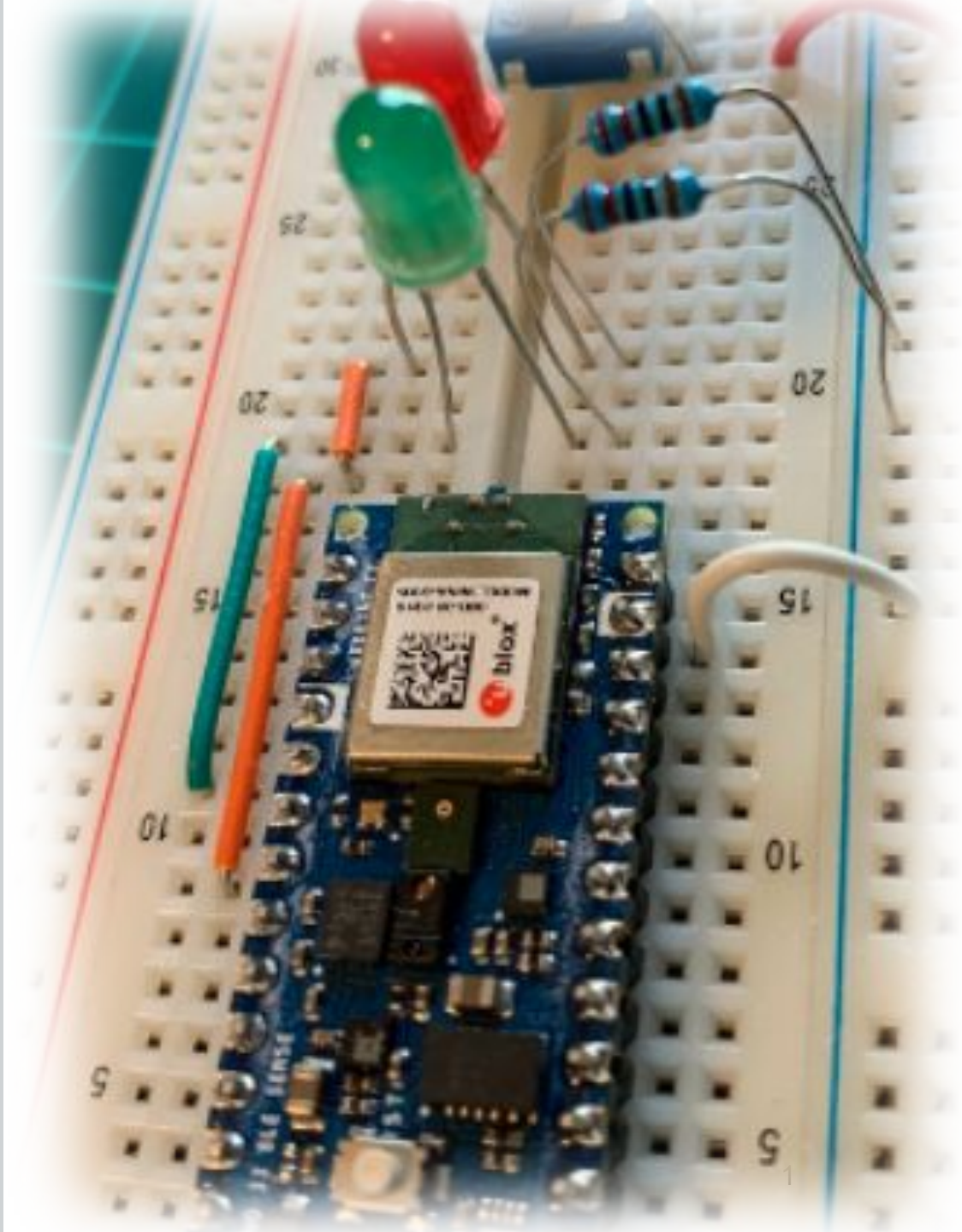
IESTI01 – TinyML

Embedded Machine Learning

About the Course & Syllabus



Prof. Marcelo Rovai
UNIFEI

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

- Brazilian from São Paulo, **Data Science Master's degree by UDD, Chile**, and MBA by IBMEC (INSPER), Brazil.
- Graduated in 1982 as an **Engineer from UNIFEI** with Specialization from Poli/USP, both in Brazil.
- Worked as a **teacher, engineer, and executive** in several technology companies such as CDT/ETEP, 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.
- **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).
- **Volunteer Professor** at UNIFEI Engineering Institute: "Machine Learning applied to Embedded Devices" course (IESTI01).
- Active member of the **TinyML4D group**, an initiative to bring TinyML education to developing countries.

Marcelo Rovai

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**

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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**.

EdgeML (P↑)

Autonomous Car Control

Image Recognition

EdgeML (P↑)

Autonomous Car Control

Image Recognition

TinyML (P↓)

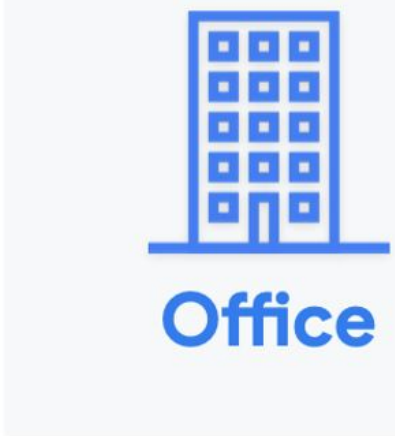
KeyWord Spotting

Environmental Control

Motion & biometric

Image Spot

TinyML Application Areas

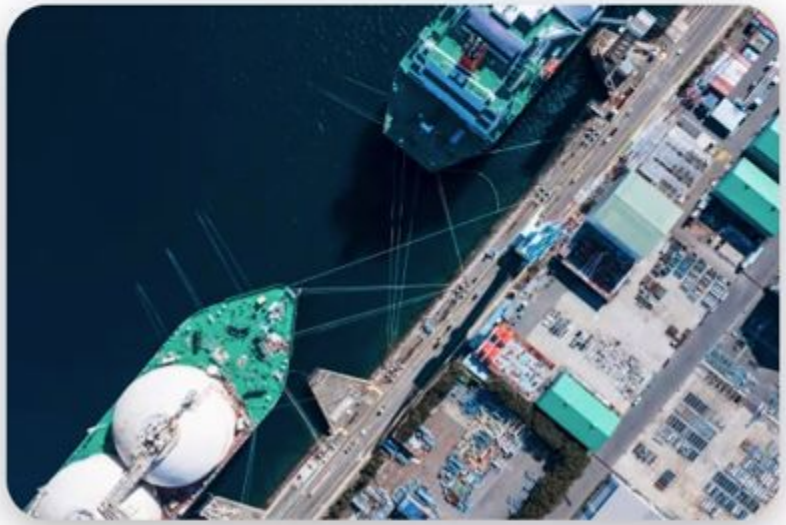


Predictive Maintenance

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

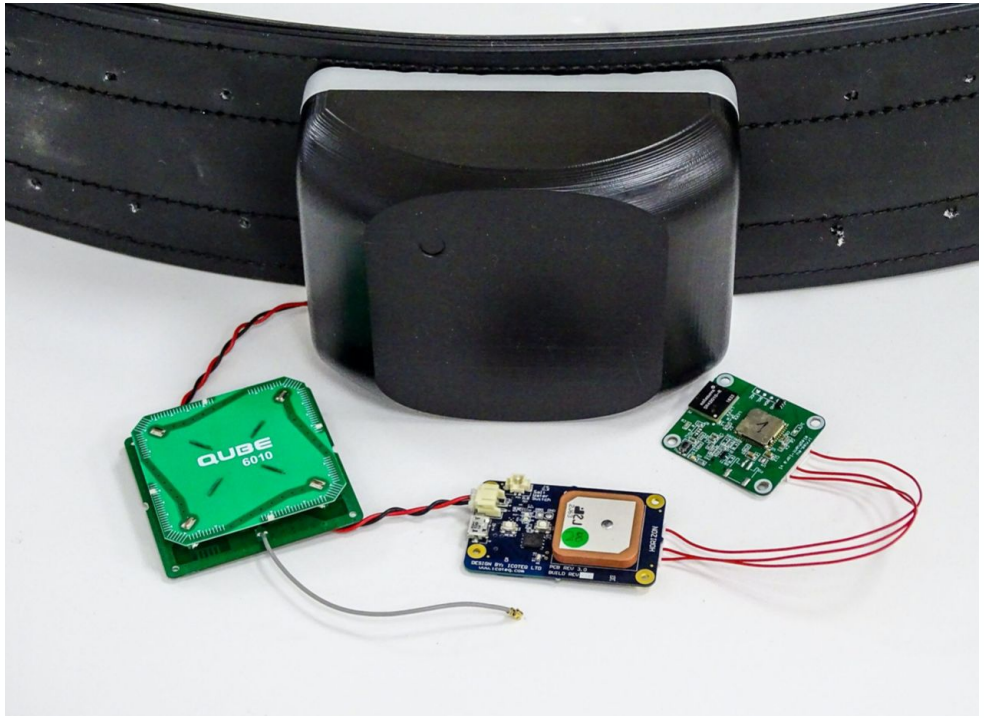
- ➔ Health
- ➔ Consumer
- ➔ Industrial

EDGE IMPULSE

[RAM-1: An Advanced Grid Monitoring Solution]

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."

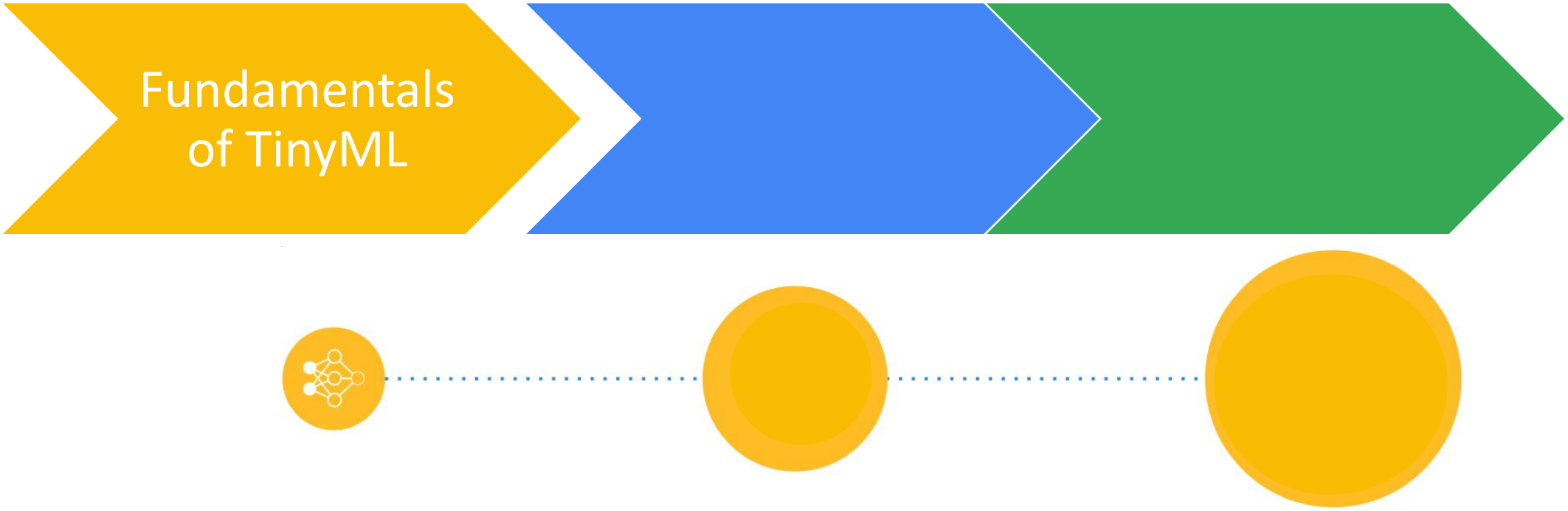
Communication Monitoring

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

ElephantEdge

What we will learn?

Part 1

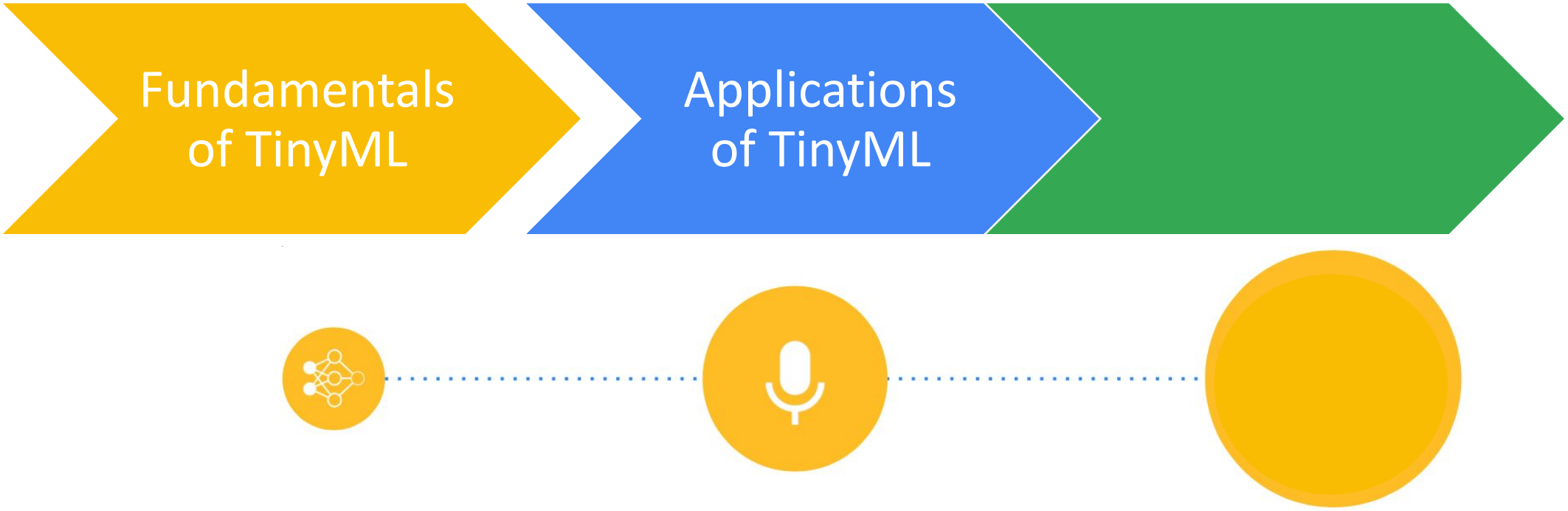


Part 1 is all about talking about what is the language of machine learning

What we will learn?

Part 1

Part 2



In 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?

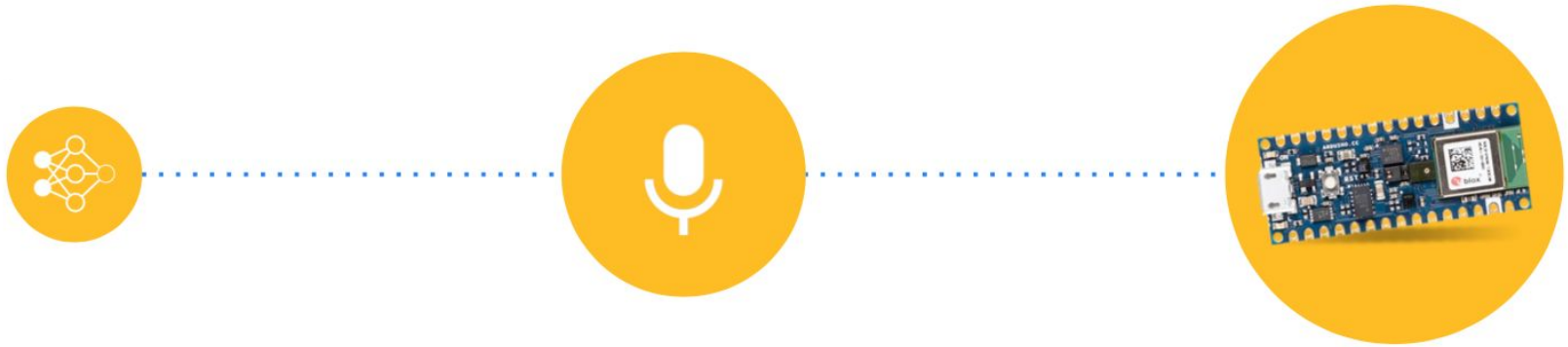
Part 1

Part 2

Fundamentals of TinyML

Applications of TinyML

Deploying TinyML



In Part 2, we will **also** 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

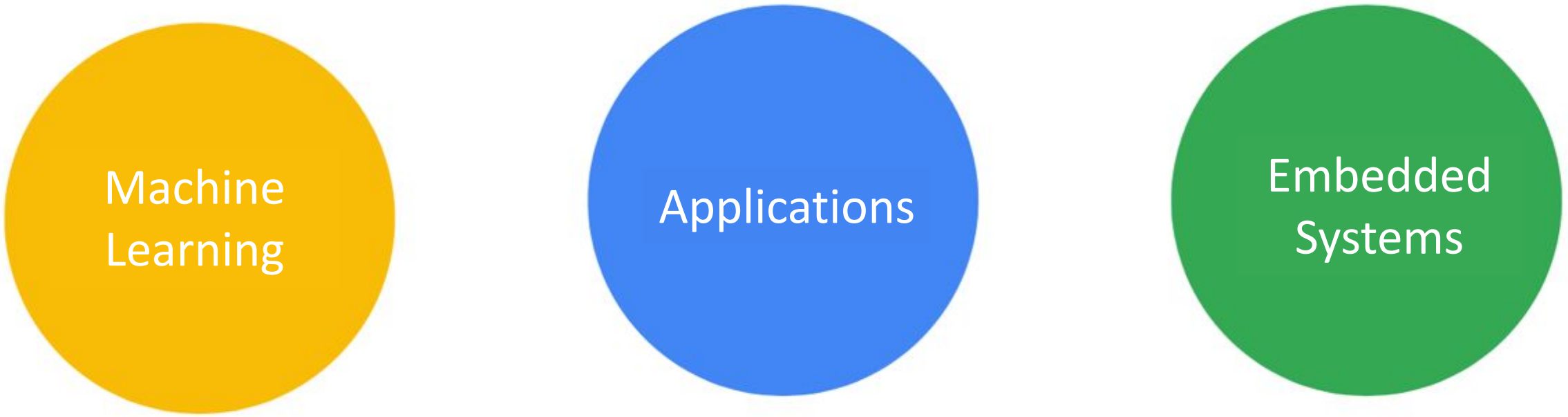
- Python
- Google Colab
- Jupyter Notebook

- 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**.

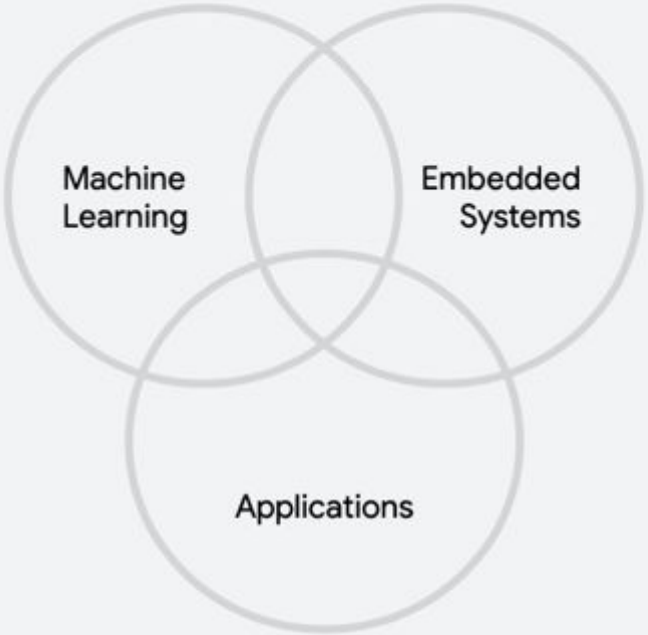
What areas we will learn?



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

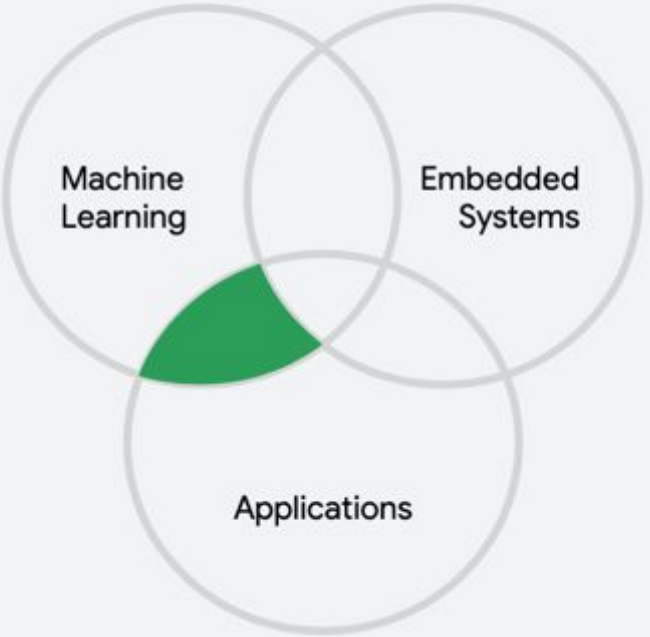
In addition, we will bring these diverse topics together to reveal the interesting learnings at the various **intersections**



Interactions

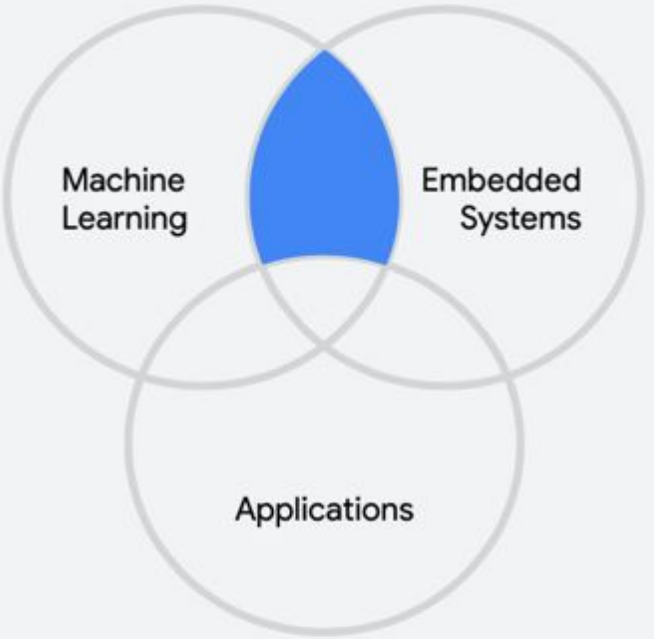
How **machine learning** can enable new and interesting **TinyML applications**?

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



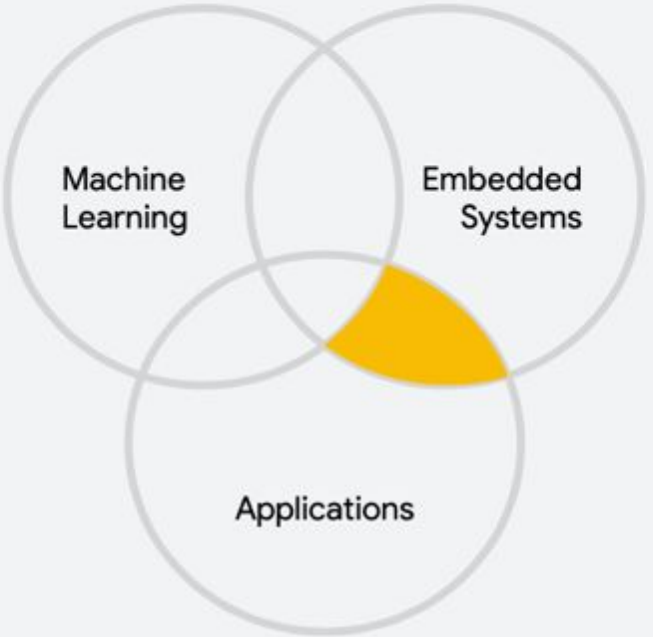
Interactions

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



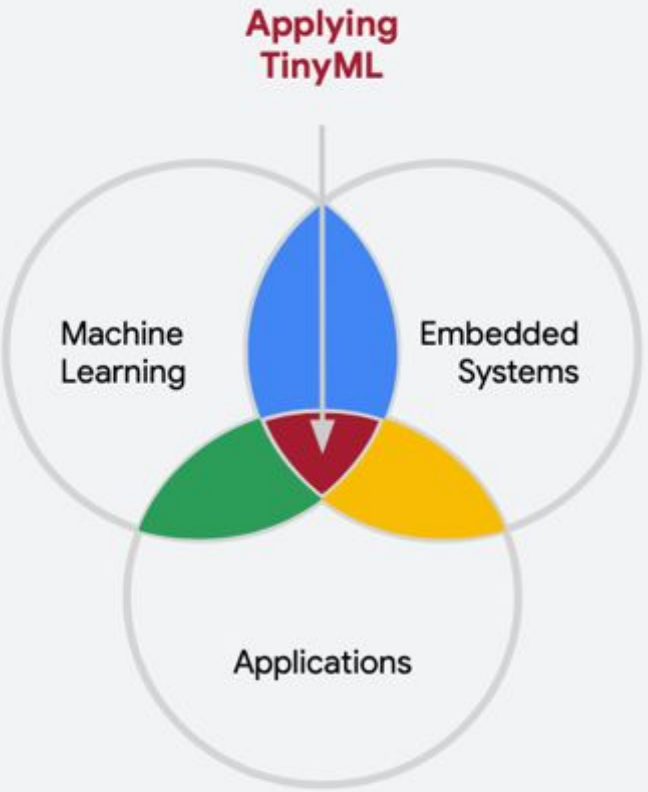
Interactions

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**

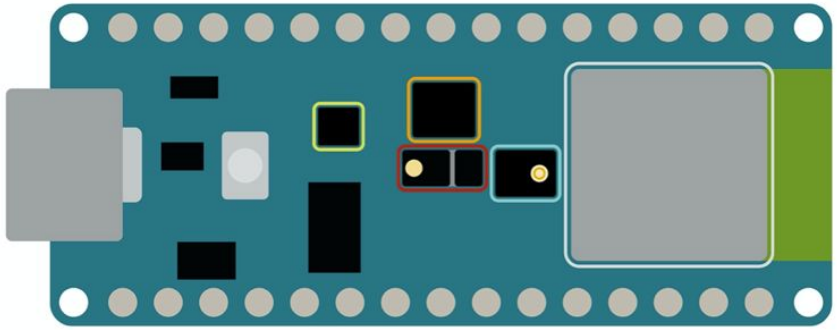


How are we going to get there?

Hands-on Learning

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

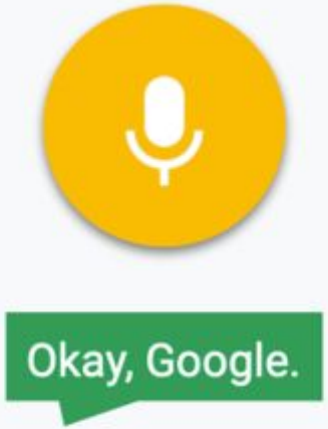
Nano 33 BLE SENSE & OV7675 Camera



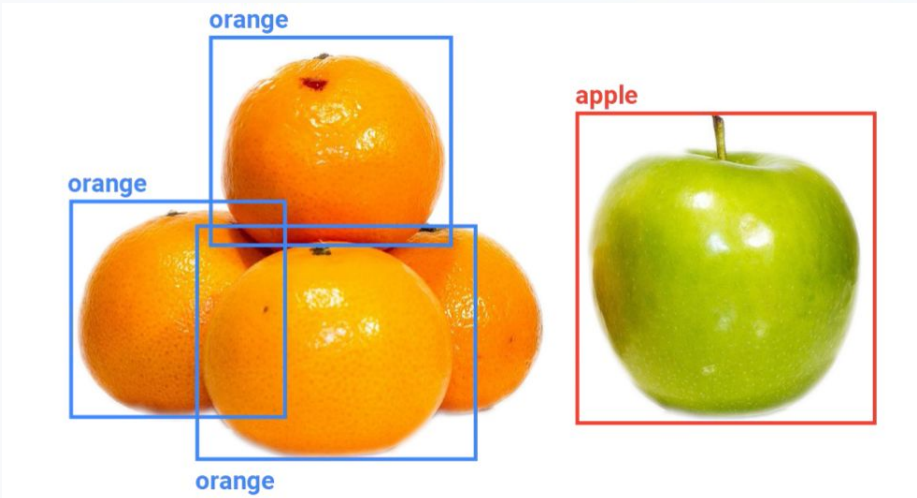
- Color, brightness, proximity and gesture sensor
- Digital microphone
- Motion, vibration and orientation sensor
- Temperature, humidity and pressure sensor
- Arm Cortex-M4 microcontroller and BLE module

Hands-on Activities

Speech



Vision



IMU

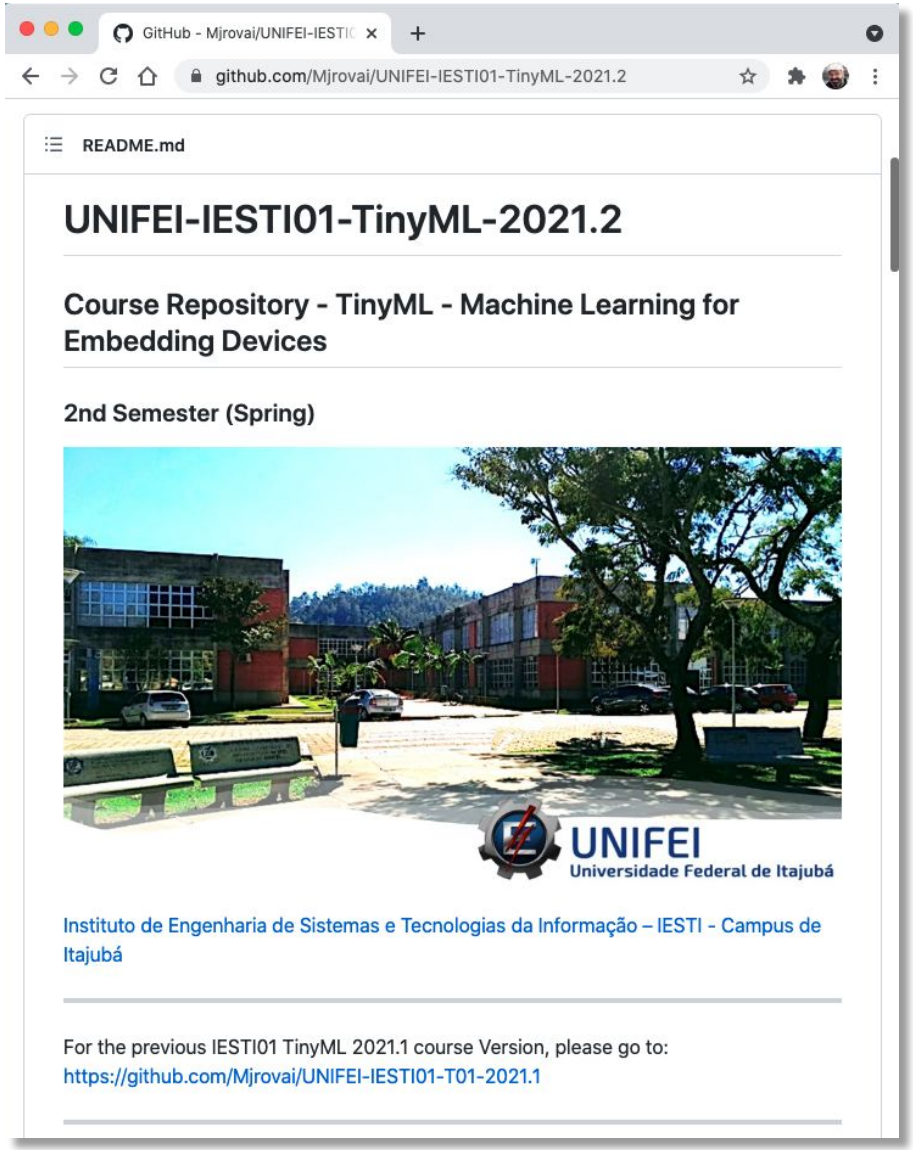
TinyML Kit


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

How is the course structured?

Course Structure

- Weekly live lectures (15 weeks)
  - Slides
  - Hands-on coding (by teacher & students)
- Weekly Additional Readings
- Guest Lecturer (i.e., Daniel Situnayaki, EI)
- Assignments
  - Quizzes (Weekly)
  - Notebooks with codes (5)
  - Hands-on lab reports (4)
- Final Project (Groups of 3 or 4 students)
  - Report
  - Presentation



https://github.com/Mjrovai/UNIFEI-IESTI01-TinyML-2021.2

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%

(*) Examples: Harvard CS249r – TinyML - Final Projects

UNIFEI IESTI01 2021.1 – Final Projects

Class schedule and assignment deadlines *

	Class #		* Content/dates can be changed during the course	Assignments
Fundamentals	1	01-09-21	About the Course and Syllabus	
	2	01-09-21	Introduction to TinyML	
	3	08-09-21	TinyML - Challenges	
	4	08-09-21	Jupyter Notebook, CoLab and Python Review	Coding Exercices List 1 (2 weeks to delivery)
	5	15-09-21	The Machine Learning Paradigm	
	6	15-09-21	The Building Blocks of Deep Learning (DL) - Introduction	Coding Exercices List 2 (2 weeks to delivery)
	7	22-09-21	The Building Blocks of DL - Regression with DSS	Deadline delivery List 1
	8	22-09-21	The Building Blocks of DL - Classification with DSS	Coding Exercices List 3 (2 weeks to delivery)
	9	29-09-21	The Building Blocks of DL - DNN Recap, Datasets and Model Performance Metrics	Deadline delivery List 2
	10	29-09-21	Introducing Convolutions (CNN)	Coding Exercices List 4 (2 weeks to delivery)
	11	06-10-21	Convolutions (CNN) Recap	Deadline delivery List 3
	12	06-10-21	Preventing Overfitting	
	13	13-10-21	Preview of TinyML Applications	Deadline delivery List 4
	14	13-10-21	AI Lifecycle and ML Workflow	
Application & Deploy	15	20-10-21	Introduction to Edge Impulse Studio	Deadline delivery Group Project Proposal
	16	20-10-21	Lab 1 - Gesture Classification (EI Studio Project)	
	17	27-10-21	Anomaly Detection with TinyML	
	18	27-10-21	Data Engineering for TinyML	
	19	03-11-21	TinyML Kit Overview, Installation and test	Deadline delivery Lab 1 Report
	20	03-11-21	Lab 2 - Gesture Classification & Anomaly Detection using MCU	
	21	10-11-21	Keyword Spotting - Introduction	
	22	10-11-21	Lab 3 - KWS using MCU	
	23	17-11-21	Lecturer with an industry invitee	Deadline delivery Lab 2 Report
	24	17-11-21	Collecting Data	
	25	24-11-21	Visual Wake Words - Introduction	Deadline delivery Lab 3 Report
	26	24-11-21	VWW - Demo/Lab -	
	27	01-12-21	Image Classification using Edge Impulse Studio	
	28	01-12-21	Responsible AI & Course Wrapup	
	29	08-12-21	Group Presentations	Deadline delivery Lab 4 Report
	30	08-12-21	Group Presentations	Deadline delivery Project Report and Presentation

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 Shawn Hymel and Edge Impulse, Pete Warden and Laurence Moroney from Google and specially Harvard professor Vijay Janapa Reddi, Ph.D. student Brian Plancher and their staff for preparing the excellent material on TinyML that is the basis of this course at UNIFEI.

The IESTI01 course is part of the TinyML4D, an initiative to make TinyML education available to everyone globally.

Thanks

And stay safe!

UNIFEI