Efficient Methods for Prediction and Control in Partially Observable Environments

Abstract:
State estimation and tracking (also known as filtering) is an integral part of any system performing inference in a partially observable environment, whether it is a robot that is gauging an environment through noisy sensors or a natural language processing system that is trying to model a sequence of characters without knowledge of the syntactic or semantic state of the text.

In this work, we develop a framework for constructing state estimators. The framework consists of a model class, referred to as predictive state models, and a learning algorithm, referred to as two-stage regression. Our framework is based on two key concepts: (1) predictive state: where our belief about the latent state of the environment is represented as a prediction of future observation features and (2) instrumental regression: where features of previous observations are used to remove sampling noise from future observation statistics, allowing for unbiased estimation of system dynamics.

These two concepts allow us to develop efficient and tractable learning methods that reduce the unsupervised problem of learning an environment model from data to a supervised regression problem: first, a regressor is used to remove noise from future observation statistics. Then another regressor uses the denoised observation features to estimate the dynamics of the environment.

We show that our proposed framework enjoys a number of theoretical and practical advantages over existing methods, and we demonstrate its efficacy in a prediction setting, where the task is to predict future observations, as well as a control setting, where the task is to optimize a control policy via reinforcement learning.