

Pontificia Universidad
JAVERIANA
Bogotá

Facultad de Ingeniería



T I N Y



edu

The Challenging First Steps of Graduate Students on TinyML

Workshop on Widening Access to TinyML Network
by Establishing Best Practices in Education

July 4th, 2023

Diego Méndez Chaves, Ph.D

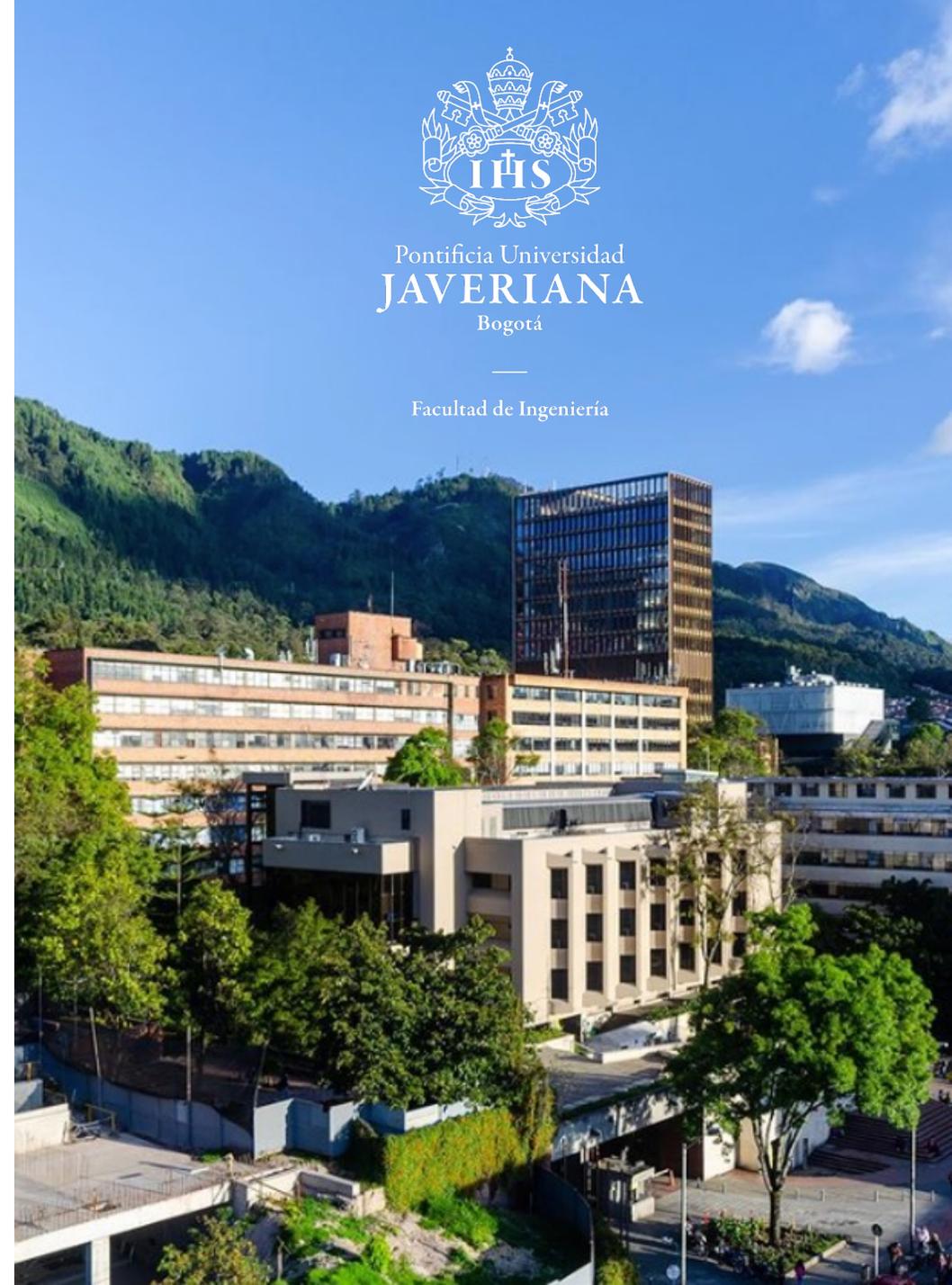
diego-mendez@javeriana.edu.co

- Associate professor at the Electronics Engineering Dept.
- Director of the Master Program in Internet of Things and the Master Program in Electronics Engineering.
- Technical director of the Center of Excellence and Adoption in IoT (CEA-IoT).
- Research associate at the MarconiLab in the International Centre for Theoretical Physics (ICTP), Trieste - Italy.
- Research interests: IoT, embedded systems, wireless sensor networks, participatory sensing, digital systems design and embedded operating systems.



Pontificia Universidad
JAVERIANA
Bogotá

—
Facultad de Ingeniería



Latin American regional workshop on SciTinyML: Scientific Use of Machine Learning on Low-Power Devices



11 - 15 July 2022
An ICTP Virtual Meeting
Trieste, Italy

Further information:
<http://indico.ictp.it/event/9811/>
smr3721@ictp.it

The workshop will be bilingual (English and Spanish).

TinyML is a subfield of Machine Learning focused on developing models that can be executed on small, real-time, low-power, and low-cost embedded devices. This allows for new scientific applications to be developed at an extremely low cost and at large scale.

Description:

The TinyML process starts with collecting data from IoT devices, then training the collected dataset to extract knowledge patterns; these patterns are then packaged into a TinyML model that considers the target microprocessor's limited resources such as memory and processing power.

The resulting model is then deployed on embedded devices where it is used to evaluate new sensor data in real-time. Typically, power requirements are in the mW range and below which enables a variety of use-cases targeting battery operated devices. TinyML represents a collaborative effort between the embedded power systems and Machine Learning communities, which traditionally have operated independently.

Topics:

- ML general concepts
- Introduction to TinyML
- Getting started with the TinyML training kit
- Examples of TinyML applications
- Scientific Applications of ML

Directors:

V. J. REDDI, John A. Paulson School of Engineering and Applied Sciences, Harvard University, USA
M. ROVAL, UNIFEI, Brazil

Local Organiser:

M. ZENINARO, ICTP, Italy

How to apply:

Online application:
<http://indico.ictp.it/event/9811/>

Female scientists are encouraged to apply.

Grants:

There is no registration fee. Priority will be given to the participants from Latin America that are part of the ICTP TinyML Academic Network.

Deadline:

29 June 2022



Introduction to Deep Learning (SPA) 40'

Workshop on Scientific Use of Machine Learning on Low-Power Devices: Applications and Advanced Topics



17 - 21 April 2023
An ICTP Virtual Meeting
Trieste, Italy

Further information:
<http://indico.ictp.it/event/10166/>
smr3432@ictp.it

TinyML is a subfield of Machine Learning focused on developing models that can be executed on small, real-time, low-power, and low-cost embedded devices. This allows for new scientific applications to be developed at an extremely low cost and at large scale.

Description:

TinyML represents a collaborative effort between the embedded power systems and Machine Learning communities, which traditionally have operated independently.

TinyML has a significant role to play in achieving the SDGs and facilitating scientific research in areas such as environmental monitoring, physics of complex systems and energy management.

The TinyML process starts with collecting data from IoT devices, then training the collected dataset to extract knowledge patterns; these patterns are then packaged into a TinyML model that considers the target microprocessor's limited resources such as memory, processing power, and energy.

Through hands-on examples, this workshop will focus on both introductory and advanced topics in TinyML to pave the way to the development of real-world applications.

Topics:

- Introduction to TinyML
- Getting Started with the TinyML Kit
- Examples of TinyML Applications
- The TinyML Development Workflow
- Scientific Applications of ML
- Recent Research and Advanced Topics in TinyML

Directors:

B. PLANCHER, Barnard College, USA
V. J. REDDI, Harvard University, USA
M. ROVAL, Federal University of Itajubá, Brazil

Local Organiser:

M. ZENINARO, ICTP, Italy

How to apply:

Online application:
<http://indico.ictp.it/event/10166/>

Female scientists are encouraged to apply.

Registration:

There is no registration fee.

Deadline:

7 April 2023

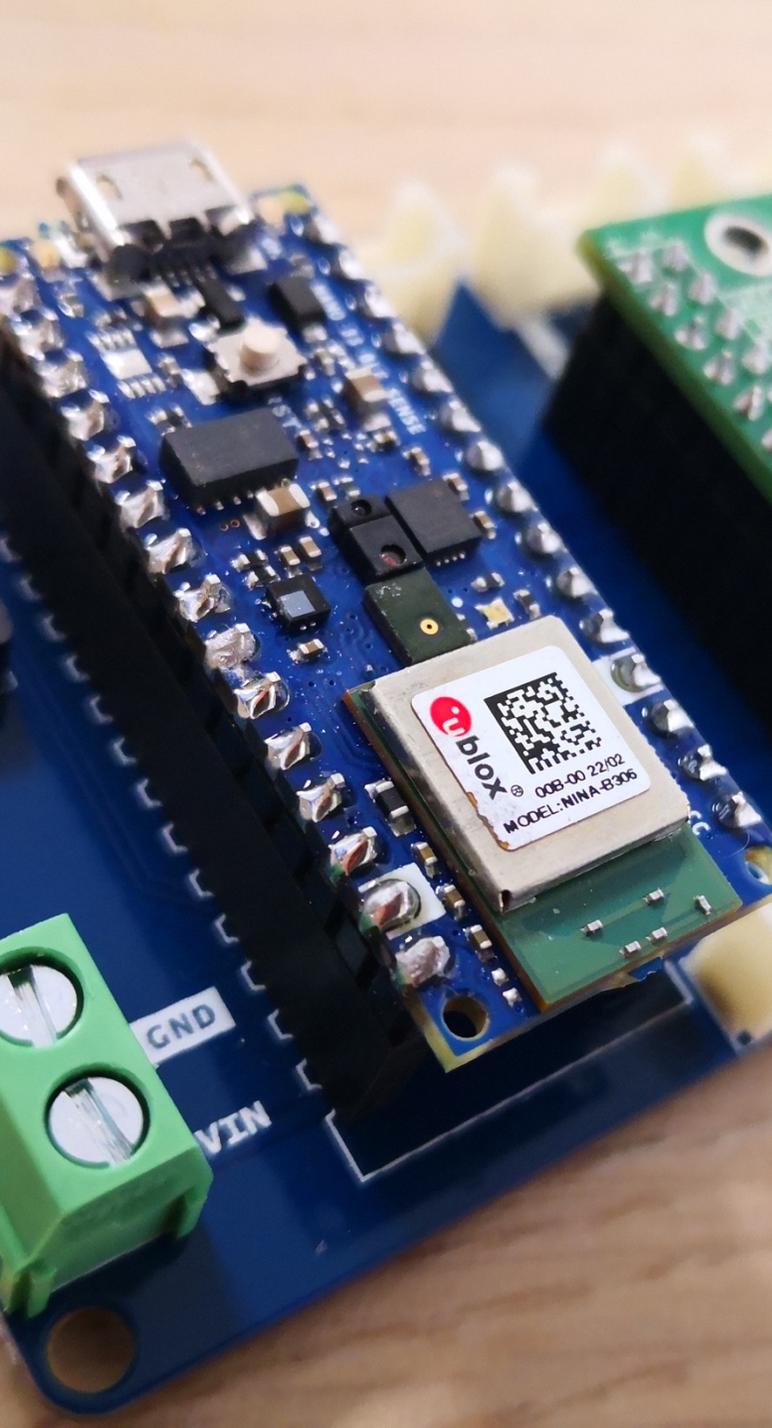


Introduction to Machine Learning (ENG) 60'

- AI vs ML vs DL
- The Machine Learning Paradigm
- Finding the Best Solution and Fitting a Model
- Regression and Classification with NN
- ML Issues



Did they learn anything?



Scientific Use of Machine Learning Mechanisms on Embedded Devices

- Monday (4h)
 - **IoT: fundamentals**, challenges and applications
- Tuesday (4h)
 - Getting Started with our Development Kit
 - Fundamentals of **Machine Learning**
- Wednesday (4h)
 - ML Applications and Workflow
 - Deploying a TinyML Model to a **Smartphone**
- Thursday (4h)
 - Deploying TinyML Models to an **Embedded System**
- Friday (1h)
 - Poster Presentations

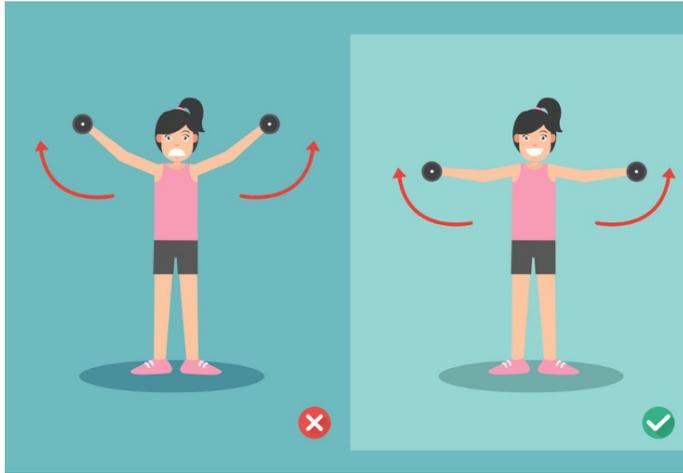


International Project Week
HOCHSCHULE NORDHAUSEN

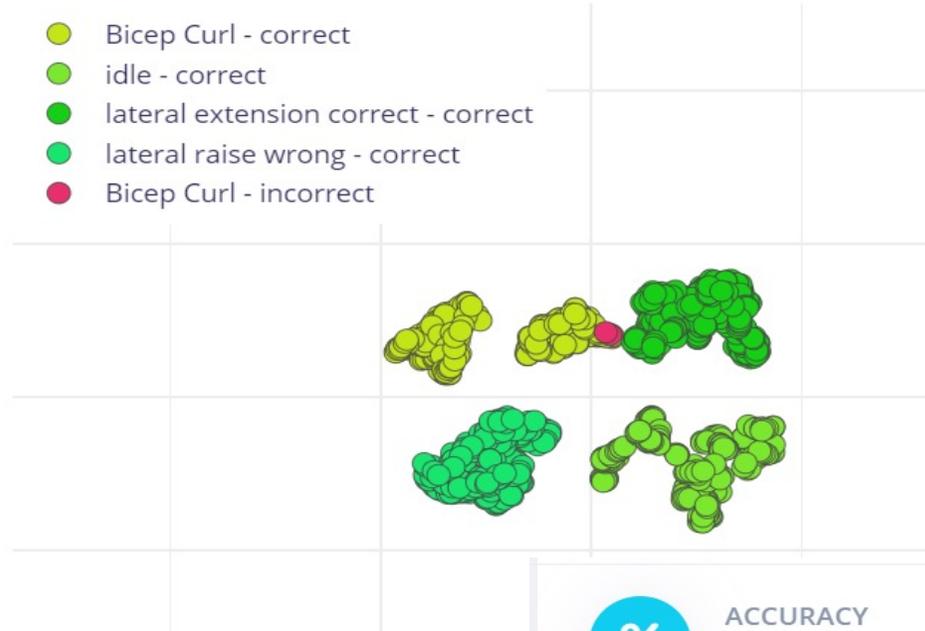


Gym Training with the Accelerometer

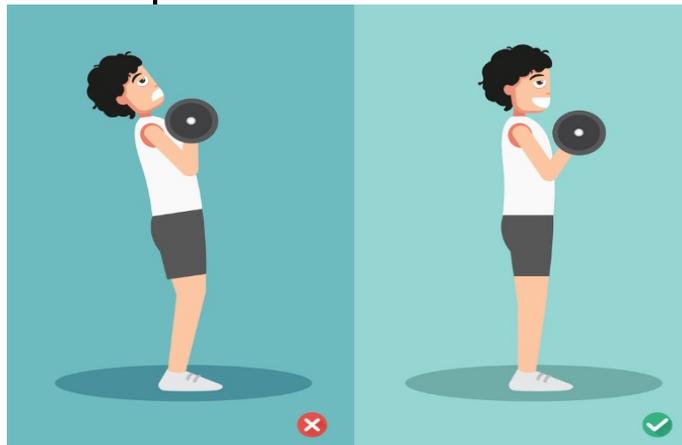
Lateral Raises



- Bicep Curl - correct
- idle - correct
- lateral extension correct - correct
- lateral raise wrong - correct
- Bicep Curl - incorrect



Bicep Curl



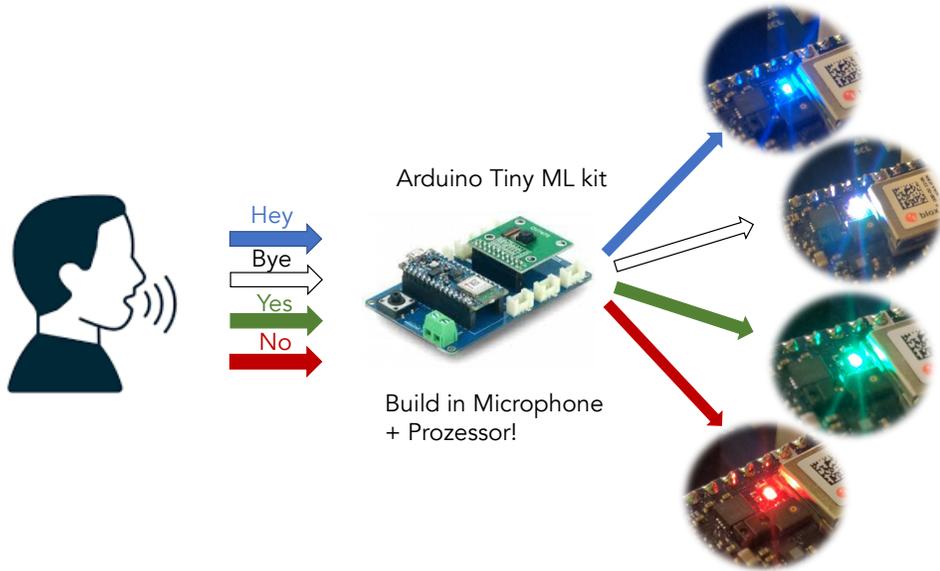
% ACCURACY
99.7%

📈 LOSS
0.02

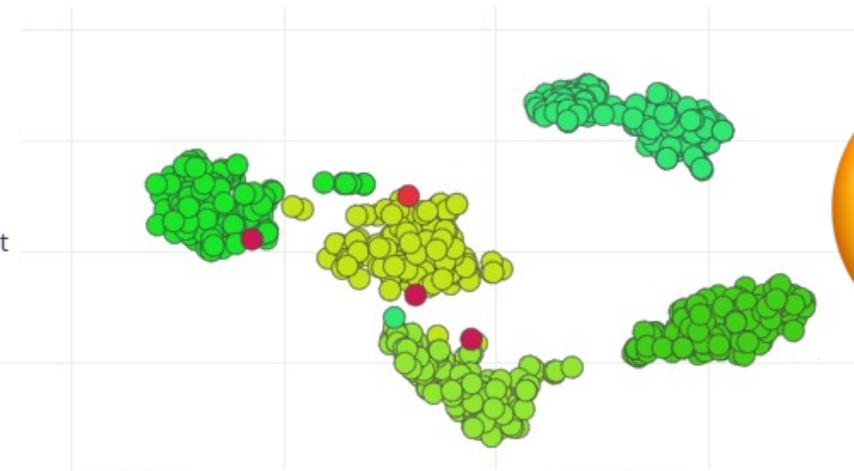
Confusion matrix (validation set)

	BICEP CURL	IDLE	LATERAL EX	LATERAL RA
BICEP CURL	98.9%	0%	1.1%	0%
IDLE	0%	100%	0%	0%
LATERAL EX	0%	0%	100%	0%
LATERAL RA	0%	0%	0%	100%
F1 SCORE	0.99	1.00	0.99	1.00

Keyword-Spotting using Tiny ML



- Noise - correct
- bye - correct
- hey - correct
- no - correct
- yes - correct
- Noise - incorrect
- hey - incorrect



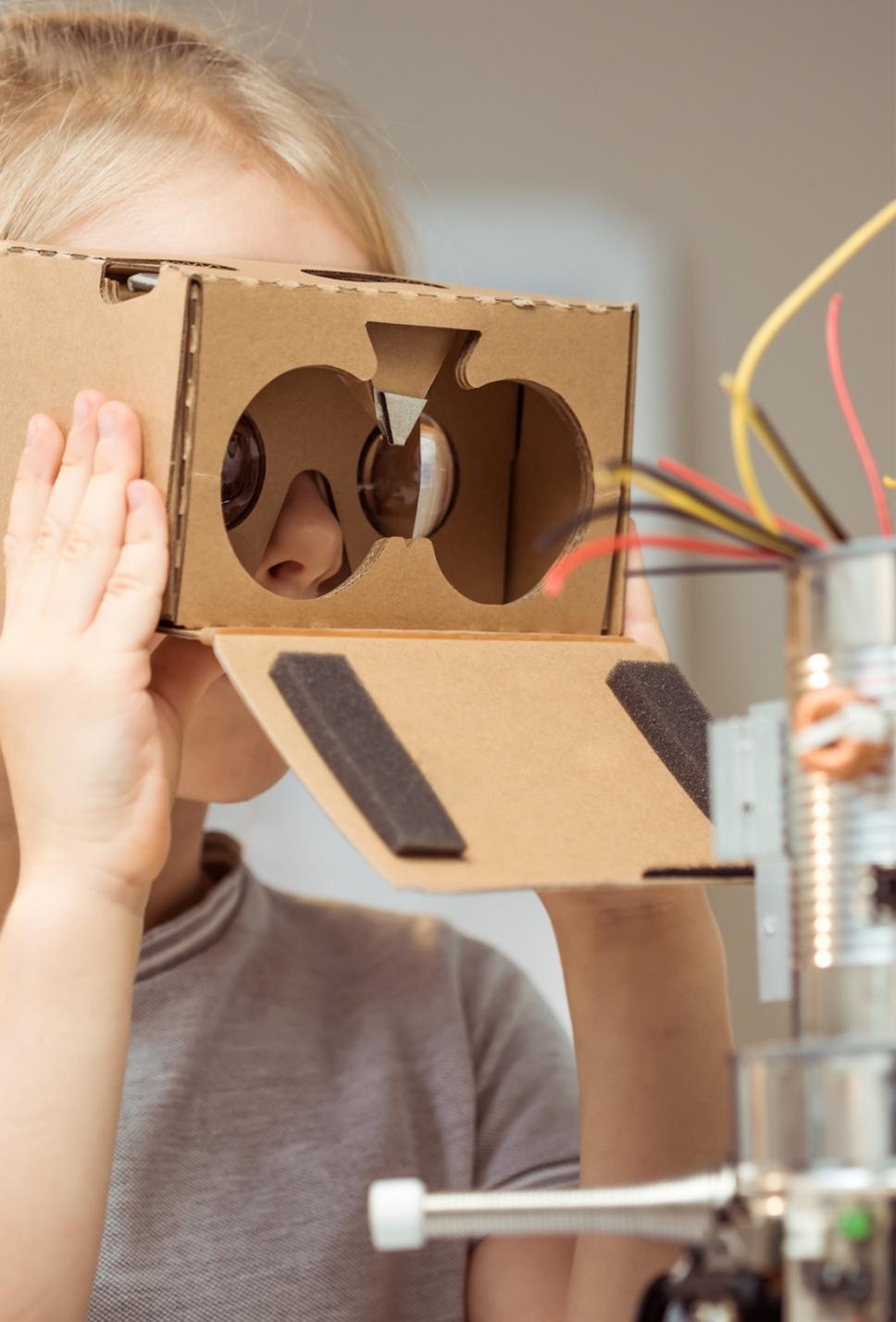
% ACCURACY
96.7%

📈 LOSS
0,09

Confusion matrix (validation set)

	NOISE	BYE	HEY	NO	YES
NOISE	88%	8%	0%	4%	0%
BYE	0%	100%	0%	0%	0%
HEY	4.8%	0%	95.2%	0%	0%
NO	0%	0%	0%	100%	0%
YES	0%	0%	0%	0%	100%
F1 SCORE	0.92	0.95	0.98	0.98	1.00





What should the goal of a 1w course be?

- A **brief presentation** of the fundamentals on ML.
- Explore some **available tools** (SW, HW, platforms...).
- Project-oriented **hands-on approach** on deploying ML-models. **It must work!**
- Identify the current **challenges on TinyML**.



Inspire
Motivate
Engage

Master Theses on TinyML

M.Sc on Electronics Engineering
(mostly basic research)

more homogenous backgrounds
Electronics, Computer Science

M.Sc on Internet of Things
(mostly applied research)

heterogenous backgrounds
Electrical, Electronics, Computer Science, Industrial
Telecommunications, Automation, Renewable Energies...

2-3 semesters

- 1st semester for project proposal preparation.
- 2nd semester they must start working on the project. Course rotation affects this.
- Should they learn on their own? Available material is key!

Interdisciplinary programs

- Heterogenous backgrounds are ideal, but
- It becomes a challenge for students not coming from EE or CS

Skills

- Students coming from different backgrounds,
- but also coming from different institutions (different skill levels).

Master Theses on TinyML

BLE-based Indoor Localization

- Fully-customized hardware.
- Big effort for data collection.
- NN classifier (supported by EI).

TinyML

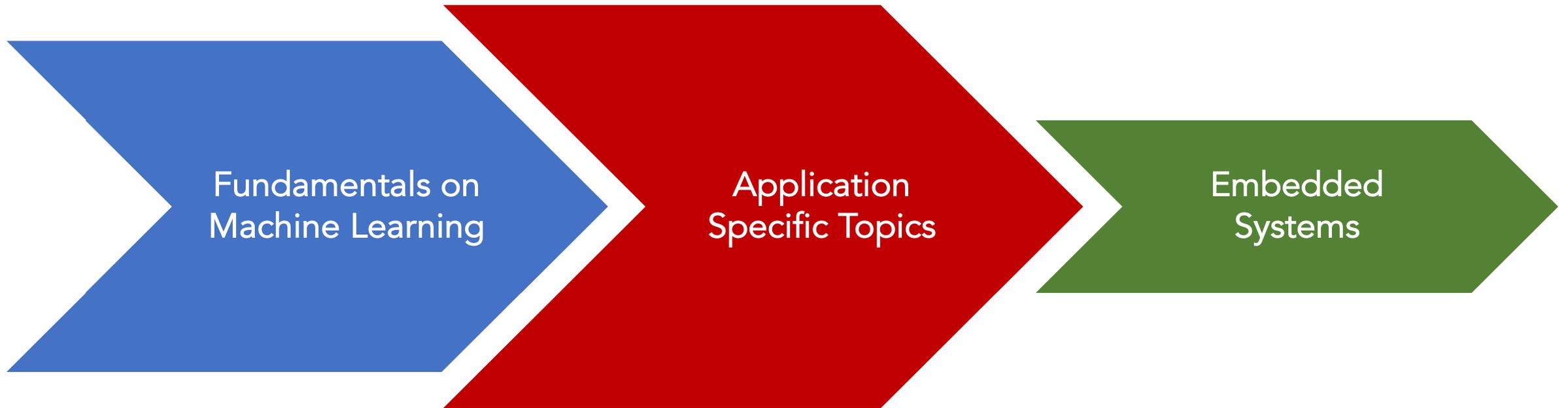
Estimation of Particulate Matter Levels

- Available air pollution DB.
- Long short-term memory (LSTM) model.
- Integration with other platforms (weather.com).

Irrigation Prediction for Precision Agriculture

- Big effort for data collection.
- LSTM model.
- Strong application specific knowledge (geoscience, soil science).

It is clear that not every TinyML project requires the same depth on each component



A flexible curriculum is paramount!



Grazie mille!

Prof. Diego Méndez Chaves, Ph.D

Associate Professor - Electronics Engineering Department
Director of the Master Program in Internet of Things
Director of the Master Program in Electronics Engineering
email: diego-mendez@javeriana.edu.co