PhD Position F/M [DOCT2024-COATI] Problem Size Generalization in Neural Combinatorial Optimization

Le descriptif de l’offre ci-dessous est en Anglais

Type de contrat : CDD

Niveau de diplôme exigé : Bac + 5 ou équivalent

Fonction : Doctorant

A propos du centre ou de la direction fonctionnelle

The Inria centre at Université Côte d’Azur includes 37 research teams and 8 support services. The centre’s staff (about 500 people) is made up of scientists of different 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.

Contexte et atouts du poste

The PhD candidate will be supervised by Dr. Frederic Giroire and Dr. Emanuele Natale, both permanent researchers within the COATI Project-Team. The COATI team focuses on innovative algorithmic approaches for solving challenging combinatorial optimization problems. The candidate will be provided with an office space within the team building at the INRIA d’Université Côte d’Azur, a cutting-edge research center. The Inria centre at Université Côte d’Azur includes 37 research teams and 8 support services. The centre’s staff (about 500 people) is made up of scientists of different 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 regional economic players. With a presence in the fields of computational neuroscience and biology, data science and modelling, 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.

An added perk of this position is the idyllic location. Sophia Antipolis, where the INRIA center is situated, is renowned for its concentration of research centers, creating a vibrant atmosphere for intellectual exchange. Moreover, Sophia Antipolis is a short distance from the French Riviera, with the beautiful coastal towns of Antibes and Nice offering a high standard of living, stunning beaches, and a rich cultural scene.

Mission confiée

The PhD candidate will be supervised by Dr. Frederic Giroire and Dr. Emanuele Natale, both permanent researchers within the COATI Project-Team. The core research project will be centered on neural combinatorial optimization.

Research context

A lot of real-life problems can be modeled as a Combinatorial Optimization (CO) problem. The goal is to find the optimal solution among a set of finite discrete candidates. For example, the famous Traveling Salesman Problem (TSP) consists in finding the shortest route that visits each city exactly once. Such problems are NP-hard, meaning that the time required to find the optimal solution grows exponentially with the problem size (assuming the Exponential-Time Hypothesis [17] is true).

To circumvent this issue, a lot of sub-optimal algorithms have been proposed so that good solutions can be found even if they are not the best solutions. Such approximation rely heavily on heuristics, which are typically hand-made and refined over the years by researchers. Due to their essence, those heuristics are often problem-specific and sub-optimal.

As Bengio et al. [5] phrase it, the “techniques, and the parameters controlling them, have been collectively learned by the community”. This is why a new approach has been proposed recently: using...
neural networks to learn the heuristics. They are trained on a large set of instances of the problem, and learn to generalize to unseen instances. Those new heuristics can be trained within days and be specialized onto the specific distribution of problems seen during training. Moreover, they require little human intervention and profit from the research done in the field of machine learning. This is a promising way for enterprises to quickly build a solver for their very specific problem, where available solvers may not be adapted.

The idea to train a model incorporated inside a solver is not new [24], but recent advances in deep learning made it possible to train a model to solve a problem end-to-end without relying on hand-made features nor external algorithm [28, 19, 10]. Those methods are encapsulated in the Neural Combinatorial Optimization (NCO) [4, 6] framework. Such methods showed good results when compared to classical solvers on small instances. But their performance quickly degrades when the problem size increases, and they do not generalize well to big instances [18, 6]. This is why currently the best approach is to use the NCO model within another optimization algorithm such as the Monte Carlo Tree Search [13] or as a policy space search [7]. This causes a much longer computation time and it raises the question of the generalization capabilities of the NCO models.

Interestingly, a field of research called “Adaptive Neural Computation” [16] has been developed with the goal of improving the generalization capabilities of neural networks.

Specifically, the idea of an “Adaptive Computation Time” (ACT) is that the network should adapt its computational depth to the complexity of the input [2, 12]. It lets the model “ponder” deeper for hard tasks, based on what it has learned during training. Researchers developed several methods to achieve this goal and showed that it allows the network to be trained on easy examples and still generalize well to hard examples [3]. Those methods have not been applied to NCO models and it remains to be seen if they can improve the generalization capabilities of NCO models. This line of work follows the algorithmic alignment hypothesis from Xu et al. [29].

**Research activities**

The goal of this project is to study the generalization capabilities of NCO models and to propose new methods based on the theory of adaptive neural computation. Such work aligns well with the expertise of the COATI team, as it involves graphs, optimization, and deep learning – all areas the team has experience in. Their past work includes research on plain graph problems [27, 15, 20, 21], theoretical deep learning [8, 9, 11], and optimization problems using reinforcement learning [14, 23].

**Improve Algorithmic Alignment of GNNs using Methods from ACT**

ACT methods have been shown to improve the complexity generalization of neural networks [1]. While rarely applied to NCO models (though some early work exists [26]), the first project goal is to utilize ACT methods with NCO models and evaluate their performance.

The Traveling Salesman Problem (TSP) will serve as a benchmark to assess the methods’ generalization performance. The TSP is a well-known problem and has been shown to be representative of NCO model behavior [22].

An initial approach would be to build upon the work of Joshi et al. [18] and compare their results with and without ACT. Methods from Banino et al. [2] and Bansal et al. [3] could be used to implement ACT due to their status as recent state-of-the-art and their conceptual simplicity compared to other methods. It’s worth noting that these methods were designed for a supervised training setup, so it will be interesting to see how they can be adapted to a reinforcement learning setup.

**Validate on Other Problems**

As a second objective, we could validate the approach by experimenting on other Combinatorial Optimization (CO) problems such as the Satisfaction Problem (SAT) or the Vehicle Routing Problem (VRP). We could also go a step further and use other methods from adaptive neural computation such as mixture-of-experts or hypernetworks to give more modularity to the network’s flow of execution [25].

**Research assignments**

The candidate will be expected to:

- Gain a thorough understanding of the field of neural combinatorial optimization.
- Regularly meet with their supervisors to discuss research progress, challenges, and potential solutions.
- Attend relevant seminars, workshops, and conferences to stay up to date of the latest research developments.
- Participate actively in writing research papers and presenting findings at conferences.

**References**


Principales activités

- **Researching and developing novel neural network architectures:** The candidate will design and implement new neural network models specifically tailored for tackling combinatorial optimization problems.

- **Exploring reinforcement learning techniques:** This will involve integrating reinforcement learning principles into the candidate's neural network models to enable them to learn effective solution strategies.

- **Applying the models to real-world problems:** The candidate will identify and adapt their models to solve specific combinatorial optimization problems relevant to various industry sectors (e.g., logistics, scheduling, resource allocation).

- **Evaluating and comparing the approach:** The candidate will develop and conduct rigorous experiments to assess the performance of their models compared to existing methods (exact algorithms, heuristics).

- **Contributing to scientific publications:** The candidate will actively participate in writing research papers for publication in top-tier conferences and journals in computer science and artificial intelligence.

Compétences

**Technical Skills:**

- Strong background in computer science and machine learning.
- Proficiency in deep learning frameworks (e.g., PyTorch).
- Experience with optimization techniques and algorithms.
- Programming skills in Python (essential) and potentially other languages (Julia).

**Relational Skills:**

- Excellent written and oral communication skills in English.
- Ability to collaborate effectively with supervisors and colleagues.

**Other Valued Skills:**

- Experience with conducting research and writing scientific reports.
- Familiarity with combinatorial optimization problems.
- Strong work ethic and a passion for research.

Avantages

- 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 and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
Rémunération

Duration: 36 months
Location: Sophia Antipolis, France
Gross Salary per month: 2100€ brut per month (year 1 & 2) and 2190€ brut per month (year 3)

Informations générales

- **Thème/Domaine**: Réseaux et télécommunications
- **Statistiques (Big data) (BAP E)**
- **Ville**: Sophia Antipolis
- **Centre Inria**: Centre Inria d'Université Côte d'Azur
- **Date de prise de fonction souhaitée**: 2024-10-01
- **Durée de contrat**: 3 ans
- **Date limite pour postuler**: 2024-04-28

Contacts

- **Équipe Inria**: COATI
- **Directeur de thèse**: Natale Emanuele / emanuele.natale@inria.fr

A propos d'Inria

Inria est l'institut national de recherche dédié aux sciences et technologies du numérique. Il emploie 2600 personnes. Ses 215 équipes-projets agiles, en général communes avec des partenaires académiques, impliquent plus de 3900 scientifiques pour relever les défis du numérique, souvent à l'interface d'autres disciplines. L'institut fait appel à de nombreux talents dans plus d'une quarantaine de métiers différents. 900 personnels d'appui à la recherche et à l'innovation contribuent à faire émerger et grandir des projets scientifiques ou entrepreneuriaux qui impactent le monde. Inria travaille avec de nombreuses entreprises et a accompagné la création de plus de 200 start-up. L'institut s'efforce ainsi de répondre aux enjeux de la transformation numérique de la science, de la société et de l'économie.

L'essentiel pour réussir

This PhD position thrives on a combination of strong research alignment and personal qualities.

**Research Focus:**

- Passion for the field of neural combinatorial optimization.
- Strong understanding of deep learning and machine learning concepts.
- Ability to think critically and propose innovative solutions.

**Personal Qualities:**

- Excellent communication and collaboration skills.
- Self-motivated and driven to achieve research goals.
- Ability to work independently and as part of a team.
- Eagerness to learn and stay updated on the latest advancements.

**Attention**: Les candidatures doivent être déposées en ligne sur le site Inria. Le traitement des candidatures adressées par d'autres canaux n’est pas garanti.

Consignes pour postuler

Before applying, it is strongly recommended that you contact the Scientific manager beforehand.

**Sécurité défense** :
Ce poste est susceptible d'être affecté dans une zone à régime restrictif (ZRR), telle que définie dans le décret n°2011-1425 relatif à la protection du potentiel scientifique et technique de la nation (PPST). L'autorisation d'accès à une zone est délivrée par le chef d'établissement, après avis ministériel favorable, tel que défini dans l'arrêté du 03 juillet 2012, relatif à la PPST. Un avis ministériel défavorable pour un poste affecté dans une ZRR aurait pour conséquence l'annulation du recrutement.

**Politique de recrutement** :
Dans le cadre de sa politique diversité, tous les postes Inria sont accessibles aux personnes en situation de handicap.