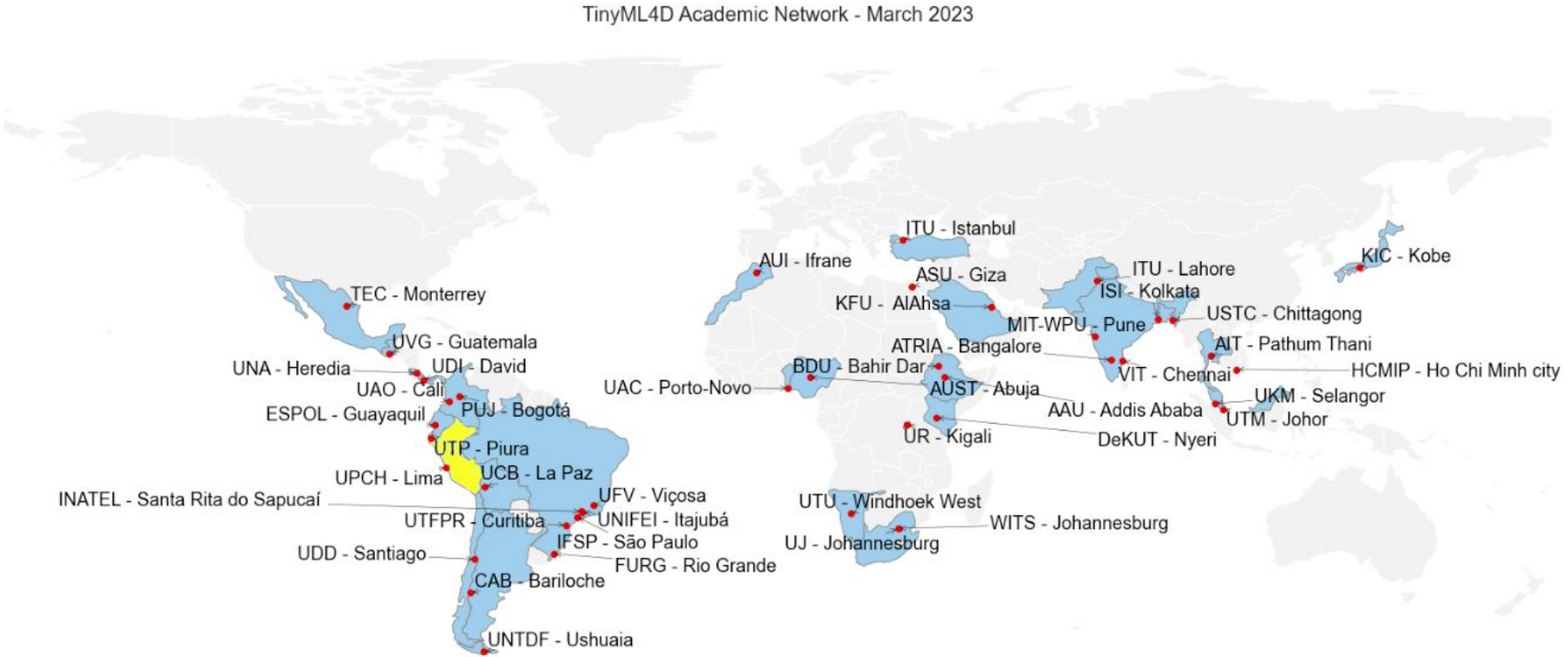
Experiences using TinyML Tools in Teaching Biomedical Engineering

Msc. Eng. Moises Meza


North America
North Atlantic Ocean
Caribbean Sea
North Pacific Ocean
EQUATOR
SOUTH AMERICA
Peru
South Pacific Ocean
South Atlantic Ocean
1000mi
1000km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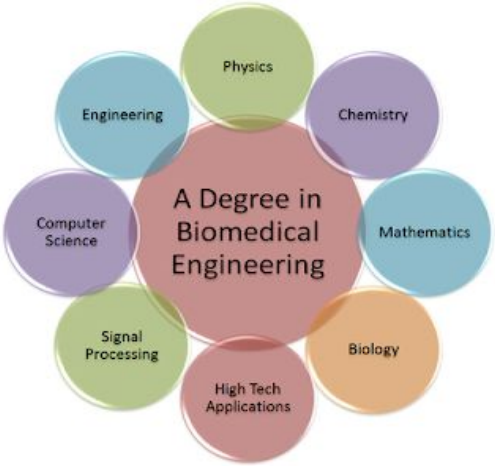
Biomedical Engineering

Biomedical engineering is the branch of engineering that applies principles of engineering to the medical field. It can encompass a wide range of topics, from developing new medical devices to improving healthcare delivery systems.

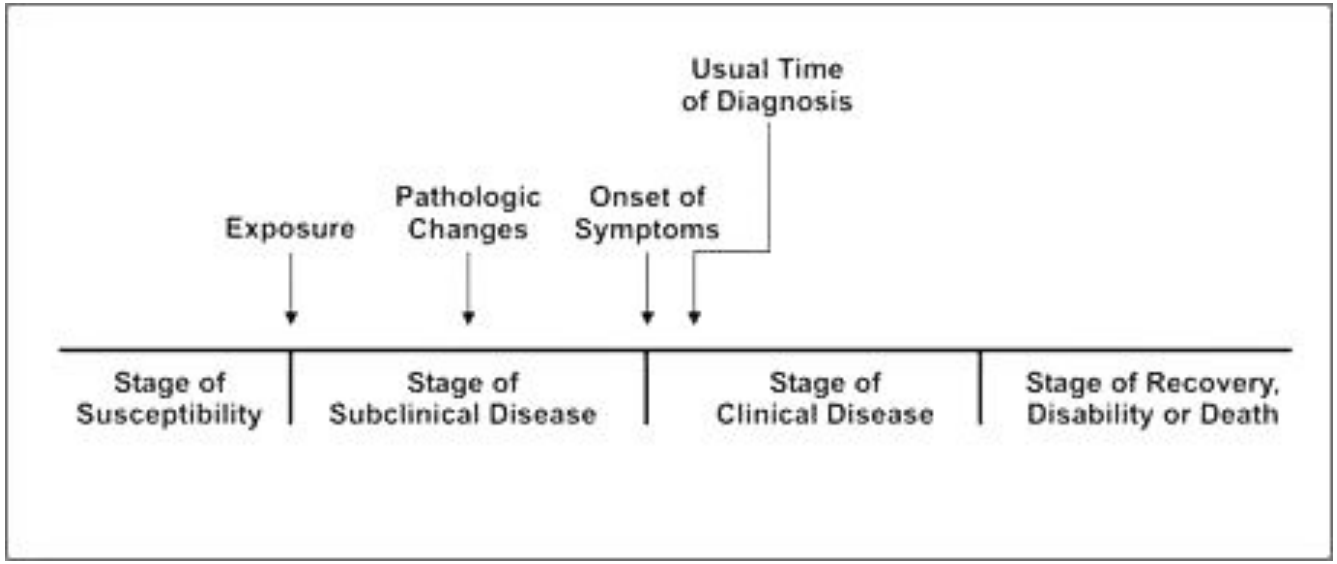
Competencies required on each student's profile: Analytical skills, Communication skills, advanced mathematics techniques, creativity, programming, and problem-solving skills.



Introduction to biomedical signal (ISB)

Pattern recognition

Natural history of disease



Introduction to biomedical signals

UNIT 1: INTRODUCTION, ACQUISITION AND PHYSIOLOGICAL PRINCIPLES OF BIOMEDICAL SIGNALS

↓

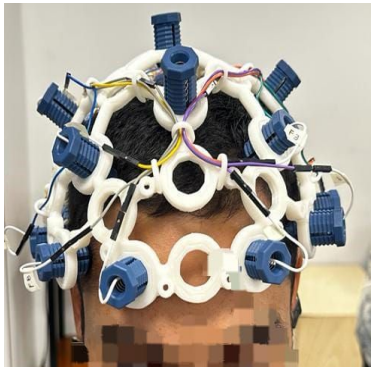
UNIT 2: ECG, EMG, AND EEG ANALYSIS

↓

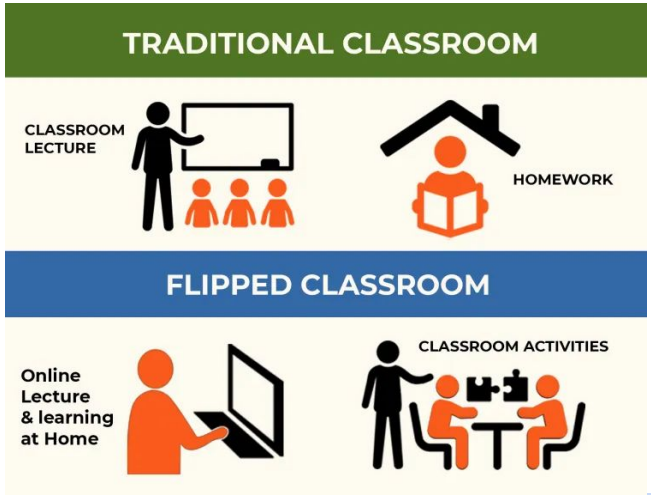
UNIT 3: INTRODUCTION TO DIGITAL SIGNAL PROCESSING

↓

UNIT 4: BIOMEDICAL COMPUTING AND INTRODUCTION TO ARTIFICIAL INTELLIGENCE IN BIOMEDICAL SIGNALS



METHODOLOGY



On flipped classrooms, students encounter information before class, freeing class time for activities that involve higher order thinking.

1 week before is sent these materials:

- laboratory guide.
- Scientific papers.
- Short videos.
- Manual of use from Bitalino/UltraCortex.

The didactic experience in a biomedical engineering course at a Peruvian university

Publisher: IEEE

Cite This PDF

Lewis De La Cruz ; Moises Meza-Rodriguez ; José Alonso Cáceres-DelAguila ; Paulo Vela-Anton **All Authors**

Abstract:
The systematization of the didactic experience, delivered in a university course on the processing of biosignals, becomes relevant for continuous improvement in its subsequent editions. This applies both at the structural level and for enhancing the content of the course, not only in the theoretical aspect but also in practical aspects. The following study describes the experiences under a flipped learning approach obtained from questionnaires related to the student's perception of the delivery of the course "Introduction to Biomedical Signals", which is part of the biomedical engineering program offered by a Peruvian University during the 2023-I semester from March to July 2023. The course showed an overall evaluation over the average, demonstrating its adequate implementation and satisfaction of students. Qualitative questions captured the perception of students regarding how to improve the course experience as well.

Published in: 2023 IEEE 3rd International Conference on Advanced Learning Technologies on Education & Research (ICALTER)

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Date Added to IEEE *Xplore*: 29 December 2023

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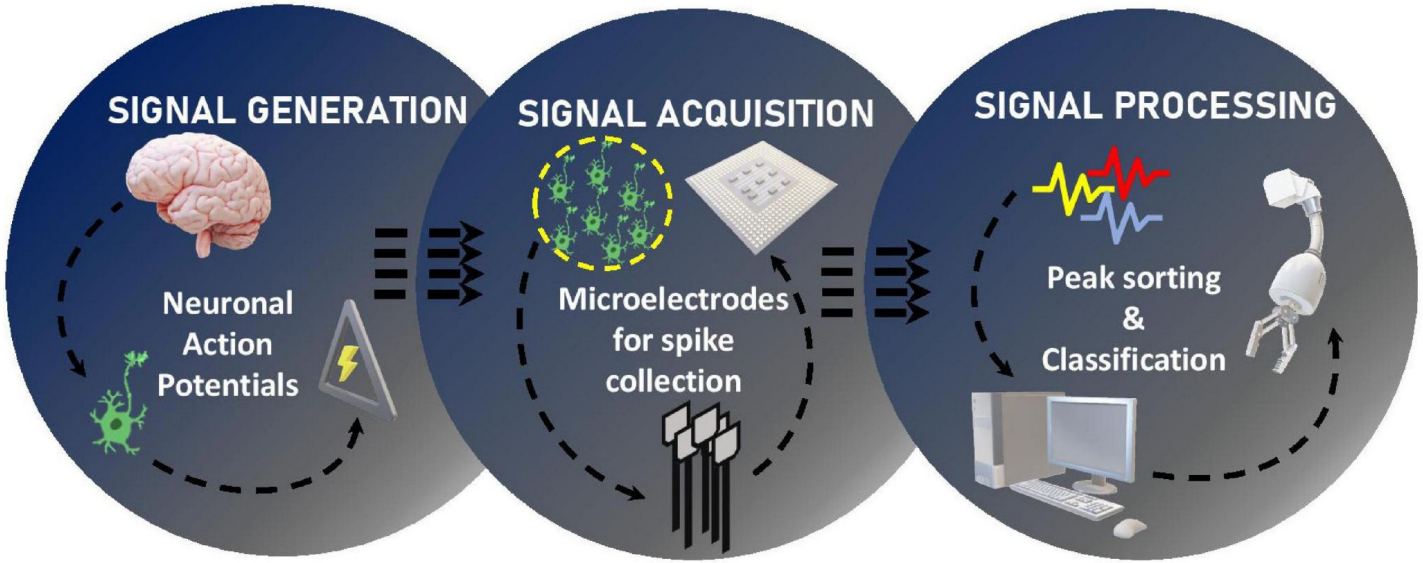
ISBN Information:

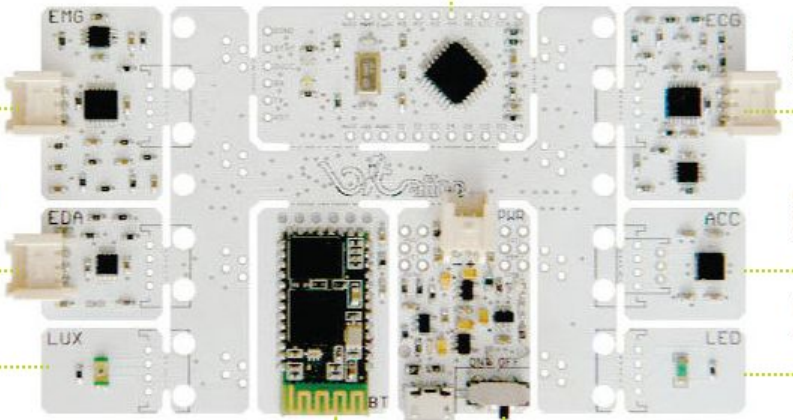
Conference Location: Chiclayo, Peru

I. Introduction

ABOUT THE COURSE ”INTRODUCTION TO BIOMEDICAL SIGNALS”



Anatomy of a Bitalino



Micro-Controller Unit
up to 1000Hz sampling rate
6 analog inputs (4@10-bit + 2@6-bit)
4 digital inputs, and 4 digital outputs

Electromyography (EMG)
measures the electrical activity produced by your muscles

Electrocardiography ECG
tracks the electrical changes associated with your heartbeat

Electrodermal Activity (EDA)
senses your sympathetic nervous system reactions

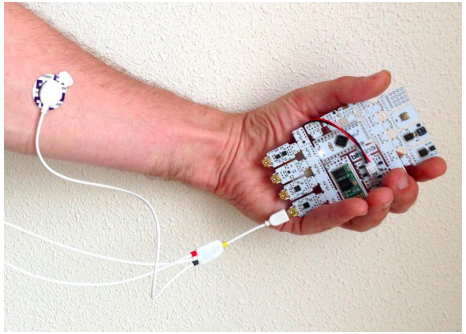
Accelerometry (ACC)
know your physical activity and movement related information

Light-Emitting Diode (LED)
make your BITalino shine

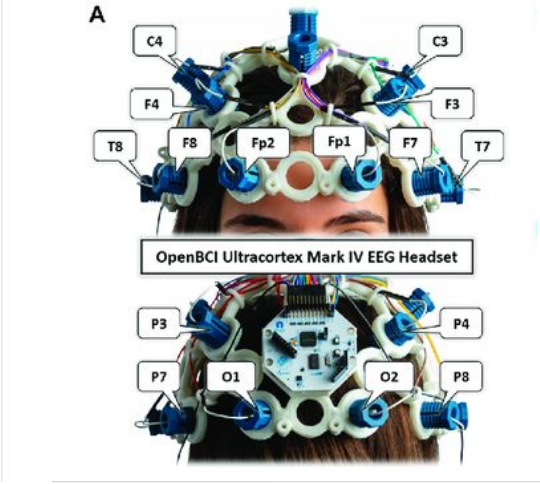
Light (LUX)
know the changes in ambient light or other light sources

Bluetooth
a widespread standard for short-range wireless connectivity

Power
so that you can operate your creations




OPENBCI
ULTRACORTEX
BIOSENSING HEADSET
OPENBCI.COM


A
C4
C3
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OpenBCI Ultracortex Mark IV EEG Headset
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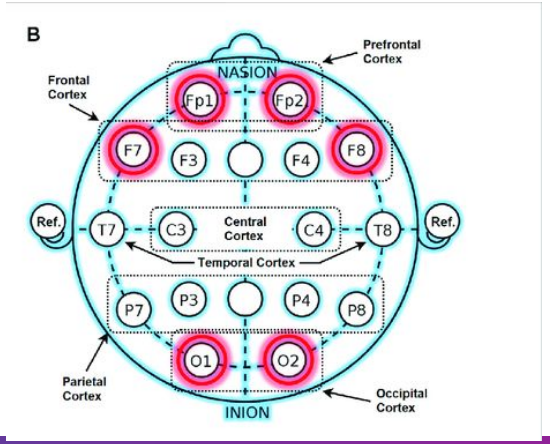
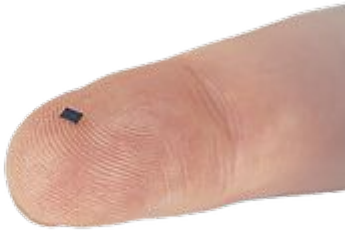
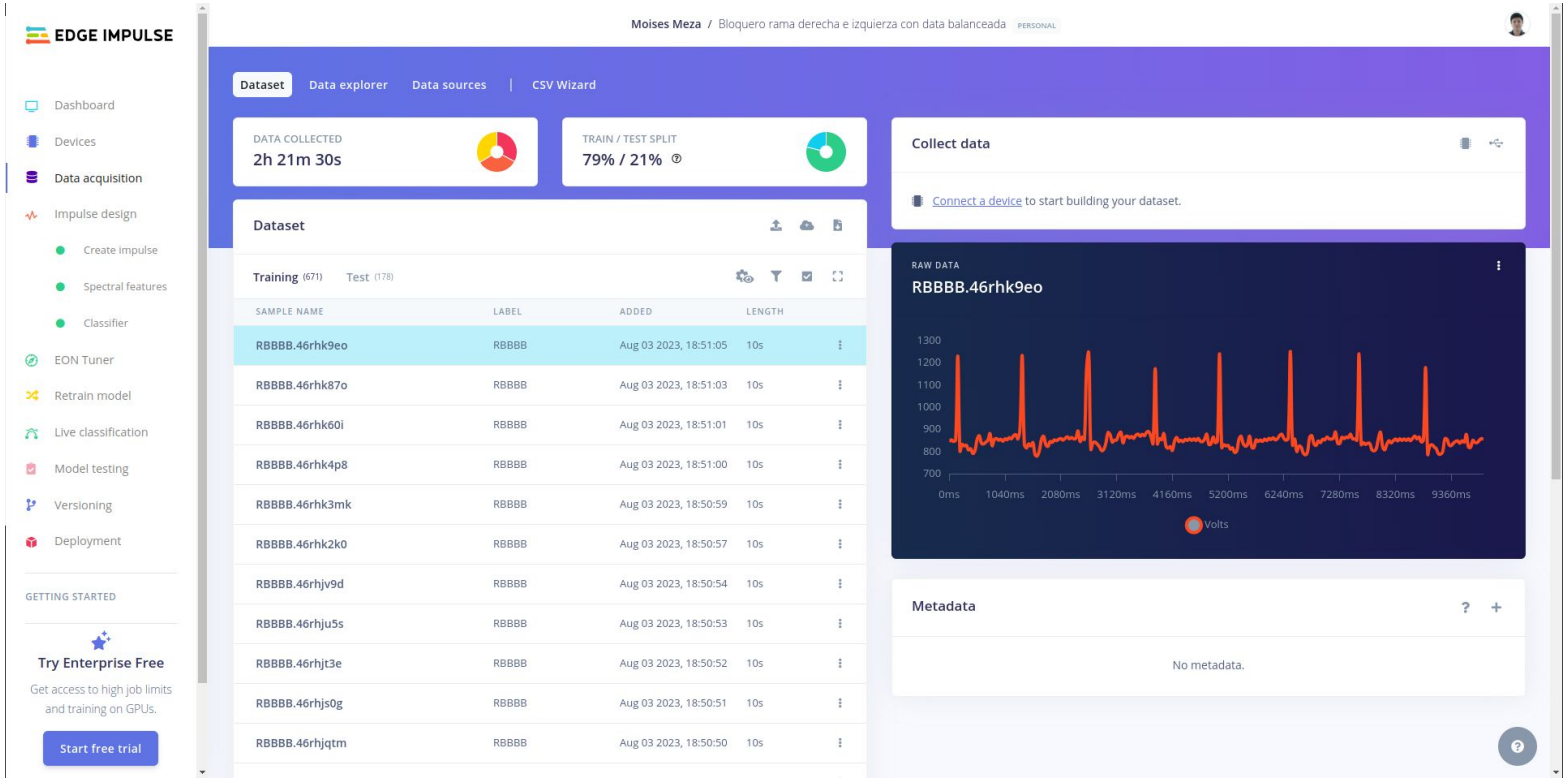
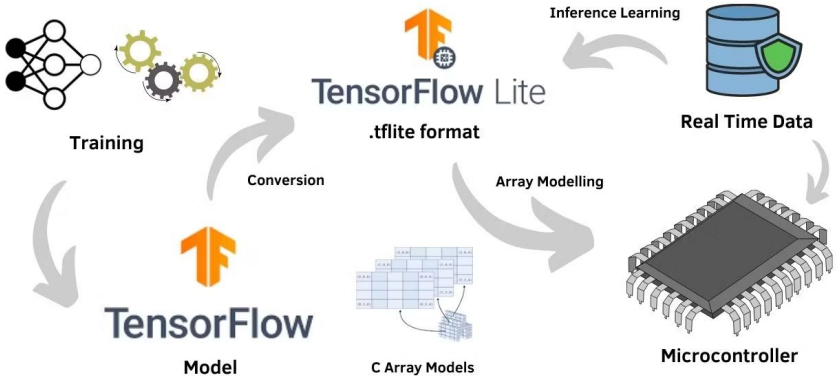

B
Prefrontal Cortex
Frontal Cortex
NASION
Fp1
Fp2
F7
F3
F4
F8
Ref.
T7
C3
Central Cortex
C4
T8
Ref.
Temporal Cortex
P7
P3
P4
P8
O1
O2
Parietal Cortex
Occipital Cortex
INION

The Future of ML is Tiny and Bright

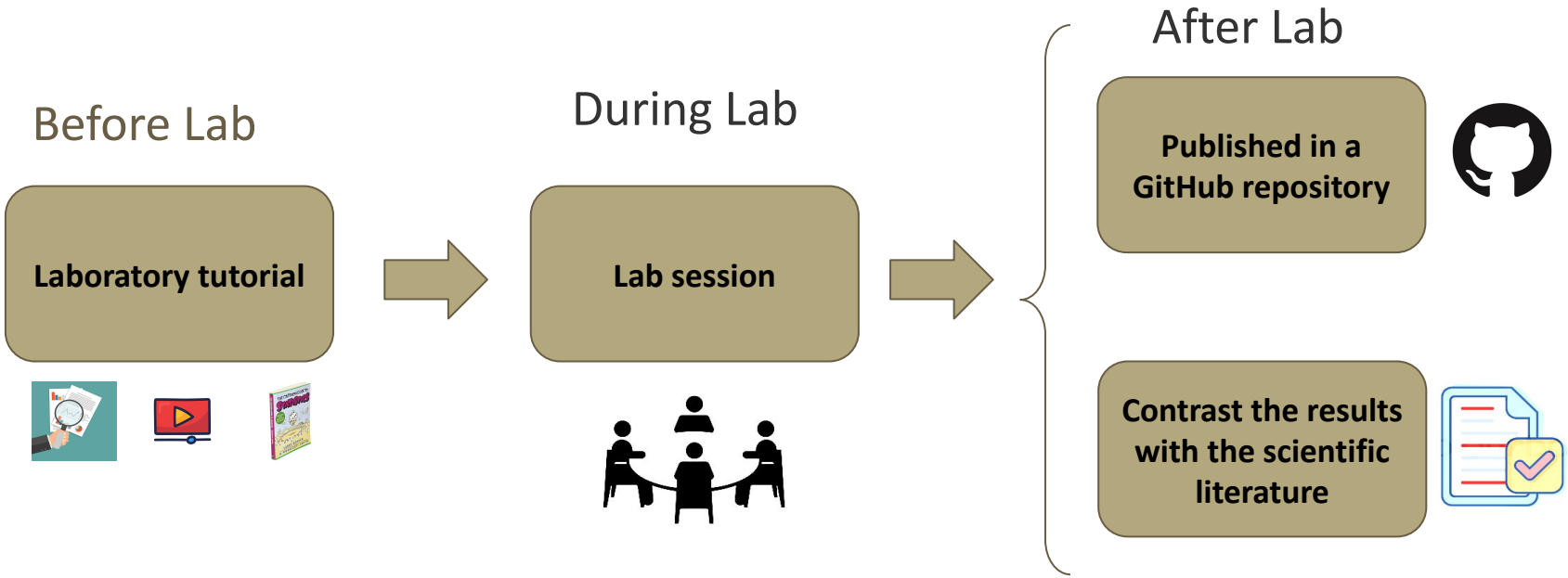


Edge impulse





EloquentTinyML



- Students rated the course on a scale of 1 to 5, where 1 is nothing/poor/never and 5 is much/excellent/always on 22 questions about methodology, teachers and what they learned.

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Development of an electrocardiographic signal classifier for bundle branch blocks, applying Tiny Machine Learning

Meza-Rodriguez, Moises; De La Cruz, Lewis; Caceres-Delaguila, Jose Alonso

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[a] Universidad Peruana Cayetano Heredia, Laboratorio de Ingenieria Biomédica, Lima, Peru

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Abstract

cardiovascular diseases are still the pathologies that generate the highest mortality and economic costs globally. In Latin America, low-income populations are the most vulnerable. Singularly, this population has an incidence of endemic diseases that can lead to blocks of the bundle branch of His. The following study seeks to develop a cardiac abnormality detection system using machine learning techniques and microcontrollers with limited resources to benefit populations with limited access to health environments. The Arduino Nano 33 BLE Sense is employed as the hardware platform due to its ARM Cortex M4 processor and support for TensorFlow Lite. An electrocardiogram (ECG) database is processed using oversampling and under-sampling techniques to address class imbalance. Spectral features are extracted using wavelet transforms, and a multilayer neural network is implemented for classification. Two class balancing approaches are compared: oversampling and undersampling. Results indicate notable improvements in the model's ability to identify instances of minority classes with the oversampling approach, while undersampling may lead to information loss. The system's performance is evaluated using key metrics such as precision, recall, and F1-Score. Additionally, computational resources required to implement the model on the Arduino Nano 33 BLE Sense are estimated, with an assessment of Flash and RAM consumption. This analysis is essential to ensure the feasibility of implementation on resource-constrained devices. This work contributes to the advancement of early detection of cardiac anomalies in resource-limited settings, with significant implications for healthcare in underserved communities and rural areas. © 2023 IEEE.

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INTRODUCCIÓN

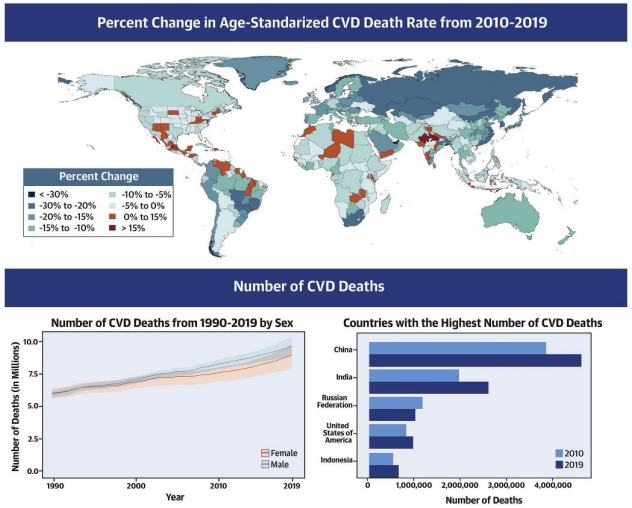


Figure 01.- CVD Deaths rate from 2010-2019 [1]

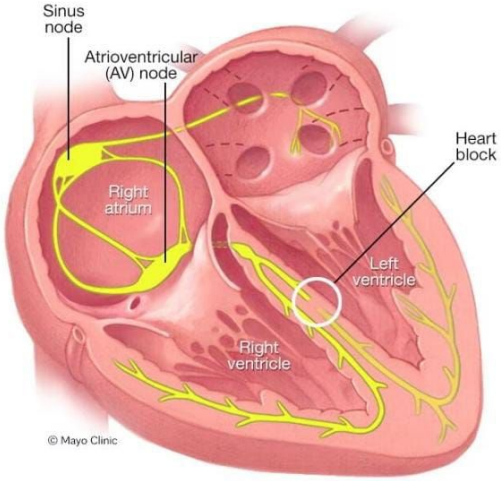


Figure 02.- Bundle branch block [2]

Objectives

- Develop a classifier for right and left bundle branch block pathologies based on electrocardiogram signals.
- Deploy the classifier model onto a microcontroller.

[1] A. Roth MD *et al.* (2020) *Global burden of cardiovascular diseases and risk factors, 1990–2019: Update from the GBD 2019 Study*, *Journal of the American College of Cardiology*. Available at: https://www.sciencedirect.com/science/article/pii/S0735109720377755 (Accessed: 01 November 2023).

[2] "Bundle branch block," Mayo Clinic, https://www.mayoclinic.org/diseases-conditions/bundle-branch-block/symptoms-causes/syc-20370514 (accessed Nov. 1, 2023).

METHODOLOGY

About the dataset

The electrocardiogram (ECG) database was employed, where 1000 randomly selected 10-second segments were extracted from 45 patients in the MIT-BIH Arrhythmia database [5]. The cohort consisted of 19 females aged 23 to 89 years and 26 male individuals aged 32 to 89. The ECG signals spanned across 17 distinct classes, encompassing normal sinus rhythm, pacemaker rhythm, and 15 other dysfunctions. These signals were exclusively derived from the Modified Limb Lead II (MLII). The ECG signals were sampled at a frequency of 360 Hz.

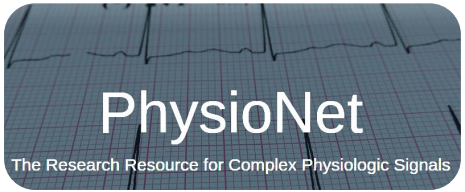
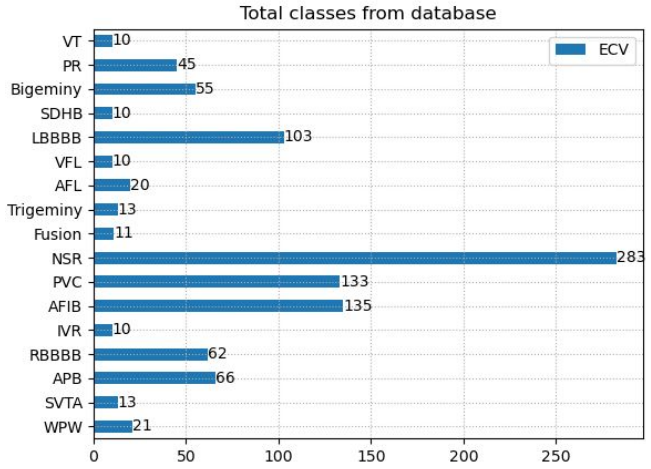


Figure 06.-Physionet dataset [5]



[5] https://www.physionet.org/content/mitdb/1.0.0/

METHODOLOGY

Uploading to Edge Impulse

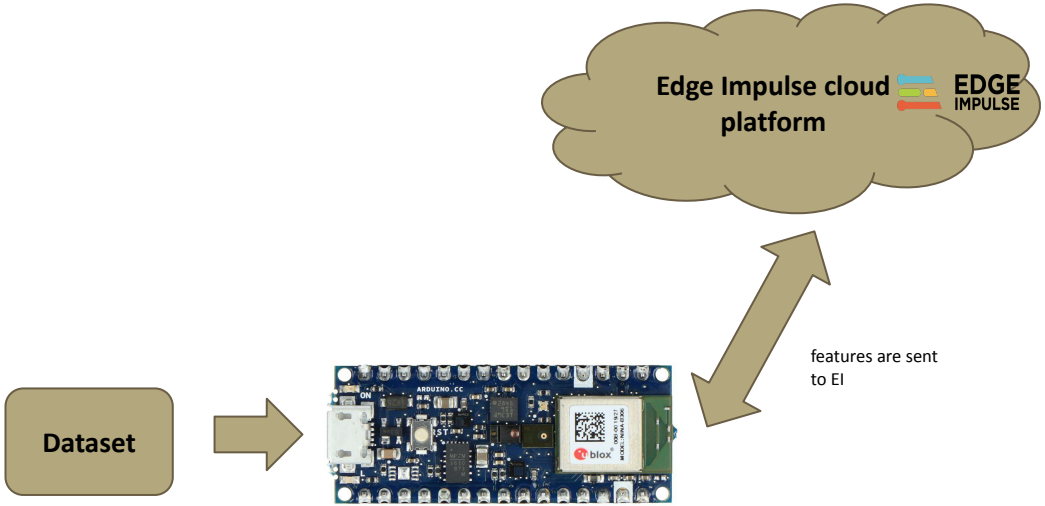


Figure 10.-Data flow diagram

```python
data = {
    "protected": {
        "ver": "v1",
        "alg": "HS256",
        "iat": time.time() # epoch time, seconds since 1970
    },
    "signature": emptySignature,
    "payload": {
        "device_name": "ac:87:a3:0a:2d:1b",
        "device_type": "NANO33BLE",
        "interval_ms": (1/360)*1000,
        "sensors": [{ "name": "Volts", "units": "adu/mv" }],
        "values": _values.tolist()
    }
}
# encode in JSON
encoded = json.dumps(data)
```

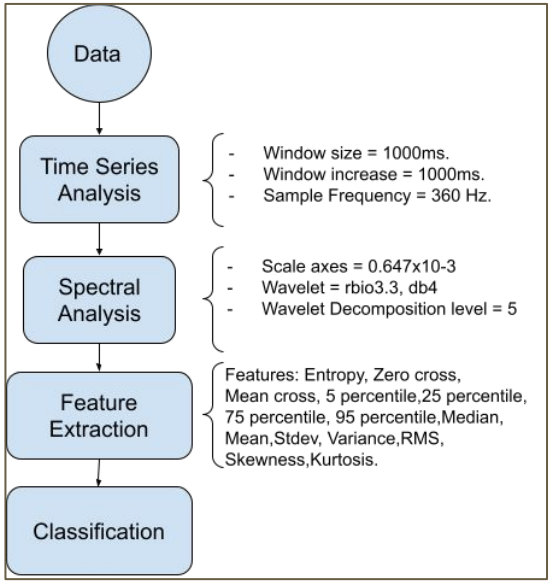
```python
res = requests.post(url='https://ingestion.edgeimpulse.com/api/training/data',
                    data=encoded,
                    headers={
                        'Content-Type': 'application/json',
                        'x-file-name': _name_label,
                        'x-api-key': API_KEY
                    })
```

Figure 11.-Code to upload data to Edge Impukse

METHODOLOGY

Feature extraction

In the implementation based on Edge Impulse's autotuning recommendation, a temporal analysis strategy was employed, using 10-second windows with 1-second increments, and the signal was scaled by a factor of 64.6 × 10−5 . Feature extraction was conducted using the "spectral features" functionality. The process involved the utilization of the discrete wavelet transform with rbio 3.3 and db4 as the mother wavelet, involving a 5-level decomposition. Subsequently, it engages in feature extraction, computing 14 specific features at each level of this decomposition.



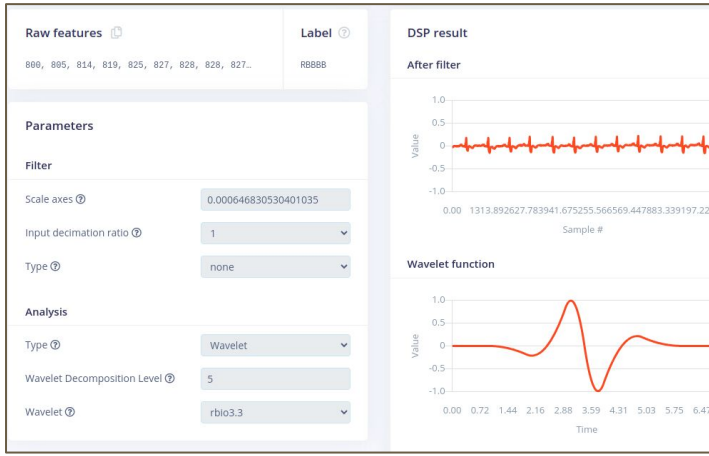


Figure 14.-Feature extraction Data flow diagram

METHODOLOGY

About Edge Impulse

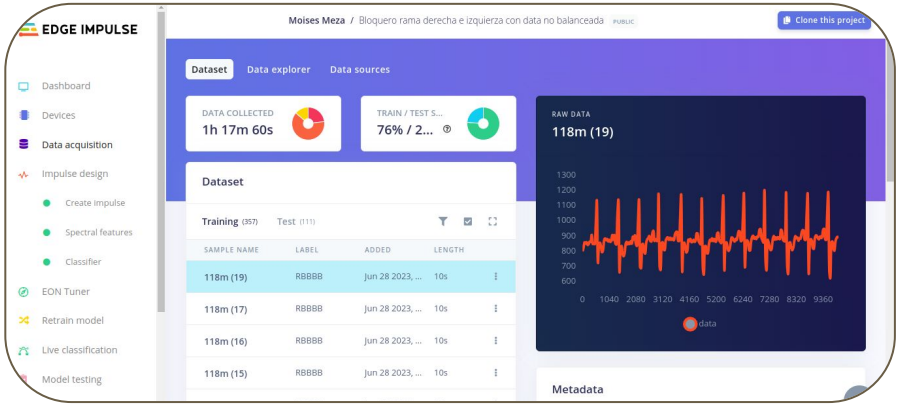


Figure 12.-Edge Impulse's principal view of Data acquisition.

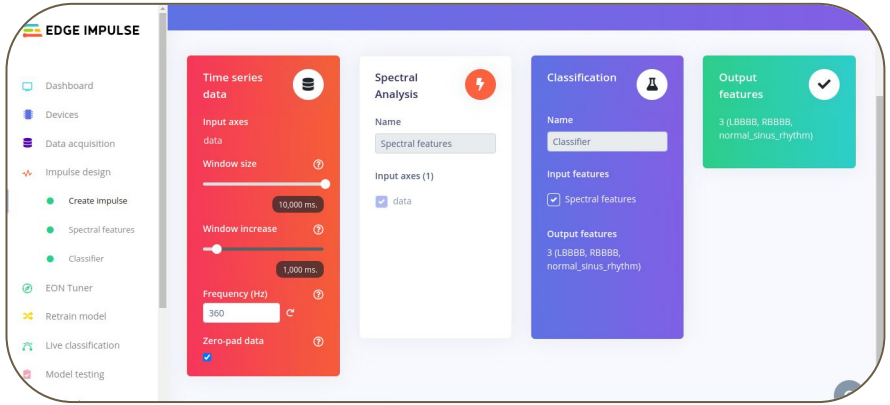


Figure 13.-Edge Impulse's principal view of Create Impulse.

RESULTS AND DISCUSSION

In Table 2, the outcomes after the implementation of the oversampling technique are showcased. Notably, a marked enhancement in the recall metrics is evident across all classes, with a particularly noteworthy escalation observed in the RBBBB class – ascending from 0.7 to 0.95. This conspicuous improvement underscores the effectiveness of the oversampling strategy in augmenting the model's aptitude for precise identification of true positives, effectively ameliorating the inherent bias towards the majority classes.

However, Table 3 presents the outcomes after applying the undersampling technique. Notably, an enhancement in the recall metric is observed for the LBBBB class, yet the precision and F1-score metrics exhibit a notable decrease for this class. This observation suggests that the undersampling approach may substantially lose crucial information when predicting the LBBBB class.

Table 02.-Imbalanced data results

IMBALANCED	LBBBB		RBBBB		NRS	
	RBIO 3.3	DB4	RBIO 3.3	DB4	RBIO 3.3	DB4
ACCURACY	1.00	0.72	1.00	1.00	1.00	0.91
PRECISION	1.00	0.87	1.00	0.70	1.00	0.85
RECALL	1.00	0.72	1.00	0.70	1.00	0.91
F1	1.00	0.79	1.00	0.70	1.00	0.88

Table 03.-Oversampled data results

OVERSAMPLING	LBBBB		RBBBB		NRS	
	RBIO 3.3	DB4	RBIO 3.3	DB4	RBIO 3.3	DB
ACCURACY	0.98	0.96	1.00	0.96	0.98	0.9
PRECISION	0.98	0.98	0.98	1.00	1.00	0.9
RECALL	0.98	0.96	1.00	0.95	0.98	0.9
F1	0.98	0.97	0.99	0.98	0.99	0.9

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MANUAL DE USUARIO DEL SOFTWARE “BitaConnectino”

Fabricante:

Roberto Edu Joao Marin Vera

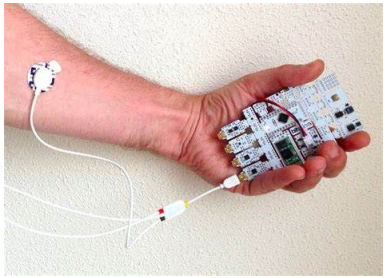
Moises Stevend Meza Rodriguez

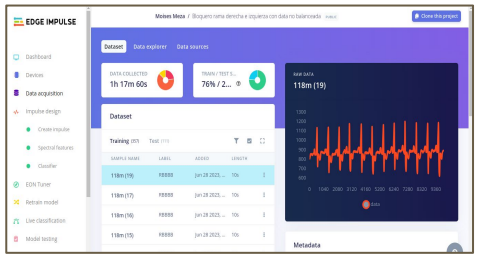
Fecha de revisión del manual del usuario:

10/04/2024

Lima - Perú

2024





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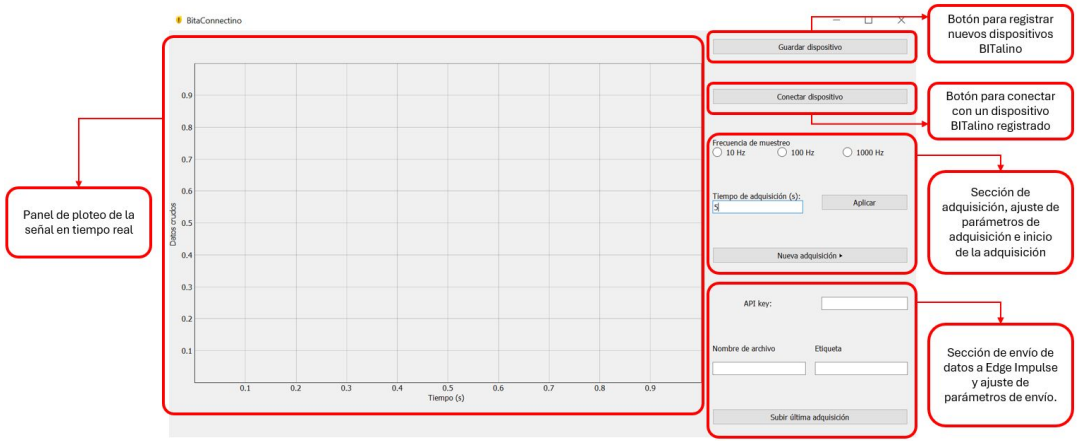

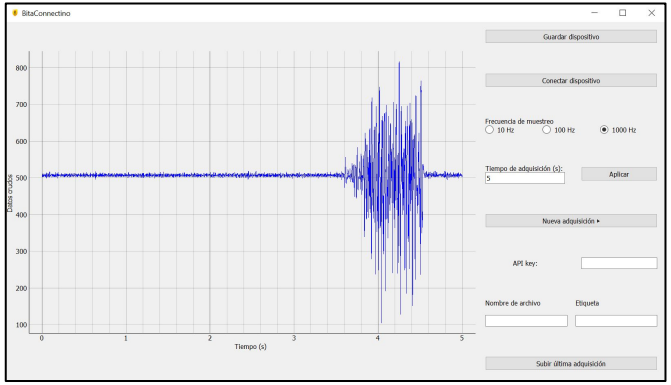

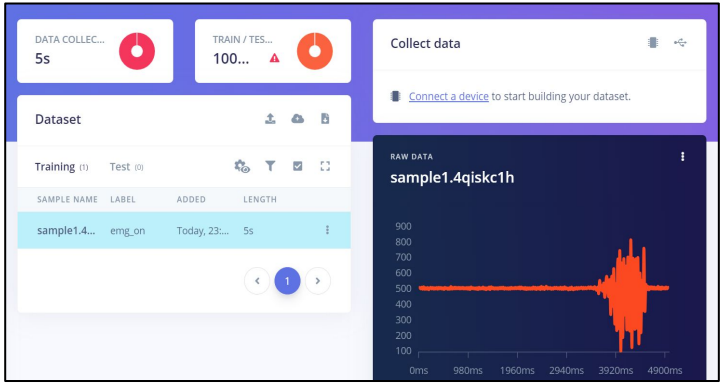

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August 31th, 2023	1. **Innovative Waste Classification through Tiny Machine Learning Recognition Approach** by Juan Manuel Mena Carrillo of Universidad Peruana Cayetano Heredia, Perú 2. **An AI powered device that detects seizures and alerts caretakers in real time** by Nickson Kiprotich of Dedan Kimathi University of Technology, Kenya 3. **Deploying a fetal heart rate classification model on RP2040 Microcontroller** by Shahzaib Ali of National Universit of Science and Technology, Pakistan	Video
May 25, 2023	1. **Inference With TinyML On Ghana Radio Astronomy Observatory (GRAO) 32-m Antenna: Track Level Profile Anomaly for Predictive Maintenance** by Joseph Akubire Kojo of Ghana 2. **A Multiply-And-Max/min Neuron Paradigm for Aggressively Prunable Deep Neural Networks** by Philippe BICH of Italy	Video Coming Soon!
March 30, 2023	1. **Automation of Coloring Process in Fashion Design Using Arduino Color Sensor** by Fatmaliza Zaki Abdad, Syafiga Arinda of Sampoerna University, Indonesia 2. **Anomaly detection for faulty motor using the arduino board Nano 33 BLE sense** by Hilal Al-Libawy of University of Babylon, Iraq 3. **First Time TinyML Experience** by Edwin Marte of Universidad Tecnologica de Santiago, Dominican Republic 4. **Voice Activated LED Voice control lighting** by Muhammad Annas Zahid of Usman Institute of Technology University, Pakistan	Video
February 23, 2023	1. **Artificial Intelligence in Point-of-Care Medical Equipment** by Hellen Cristina Ancelmo of Instituto Carlos Chagas & Universidade Tecnológica Federal do Paraná, Brazil 2. **Weep Scope: Recognizing the Unique Cries of Infants** by Gohel Amit Chandrakantbhai of Gujarat Technological University, India 3. **Crops Disease Detection with TinyML** by James Adeola of Université d'Abomey Calavi, Benin 4. **Implementation of Deep Learning on a Chick Counter** by Muhammad Suzaki Zahran of Universitas Raharja, Indonesia 5. **Identification of Cashew Nut Diseases using TinyML** by Dr. Bala Murugan MS of Vellore Institute of Technology, India	Video
January 26, 2023	1. **Personal Trainer** by Ricardo Magno do Carmo Junior of Universidade Federal de Itajubá (UNIFEI), Brazil 2. **Irrigation prediction for crops using machine learning at the edge** by Carlos Rodríguez of Pontificia Universidad Javeriana, Colombia 3. **EYE TO EYE: non-invasive anemia detector using machine learning** by Kimberly Cristel Soto Concha of Universidad Peruana Cayetano Heredia 4. **Estimating the shelf life of date palm fruit using TinyML** by Abdulrahman Fayez of King Faisal University Saudi Arabia	Video

Pattern recognition

UNIVERSIDAD PERUANA CAYETANO HEREDIA

FACULTAD DE CIENCIAS E INGENIERÍA

DEPARTAMENTO ACADÉMICO DE INGENIERÍA

SÍLABO DE RECONOCIMIENTO A PATRONES

I. DATOS GENERALES

1.1	Nombre de la asignatura	Reconocimiento de Patrones
1.2	Código	C0708
1.3	Carrera(s)	Ingeniería Biomédica
1.4	Semestre Académico	2024-I
1.5	Tipo de la asignatura	**ELECTIVO**
1.6	Prerrequisitos	**150 CRÉDITOS**
1.7	Créditos	3.0 Horas Teóricas: 48 hrs
1.8	Duración	Del: 18/03/2024 Al: 13/07/2024
1.9	Profesor coordinador	Mg. Moises Stevend Meza Rodriguez moises.meza@upch.pe
	Co-Coordinador	Mg. Jesus Alvarado Huayhuaz jesus.alvarado@upch.pe

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II. SUMILLA

El curso introduce conocimientos sobre la implementación de sistemas de computadora para el análisis de información y toma de decisiones. Se abordan conceptos sobre características en señales e imágenes, el espacio de características y reglas de decisión. Se analizan métodos de decisión estadísticos y de inteligencia artificial: Decisiones bayesianas, análisis de discriminación lineal, análisis de componentes principales, redes neuronales, máquinas de vectores de soporte, entre otros.

V. CONTENIDOS

UNIDAD 1: FUNDAMENTOS BÁSICOS

1. ¿Por qué es importante el reconocimiento de patrones? ¿Qué es machine learning?
2. ¿Qué tipos hay?
3. ¿Por qué Python? ¿Qué librerías utilizaremos?
4. Principales desafíos de Machine Learning
5. Pruebas y evaluación de modelos

UNIDAD 2: MÉTODOS DE APRENDIZAJE SUPERVISADO

1. Regresión y Clasificación
2. k-Nearest Neighbors
3. Clasificador Naïve Bayes
4. Training y Testing, Overfitting, regularization
5. Support Vector Machines
6. Árboles de decisión
7. Random Forests
8. XGBoost
9. Optimización y “tuneo” de parámetros (SGD)

UNIDAD 3: MÉTODOS DE APRENDIZAJE NO SUPERVISADO

1. Clustering
2. k-Means Clustering
3. Gaussian Mixture Model
4. Reducción de Dimensionalidad

UNIDAD 4: REDES NEURONALES

1. Neuronas Biológicas
2. El perceptrón
3. Multi-Layer Perceptron (MLP) y Backpropagation
4. Regresión MLP, Clasificación MLP
5. Deep Learning I: Redes Neuronales Convolucionales
6. Deep Learning II: Redes Neuronales Recurrentes
7. Deep Learning III: LSTM
8. Sistemas embebidos en IA
9. Presentación del Proyecto

SPECIAL THANKS

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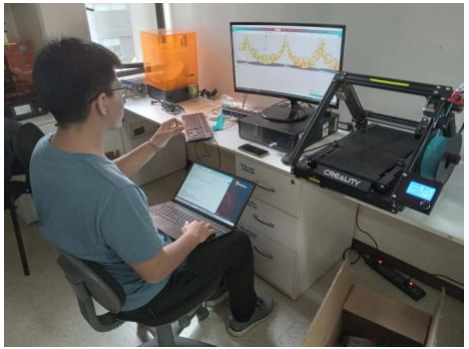
Laboratorio de ing. Biomédica



THANKS