IESTI01 - TinyML

About the Course & Syllabus

Prof. Marcelo Rovai

April 28th, 2021

Dear students,

Welcome to the first class of the IESTI01 (TinyML) course. I am Professor Marcelo Rovai, a former student here at UNIFEI, and I am pleased to be with you this semester.

IESTI01 is a discipline that mixes Machine Learning (part of Artificial Intelligence) with small devices, such as microcontrollers and sensors, whose main characteristics are ultra-low power consumption, 32-bit CPUs, and a few kilobytes of memory.

We understand that the explosive growth of the Machine Learning field, the ease of use of software development platforms such as TensorFlow (TF), based on the Python language and the current generation of powerful microcontrollers, make TinyML an indispensable topic of study for Engineering students in the areas of Electronics, as well as Computing and Control & Automation.

This mix of expertise and the pioneering nature of this type of discipline (we are the second university worldwide to have this type of course, being Harvard School of Engineering the first) leads us to significant challenges concerning the necessary basis for the minimum understanding of the matter. Thus, it is essential to emphasize that the time we have available for the course is short. So, We must commit ourselves to do our utmost in class and with complementary activities such as readings, laboratories, and assignments. You can count on me outside the hours of the weekly classes to clarify doubts and to review the necessary concepts for a good understanding of the course.

Saludos from the south of the world!

Prof. Marcelo Rovai

Who I am

Marcelo José Rovai

- I am a Brazilian from São Paulo, Data Science Master's degree by UDD, Chile, and MBA by IBMEC (INSPER), Brazil.
- I graduated in 1982 as an Engineer from UNIFEI with Specialization from Poli/USP, both in Brazil.
- I worked as a teacher, engineer, and executive in several technology companies such as AVIBRAS Aeroespacial, SID Informática, ATT-GIS, NCR, DELL, COMPAQ (HP), and more recently at IGT, where I continue as a Senior Advisor for Latin America.
- I write about electronics, publishing my works in sites as MJRoBot.org (Editor/Writer), Hackster.io (#1 Contributor), Instructables.com, and Medium.com (TDS – Towards Data Science).

Course Overview

What is Tiny Machine Learning (TinyML)?

Tiny machine learning (TinyML) is a **fast-growing field of machine learning** technologies and applications including **algorithms, hardware, and software** capable of performing **on-device sensor data analytics** at **extremely low power consumption**, typically in the mW range and below, and hence enabling a variety of **always-on ML use-cases** on **battery-operated devices**.

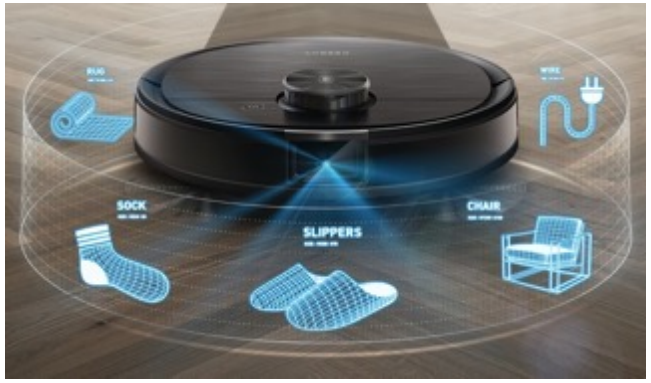
Applications: EdgeML & TinyML

Autonomous Car Control

KeyWord Spotting

Environmental Control

Image Recognition



Motion & biometric

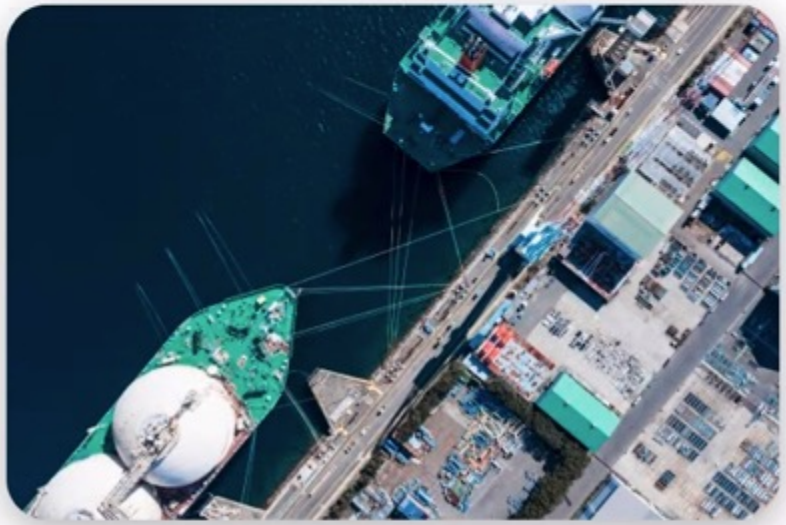
Image Spot

Predictive Maintenance

Motion, current, audio and camera

- ➔ Industrial
- ➔ White goods
- ➔ Infrastructure
- ➔ Automotive

Asset Tracking & Monitoring



Motion, temp, humidity, position, audio and camera

- ➔ Logistics
- ➔ Infrastructure
- ➔ Buildings

Human & Animal Sensing

Motion, radar, audio, PPG, ECG

- ➔ Health
- ➔ Consumer
- ➔ Industrial

EDGE IMPULSE

ElephantEdge

Building The World's Most Advanced **Wildlife Tracker**.

smart parks · hackster.io · EDGE IMPULSE · Microsoft · Western Digital. · NORDIC SEMICONDUCTOR · TAOGLAS · u-blox · WWF · EARTHRANGER

Source: https://wildlabs.net/resources/competition/challenge-elephantedge

ElephantEdge

Risk Monitoring

"Know when an elephant is moving into a high-risk area and send real-time notifications to park rangers."

Conflict Monitoring

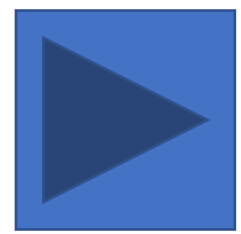
"Sense and alert when an elephant is heading into an area where farmers live."

Activity Monitoring

"Classify the general behavior of the elephant, such as when it is drinking, eating, sleeping, etc."

Communication Monitoring

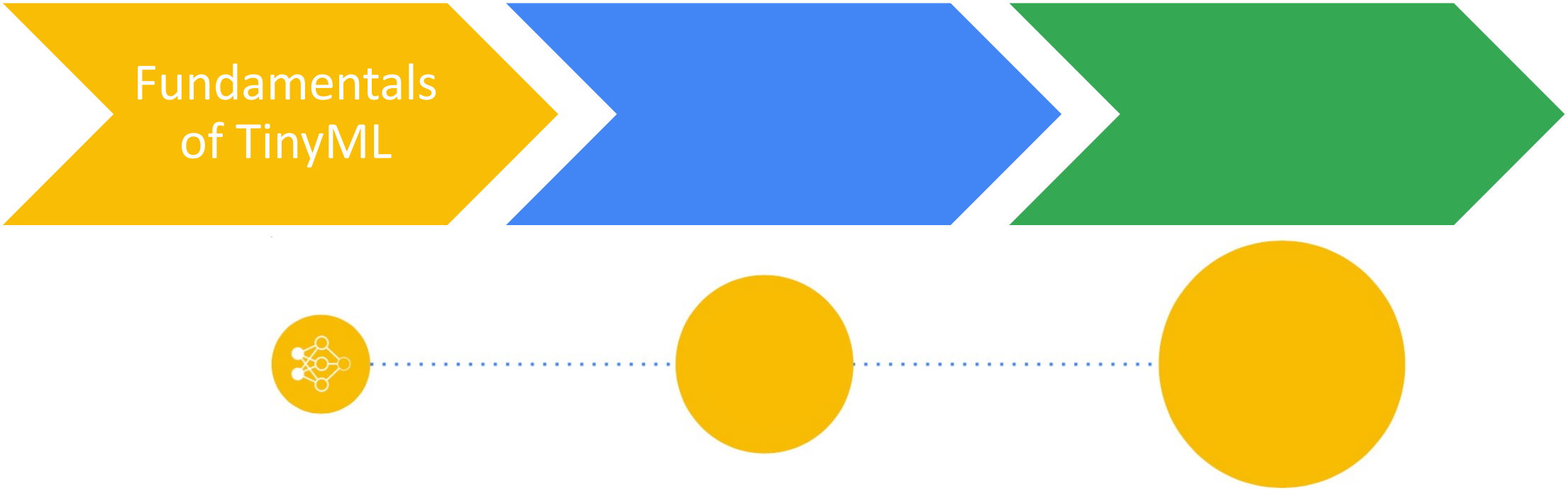
"Listen for vocal communications between elephants via the onboard microphone."



ElephantEdge

What we will learn?

April/May

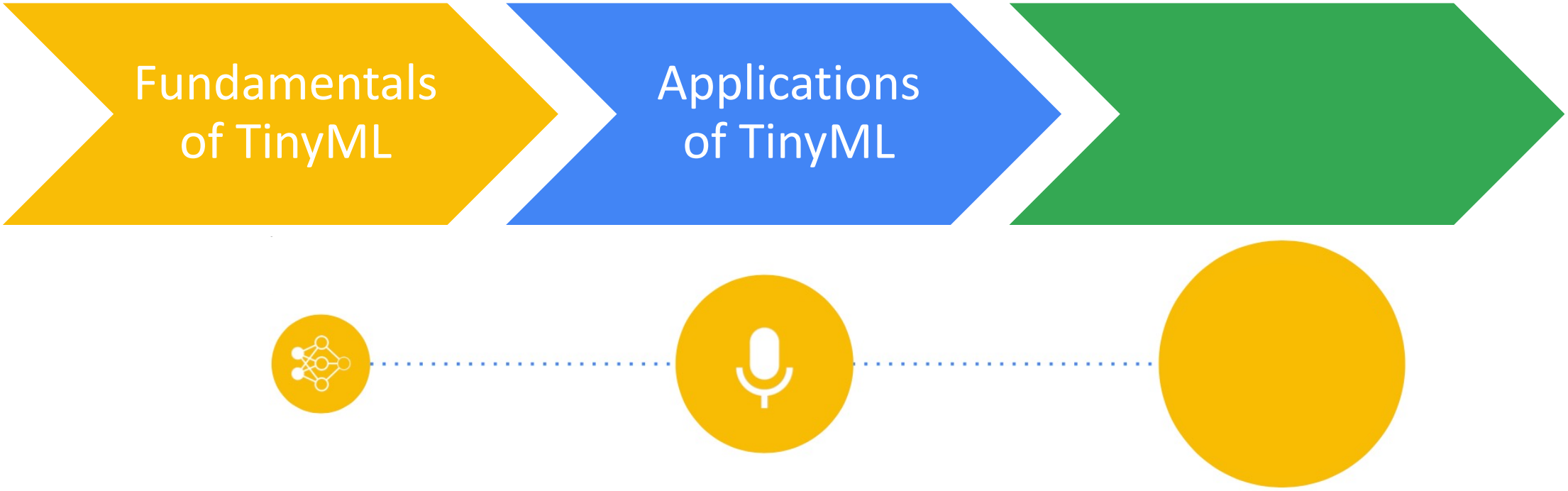


In April and May (Part 1) is all about talking about what is the language of machine learning

What we will learn?

April/May

June



In June (Part 2), We will get a sneak peek into the variety of different TinyML applications, as keyword spotting (“Alexa”), gesture recognition, understand how to leverage the sensors, and so forth.

What we will learn?

April/May

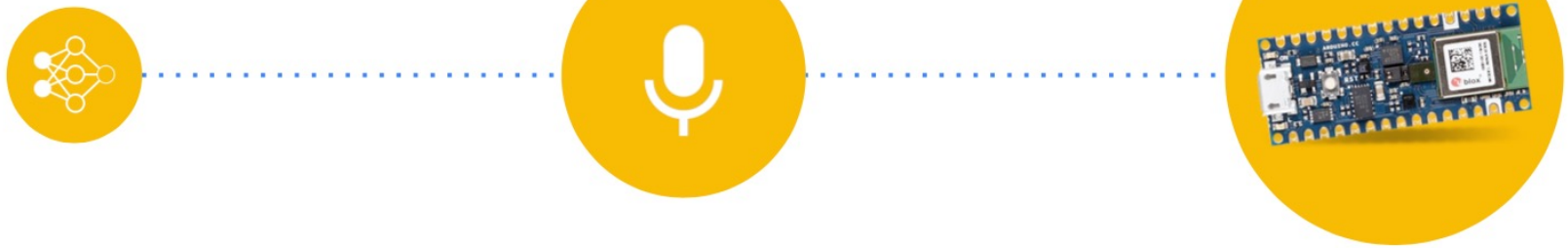
Fundamentals of TinyML

June

Applications of TinyML

July/August

Deploying TinyML



In July and August (Part 3), We will learn how to deploy models on a real microcontroller. Along the way we will explore the challenges unique to and amplified by TinyML (e.g., preprocessing, post-processing, dealing with resource constraints).

Background Requirements

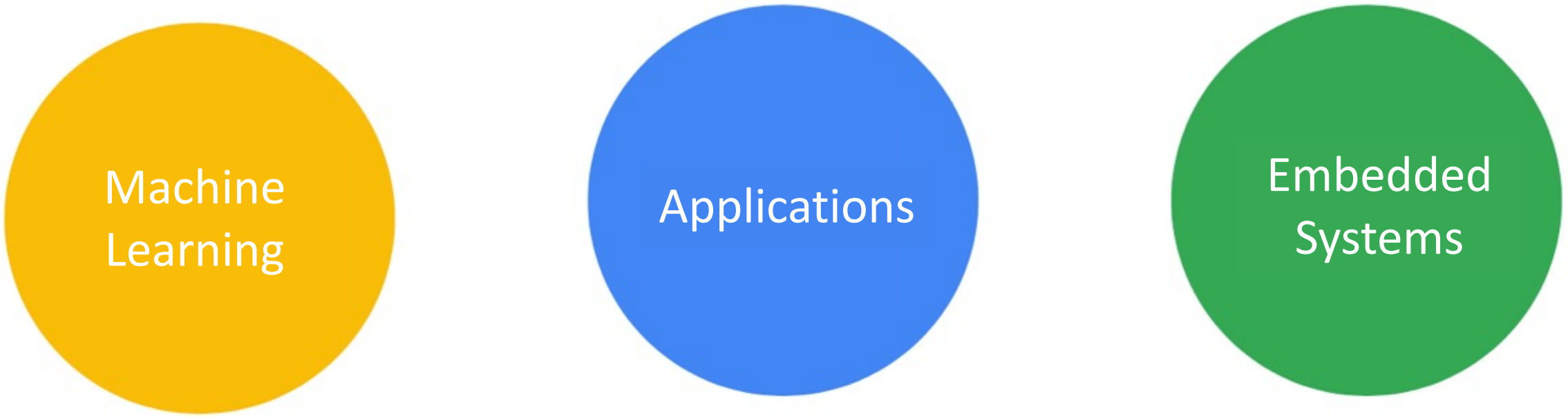
- Python
- Google Colab
- Jupyter Notebook

- Python
- Google Colab
- Jupyter Notebook
- Edge Impulse Studio

- Python
- Google Colab
- Jupyter Notebook
- Edge Impulse Studio
- IDE (as Arduino)
- C/C++

This course combines **computer science** with **engineering** to feature real-world application case studies that examine the challenges facing **TinyML deployments**.

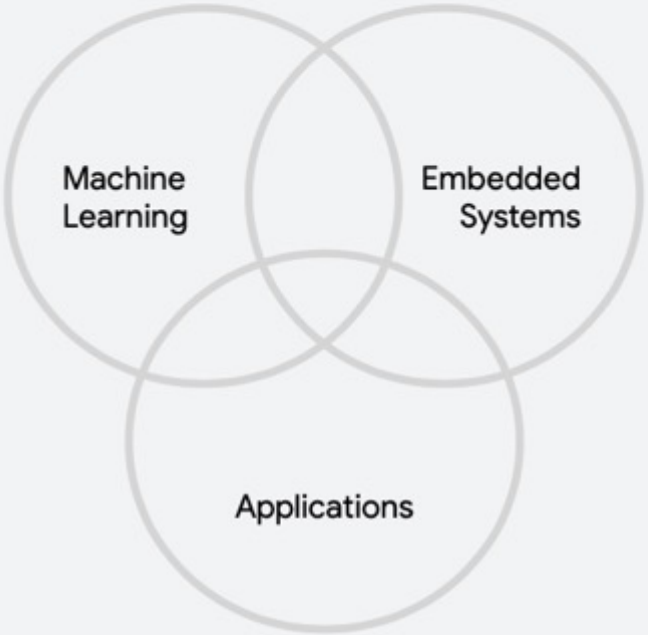
What areas we will learn?



We will learn the **fundamentals of each of these areas**, just enough to focus on the ultimate goal of being able to build TinyML applications.

Interactions

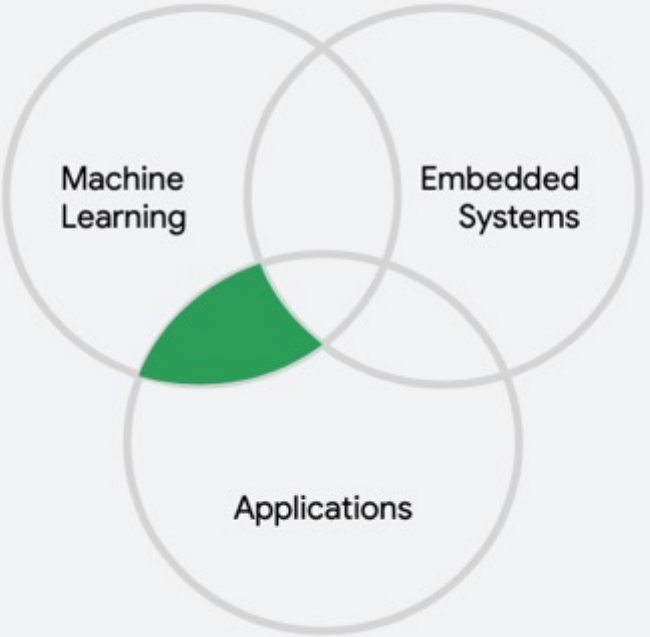
In addition, we will bring these diverse topics together to reveal the interesting learnings at the various **intersections**



Interactions

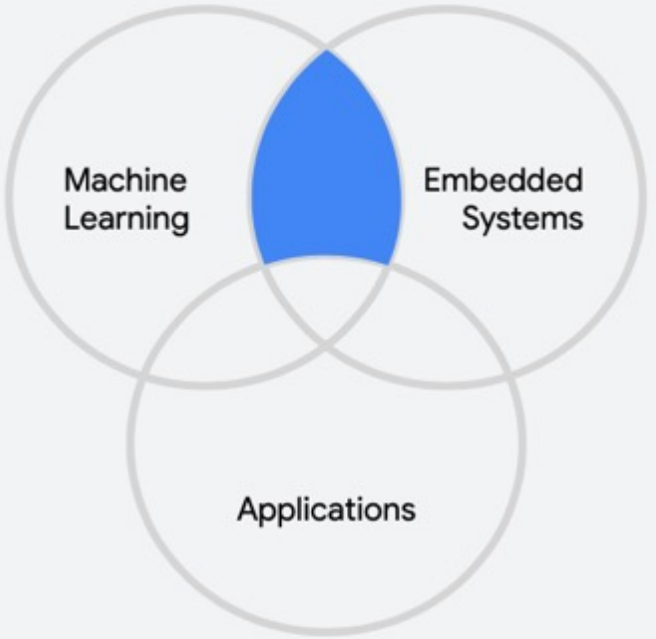
How **machine learning** can enable new and interesting **TinyML applications**?

Source: https://wildlabs.net/resources/competition/challenge-elephantedge



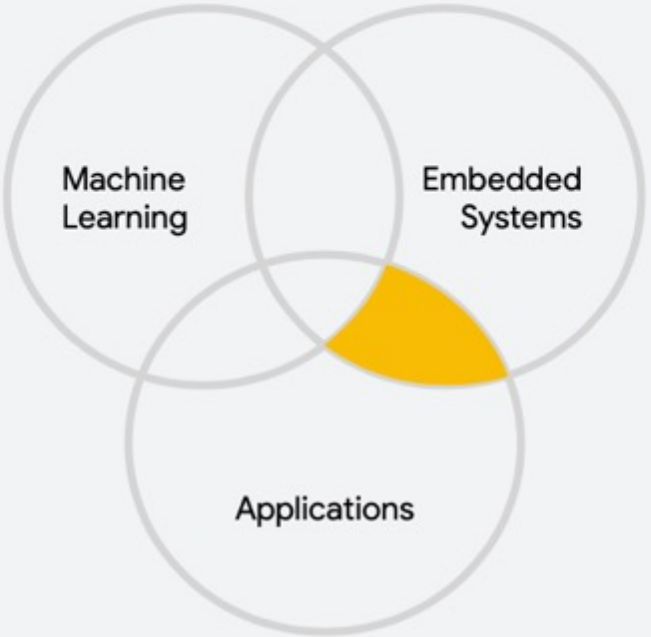
Interactions

What are the **challenges** with enabling **machine learning** on **tiny**, resource-constrained **embedded devices**?



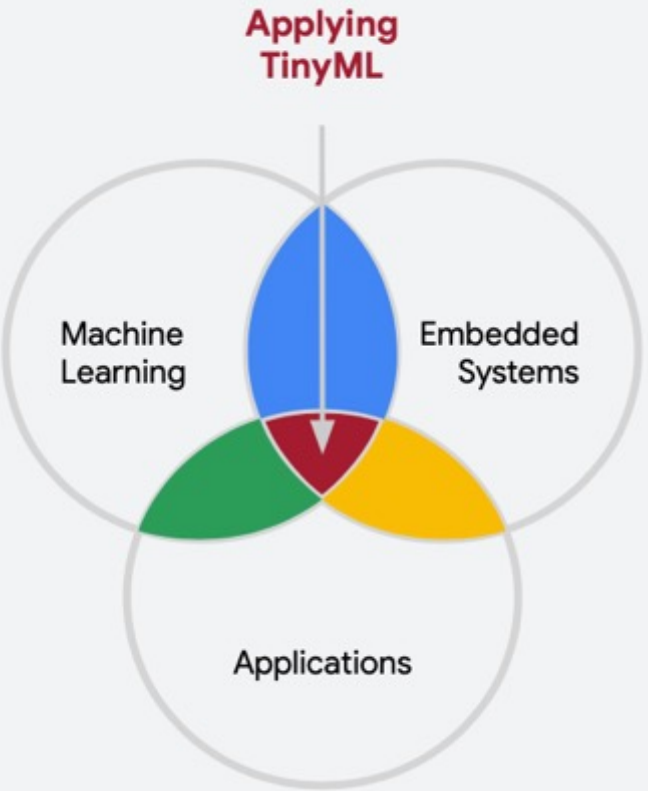
Interactions

What type of new **use cases** can we possibly enable on **embedded systems** that we could not otherwise do before?



At the End of the Day

Given your understanding of things at these various intersections, you will have a deep understanding for **how to apply TinyML**



How are we going to get there?

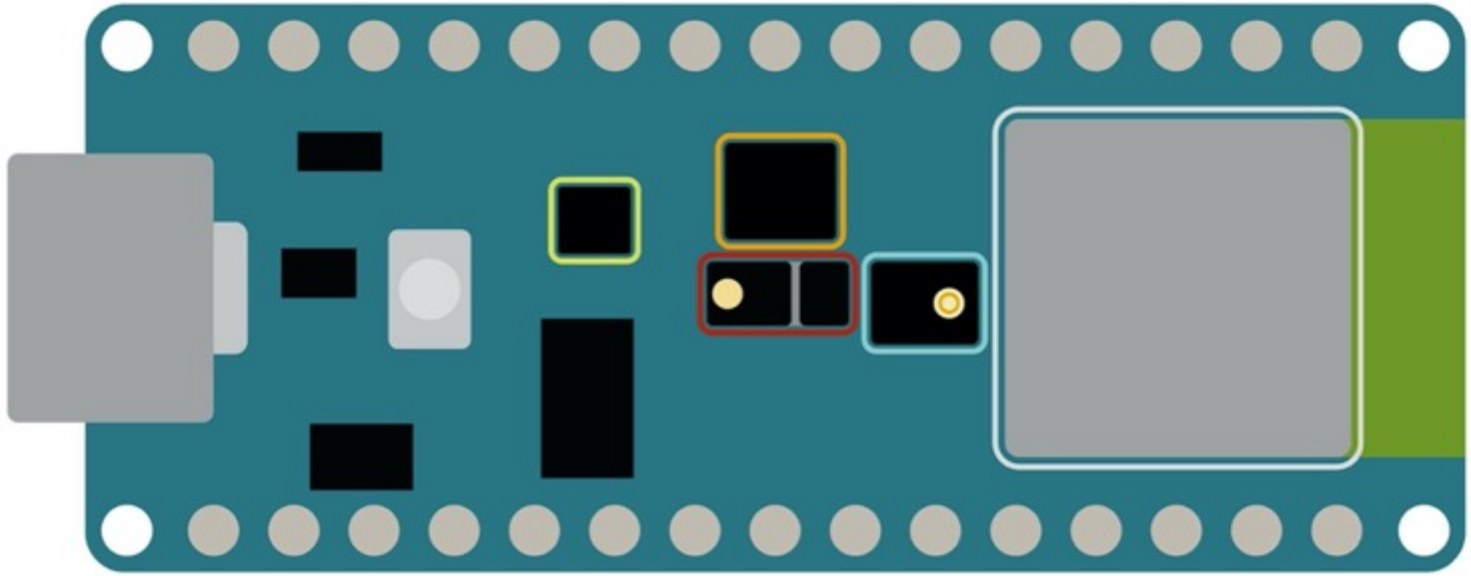
Hands-on Learning

- Software
  - Machine Learning (TensorFlow)
  - Programming environments (Jupyter and Colab)
  - Edge Impulse Studio
- Hardware (Part 3)
  - Arduino 33BLE Sense
  - Sensors

TinyML Kit


ARDUINO
TINY MACHINE
LEARNING KIT
In partnership with:
edX
TensorFlow
OV7675

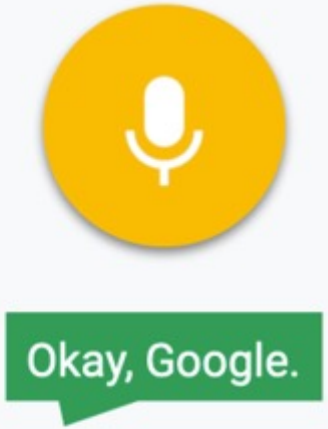
Nano 33 BLE SENSE



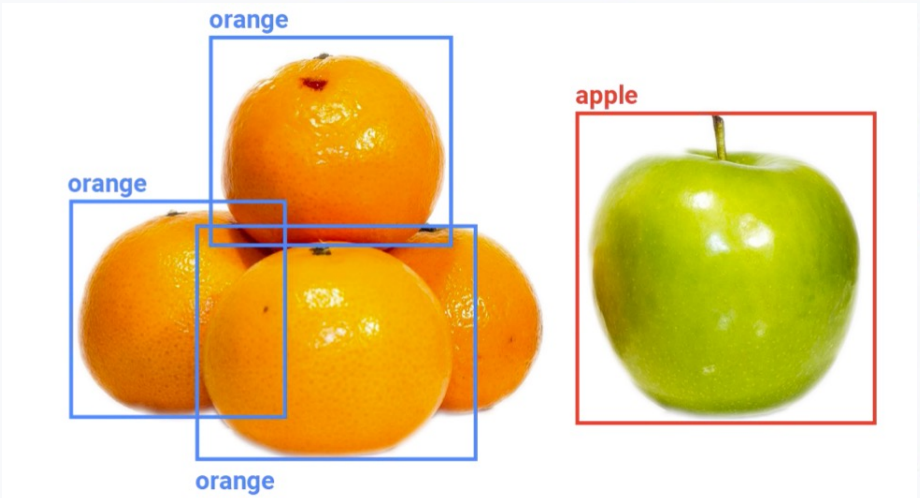
- Color, brightness, proximity and gesture sensor
- Digital microphone
- Motion, vibration and orientation sensor
- Temperature, humidity and pressure sensor
- Arm Cortex-M4 microcontroller and BLE module

Hands-on Activity (Part 1 & 2)

Speech



Vision

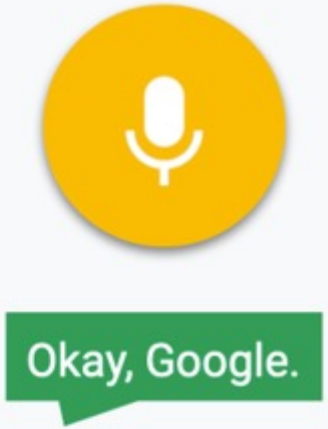


IMU

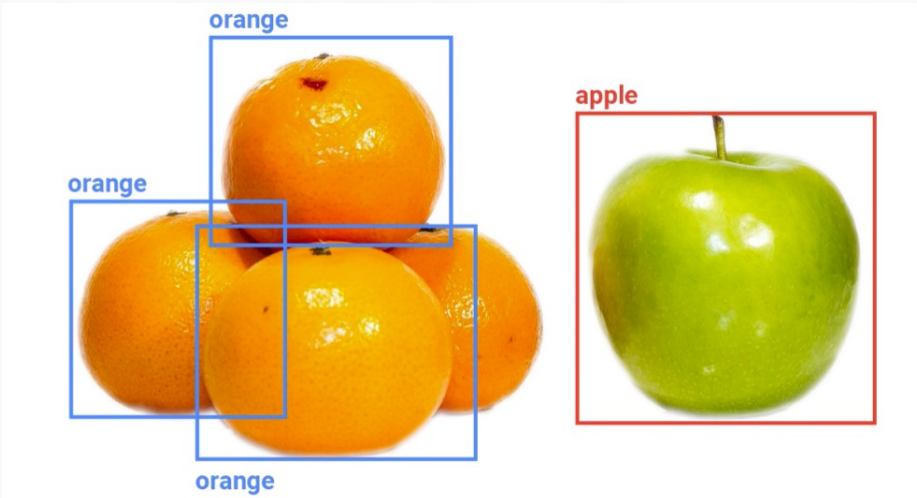
jupyter + CO +

Hands-on Activity (Part 3 – On-Device)

Speech



Vision



IMU

How is the course structured?

Course Structure

- Weekly live lectures
  - Slides
  - Hands-on coding (by teacher & students)
- Readings
- Assignments
  - Quizzes
  - Notebooks with codes
  - Hands-on lab reports
- Final Project (in group)
  - Report
  - Presentation

https://github.com/Mjrovai/UNIFEI-IESTI01-T01-2021.1

Class schedule and assignment deadlines

Fundamentals	1	28-04-21	About the Course and Syllabus	
	2	28-04-21	Introduction to TinyML	
	3	05-05-21	TinyML - Challenges	
	4	05-05-21	Jupyter Notebook, CoLab and Python Review	Coding Exercices List 1 (2 weeks to delivery)
	5	12-05-21	The Machine Learning Paradigm	
	6	12-05-21	The Building Blocks of Deep Learning	Coding Exercices List 2 (2 weeks to delivery)
	7	19-05-21	Exploring Machine Learning Scenarios	Deadline delivery List 1
	8	19-05-21	Building a Computer Vision Model	Coding Exercices List 3 (2 weeks to delivery)
	9	26-05-21	Responsible AI Design	Deadline delivery List 2
	10	26-05-21	TinyML Fundamentals Summary - Group Project rules	Coding Exercices List 4 (2 weeks to delivery)
Applications	11	02-06-21	Preview of TinyML Applications	Deadline delivery List 3
	12	02-06-21	AI Lifecycle and ML Workflow	
	13	09-06-21	Machine Learning on Mobile and Edge IoT Devices	Deadline delivery List 4
	14	09-06-21	Introduction to Edge Impulse Studio	
	15	16-06-21	Keyword Spotting	Deadline delivery Group Project Proposal
	16	16-06-21	Lab KWS	
	17	23-06-21	Visual Wake Words	
	18	23-06-21	Lab VWW	
	19	30-06-21	Anomaly Detection	Deadline delivery KWS Lab Report
	20	30-06-21	Lab Gesture Classification and Anomaly Detection	
Deploying	21	07-07-21	Deploying TinyML Applications on Embedded Devices	Deadline delivery VWW Lab Report
	22	07-07-21	Demo/Lab	
	23	14-07-21	Collecting a Custom TinyML Dataset	Deadline delivery Anomaly Detection Lab Report
	24	14-07-21	Demo/Lab	
	25	21-07-21	Pre and Post Processing for Keyword Spotting, Visual Wake Words, and Gesture Recognition	
	26	21-07-21	Demo/Lab	
	27	28-07-21	Profiling and Optimization of TinyML Applications	
	28	28-07-21	Responsible AI	
	29	04-08-21	Group Presentations	Deadline delivery Project Report and Presentation
	30	04-08-21	Group Presentations	

Class planning and approval process

- Minimal suggested Workload (4 hours per week):
  - 30 hours (Weekly online classes of 2h, for 15 weeks)
  - 15 hours of assignments/coding/labs
  - 15 hours in research, individual studies, and final project (in a group)

- Approval process:
  - 1st Evaluation:
    - Individual **Quizzes**: 10%
    - Individual **Exercise Lists** (Notebooks): 25%
    - Group **Project Proposal**: 15%
  - 2nd Evaluation
    - Individual **Quizzes**: 10%
    - Individual **Practical Projects** (Lab reports): 25%
    - Group **Project Presentation (*)** and Final Report: 15%

(*) Example: Harvard CS249r: Tiny Machine Learning – Final Projects

Main references

- Harvard School of Engineering and Applied Sciences - CS249r: Tiny Machine Learning
- Professional Certificate in Tiny Machine Learning (TinyML) – edX/Harvard
- Introduction to Embedded Machine Learning (Coursera)
- Text Book: "TinyML" by Pete Warden, Daniel Situnayake

I want to thank Harvard professor Vijay Janapa Reddi, Ph.D. student Brian Plancher and their staff for putting together a great material regarding TinyML that is the base of this course at UNIFEI.

Thanks

And stay safe!