Neuro-Symbolic Reinforcement Learning: Natural Language Driven Multi-Task Agents

Hunter W. Ellis

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Thinh T. Doan, PhD, Chair
Michael S. Hsaio, PhD, Co-chair

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(ABSTRACT)

In recent years, neuro-symbolic learning methods have demonstrated promise in tasks requiring a semantic understanding that can often be missed by traditional deep learning techniques. By integrating symbolic reasoning with deep learning architectures the interpretability of the model's reasoning becomes more evident and can provide more control during deployment. This thesis aims to apply neuro-symbolic learning to the domain of reinforcement learning. First, a simulation environment for robotic manipulation tasks based on the Gazebo Harmonic physics simulator and ROS2 middleware suite is presented. In this environment an analysis of policy-gradient based reinforcement learning algorithm is given. Then, by leveraging the performance of deep learning with the semantic reasoning and interpretability of symbolically defined programming, a novel neuro-symbolic learning method is proposed to generalize tasks and motion planning for robotics applications using natural language. This novel neuro-symbolic can be seen as an adaptation of the Neuro-Symbolic Concept Learner (Mao et. al) developed by IBM Watson, in which images and natural language are first processed by convolutional and residual neural networks, respectively and then parsed by a symbolically reasoned program. Where the architecture proposed in this paper differs, is in its use of the Neuro-Symbolic Concept Learner for preprocessing of a given input task, to then inform a reinforcement learning agent of how to act in a given environment. Finally, the novel adaptation of the Neuro-Symbolic Concept Learner is introduced as a method of controlling multi-task agents.

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(GENERAL AUDIENCE ABSTRACT)

Neuro-symbolic learning is an area in machine learning that leverages user defined symbolic programming in addition to deep learning. This method goes against the typical approach of end-to-end training of models and instead hopes to benefit from the introduction of symbolic programs.

Dedication

This is where you put your dedications.

Acknowledgments

Thank you to Dr. Thinh Doan and Dr. Michael Hsiao for your guidance and expertise throughout my undergraduate and graduate studies.

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NLP is a field of computer science, artificial intelligence, and linguistics concerned with the interactions between computers and human (natural) languages.

σ is the eighteenth letter of the Greek alphabet, and carries the 's' sound. In the system of Greek numerals, it has a value of 200.

Chapter 1

Introduction

Neuro-symbolic learning methods and concepts have been used in recent years to achieve results that standalone deep learning and symbolic programming methods have not been able to achieve. [EXAMPLES]. The emerging developments in the field of neuro-symbolic learning has created opportunities to explore applications and adaptations of these methods. The field of Reinforcement Learning (RL) has also made advances – demonstrating the paradigms effectiveness in creating agents that can perform complex tasks autonomously. The intersection of these two research areas has led to developments that have allowed agents to perform tasks with with both programatic interpretability and learned performance. [EXAMPLES].

1.1 Objectives

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1.2 Applications

1.3 Challenges

1.4 Contributions

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Chapter 2

Background

2.1 Markov Decision Process

2.2 Reinforcement Learning

2.3 Neuro-symbolic Architectures

2.4 Sim-to-Real

2.4.1 Transfer Learning

2.4.2 Multitask Learning

Chapter 3

Neuro-symbolic Reinforcment Learning Model

Neuro

./images/architecture_overview.png

Figure 3.1: Overview of proposed architecture.

Chapter 4

Simulations

Chapter 5

Reality

Chapter 6

Discussion

Chapter 7

Conclusions