Centre for AI-Fundamentals
RAEng Google DeepMind Summer Internship Programme 2025

Project proposal

Project Title	Edge-AI
Lead supervisor	Leandro Maio
Project Description	Edge Artificial Intelligence (Edge-AI) can play a transformative role in advancing Structural Health Monitoring (SHM) systems. By integrating AI algorithms directly into edge devices (e.g., sensors placed on structures), Edge-AI can enable real-time data processing, analysis, and decision-making on-site, without relying on centralized cloud computing or extensive data transfers. This can lead to faster, more efficient, and cost-effective monitoring of structures such as bridges, buildings, and dams. However, AI models are extremely computing intensive, especially during the training phase. The implementation and deployment of data preprocessing and training on hardware computation units represent the last opportunity for the simultaneous optimization of performance and energy consumption. There is a need to optimize this process running most of the operations on the edge rather than streaming whole data to the cloud, where the placement and scheduling of AI-models affects the performance and energy consumption greatly. Again, this strongly affects the performance and reliability of the AI system as a whole, whose complexity should be lowered down without compromising the performance. The project outlines a phased strategy to construct and deploy an ad hoc explainable data-driven neural network model for damage detection and localization in composites at the edge. The objective is to utilize a dataset of ultrasonic guided wave (UGW) measurements obtained from a distributed sensor array, process it with neural networks to forecast the sensor paths impacted by damage, and subsequently employ structural information from the system to generate a heat map indicating the most probable damage locations. To achieve this goal, publicly available dataset is exploited to obtain the UGW measurements necessary to build the ANN model up. To reduce the number of trainable parameters, a physical signal processing approach is applied to the raw data before passing the data to the model (e.g., filter, window function, feature extraction by root mean squared deviation,

	variance, standard variation). Then, this model is deployed on the edge (e.g., low cost development boards produced by TinyPICO, Espressif) to obtain a real-time low-computation diagnosis. This activity lays the foundation to realize an advanced system for Structural Health Monitoring (SHM) through the implementation of Edge-AI.
	-- Work Plan for the 7 weeks of the internship -- **Week 1 - Features from time histories**: extracting of statistical features (e.g. energy of the signal, zero-crossing rate, spectral centroid, spectral flatness, peak-to-peak amplitude, root mean square, crest factor, Kurtosis, skewness, Shannon entropy, Hjorth parameters) from time signals representing ultrasonic guided waves measurements (e.g., available as public dataset). **Week 2-3 - Pre-trained machine learning model**: creating and training a neural network model for data classification (e.g., by using TensorFlow developed by Google). **Week 4-5 - Tiny device implementation**: deploying the trained model onto a microcontroller (one among these: Arduino Nano 33 BLE Sense, SparkFun Edge, Kit Discovery STM32F746, Adafruit EdgeBadge, Espressif ESP32-DevKitC, Sony Spresense) and running the code. **Week 6-7 – System test and model optimization**: (i) testing the system with new ultrasonic data (real scenario or simulated) to ensure accuracy; (ii) using quantization-aware training to reduce model size; (iii) optimizing the model architecture for low latency and memory usage. **Goal**: Tiny ML (machine learning models optimized to run on small, low-power devices such as microcontrollers) for SHM. **-- Learning outcomes/Learned skills and competencies --** By implementing Tiny ML applications, students not only learn machine learning but also gain hands-on experience with real-world hardware, embedded systems, and practical AI deployment. The combination of these competencies will make students well-prepared for careers in embedded AI, IoT development, edge computing, and smart device industries. A

	breakdown of what students can gain from this kind of project is listed below: 1. **Understanding Embedded Systems**: *Learning Outcome*: knowledge of embedded systems, which are small-scale computing devices (e.g., microcontrollers) designed for specific tasks. *Skills & Competencies*: ▪ Embedded Hardware: learning how to work with sensors (like accelerometers) and microcontrollers (like Arduino). ▪ Real-time Processing: understanding how to handle real-time data processing with limited resources. 2. **Practical Machine Learning (ML) Skills**: *Learning Outcome*: how machine learning models are designed, trained, optimized, and deployed, especially when constrained by memory and processing power. *Skills & Competencies*: ▪ Data Collection & Preprocessing: understanding how to collect sensor data and preprocess it for training models. ▪ Model Training & Evaluation: hands-on experience in selecting, training, and evaluating ML models using frameworks like TensorFlow or Keras. ▪ Model Conversion for Edge Devices: converting machine learning models into lightweight formats (e.g., TensorFlow Lite) for embedded systems. 3. **Programming Skills**: *Learning Outcome*: enhancing programming skills, especially in Python (for machine learning model development). *Skills & Competencies*: developing proficiency in using Python for data science and machine learning tasks. 4. **Problem Solving and Debugging**:

Learning Outcome:
working on Tiny ML applications involves overcoming many challenges, such as optimizing model size, managing hardware limitations, and troubleshooting errors.

Skills & Competencies:
- Optimization: learning to optimize code and models to fit the constraints of low-power devices.
- Creative Thinking: coming up with creative solutions to challenges such as limited memory, processing power, or data quality.

5. **Knowledge of Machine Learning Deployment at the Edge**:

Learning Outcome:
understanding how machine learning can be applied to edge devices (edge computing) and the benefits it brings.

Skills & Competencies:
- Edge AI Concepts: gaining expertise in edge AI, which refers to performing machine learning tasks locally on a device instead of sending data to the cloud for processing.
- Real-Time AI Inference: understanding how real-time decisions can be made locally without relying on an internet connection.
- Low-latency Applications: developing a sense of how to reduce latency in ML models for responsive applications.

6. **Understanding of the Future of AI and Edge Computing**:

Learning Outcome:
Tiny ML is at the cutting edge of the intersection between AI, IoT, and edge computing. By working on such projects, students will develop an understanding of how AI is evolving toward decentralized, edge-based solutions.

Skills & Competencies:
- Future-proof Skills: acquiring skills in machine learning and embedded systems that are increasingly in demand in industries like IoT, smart devices, healthcare, and robotics.