Offer #2025-08713

PhD Position F/M Phase Transitions in Artificial Neural Networks

Contract type : Fixed-term contract

Level of qualifications required : Graduate degree or equivalent

Fonction : PhD Position

About the research centre or Inria department

The Inria centre at Université Côte d'Azur includes 42 research teams and 9 support services. The centre's staff (about 500 people) is made up of scientists of di?erent nationalities, engineers, technicians and administrative staff. The teams are mainly located on the university campuses of Sophia Antipolis and Nice as well as Montpellier, in close collaboration with research and higher education laboratories and establishments (Université Côte d'Azur, CNRS, INRAE, INSERM ...), but also with the regiona economic players.

With a presence in the fields of computational neuroscience and biology, data science and modeling, software engineering and certification, as well as collaborative robotics, the Inria Centre at Université Côte d'Azur is a major player in terms of scientific excellence through its results and collaborations at both European and international levels.

Assignment

It is well known that large ANNs can be trained to achieve very good performance on a variety of tasks, and *once* they have achieved such good performance, they can be *pruned (i.e., sparsified)* to a small fraction of their initial weights without significant loss of performance. It is then natural to ask whether one could *directly train sparse ANNs* that are as sparse as those obtained by first training and then pruning a large ANN. It is empirically observed, however, that trying to train a

sparse ANN naively in this way doesn't lead to good performance. The *Lottery Ticket Hypothesis (LTH)* [FC18] establishes that such sparse ANNs (called *lottery tickets*) do exist by empirically showing that, through a relatively computationally expensive procedure, *sufficiently large randomly initialized ANNs contain a sparse subnetwork that can be trained to good performance*.

In 2019 and 2020, a couple of papers [ZLL19,RWK20] showed that it is possible to use gradient descent to *train by pruning*: given a sufficiently large and randomly initialized ANN, one can efficiently learn to *identify a subnetwork* that *performs well* on a given classification task, *without changing to the initial random weights*. Such an empirical observation was very relevant in the context of the LTH: not only do sufficiently large randomly initialized ANNs contain subnetworks that can be efficiently trained, but they also contain subnetworks that already perform well. This motivated subsequent research on a stronger version of the LTH: the *Strong Lottery Ticket Hypothesis* [PRN20,MYS20], which investigates how large the initial random ANN should be in order to be able to approximate *any* function within a given class by appropriate pruning (in other words, one tries to understand how *complete* is the space of possible functions represented by the set of possible subnetworks of the random ANN).

The SLTH has been proven for several ANN architectures [NFG24], with the goal of providing insights on the tradeoff between sparsity and overparameterization, and the limits of ANN compression techniques such as pruning. Current results suffer, however, of two fundamental limitations. First, they exhibit a gap between upper and lower bounds for the SLTH, which hinders practical predictions. Secondly, they mathematically rely on the ANN weights being continuous. Not only are practical ANNs finite precision, but they also heavily rely on quantization techniques.

Research on the SLTH has crucially relied on the fundamental problem of Random Subset Sum (RSS) [L98,DDG23], in which one is asked to prove how large a set of random numbers $\boxtimes$ needs to be so that every number in a given target set $\boxtimes$ can be approximated by the sum of a suitable subset of $\boxtimes$. Interestingly, the RSS is closely related, in a precise way, to the problem of Random Number Partition (RNP), for which sharp analyses in the discrete setting have been provided [BCP01,BCM04]. The purpose of this project is to leverage these classical results on RNP to provide sharp bounds on the SLTH which also account for weight quantization. The latter aspect, in particular, would be a first of its kind and could offer deep insights into a technique which is universally used nowadays for making deep learning viable.

References

BCM04. Borgs, C., Chayes, J. T., Mertens, S. & Pittel, B. Phase diagram for the constrained integer partitioning problem. Random Structures & Algorithms, 2004.

BCP01. Borgs, C., Chayes, J. & Pittel, B. Phase transition and finite-size scaling for the integer partitioning problem. Random Structures & Algorithms, 2001.

DDG23. Da Cunha, A. C. W., d'Amore, F., Giroire, F., Lesfari, H., Natale, E. & Viennot, L. Revisiting the Random Subset Sum Problem. In *ESA 2023.*

FC18. Frankle, J. & Carbin, M. The Lottery Ticket Hypothesis: Finding Sparse, Trainable Neural Networks. in *ICLR* 2018.

L98. Lueker, G. S. Exponentially small bounds on the expected optimum of the partition and subset sum problems. *Random Structures & Algorithms* 1998.

MYS20. Malach, E., Yehudai, G., Shalev-shwartz, S. & Shamir, O. Proving the lottery ticket hypothesis: pruning is all you need. In *JMLR 2020.*

NFG24. Natale, E., Ferré, D., Giambartolomei, G., Giroire, F., Mallmann-Trenn, F. On the Sparsity of the Strong Lottery Ticket Hypothesis. In *Neurips 2024*.
PRN20. Pensia, A., Rajput, S., Nagle, A., Vishwakarma, H. & Papailiopoulos, D. Optimal lottery tickets via SUBSETSUM: logarithmic over-parameterization is sufficient. In *Neurips 2020*.
RWK20. Ramanujan, V., Wortsman, M., Kembhavi, A., Farhadi, A. & Rastegari, M. What's Hidden in a Randomly Weighted Neural Network? In *CVPR* 2020.
ZLL19. Zhou, H., Lan, J., Liu, R. & Yosinski, J. Deconstructing Lottery Tickets: Zeros, Signs, and the Supermask. In *NIPS (Neurips)* 2019.

Main activities

- Analyze the requirements and current challenges in the field of sparse artificial neural networks (ANNs).
- Study and review relevant literature on the Lottery Ticket Hypothesis and the Strong Lottery Ticket Hypothesis.
- Develop theoretical frameworks and models for training sparse subnetworks effectively.
- Write documentation and research papers detailing the methodologies, findings, and implications of the project.
- Present research progress and findings at academic conferences and seminars to engage with the machine learning community.

Benefits package

- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working hours) + possibility of exceptional leave (sick children, moving home, etc.)
- Possibility of teleworking (after 6 months of employment) and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social, cultural and sports events and activities
- Access to vocational training
- Social security coverage

Remuneration

Duration: 36 months
Location: Sophia Antipolis, France
Gross Salary per month: 2200€ (2025)

General Information

- **Theme/Domain :** Distributed and High Performance Computing
  Scientific computing (BAP E)
- **Town/city :** Sophia Antipolis
- **Inria Center :** Centre Inria d'Université Côte d'Azur
- **Starting date :** 2025-06-01
- **Duration of contract :** 3 years
- **Deadline to apply :** 2025-04-12

Contacts

- **Inria Team :** COATI
- **PhD Supervisor :**
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About Inria

Inria is the French national research institute dedicated to digital science and technology. It employs 2,600 people. Its 200 agile project teams, generally run jointly with academic partners, include more than 3,500 scientists and engineers working to meet the challenges of digital technology, often at the interface with other disciplines. The Institute also employs numerous talents in over forty different professions. 900 research support staff contribute to the preparation and development of scientific and entrepreneurial projects that have a worldwide impact.

Warning : you must enter your e-mail address in order to save your application to Inria. Applications must be submitted online on the Inria website. Processing of applications sent from other channels is not guaranteed.

Instruction to apply

Defence Security :
This position is likely to be situated in a restricted area (ZRR), as defined in Decree No. 2011-1425 relating to the protection of national scientific and technical potential (PPST).Authorisation to enter an area is granted by the director of the unit, following a favourable Ministerial decision, as defined in the decree of 3 July 2012 relating to the PPST. An unfavourable Ministerial decision in respect of a position situated in a ZRR would result in the cancellation of the appointment.

Recruitment Policy :
As part of its diversity policy, all Inria positions are accessible to people with disabilities.