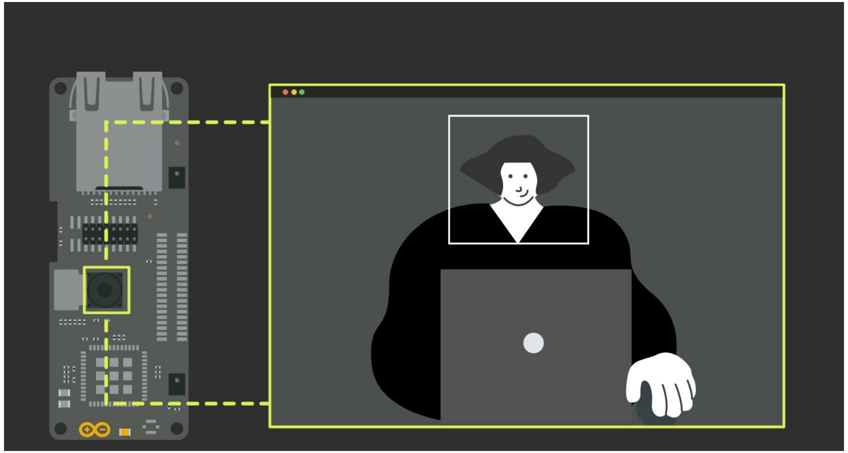
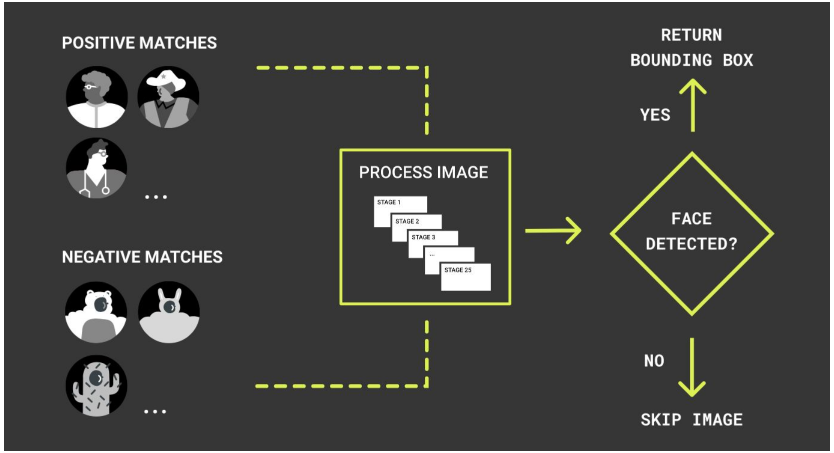
Tiny machine Learning example - Portenta



Creating a Basic Face Filter With OpenMV editor

In this tutorial you will build a MicroPython application with OpenMV that uses the Portenta Vision Shield to detect faces and overlay them with a custom bitmap image.



The Haar Cascade Algorithm

Algorithms can be trained to detect the desired type of object.

Tiny Machine Learning applications

[Epilet]

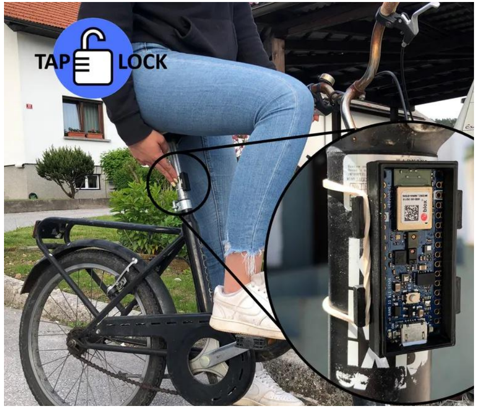
TinyML-powered bracelet for detecting epileptic seizures

[TapLock]

Uses tinyML on Arduino to protect your bike from thieves

[PUPPI]

A tiny, portable, edge ML device ready to interpret a dog's mood based on vocal signals.



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Arduino Tiny machine learning

Coming soon

What do you need to get started?

- **ML theory:** Knowing the basics of ML theory will give you a foundation to build on, and help you troubleshoot when something goes wrong.

- **Coding skills:** Building ML requires coding in order to do the data management, parameter tuning, and parsing results needed to test and optimize your model.

- **Math and stats:** ML is a math heavy discipline, so if you plan to modify ML models or build new ones from scratch, familiarity with the underlying math concepts is crucial to the process.

Build your own projects: Getting hands on experience with ML is the best way to put the concepts learned to the test.

Arduino Education

Enabling anyone to innovate by making complex technologies simple to use.

Arduino Tiny Machine Learning Kit

Research:

-Interview with teachers, experts on the field.

-Needs, content, learning approach.

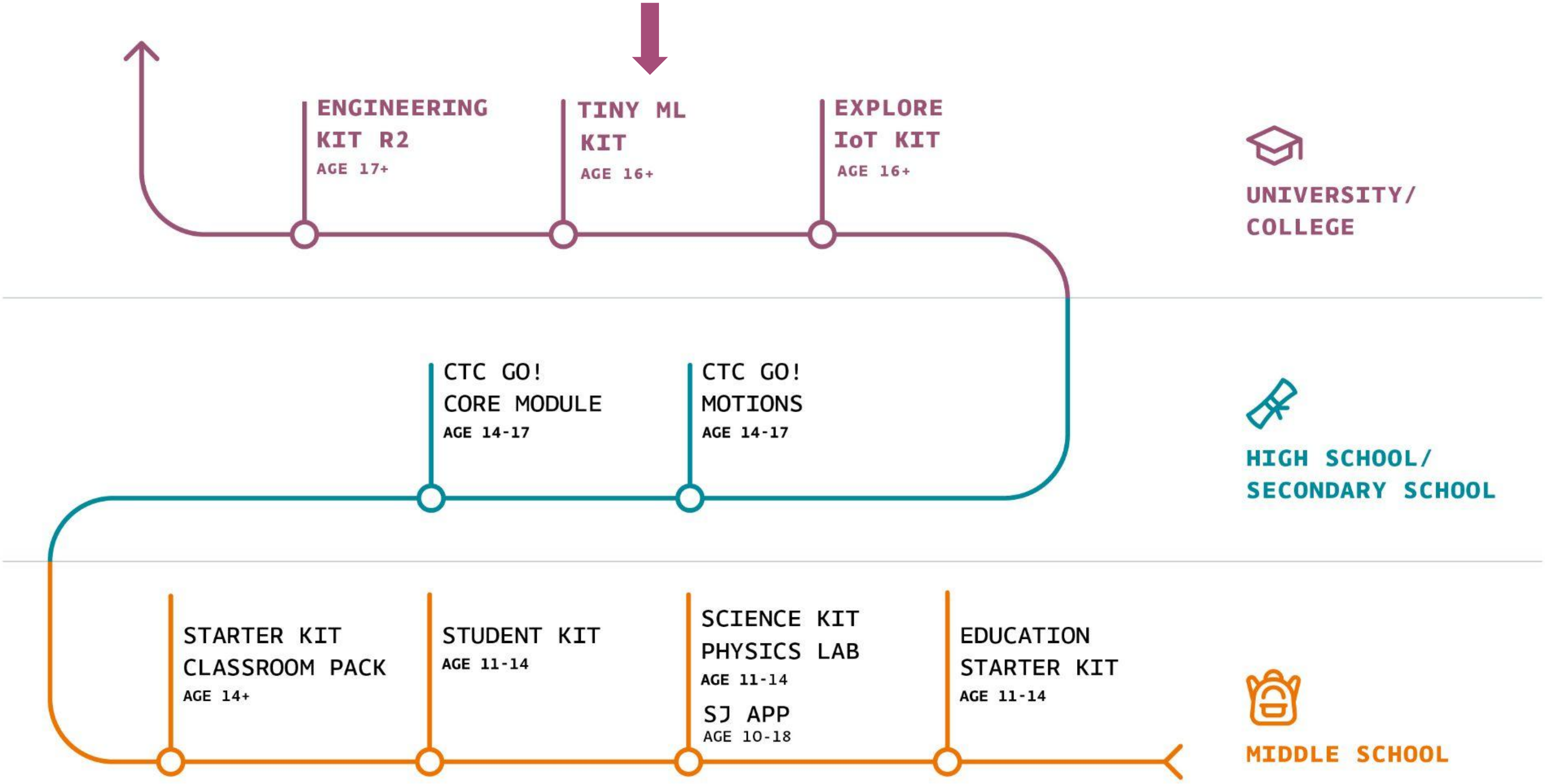
-University students / High School   17+

-Arduino Content & libraries to learn the core concepts of machine learning

-Software

-Hardware

-Step by step activities and projects



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Thank you!