Master 2 internship in Artificial Intelligence and Operations Research

Linear Constraints in Weighted Constraint Satisfaction

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Internship level: Master 2 in Computer Science or Applied Mathematics
Salary: ≈ 550 euros / month
Duration: 4–6 months
Location: Institut National de la Recherche en Agronomie (INRA)
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Requested skills: Algorithms, Theory of linear and integer programming, C++

Constraint programming (CP [Rossi et al, 2006]) is an AI *Automated Reasoning* technology with tight connections with propositional logic. It offers a problem modeling and solving framework where the set of solutions of a complex (NP-hard) problem is described by discrete variables, connected by constraints (simple Boolean functions).Together with propositional satisfiability, it is one of the automated reasoning approaches of AI, where problems are solved *exactly* to provide rigorous solutions to hardware or software testing and verification, system configuration, scheduling or planning problems.

Discrete Stochastic Graphical Models (GMs [Koller et al, 2009]) define a *Machine Learning* technology where a probability mass function is described by discrete variables, connected by potentials (simple numerical functions). GMs can be learned from data and the NP-hard problem of identifying a Maximum a Posteriori (MAP) labelling is often solved *approximately* to tackle several problems in Image [Kappes et al, 2013] and Natural Language Processing [Bilmes, 2004], among others.

The Cost Function Network framework [Cooper et al, 2010] with its associated C++ open source award-winning solver toulbar2, http://www.inra.fr/mia/T/toulbar2, developed in our team, combines the ideas of Constraint Programming and Stochastic Graphical Models. By solving the so-called Weighted Constraint Satisfaction problem, toulbar2 is capable of simultaneously reasoning on logical information described as Boolean functions and gradual, possibly Machine Learned, information described as local numerical functions.

To properly deal with the available information, the solver relies on a guaranteed Branch and Bound-based algorithm [Allouche et al, 2015] where pruning follows from efficient algorithms, processing local information, known as “local consistency filtering” in CP or “message passing” in GMs [Koller et al, 2009]. Because feasibility alone is NP-complete in

CP, efficiency is crucial and depends a lot on the *strength* and *computational cost* of the pruning mechanisms used during search. Our experience is that the ideal compromise needed to solve a specific problem depends on the problem to be solved. Most existing pruning mechanism are very fast but not always sufficiently strong enough for the hardest problems.

These bounds can all be seen as approximating the linear relaxation of the problem, but have much better performance. Unfortunately, while they work well in many cases, their handling of arbitrary linear constraints is suboptimal. First, the best practical methods for encoding such constraints require size linear in the largest coefficient, and second, these encodings can lead to pathological behavior where the lower bound is not augmented as much as it should be. This forbids interesting uses of such constraints, not only in modeling, in particular in bioinformatics (e.g., [Elsen et al., 2013]), but also in algorithmic settings, such as constraint decomposition and learning.

The aim of this Master internship is therefore to explore a recent theoretical result [Průša and Werner, 2015, 2019] that shows that linear constraints can be encoded in strongly polynomial size, under some restrictions. We will simplify this encoding and devise a specialized algorithm for propagating these constraints while avoiding pathological behaviors, as we have done recently for a special class of linear constraints [de Givry and Katsirelos, 2017]. Beyond that, we will study new techniques for computing lower bounds that avoid these potential pathological behaviors altogether by guaranteeing that they converge to the same dual bound as the linear relaxation of the WCSP [Savchynskyy et al., 2012].

Candidate profile

The subject is at the intersection of CP, SAT, and (01)LP. The ideal candidate should be familiar with CP or SAT algorithms and be mathematically comfortable with the theory and algorithms of linear optimization and duality. Some of the algorithms developed during the internship will be implemented and empirically tested on large benchmarking problems sets, https://forgemia.inra.fr/thomas.schiex/cost-function-library, possibly using computing clusters. This requires a good programming ability (in C++, some additional proficiency in scripting languages such as python being welcome).

Send by email to the postdoc advisors in French or English your detailed CV, a motivation letter, and transcripts of Licence and Master 1 degrees. Reference names (professors to contact) will be a plus.

There will be an opportunity to continue for a PhD inside the ANITI Toulouse institute for AI https://www.univ-toulouse.fr/ANITI.

References

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