Towards a Metacognitive Reinforcement Learning Approach for Planning in Adaptive Learning Systems

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Abstract

Learners face metacognitive challenges in planning efficient allocation of limited study time and cognitive resources. Our work draws cognitive science research showing how humans use reinforcement learning to adaptively develop metareasoning heuristics that balance deliberation and exploitation in learning sequence planning. We model this framework computationally by formulating adaptive content sequencing as a Markov Decision Process with meta-level states, actions, and rewards. A neural meta-policy module governs deliberation on building new personalized learning plans versus the reuse of prior recommendations through simulated user interactions. Testing using 100 simulated agents exhibiting the evolution of knowledge, interests, and consumption patterns provided longitudinal data on meta-policy responsiveness to dynamic learning requirements. Analyzing trends over time and trigger-reaction lags quantified opportunities for improving deliberation latency and relevance. The simulated experiments demonstrate promising progress in computationally modeling the metacognitive capacity for resource-rational planning by strategically balancing plan quality and computational effort in education content recommendation.

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