Master thesis for Spring-Summer 2023

Bridging discrete and continuous neural network models

Keywords: Neural networks, differential equations, image recognition

Context and description

Université Gustave Eiffel is a multi-campus national university in France which was born in 2020 to cover all societal challenges generated by the design of the cities of tomorrow. Part of the COSYS ("Components and Systems") department of this university, the ESTAS laboratory "Evaluation and Safety of Automated Transport Systems" develops methods, techniques and tools intended to facilitate and improve the analysis and assessment of the safety functions of guided transport systems.

The work planned in this Master thesis takes its main motivation in the use of artificial intelligence modules in perception tasks of autonomous vehicles (detection and recognition of road signs, rail signals, or other elements of the vehicle's environment). Most of these perception modules currently rely on neural networks, which take the form of a discrete graph with a finite sequence of layers, each containing a finite number of neurons where mathematical operations (linear transformations and non-linear activation functions) are applied. However, a new class of model called neural ODE (neural ordinary differential equation) has recently been introduced, where the differential equation can be seen as a continuous generalization of a neural network.

The main objectives of this Master thesis are the following:
- Literature review of existing neural ODE models and their relation to discrete neural networks.
- Designing new neural ODE models based on the continuous generalization (of the time, depth, width, ...) of a neural network.
- Establishing formal relations between the discrete and continuous neural models, and using them to deduce the safety properties of one model based on the safety verification of the other.
- Comparisons, on image recognition benchmarks, of the performances of the discrete and continuous neural models, in terms of both training and safety verification.

Desired profile

- The applicant should be in their last year of Master or engineering school, in control engineering, computer science, artificial intelligence, or other related fields.
- Good knowledge on modelling and analysis of differential equations, both linear and non-linear.
- Experience with discrete and finite models such as graphs, automata, finite transition systems.
- Experience with artificial intelligence, machine learning, neural networks.

Details

- Location: ESTAS lab, on the Lille campus of Université Gustave Eiffel, at Villeneuve d'Ascq
- Duration: 6 months, with flexible dates in Spring-Summer 2023
- Compensation: 3,90€/hour (around 570€/month on average)
- Application procedure: send your CV, motivation letter and copy of recent grades to

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PhD thesis

This Master thesis is also related to the topic of an open PhD position on "Formal verification of neural ODE for safety evaluation in autonomous vehicles", with an application deadline on the 31st of January 2023, and a start date on the 1st of November 2023. More details on this PhD topic and the eligibility criteria to apply to it can be found at this link:
https://euraxess.ec.europa.eu/jobs/846749