

# Incremental Learning for Resource-Constrained Smart Sensors

## 1. About *Edge Spectrum*

*Edge Spectrum* is a French startup specializing in the development and commercialization of end-to-end predictive maintenance solutions for industry. Its mission is to help industrial companies anticipate equipment failures, optimize the lifespan of their equipment, and reduce the costs associated with unplanned downtime. The company's solutions rely on smart connected sensors that can collect, analyze, and transmit data in real time. *Edge Spectrum* leverages the latest embedded artificial intelligence and frugal computing technologies to make these sensors increasingly autonomous, efficient, and adapted to industrial constraints. Thanks to this approach, the company enables clients to combine operational performance, cost control, and a transition toward a more sustainable industry.

Website for more information: [www.edge-spectrum.com](http://www.edge-spectrum.com)

## 2. Internship Context

Artificial intelligence (AI), particularly Machine Learning (ML) and Deep Learning (DL), is gaining growing interest in the industrial world. Every day, new use cases emerge, and predictive maintenance is among the most promising. Thanks to modern microcontrollers such as the STM32N6 series, which include computation units optimized for inference, it is now possible to embed a pre-trained DL model directly into a sensor. However, several obstacles still limit the large-scale adoption of these systems.

Training complex models such as convolutional neural networks (CNNs) require very large volumes of data and computational resources far beyond the capabilities of embedded microcontrollers. Additionally, transferring these large amounts of data from sensors to the cloud for training is difficult due to limited bandwidth and the time this requires in an industrial context. To overcome these constraints, *Edge Spectrum* is exploring a promising approach, **incremental learning**. This method allows a model to be updated gradually as new data is collected, without needing to be fully retrained each time. Incremental learning enables continuous adaptation of the model to changes in the industrial environment, such as progressive equipment wear or evolving operating conditions. It also reduces the amount of data that needs to be transferred and stored, because only the most recent and relevant information is used. *Edge Spectrum*'s goal is to develop new learning methods adapted to embedded systems, making sensors smarter and more autonomous. These methods should also provide benefits in a traditional cloud environment, optimizing resource use, and

minimizing the storage needed for datasets. This approach follows the concept of frugal AI, focusing on efficiency and resource-conscious design.

### 3. Objectives

This Master's internship represents the first step in a detailed study of incremental learning in constrained environments. The main objectives of this internship are:

- To conduct an exhaustive review of state-of-the-art in incremental learning methodologies, with the aim of understanding their theoretical foundations, strengths, and limitations. The intern will additionally perform a comparative analysis between these emerging approaches and the conventional methods currently employed, to assess their respective advantages, drawbacks, and potential contributions.
- To design and implement a prototype addressing a practical case of time-series prediction of physical quantities, such as temperature, using one or more incremental learning algorithms. This prototype will be developed both on a PC environment using Python and on an STM32-based microcontroller evaluation board from STMicroelectronics, enabling a thorough assessment of performance differences and potential implementation constraints across platforms.

This work will result in some concrete, validated contribution to Edge Spectrum's sensor technology, including documented methods, experimental results, and actionable recommendations for deploying incremental learning in real industrial environments

### 4. Processus de Candidature

The internship will take place at the LII (Interactive Computer Science Laboratory) of ENAC in Toulouse. The start and end dates are flexible, with a weekly workload between 30 and 40 hours. The monthly salary is approximately €640. To apply, candidates should send the following documents to [\*\*frederic.zbierski@edge-spectrum.com\*\*](mailto:frederic.zbierski@edge-spectrum.com) and [\*\*dorra.ben-khalifa@enac.fr\*\*](mailto:dorra.ben-khalifa@enac.fr)

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