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Autonomous State-Space Construction for Continuous and Multi-Dimensional Observation Space in Partially Observable Environment

This research group proposes a learning method in which a robot with incomplete and unreliable sensor-input learns behaviors while acquiring adequate state-recognition mechanism according to the interaction with its environment.

The way to convert the perceptual inputs from its sensors to state-recognition sufficiently accurate to output its action is not trivial for embodied agents such as robots. Therefore, in order to realize autonomous behaviors without embedding some prior knowledge by a human designer, the agent have to construct this conversion mechanism through the interaction with the environment.

In order to realize this, it is necessary to solve the following essential problems: (1) estimation of the present Markovian state using sensory inputs that loses its Markovian property owing to its locality and noise, and (2) segmentation of continuous and multidimensional sensor-space based on the significance for the ongoing task. The proposed method deals with non-Markovian perceptual inputs by the use of a state-representation of decision-tree structure representing state-distinction based on the short-term memory (observations and actions of the past) (Figure 1). The agent constructs a state-representation realizing state-distinction necessary and sufficient for the task by incrementally segmenting the representation according to the experience obtained through the task execution. Besides, it realizes an autonomous interpretation of sensor values without any heuristic prior designs of sensor-space by adequately segmenting spaces representing observations in the state-representation.

In the simulation of a navigation task in an environment shown in Figure 2, the agent constructed an appropriate state-representation and acquired the optimal behavior (Figure 3).

Keywords: Partially Observable Markov Decision Process (POMDP), Autonomous State-Space Segmentation.

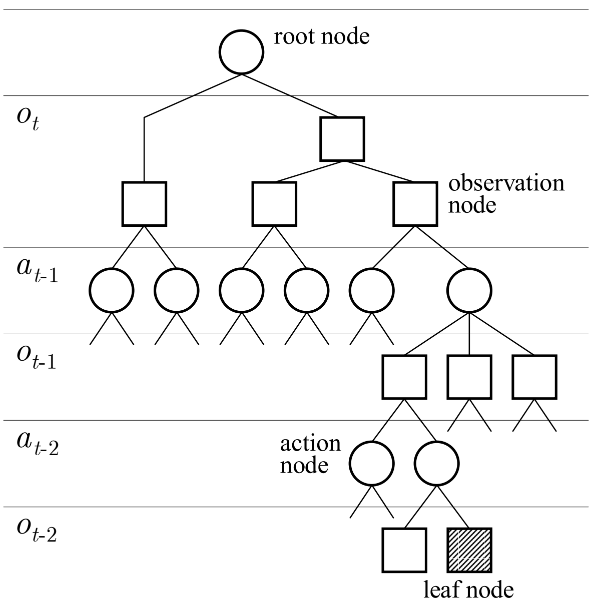

Figure 1: State-representation

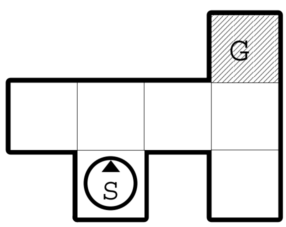

Figure 2: Simulation environment

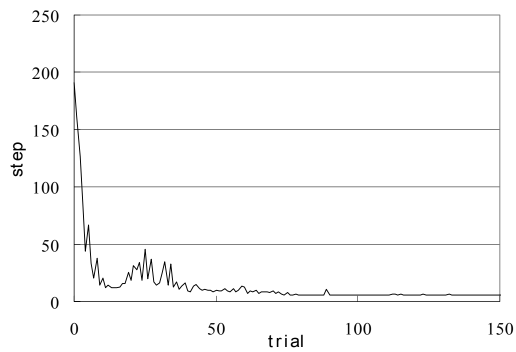

Figure 3: Performance improvement