– Thesis Offer –

Toward Frugal Machine Learning with Physics-Aware Models: Application to Road Monitoring

Advisors: Olivier Alata (Professor) and Jordan Frecon-Deloire (Associate Professor)
Host laboratory: Hubert Curien Lab UMR CNRS 5516, Saint-Etienne, France
Starting date: Early 2024 - at your earliest convenience

Keywords: Physics-based machine learning; Frugal AI; Incremental learning; Action recognition.

Context The present thesis proposal is part of the *GreenAI research project* resulting from the collaboration between academic (Hubert Curien Lab) and industrial partners (Asygn, DRACULA Technologies). Its main objective is to create autonomous smart sensors benefiting from a low ecological footprint for road monitoring purposes. As such, this project is inherently a vector of cross-cutting developments in machine learning and embedded systems design.

Description This subject focuses on the development of a learning algorithm for action recognition [1] and rare events' detection in videos, with a specific emphasis on its environmental impact. On one hand, we aim to minimize its memory usage by learning and imposing both physics and geometric constraints. On the other hand, we will employ incremental learning techniques to ensure its long-term sustainability.

- *Physics-aware models.* Recently, physics-guided machine learning models [2] have shown to be a promising tool to incorporate known physical priors in the learning process of the model. In the context of road monitoring, known physical priors could potentially include the modeling of lighting and weather variations over different time scales. Conversely, some approaches have been designed to discover the underlying dynamical system from observations [3]. In this thesis, the candidate should contribute to the development of physic-based models in order to learn the dynamics of "normal" road traffic baselines from which rare "dangerous" events can be detected.

- *Equivariance and invariance.* Another research direction will focus on the development of physic-aware models invariant/equivariant to geometric and physical parameters. For instance, the same actions in the scenes can be seen from different perspectives, hence modifying the angles and changing the scales of the captured images. It will therefore be necessary to develop a decision model that is, by design, invariant to certain transformation groups (scaling, translation, etc.) [4]. Departing from these standard transformations, the model should also be robust to slight variations in the sensors' calibration settings.

- *Incremental learning.* Before deployment, the autonomous smart sensors will undergo training on a batch of videos. However, the environments in which they will be installed can vary. To dynamically adapt the model to its new environment, the candidate should leverage the latest advances in incremental learning to update the model parameters as data is acquired. Additionally, given that the environment itself may change over time, the candidate should devise a framework for updating the physical priors of the physics-aware models as well. Contributions could explore the connections with incremental learning for physics-informed neural networks [5].

Candidate profile

- Master or Engineer school in computer science, applied mathematics or related.
- Good Python programming skills. PyTorch experience is welcomed.
- Good knowledge of neural networks. Additional knowledge in probabilities, statistics and physical models would also be appreciated.
- High proficiency in English.

Application Candidate must send the following documents to both jordan.frecon.deloire@univ-st-etienne.fr and olivier.alata@univ-st-etienne.fr as soon as possible:

- Cover letter with justification of your skills for the topic
- A complete Curriculum Vitae
- Transcript of your bachelor and master's/Engineer school's grades.
- CEFR level in English (except if university courses were taught in English)
- Any additional document: letter(s) of recommendation, publications, master thesis, etc.

Please feel free to contact us beforehand for any further pieces of information.

Funding The selected candidate will obtain a 36-month funding. The net salary will be around 1700€. Additional paid teaching activities can be envisaged on demand.

Host laboratory Created in 2006, the Hubert Curien laboratory is a joint research unit (UMR 5516) of the Jean Monnet University, Saint-Étienne, the National Research Centre "CNRS" and the Institut d'Optique Graduate School. It is composed of about 90 researchers, professors and assistant professors, 20 engineers and administrative staff and 130 PhD and post-PhD students. More information at `https://laboratoirehubertcurien.univ-st-etienne.fr`.

References

[1] J. Park, M. Kang and B. Han, "Class-Incremental Learning for Action Recognition in Videos", ICCV 2021.

[2] M. Raissi, P. Perdikaris and G. Karniadakis, "Physics-Informed Neural Networks: A Deep Learning Framework for Solving Forward and Inverse Problems Involving Nonlinear PDE", Journal of Computational Physics 2019.

[3] M. Buisson-Fenet, V. Morgenthaler, S. Trimpe and F. Di Meglio, "Recognition Models to Learn Dynamics from Partial Observations with Neural ODEs", TMLR 2023.

[4] J. Bruna and S. Mallat, "Invariant scattering convolution networks", IEEE TPAMI 2013.

[5] A. Dekhovich, M. Sluiter, D. Tax and M. Bessa. "iPINNs: Incremental learning for Physics-informed neural networks", preprint ArXiv 2023.