Summary of “A Lazy Approach to Neural Numerical Planning with Control Parameters”

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Abstract

This is an extended abstract of the manuscript “A Lazy Approach to Neural Numerical Planning with Control Parameters” [2]. The paper presents a lazy, hierarchical approach to tackle the challenge of planning in complex numerical domains, where the effects of actions are influenced by control parameters, and may be described by neural networks.

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1 Extended Abstract

This paper is an extended abstract of the manuscript “A Lazy Approach to Neural Numerical Planning with Control Parameters” that was published at the 27TH European Conference on Artificial Intelligence [2]. We refer the interested reader to that version for more details on our work.

Planning is essential for managing complex processes in real-world domains, such as factory automation, where actions must be sequenced and their control parameters be defined accordingly. While rule-based representations may struggle to model real world processes, neural networks (NNs) can approximate even complex dependencies, based on recorded or simulated data[1]. In the paper “A Lazy Approach to Neural Numerical Planning with Control Parameters” [2], we address the challenge of planning in complex numerical domains, where actions are indexed by control parameters, and their effects may be modeled using NNs [3]. We refer to this type of action as neural actions. Our work introduces the Lazy

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Neural Planner (LNP), a Satisfiability Modulo Theory (SMT) based planner, which allows for the integration of neural actions. LNP leverages on two core aspects: the abstraction of the neural actions on the SMT level and their subsequent concretization of control parameters.

First, an abstract plan is generated by an SMT solver, where NNs are treated as uninterpreted functions. This abstraction simplifies the planning problem by avoiding the complexity of direct reasoning about the internal structure of the NN and thus avoids the restriction to architectures that could be handled by SMT solvers. Once an abstract plan is found, this plan is concretized by querying the NNs to determine specific values for the control parameters. If a valid set of control parameters can be found, a final plan is found. If the concretization fails – meaning that no suitable parameters could be found – the system refines the abstraction by incorporating additional constraints, which are then lifted back to the SMT solver. The solver then continues searching for another abstract plan.

This lazy, hierarchical approach offers several advantages over existing methods. One key benefit is the flexibility to handle NNs as black-box models, where the internal details of the network, such as architecture and weights, are unknown or inaccessible. We differentiate three types of NN models in our approach: (i) full-access white-box models, where the network's details are fully known, (ii) function-access black-box models, which allow certain functionalities like backpropagation but do not make the entire model accessible, and (iii) no-access black-box models, where the network is treated purely as an input-output mapping. For full-access and function-access models, we apply a gradient-based optimization technique to find control parameters. For no-access models, we employ a search algorithm to explore the parameter space and identify a feasible solution.

Experimental evaluations on four different planning domains demonstrate the efficiency of the LNP approach. The results indicate that avoiding symbolic reasoning about NNs not only improves computational efficiency but also enables the integration of NNs as black-box models, expanding the applicability of numerical planning in domains where exact NN specifications are not available. Furthermore, we analyze the effects of integrating information from the training process of the neural actions. We show that integrating this information can reduce the runtime with the risk of increasing incompleteness.

While our LNP approach offers efficiency and generality compared to eager encodings, it trades off completeness due to the abstraction process. The approach is correct in that every plan found is valid, but it may not find all possible solutions. Nonetheless, LNP represents a significant advancement in the integration of NNs into planning problems, particularly for scenarios where explicit symbolic reasoning about NNs is either impractical or impossible.

In future work, we plan to explore a tighter integration of NN reasoning within the SMT solver, aiming at balancing the trade-offs between completeness and efficiency. We additionally intend to expand our approach to temporally extended planning problems and to investigate different optimization techniques for control parameter estimation in various NN access scenarios.

Our LNP approach enables automated planning in complex, real-world domains with control parameters. Moreover, it presents a method of integrating ML models into symbolic reasoning, which reduces the modeling effort and hence could enhance the capabilities of symbolic AI approaches in other applications, such as diagnosis.

References

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