Towards low-cost A.I.-based sensors

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Outline

1. Application needs
2. Sensor Development (traditional)
3. Sensor Development (future)
4. H2020 ASTRAL

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Robotics

Sensors

Machine Learning Modelling

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NVIDIA

DEEP LEARNING INSTITUTE

UNIVERSITY AMBASSADOR

Aquaculture Facilities (EMA)

16 saltwater-based tanks

Brazil - Rio Grande do Sul

Ireland - Bertraghboy Bay

Application needs

- Eco-friendly value chains for fishery and aquaculture
- Remote, unattended sites
- Off-grid power supply (wind/solar)
- Improved communication coverage
- In-situ continuous monitoring and real-time visualisation incl. configurable trigger alerts
- Monitoring of water, crop and site related variables
- Water sample collection for chemicals to manage fish diseases and pests
- A.I-based Data analytics:
    - enhance the knowledge of local producers, lower existing acceptance barriers of aquaculture activities by the society
    - predictive data modelling (forecasting)
- ***VERY LOW-COST*** "IoT Intelligent Sensors"; low-cost installation;

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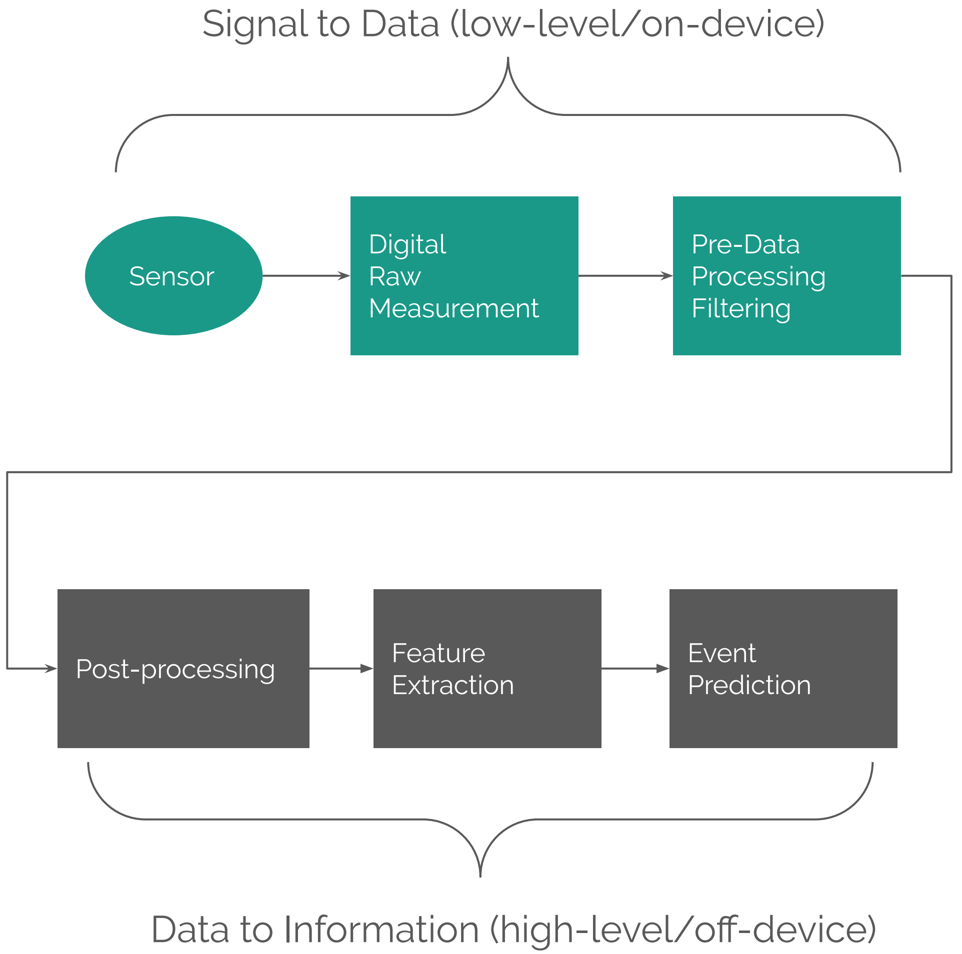
2. Sensor Development (traditional way)

Sensor Development (traditional way)



LOW-LEVEL Processing

HIGH-LEVEL Processing

Software packages for data analysis

Cloud-based analysis

Visualisation of relevant events

Automated detection (Classification in ML)

Forecasting of future events (regression in ML)

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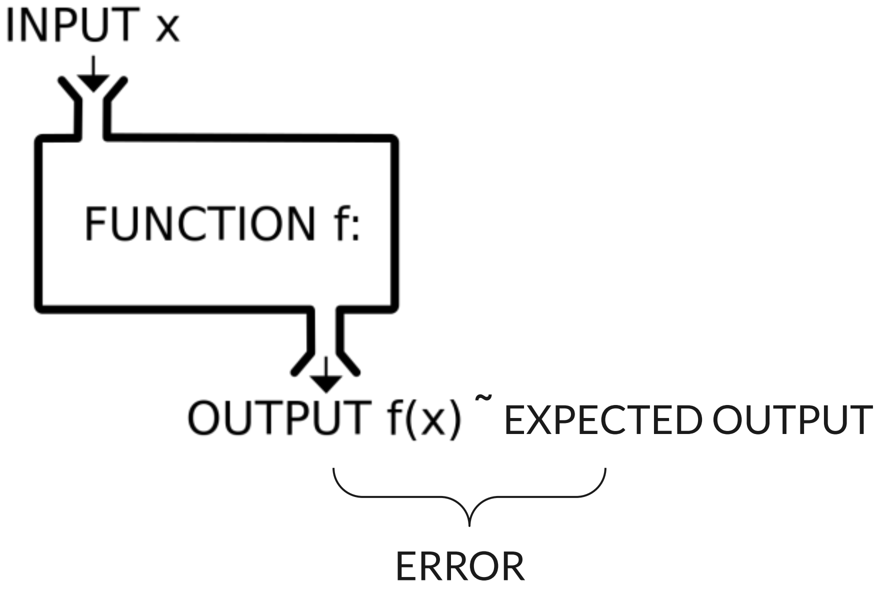
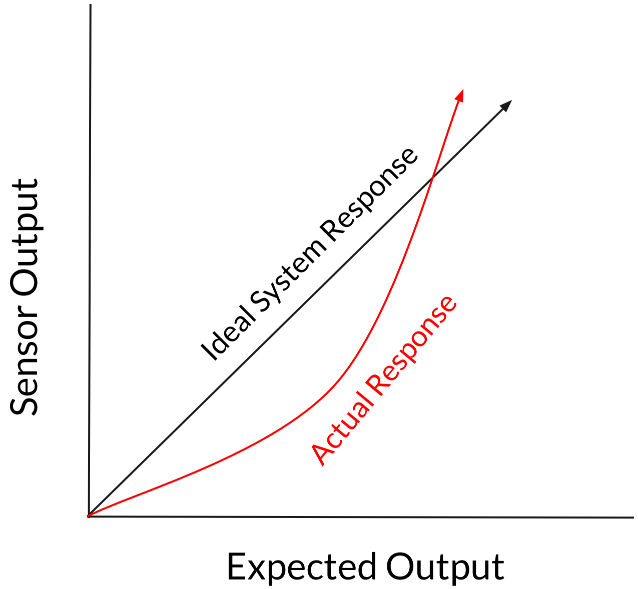
Sensor Calibration

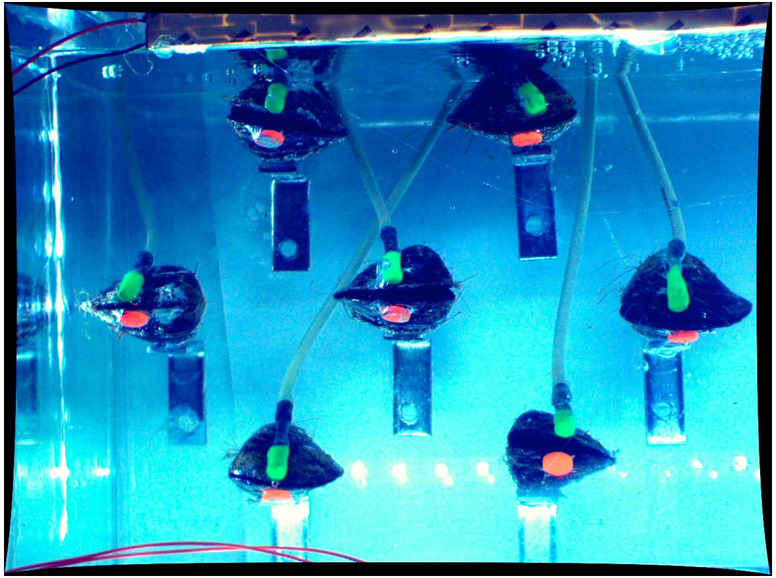
- Remove structural errors
  - Differences between a sensor expected output and its measured output
- Standard References
  - Standard physical reference
    - Accelerometer: gravity is a constant **1g**
  - A calibrated sensor (more accurate)
- Calibration Methods
  - **One Point Calibration:** linearity over the measurement range; useful to correct for offset errors
  - **Two Point Calibration:** linearity over the measurement range; useful to correct for slope and offset errors
  - **Multi-Point Curve Fitting:** not linear over the measurement range requires curve-fitting

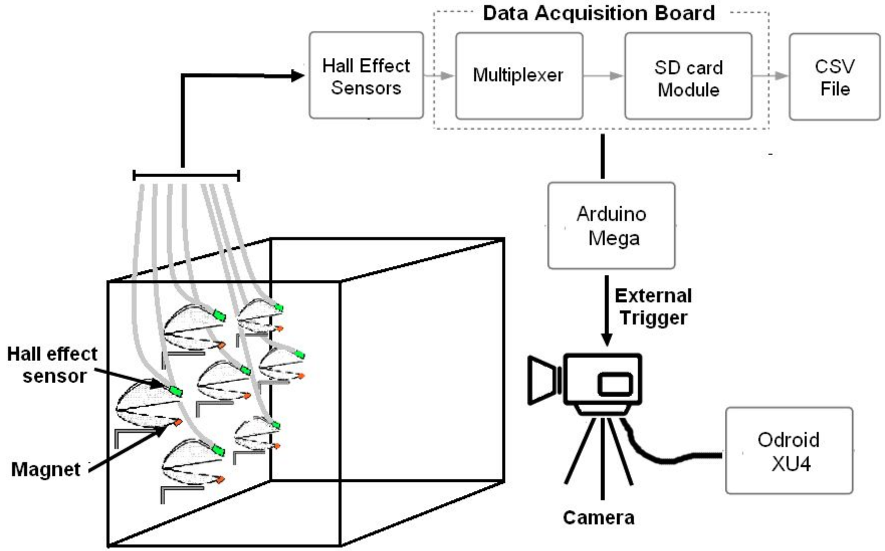

INPUT x
FUNCTION f:
OUTPUT f(x) ˜ EXPECTED OUTPUT
ERROR


Sensor Output
Ideal System Response
Actual Response
Expected Output

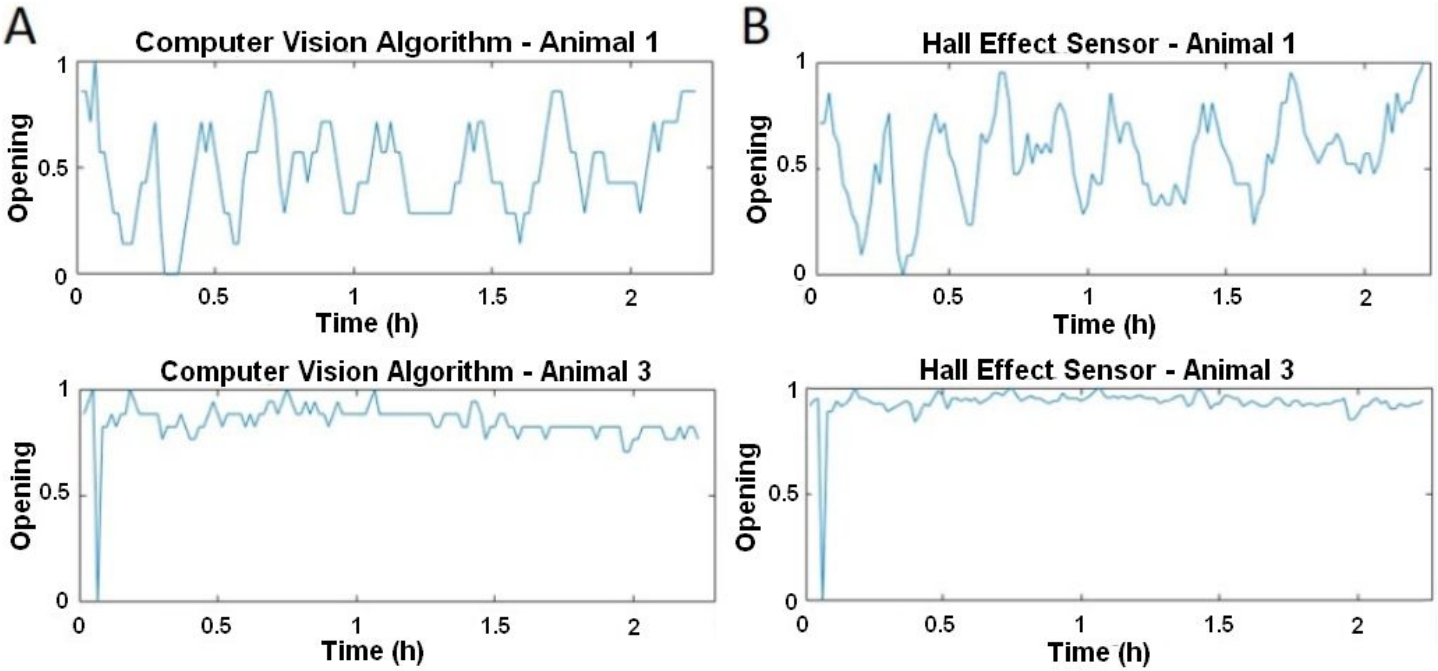
Mussels as Aquatic Pollution Biosensors

Calibration: multi-point Non-linear Autoregressive (NAR) neural networks





DE VARGAS GUTERRES, Bruna et al. Feasibility of visual signals on the construction of biosensors based on behavioral analysis of Perna perna mussels. Ecological Informatics, p. 101118, 2020.



Multi-point calibration
Non-linear Autoregressive (NAR) neural networks
(“shallow” neural network, 3 layers)

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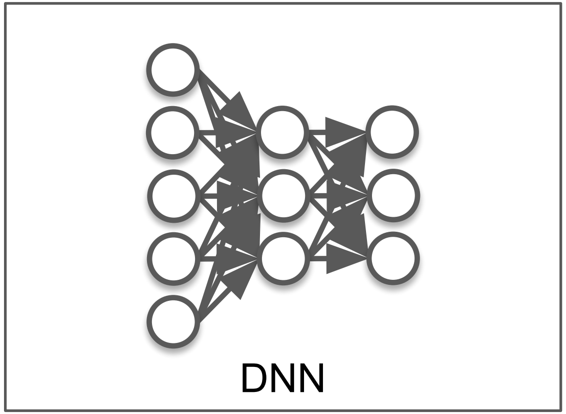
3. Sensor Development (future)

Edge-based AI - Sensor Calibration and Event Detection



M. Pias, et al, "Perfect Storm: DSAs Embrace Deep Learning for GPU-Based Computer Vision," *2019 32nd IEEE SIBGRAPI Conference on Graphics, Patterns and Images Tutorials (SIBGRAPI-T)*, Rio de Janeiro, Brazil, 2019, pp. 8-21

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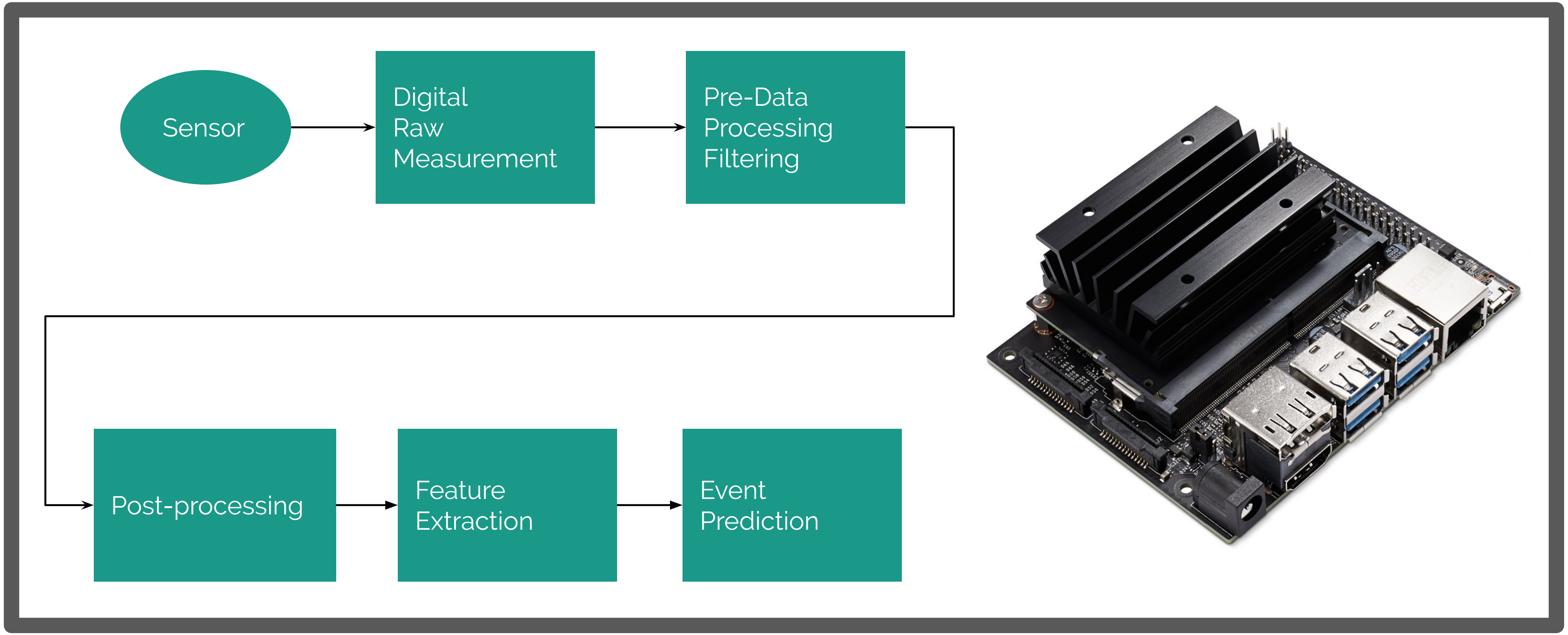
Why edge-based computing for (remote, in-situ) measurements

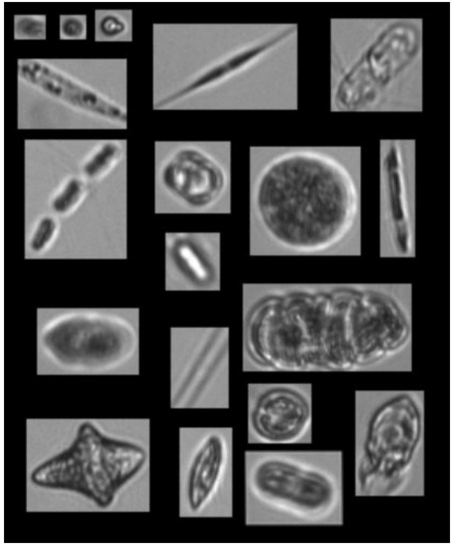
- Opportunity for higher sensor sampling frequency
- Image-based data
- Sub-sea sound-based data
- Data communication throughput limited, expensive
- On-board processing

Sensor Development (future)

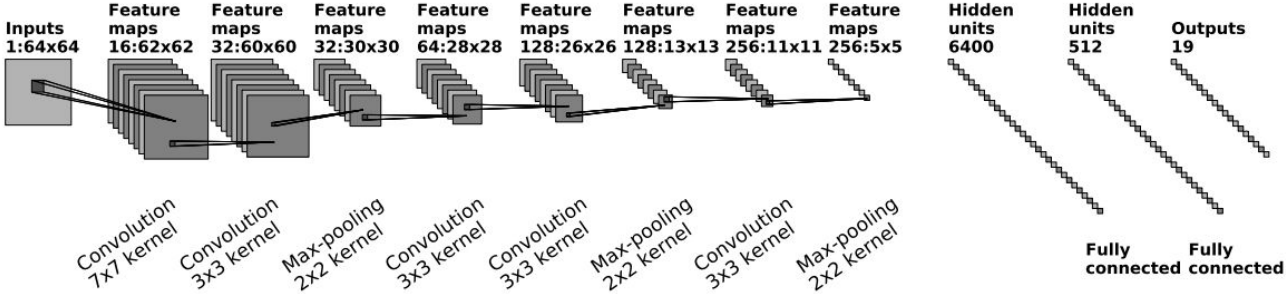
GPU-based Edge Computer



Sensor Development (future)



Microalgae dataset:
19 classes; 29,449 images



Correia, I. et al,, "Deep Learning for Microalgae Classification," *2017 16th IEEE International Conference on Machine Learning and Applications (ICMLA)*, 2017, pp. 20-25.

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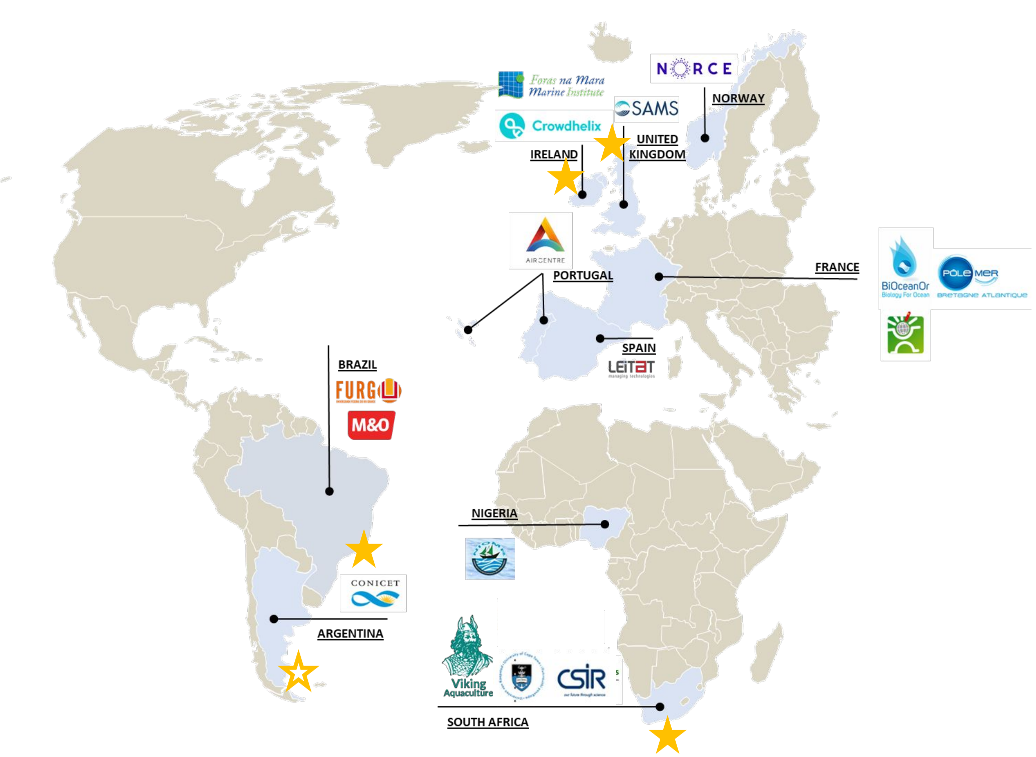
Low-cost Vision-based sensors

- Low-cost vision-based sensors embedded with A.I Deep Learning Models
- Affordable GPUs - NVIDIA Jetson Nano under US$99
- Processing based on multiple operations on the same data element.
  - Matrix transformations, vector and scalar operations
- TinyML software stack
- In-situ sensing
  - Detection of micro particles
  - Particle size and camera resolution
  - How to “a take picture” in water fluid (microflow system, camera rig, visibility, lighting, etc)
  - Library of Pre-Trained Deep Learning models (microplastic, HABs and so forth)
  - Cost, accuracy, energy consumption for unattended operation
  - Micron-level resolution, off-the-shelf cameras used in smartphones

4. H2020 ASTRAL

ASTRAL: Sustainable, ProfiTable and Resilient AquacuLture (2020-2024)

BG-08-2019: All Atlantic Ocean Research Alliance Flagship – [C] New value chains for aquaculture production



★ **IMTA labs:** Scotland, Ireland, South Africa, Brazil.

☆ **Prospective IMTA lab:** Argentina

The overall objective of ASTRAL is to develop new, sustainable, profitable and resilient value chains for integrated multi-trophic aquaculture (IMTA) production within the framework of existing, emerging and potential Atlantic markets.

ASTRAL specific goals:

(1) defining and assessing IMTA production chains in open, recirculating and flow through systems;

(2) evaluate their potential for productivity, sustainability, profitability, consumers' trust and regulatory frameworks;

(3) design and validate innovative technology for the monitoring of the production and environment;

(4) transfer knowledge between partners and at Atlantic level, promoting stable business development through the Atlantic Aquaculture Alliance (3A).

ASTRAL Technology Pool

- Partners: NORCE, LEITAT, EGM, BIOCEANOR, SAMS, FURG, CSIR
- Development of new sensors
- IoT Kits for Aquaculture
- A.I. Vision Sensors
- Data Analytics Platform

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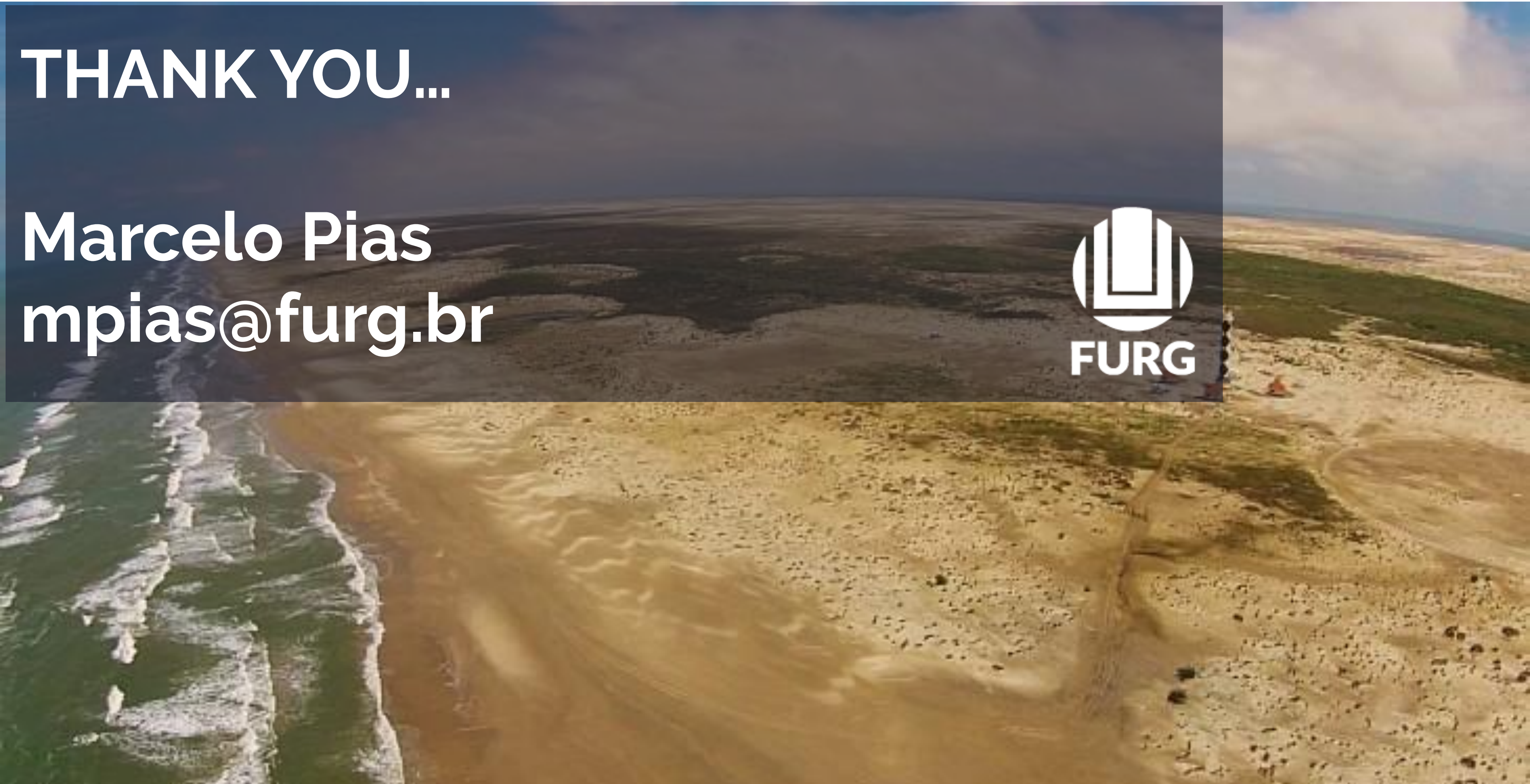

THANK YOU…

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Aquaculture Sites

Brazil - Rio Grande do Sul

Ireland - Bertraghboy Bay

Challenges for technology deployment

1. Site area: anything between 5 to 30 hectares

2. Difficult access (boats or off-road vehicles)

3. Power supply: none in open-water; none to limited in land-based

4. Communication coverage: limited to none

5. Climate and adverse weather conditions

6. Lack of **AFFORDABLE** Monitoring Technology

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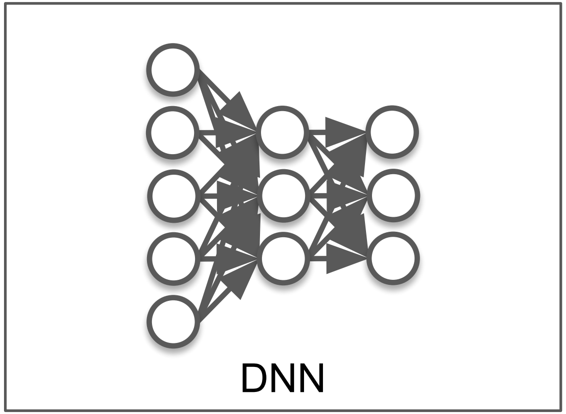
Edge-based AI - Sensor Calibration and Event Detection



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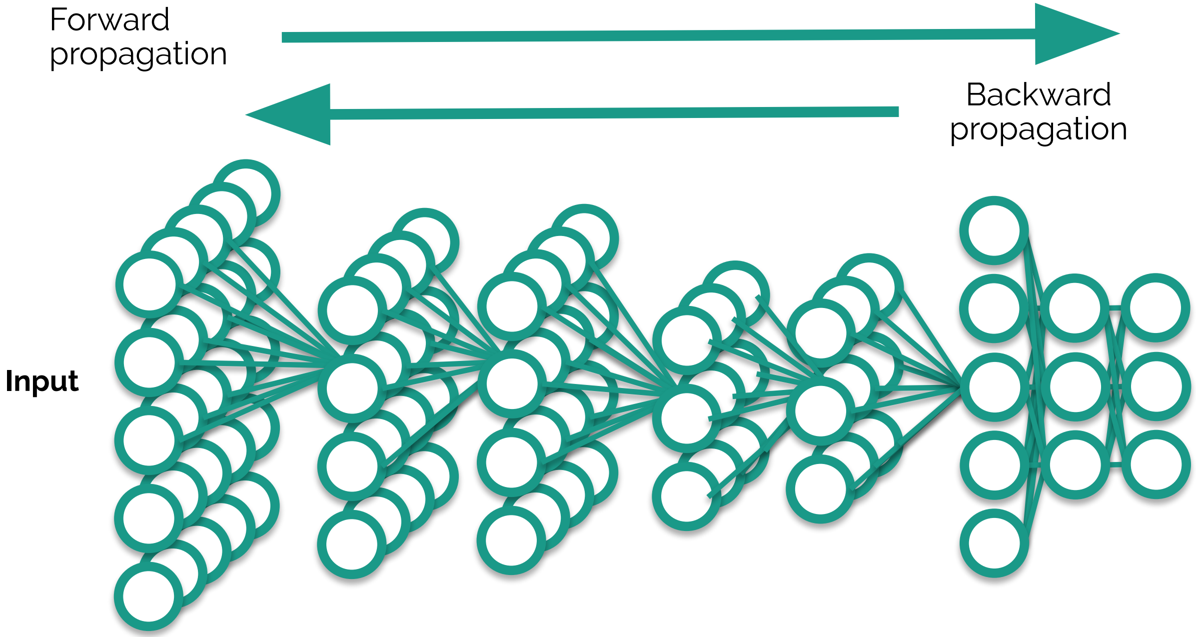
Sensor Development (future)

DEEP LEARNING APPROACH - TRAINING



Process

- Forward propagation yields an inferred label for each training image
- Loss function used to calculate difference between known label and predicted label for each image
- Weights are adjusted during backward propagation
- Repeat the process