Discovering Representations by Mining State-Space Graphs

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October 14, 2011

Project Proposal

The engineering of an appropriate state space representation is one of the essential prerequisites to applying reinforcement learning (RL) in a new domain. The choice of representation is often critical to the success of an RL agent, just as feature engineering is often critical to the success of a supervised learning method. This representation is usually constructed by hand, and requires an understanding of the peculiarities of a given domain.

Many domains, however, are naturally represented as a discrete state space graph: the game of Tic-Tac-Toe, for example, is easily described as a set of boards (3x3 grids), with the possible moves linking boards with directed edges. This type of representation is verbose, and not directly amenable to well-studied standard RL methods, but may serve as a useful starting point—an initial representation, to which data mining tools can be applied to extract useful lower-dimensionality state descriptions.

Recent work [Wang and Mahadevan, 2009, Mahadevan and Maggioni, 2006, Coifman and Maggioni, 2006] has begun to examine the use of harmonic analysis of graphs in this framework, focusing on diffusion wavelets and the eigenvectors of the graph Laplacian, but important questions remain: how can this approach be scaled to large state spaces? Can it be made to work given only sampled walks through the state space (e.g., data from human gameplay)? Which methods generate state descriptions suitable for which RL algorithms?

To address scalability, one possible research direction would be to apply a multilevel graph clustering algorithm, such as graclus [Dhillon et al., 2007], then perform harmonic state space analysis on the clusters separately or on a coarsened representation of the state graph. It may also be worthwhile to use the clusters directly as binary functions; many RL algorithms become simple and efficient in the binary-feature case.

Our project will tackle these questions in applying data mining tools to automatically derive state representations for two complex, large-scale domains: the board game of Go, using state trajectories extracted from expert human games; and the operation of a modern satisfiability (SAT) solver, `MiniSat`, on standard benchmark collections. The success of our approach will be measured against current state-of-the-art handcrafted template features [Silver et al., 2007] in the case of Go, and against default solver configurations in the SAT domain.

Tentative Schedule

- 10/14: Demonstrate learning in the tic-tac-toe (TTT) domain using the eigenvectors of the graph Laplacian as basis functions.
- 10/21: Demonstrate learning in the 5x5 Go domain, again using the eigenvectors of the graph Laplacian. Consider how to generalize outside the state space graph. Analyze performance as the number of basis functions varies.
- 10/28: Implement and compare strategies for handling the state space size in Go at larger board sizes, focusing on graph coarsening approaches.
- 11/4: Explore the approaches that appear promising from results collected so far. Implement a proof-of-concept application to SAT.
- 11/11–: Continue to iterate.

References

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