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Perturbational Complexity by Distribution Mismatch: A Systematic Analysis of Reinforcement Learning in Reproducing Kernel Hilbert Space

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Summary for general readers:
Reinforcement learning is a field of machine learning concerned with how agents interact with an unknown environment sequentially to maximize the expected cumulative reward. In practical problems with enormous states, function approximation is necessary to represent value or policy functions. However, when estimating the value or policy functions, one can not access the probability distribution under which the functions should be approximated. That is the state distribution induced by the estimated value or policy functions, which are unknown a priori. This phenomenon is termed distribution mismatch in this paper: a mismatch between the distribution used for the estimation and the distribution induced by the current approximation of the value or policy functions. This phenomenon is ubiquitous in the analysis of reinforcement learning algorithms and poses significant challenges for analysis.

This paper provides a new perspective to deal with this difficulty. An obvious sufficient condition is to show that the errors are uniformly small under the probability distributions induced by all possible policies. This work shows that this condition is also necessary, in the setting when the problem is defined in the reproducing kernel Hilbert space. It also introduces a key new concept, perturbational complexity by distribution mismatch, which characterizes the complexity of the corresponding reinforcement learning problem.

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