Research project offer

Location : ISAE SUPAERO, Toulouse, France

Department : Department of Complex Systems Engineering (DISC)

Research group : ADO

Supervisor : Emmanuel Rachelson, Paul Strang + collaborators at CNAM, ENSTA and EDF R&D

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OFFER DESCRIPTION

Title : Deep reinforcement learning for exact combinatorial optimization

Proposed duration and period : April 1 to Oct 1, 2024 (flexible)

Context	Mixed-Integer Programming (MIP) is a subfield of combinatorial optimization, a discipline that aims at finding solutions to optimization problems with large but finite sets of feasible solutions. This internship aims at exploring some of the latest model-based RL algorithms and adapting them to the mixed-integer programming framework.
Objectives and work	MIP solvers developed over the last decades have relied on the Branch and bound (B&B) algorithm to efficiently explore the space of solutions while guaranteeing the optimality of the returned solution. Despite great progress in the design of branching strategies, the exploration strategies used in B&B, mixed-integer programs remain NP-hard problems for which computational load becomes intractable as the number of integer variables increases. Besides, the most efficient branching strategies are based on complex heuristics, fine-tuned by experts on large MIP datasets to obtain the best average performance. In the context of real-world applications, in which similar instances with slightly varying inputs are solved on a regular basis, there is a huge incentive to reduce the B&B solving time by learning efficient tailor-made heuristics. Several contributions in the literature have sought to learn branching strategies by reinforcement to improve the B&B algorithm. These contributions have overwhelmingly adopted a model-free framework, while model-based reinforcement learning algorithms have been found to be more competitive in combinatorial environments such as board games (go, chess, shogi). In fact, the solving of a mixed-integer program can be reformulated as a special type of Markov decision process with combinatorial state-action space. In particular, this internship aims at adapting Deepmind's MuZero algorithm to the B&B framework. L. Huang et al., 'Branch and Bound in Mixed Integer Linear Programming Problems: A Survey of Techniques and Trends', arXiv, 2021. Prouvost et al. 'Ecole: A Gym-like Library for Machine Learning in Combinatorial Optimization Solvers', arXiv, 2020. (www.ecole.ai) M. Gasse, D. Chetelat, N. Ferroni, L. Charlin, and A. Lodi, 'Exact Combinatorial Optimization with Graph Convolutional Neural Networks', NeurIPS 2019. G. Zarpellon, J. Jo, A. Lodi, and Y. Bengio, 'Parameterizing Branch-and-Bound Search Trees to Learn Branching Policies'. AAAI, 2021. M. Etheve, Z. Alès, C. Bissuel, O. Juan, and S. Kedad-Sidhoum, 'Reinforcement Learning for Variable Selection in a Branch and Bound Algorithm', CPAIOR 2020 L. Scavuzzo et al., 'Learning to branch with Tree MDPs'. NeurIPS, 2022 C. W. F. Parsonson, A. Laterre, and T. D. Barrett, 'Reinforcement Learning for Branch-and-Bound Optimisation using Retrospective Trajectories'. AAAI, 2023. D. Silver et al., 'A general reinforcement learning algorithm that masters chess, shogi, and Go through self-play', Science, vol. 362, no. 6419, pp. 1140–1144, Dec. 2018 J. Schrittwieser et al., 'Mastering Atari, Go, chess and shogi by planning with a learned model', Nature, vol. 588, no. 7839, Art. no. 7839, Dec. 2020.
Required profile and skills	Strong mathematical skills and the Python programming language are all highly recommended. Knowledge of RL algorithms. Knowledge of MIP is a plus.