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From Prediction to Solution: Enhancing Constraint Solvers with Machine Learning for Perceptual Decision-Making Problems

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Abstract

Many real-world tasks, from scheduling to path planning, require both accurate prediction of unknown parameters from raw data and complex reasoning to find optimal solutions. We focus on predict-then-optimize problems, where unknown parameters must first be predicted from contextual data before solving can occur. While symbolic systems excel at automated reasoning, and neural networks efficiently learn from data, designing a neuro-symbolic framework that combines these approaches remains challenging.

This thesis explores the intersection of symbolic and neural approaches in artificial intelligence to solve predict-then-optimize problems. We investigate the inference and learning aspects of solving such problems.

In the second chapter, we develop a framework combining convolutional neural networks with constraint programming to solve perception-based constraint solving problems through joint inference. Our approach uses perception variables as a bridge between neural predictions and decision variables, enabling robust inference even with noisy predictions or erroneous input.

The remaining of the thesis focuses on learning. The third chapter introduces decision-focused learning methods that train neural networks to make predictions refined for a specific downstream decision-making task. We introduce a new surrogate loss function and an efficient caching scheme to address computational challenges inherent in these methods. Finally, in the fourth chapter, the thesis examines the applicability of decision-focused learning to perception-based constraint solving problems. We explore the use of decision-focused learning and other related neuro-symbolic learning methods, jointly with perception variables, to train a neural network end-to-end for such problems.

By addressing these aspects, this thesis aims at bridging the gap between prediction and reasoning by reducing the computational burden and improving the solution quality.